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EREF Auction Raises Over \$1 Million!

The Environmental Research and Education Foundation hosted its annual live action at WasteExpo in Dallas, Texas on May 11. The auction, led by the charismatic Gary Seybold of Ritchie Bros. Auctioneers, featured 32 lots and raised over \$1 million – making it the foundation's third largest Auction in history – to further the EREF mission. There were many items new to the live auction this year, including a ride on the Goodyear blimp, golf with Ron Mittelstaedt, CEO of Waste Connections, a Volvo Skid Steer, a tour of the NYSE and dinner with Don Slager, CEO of Republic Services, and a remanufactured transmission from Reliable Transmission Service. During the live auction, EREF Board member Ron McCracken took the podium to ask bidders for donations that would go directly into EREF's scholarship fund. The generous bidders donated more than \$13,000.



EREF staff stayed busy with a few other major events at WasteExpo 2011, including the raffle of a 1959 Chevrolet Apache truck. The beautiful red pickup truck attracted a great deal of attention and helped EREF raise over \$40,000. Junior Thompson of ESI was the winner for the second time in the EREF raffle history!

(continued on page 4)

EREF's New Logo and Enhanced Communications Plan

Earlier this year EREF unveiled a new logo with a design that more accurately reflects the foundation's mission to fund and direct scientific research and educational initiatives for waste management practices to benefit industry participants and the communities they serve.



Environmental Research & Education Foundation

Lighting a path to sustainable waste management practices

The updated logo incorporates the EREF acronym with the profile of a head with a tree growing inside it and branching off as if a brain. The new image is accompanied by EREF's new tagline – "Lighting a path to sustainable waste management practices."

The redesign is part of a larger strategic effort to increase awareness of EREF's research and education in the waste industry, a plan approved by the EREF Board of Directors during its September 2010 strategic planning meeting. The foundation plans to triple its communications efforts in 2011, to include targeted messages focusing on research projects and scholars, technical research updates and an increased presence at industry and public events. This is part of a larger strategic plan noted in the letters from the Chairman (page 2) and the President (page 3).

"The new logo design promotes the knowledge of environmental issues that EREF's research and education initiatives provide," said Pat Carroll, President of Environmental Solutions Group and Chairman of the EREF Strategic Planning Committee. "EREF is dedicated to increasing awareness of the foundation and the value it adds to the solid waste industry." •

CHAIRMAN'S MESSAGE

I am honored to write my first letter to you as Chairman of the EREF Board of Directors. I would like to start by thanking our outgoing Chairman, Paul Mitchener of Maquarie, for an outstanding job during his term. I would also like to welcome Joe Ursuy of Comerica Bank to the Board.

This is an interesting time for the industry since a number of megatrends are now occurring that directly affect how solid waste is managed. One example is how resources are becoming more scarce every year, thus driving society to re-consider how waste can be utilized to curb use of virgin materials from what seems dwindling supplies. The struggle for meeting increased energy demands while reducing dependency on foreign oil is a prime example since the conversion of waste to energy or useful materials has faced significant scrutiny as one way to develop a significant source of non-petroleum based domestic energy supply. Such megatrends are driving the foundation to enlarge the scope of its activities from funding far-reaching scientific research, to developing a new generation of scientists who know no limits via our scholarship program, to increasing awareness of what is happening now in terms of trends and scientific findings. The increase in EREF's scope is part of a strategic plan that re-defines the foundation for the future.



As mentioned in the article announcing EREF's new logo and communications plan, the EREF Board of Directors developed a new mission and objectives for EREF in an effort to broaden the foundation's scope of research to encompass new industry trends. The new mission, vision and strategic objectives adopted by the Board are as follows:

Mission

To fund and direct scientific research and educational initiatives for waste management practices to benefit industry participants and the communities they serve.

Vision

The leading institution lighting a clear path, through research and education, translating ideas into action for sustainable waste management practices

Strategic Objectives

- Unbiased, scientific reports and analysis on waste management practices
- Scholarships for high potential graduate students and internships for highly qualified undergraduate students
- Targeted research to expand industry knowledge and understanding of the waste stream from generation to final disposition
- Improved public understanding of solid waste stream and sustainable solid waste management practices
- Increasing industry knowledge through educational programs

These strategic objectives are being realized in funded research that supports existing technologies, such as more accurately quantifying how much methane is oxidized through landfill covers and how to develop a data driven landfill post closure process that reduces long-term environmental risk. Complex questions are also being answered with life cycle analyses that determine the most environmentally sound disposal options for a given set of policies/collection scenarios or comparing the development of biofuels from MSW to existing technologies such as waste to energy. EREF scholars are also supporting research efforts by evaluating how policy can intersect with science to provide sound practices in managing wastes. New projects have recently been funded to evaluate how human behaviors influence recycling rates and how concrete wastes can be re-polymerized for use in structural applications. The work EREF is doing is helping the industry move from traditional waste management services to next generation resource strategies that answer the megatrends driving society, now and in the future.

Sincerely,



Senior Vice President of Strategy, Suez Environnement
Chairman, EREF Board of Directors

PRESIDENT'S MESSAGE

Dear Friends and Colleagues,

At roughly 7 months into my role as president... thus far I can say that it has already been an exceedingly rewarding and challenging experience. For many, I'm still a new face in the crowd and there are still many hands to yet shake. Despite this, it has been a truly humbling experience to witness the kindness and generosity that is ingrained in this industry. As the 3rd person to take the helm as EREF president, there are new tasks to undertake while at the same time honoring the traditions and legacy left by my predecessors. In this spirit, I'd like to share with you where EREF is going and how we are positioning ourselves to expand our service to this industry and the public it serves.



Nearly a year ago now, the EREF Board of Directors held a strategic planning meeting where it set 4 strategic goals, based on strategic objectives noted in the Chairman's letter, for the foundation moving forward:

1. Build EREF's communications program and raise awareness of what the foundation does.
2. Broaden the scope of EREF's research program.
3. Expand the foundation's educational mission.
4. Increase revenue to the foundation and build its endowment.

To accomplish these goals, EREF staff developed a 3 year action plan. As part of this plan, you may have noticed more communication from us, which is part of a greater effort to triple our communication efforts compared to prior years. To broaden the scope of our research program, EREF began Regional Summit meetings this year and has increased efforts at disseminating research via speaking engagements at various industry events. To expand our educational mission, EREF began a trial intern program that provides solid waste education to undergraduate and graduate college students. Thus far our interns have analyzed industry trends, aggregated information on recycling policies across the U.S. and are in the process of evaluating zero waste initiatives nationally.

To build the foundation's revenue and its endowment, more earnest efforts have been made to involve a wider array of stakeholders. Financial commitments have increased, and key steering committees, such as EREF's Research Council and its Auction Committee, have been expanded. When people ask me, "Who or what is EREF?" my response is: YOU ARE. Without the support of those with a vested interest in solid waste management, EREF would cease to exist.

If you are interested in the future of the industry then join us in these efforts. Become a stakeholder... or get more involved. Help guide the foundation to be one of the voices that helps make others aware that this industry is not a separate corporate entity, but is woven into the fabric of our society. Part of that effort is ensuring an industry 'think tank' exists to share unbiased, accurate and relevant information with the industry and the public on how solid waste can be sustainably managed.

Please don't hesitate to contact me. I invite your feedback, criticism, and praise as we branch out in new directions, while at the same time remaining firmly rooted in what has made the foundation successful over the past 19 years.

Kind regards,



Bryan Staley, PhD, PE
EREF President and Chief Executive Officer

HONORARIUMS & MEMORIALS

In search of a special way to honor a loved one, friend or colleague? Looking for a simple, complementary means for recognizing employee dedication and accomplishment? Consider an honorarium or memorial in EREF's newsletter. Honorariums most often expressed represent the birth or adoption of a child, an anniversary or wedding, a personal milestone, retirement or receipt of a distinguished award. A contribution* is requested in exchange. Please contact EREF at 919.861.6876 ext. 103 or kpickurel@erefdn.org for questions regarding your honorarium or memorial. *Donations are tax deductible to the extent allowed by law.

"In memory of Mr. Sidney Robbins, a generous man who cared greatly for the environment."

Mrs. Amy S. Robbins-Dickstein
April 2011

EREF Auction (continued from cover)

New this year was EREF's silent auction, which allowed more WasteExpo exhibitors to participate in the EREF auction while providing a way to draw attendees into their booths. It was a great success, raising over \$50,000! Items donated to the Silent Auction included iPad 2s, baseball game tickets, an Outer Banks beach house rental, tickets to the Indianapolis 500, a day of

training, golf outings, dinner for 6 at Picasso in Las Vegas and a pheasant hunting trip.

EREF would like to thank the generous donors, sponsors and auction and raffle participants for their continued enthusiasm for and support of the foundation. ●

Live and Silent Auction Donors

Accent Wire
Air-Weigh
Allison Transmission, Inc.
Ameri-Kan
Assurance Agency Ltd.
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Bayne Premium Lift Systems
Big Truck Rental
Calvert Street Group
Cascade Cart Solutions
Caterpillar
Clean Energy
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DURAPLAST by DURABAC
Environmental Industry Associations
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Auction Sponsors

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Professional Auctioneer Services
Ron McCracken
Photography ●



(above left) Raffle Vehicle: 1959 Chevrolet Apache Pickup



(above right) John Curotto and his team generously donated two limited edition Komen Pink Slammin' Eagles. Because there were two winners (Veolia Environment and Land & Lakes Disposal Services), Curotto-Can doubled its matching contribution to \$5,000 for the Dallas Affiliate of Susan G. Komen for the Cure.



(right) WasteExpo attendees peruse the Silent Auction items



Tom Miller, Skip Berg, Mickey Flood, Ron McCracken



Tim Hurst, Eric Tremblay, Claude Boivin



Rita Ugianskis, Lonnie Poole, Keyna Cory



Jim Johnston is thrilled with his winning bid



Denisse Ike raises her paddle for research



Auctioneer Gary Seybold poses with Norm Aardema, who made the first donation to the EREF Scholarship Fund

2011 EREF Fall Classic Golf Tournament



**Environmental Research
& Education Foundation**

Lighting a path to sustainable waste management practices

October 13, 2011
Pinehurst, North Carolina

Sponsored by:



Hotel Reservations

(800) 487-4653

When you get the Pinehurst recording, press 1 and ask for Group Reservations; Reference the EREF Golf Tournament

Single Occupancy: \$198 per person, per night
Double Occupancy: \$109 per person, per night

Guestrooms may be assigned to Carolina, Holly, Villas, Manor or Golf Course/Lake View Condos. Reservations must be made by 5:00 p.m. (eastern) on September 20.

Visit www.erefndn.org for more information and registration.

Tournament Details

Wednesday, October 12

6:00 - 8:00 pm

Welcome Reception and Nite Lite Putting Contest

(pre-registration is required for the putting contest)

Thursday, October 13

7:00 - 8:45 am

Breakfast and Registration

9:00 am

Shotgun Start on Pinehurst Course #5

12:30 - 2:00 pm

Awards Luncheon

Player registration is \$750 per player, or \$3,000 for a foursome.

"Nite Lite" Putting Contest



Golf Favors



Welcome Reception



Shirts



Hole Signs



Golf Carts



Beverage Carts



waste expo



Breakfast



Hole-in-One Insurance
Goody Bags



Driving Range



Golf Towels



Putting Contest



Golf Balls



Coolers



Cigars



Welcome Bags



Holes



BOARD NEWS

The EREF Board of Directors is pleased to announce its 2011 Officers:

Chairman

Henry Saint Bris

Senior Vice President of Strategy
Suez Environnement



Henry Saint Bris joined the Suez Group in 1996 and has held positions of increasing responsibility since he joined the organization, serving as Vice President of Strategy and Development at Sita, the waste management arm of the group, and, as of 2003, posted in the US as Senior Vice President of SUEZ Environnement North America, managing water and waste assets across the US and Canada. Since 2009, he has taken over responsibility of Strategy and Marketing at corporate headquarters.

Prior to joining Suez, Saint Bris spent seven years with Ernst & Young where he was a founder of their Environment Group in France and a Senior Manager for the Strategy Consulting Group. Saint Bris also spent 2 years with Aerospatiale/EADS in India where he gained marketing and sales experience.

Vice Chairman

Richard Burke

President and Chief Executive Officer
Veolia Environmental Services



As President and CEO of Veolia Environmental Services North America (VESNA), Richard Burke is responsible for the overall operations of the largest, fully-integrated environmental services company in North America. Burke joined VESNA in 1999 as area manager for Southeast Wisconsin for the Solid Waste division. He was soon promoted to Regional Vice President for the Eastern and Southern markets and was appointed President and CEO of the Solid Waste business in 2007, a role he held until his current appointment with VESNA in 2009. Prior to joining Veolia, Burke spent 12 years with Waste Management in a variety of leadership positions.

Burke is a member of the Board of the Sanitation Service Grand Bahamas Port Authority, and a Trustee member of the National Solid Waste Management Association.

Secretary/Treasurer

Leonard "Butch" Joyce, Jr., P.E.

President, Joyce Engineering, Inc.



Butch Joyce is president of Joyce Engineering, Inc., Richmond, Va., which he founded in 1983 and which offers con-

sulting engineering, training, and environmental and operations management services exclusively to the waste industry.

Joyce has functioned as chairman of the Virginia Waste Industries Association, the Virginia state chapter of the National Solid Wastes Management Association.

The Board of Directors is also pleased to announce the election of its newest member:

Joseph G. Ursuy

Group Manager
Environmental Services Group
Comerica Bank



Joe Ursuy is Senior Vice President and Group Manager of Comerica Bank's Environmental Services Group in Detroit, Michigan. His responsibilities include managing a rapidly growing group of professional lenders and staff that are entirely dedicated to lending to Environmental Service companies. This national platform is focused on profitably growing its lending portfolio and becoming key advisors to the clients they serve through a relationship banking approach and exceptional client service.

Prior to founding the Environmental Services Group in 2006, he held various positions in Comerica's Middle Market Banking Department since 1998.

December 2010 Board Meeting (London, UK)

The EREF Board of Directors convened "across the pond" for its last meeting of 2010. In addition to taking

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(above) The EREF staff and Board of Directors touring a London waste facility

(right) Closed Loop Recycling plant



Board News (continued from page 7)

care of business at the board meeting, the directors were treated to a tour of several British waste facilities, including Closed Loop Recycling (a company that recycles plastic drink bottles back into food-grade plastic) and the Lakeside Energy from Waste (a facility that uses a mass-burn process to generate high temperatures to produce high pressure steam, which drives a turbine to produce electricity).

April 2011 Board Meeting (New York, NY)

Highlights of the Board's April meeting included an update on EREF's enhanced communications plan, last minute preparations for the Auction and the approval of three new research projects. •

(top right) Bryan Staley, Pat Carroll, Michael Hosfeld and Ven Poole enjoy a pint during the December 2010 Board Meeting in London, UK

(bottom right) Tom VanWeelden, Debra Reinhart, Henry Saint Bris, Paul Mitchener and Butch Joyce at the April 2011 Board Meeting in New York, NY



REGIONAL SUMMIT

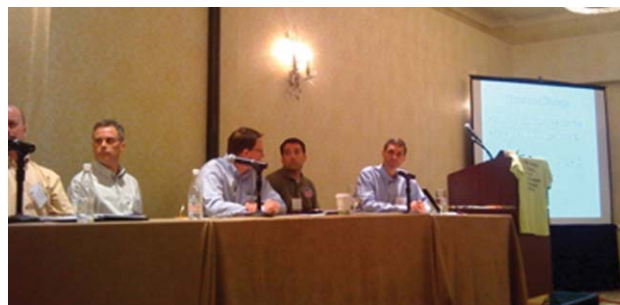
EREF's Holds First Regional Summit

First Summit in Indianapolis a Big Success

The first Regional Summit on Sustainable Solid Waste Management Practices was held in Indianapolis, Indiana in late April and was a huge success. Over 133 attendees came to the 2-day meeting to hear presentations by EREF grantees and stakeholders on research and technical issues. Dr. Bryan Staley, EREF's president, noted: "These summits are structured to be low cost, information sharing events that highlight relevant research activity and touch on regional issues of interest." Attendees included roughly 20% regulatory personnel, 10% from academia, 40% industry personnel and 30% consultants. The first day included talks on various topics, including how research improves performance in solid waste management, landfill gas collection, and post-closure issues. The second day was comprised of a morning workshop on safe and effective disposal of aluminum wastes, followed by an afternoon session on bioreactor landfills. Sponsors included Republic Services, Cornerstone Environmental Group, Weaver Boos Consultants, American Environmental Group, Golder and Associates, and Civil & Environmental Consultants. The event was planned in cooperation with the U.S. EPA's Region 5.

Next Summit in Raleigh, NC will focus on Landfill Gas to Energy (September 7-8, 2011)

A second summit is scheduled for September 7 and 8 in Raleigh, NC that includes unique content and a special focus on landfill gas to energy, including a bus tour of the Black Creek renewable energy facility in Roseboro, NC. For more details, please see the EREF Web site at www.erefndn.org. Registration is \$100/person for industry personnel and free for regulators and academia. •



The panel discusses safe aluminum waste disposal at the EREF Regional Summit in Indianapolis.

Meet the EREF Staff

Bryan Staley

President and Chief Executive Officer

Bryan joined EREF 3 years ago as Vice President of Environmental Programs. He has 17 years' experience in the environmental engineering field and has held key positions in consulting firms. In addition to design and permitting responsibilities, Bryan led key management and growth efforts at the firms he worked for. He has been a licensed professional engineer since 2000.



Bryan holds a Ph.D. in civil engineering (with a minor in biotechnology) from North Carolina State University where his work focused on solid waste research, specifically the optimization of methane generation and recovery from landfills. During his tenure as a Ph.D. candidate, Bryan held a 4.0 grade point average and received a Francois Fiessinger scholarship from EREF. In addition to a Ph.D., he holds a Master's degree in Biosystems Engineering from the University of Tennessee and a B.S. in Biological and Agricultural Engineering from North Carolina State University. He also earned an Eagle Scout award from the Boy Scouts of America. Bryan grew up on a dairy farm in rural Maryland, and later a produce farm in the North Carolina mountains, where he became grounded in a strong work ethic, self-reliance and juggling multiple responsibilities. One of his favorite mottos is: "Don't be afraid to try new things. After all, a lone amateur built the ark... while a team of professionals built the Titanic." He lives in north Raleigh with his wife and two children, Isaac (4) and Isabelle (1 1/2).

Kristy Pickurel

Director of Development and Communications

Kristy joined EREF in March 2010. She is responsible for developing and carrying out strategic plans for the foundation's fundraising and communications programs, as well as planning and executing the annual Live and Silent Auctions, Golf Tournament, Regional Summit meetings and other events.



A graduate of Elon University, Kristy has more than 13 years of experience in non-profit marketing, communications and event planning. She has held positions with the Financial Planning Association (FPA) of the Triangle, National Council of Teachers of Mathematics (NCTM), Society of American Florists (SAF) and the Cable & Telecommunications Association for Marketing (CTAM).

Kristy is a member of the EIA Women's Council and Association of Fundraising Professionals, and is a Team Captain with the National Multiple Sclerosis Society. She lives in Cary with her husband John and two sons, Jacob (5) and Justin (3).

Stephanie Hollomon

Administrative Director

Stephanie Hollomon feels very fortunate to be a part of the EREF family. She is new to the industry and has enjoyed learning about it – trips to a landfill and a MRF were very interesting. She earned a BBA from James Madison University and has continued her education by taking classes at the local community colleges.



She's blessed to have three fantastic children, wonderful parents, a great brother, two dogs and one cat. She is a do-it-yourselfer and her greatest accomplishment was laying 1,100 square feet of hard wood flooring in her house (She's the proud owner of a pneumatic nailer!). She also enjoys gardening, yard work, working out at the Y and driving her convertible.

Premila Goddard

Project Coordinator

Premila Goddard joined EREF in January of 2011 to assist with the planning and logistics of the Silent Auction that was re-introduced earlier this year at WasteExpo in Dallas. Premila brings to EREF her skills and expertise in account management, project management and event planning. Premila is excited to be working at EREF in the non-profit arena and learning about this dynamic industry.



Premila graduated with a BA in Psychology and Diploma in French Literature and Language. She loves to travel, has lived in several countries in Asia and Europe, speaks French and enjoys meeting people from different countries and cultures. She is very passionate about helping her community and volunteers her time through her church to help the Raleigh Rescue Mission, Durham Urban Ministries and Stop Hunger Now. Premila also leads the Meal Ministry of All Saints United Methodist Church of Brier Creek, supporting her church family with home cooked meals and visits. Premila lives in Raleigh with her wonderful husband Peter and girls (kitties) Lily and Layla.

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Jane M. Casteline

Project Coordinator

Jane coordinates the activities for EREF's research program, aids with research summit initiatives and will coordinate the direction of EREF's new continuing education program. Her responsibilities include managing the research proposal process, following and implementing EREF's strategic research planning process and communicating research findings to the solid waste community.



Jane has over 11 years of experience in the environmental field and previously worked as a geoscientist for McLaren-Hart and Earth Tech. Beginning in 2004, she began working in the non-profit environmental research foundation arena, starting with the WaterReuse Foundation and then the Water Environment Research Foundation as a project manager and program manager, respectively. She managed projects in water reuse, aquifer storage and recovery (ARS), waste minimization, watershed and water quality, stormwater and decentralized systems. Jane has a bachelor's degree in geology from the University of Kansas and a master's degree in geological sciences from Lehigh University. •

EREF Implements An Intern Program

As part of its effort to expand the foundation's educational mission, the EREF staff has implemented a trial internship program. Two interns were brought on initially. After one left following her college graduation, the staff then welcomed three additional interns, giving us a current total of four. We'd like to introduce you to these outstanding new team members and give you a peek at the work they are doing:

Julia Jackson

Julia was raised in Chapel Hill, North Carolina and graduated from Meredith College (Raleigh) with a bachelor's degree in Environmental Sustainability in May 2011. Her interests for this degree include the conservation of animals and the environment. During Julia's junior year at Meredith, she studied abroad with an environmental studies field school in the rainforest of Queensland, Australia.



Julia was with the EREF team from February – June 2011 and spent most of her time gathering information to develop an industry wide sustainability report, which builds upon and updates EREF's 2001 "Size of the Industry Report," which has been one of the foundation's most requested reports. To date, there has been significant interest by industry professionals, EREF stakeholders, and EREF Board members to update the report. Julia considers her time at EREF to have been a great learning experience not only in the workforce, but also in her degree.

Jessica Stone

Jessica attended college at Eckerd College in St. Petersburg, FL, where she double majored in Environmental Studies and Anthropology and minored in

Biology – and coincidentally worked on the Eco-Clamshell research project funded by EREF. She worked on an archaeological field project on the island of Carriacou in the southern Caribbean the summer before her senior year that really made her want to pursue archaeology. She continued on to get her Master's at NC State in Bioarchaeology (which is the study of human remains from archaeological contexts), where her thesis research involved reconstructing diet at that same site in Carriacou using mostly environmental data. She graduated from that program this past May and will be spending this year teaching forensics at the NC School of Science and Math and preparing to apply for Ph.D. programs. Although she's moved towards working in anthropology, Jessica maintains an underlying interest in the environmental and waste industries because of her experience at Eckerd.



Jessica is picking up where Julia left off on developing an industry wide sustainability report. She is very familiar with the industry and her education gives her a "nose" for data analysis and research.

Lauren Handzel

Lauren graduated from East Gaston High School in Mt. Holly, NC in 2009. She just finished her sophomore year at North Carolina State University (Raleigh) and hopes to graduate in 2013 with a degree in environmental engineering.



Lauren began her internship at EREF in February, and it has been her first career-related job experience. For the past three months she has been assisting with two projects. The first project is aggregating industry and solid waste

composition data, which has been used in multiple presentations at various industry venues including Waste Expo. Lauren's second project involved obtaining information on state and city recycling policies and comparing them to what one could realistically expect to recycle based on waste consumption data. She is currently working on a white paper summarizing her findings.

Jenna Cameron

Jenna is a rising senior at Meredith College (Raleigh) and is majoring in Environmental Sustainability with minors in Communication and Biology. She has proudly made the Dean's List for the past four semesters and plans to keep the trend going! Before joining the EREF team, she interned with the Environmental Division of ARCADIS and gained some very valuable experience.



Jenna's first day with EREF was assisting with the equipment auction at WasteExpo in Dallas where she made a great immediate addition to the team. In addition to assisting with the foundation's various communications vehicles, Jenna is contributing to the development of EREF's continuing education program and collaborated on a recent *Waste Age* article on zero waste/zero landfilling. Jenna feels that the EREF internship opportunity is the perfect match for the combina-

tion of her environmental and communication interests.

Lele Bao

Lele has been studying Environmental Engineering since her freshman year of college. She finished all undergraduate courses at Zhejiang University (China) in three years and came to North Carolina State University (Raleigh) for graduate study in 2009. She is graduating this August with her Master of Science degree in Environmental Engineering. Her research interests lie in solid waste management, with special interests in landfill performance, landfill gas collection and climate issues related to waste management. Her thesis is entitled "Development of Appropriate Monitoring Times for the Biochemical Methane Potential Assay as Applied to Municipal Waste."



Lele will be working on a project gathering information on landfill gas collection data. She will develop a database of every permitted Subtitle D landfill in the U.S. that accepts MSW and identify the manner in which each landfill manages gas (collection and flare, collection and beneficial use, no collection). The collection of this data fills a long standing information gap that will help assess the extent to which gas collection is being beneficially utilized. ●

EREF Receives Grant for Biofuels Project

EREF has received \$93,119 in funding from the North Carolina Biofuels Center (NCBC). The NCBC (www.biofuelscenter.org) was created by the N.C. legislature as the nation's only private non-profit agency working comprehensively for all aspects of biofuels development. Its formation is based on the premise that biofuels provide enormous agricultural, economic and strategic value to the state. EREF received funding from the NCBC for a project entitled, "Utilizing Municipal Solid Waste as a Biofuel Feedstock." The overarching goal of the project, which will be done in collaboration with Maverick Biofuels, North Carolina State University and Waste Industries, is to determine the potential for using Municipal Solid Waste (MSW) as a feedstock for biofuel production by evaluating the mechanisms and infrastructure needed to make this process a viable industry in the state of North Carolina.

The project's specific objectives are as follows:

1. Compare conversion of MSW into biofuels with methods currently being used to generate energy from MSW in the form of electricity or heat, such as land

fill gas to energy, and waste to energy.

2. Summarize MSW management and operational infrastructure and evaluate how it can be used to support needed infrastructure for the biofuels industry.
3. Develop materials from this study to educate the public and policymakers about the biofuel production feasibility/capability using MSW as a feedstock.

"The application for this project was submitted in response to interest from the EREF Board of Directors in seeking funding from non-governmental entities beyond the corporate sector," said Dr. Bryan Staley, EREF's President and Chief Executive Officer. Henry Saint Bris, Senior Vice President of Strategy for Suez Environnement and Chairman of the EREF Board of Directors, noted, "This project seeks to develop ways to utilize waste as a resource via diversion from traditional end-point means. Because EREF's stakeholder base represents the majority of the solid waste industry, the foundation has the ability to leverage these results to support MSW to biofuel conversion technologies in North Carolina and beyond." ●

New Research Grants Awarded in 2011

Five new grants have been awarded by EREF in 2011, totaling nearly \$456,674 in funded research so far this year. The breadth and scope of these projects reflect the foundation's initiative to tackle issues related to traditional end-point waste technologies such as landfills, while at the same time expanding EREF's project focus to include non-landfill oriented solutions for sustainable solid waste management.

International Field Validation of a New IPCC Model for Landfill Methane Emissions

Grantee: University of Illinois-Chicago

Award: \$145,880 over 2 years

It is important for the waste industry, both in the U.S. and internationally, to develop improved, science-based, field-validated methodologies for annual greenhouse gas (GHG) inventory reporting. Based on a high level of U.S. and international interest in improved methods to replace historic landfill methane (CH₄) generation modeling with a model specifically for emissions that includes seasonal CH₄ oxidation, this project is a cost-effective extension and expansion of a 2007-2010 project funded by the California Energy Commission that developed the California Landfill Methane Inventory Model (CALMIM). This model allows for site-specific emissions which can be summed to provide regional inventory data. However, the model includes embedded information that allows its application on a national basis and is not solely limited to California. As a logical follow-up, the work conducted under this EREF grant will facilitate a broader U.S. and international field validation of the CALMIM model to match existing and continuing international datasets for emissions and oxidation, and to assist in fine-tuning the model, as appropriate. The objectives are:

1. To develop an improved landfill CH₄ inventory model for the U.S. by expanded field validation of the CALMIM model using *existing* emissions/oxidation data from U.S. research projects.
2. To develop an improved landfill CH₄ inventory model for international application under the current IPCC National Inventory Methodology for Waste using *existing* field measurements for landfill CH₄ emissions and oxidation by several research groups in Europe, Australia, and Africa.

Development and Application of a Tracer Gas Correlation Technique to Determine Whole Landfill Rates of Methane Emission and Oxidation

Grantee: Florida State University and Cygnus Environmental

Award: \$99,998 over 1 year

The determination of fugitive methane emissions from landfills is a topic of increasing environmental

importance. Approaches for measuring methane emissions such as chamber studies and radial plume mapping with tunable diode laser equipment (such as that recommended by the EPA's OTM-10 method) are not adequate for characterizing the complex terrain and the large area of source emissions such as those from a landfill. This project will utilize a tracer gas correlation technique on down-wind plumes utilizing cavity ring-down spectroscopy. The USEPA is a collaborator on the project to verify and help determine rigorous QA/QC protocols to define the deployment and use of the technique.

The primary objectives of the project are to:

1. Determine optimum weather/environmental conditions for employing this technique.
2. Determine the effect of weather/environmental conditions on results from the technique.
3. Examine methane emissions from landfills in different stages of development, specifically:
 - a. Newly constructed sites prior to gas collection
 - b. Large regional facilities with active gas collection and waste collection
 - c. Closed facilities without gas collection
 - d. Closed facilities with final cover and gas collection
4. In conjunction with the tracer gas technique, collect plume samples for isotopic analysis to determine landfill cover methane oxidation.

The research will result in a reliable, rigorous and inexpensive method for determining and monitoring whole landfill methane emissions.

Revisions to the EIA Manual of Recommended Safety Practices

Grantee: Environmental Industry Associations

Award: \$50,000 over 1 year

In 1999 the EIA release a comprehensive safety manual that was written based on a traditional, compliance-based system. However, since this time many changes have affected the industry including the movement by OSHA and many companies towards performance-based safety solutions. This, coupled with substantial revisions to safety-related ANSI standards since the last update, result in the need for an updated safety manual. The EIA safety manual provides a single, comprehensive resource for employers and employees regarding safety-related issues, including prohibitions and regulatory information. The manual is also one of the prime sources of best practices, which aids in the reduction of fatalities, injuries and accidents in the solid waste industry. The objective of this grant is to provide funding necessary to update the safety manual.

Complete Recycling of Concrete Waste Through Geopolymerization

Grantee: University of Arizona

Award: \$68,021 over 2 years

The U.S. infrastructure is at great risk and in urgent need to be repaired and upgraded, but it is a great challenge to handle the significant amount of concrete waste to be generated by doing so. An ideal solution is complete recycling of the concrete waste and utilization of it in production of new concrete. Currently, however, the recycling of concrete waste in the U.S. is predominately limited to the use of concrete aggregates in low-specification applications such as base course and non-structural fill with the remainder still being landfilled. The few methods proposed for complete recycling of concrete waste require re-clinkering of the hydrated cement in the concrete waste using the standard high temperature cement kiln procedures and thus consume significant amount of energy and release large quantity of CO₂. The major goal of this research is to investigate the feasibility of complete recycling of concrete waste using the innovative geopolymerization technology.

Specifically, the proposed research has the following objectives:

- Systematically study the macro-scale behavior of geopolymeric concrete from completely recycled concrete waste by conducting different mechanical tests.
- Investigate the micro/nano-scale structure and characteristics of geopolymeric concrete from completely recycled concrete waste at different conditions.
- Conduct simulations to explore how micro/nano-scale characteristics affect the macro-scale behavior of geopolymeric concrete from completely recycled concrete waste.

The geopolymerization method evaluated in this project can completely recycle concrete waste without using any ordinary Portland cement (OPC). Successful completion of the project will promote complete recycling of concrete waste in a sustainable way, saving the high monetary and environmental costs related to transportation and disposal of concrete waste, reducing the demand for virgin materials that would need quarrying, and decreasing the use of energy-intensive OPC. Another potential impact is that concrete stockpiled in C&D landfills may be mined for re-constitution via the geopolymerization technique, thus creating a potential revenue source for C&D landfill owners.

Impacts to Public Recycling from Psychological and Technological Stimulus

Grantee: University of Georgia

Award: \$67,775 over 1 year

Technology has a finite point relevant to attaining sustainability. Human behavior must be considered, and is especially relevant in the case of solid waste management where reducing, reusing and recycling of waste all encompass influencing human behavior. The Industrial

Revolution brought us technology, advancement and comfort, all steps in the right direction. However, advanced technology can also create a “disconnection” with nature and the natural world, exacerbate a negative mentality if people don’t understand the connection of, for example, waste collection and management with what actually occurs at a recycling facility or landfill.

Human behavior is a crucial issue related to conserving natural resources and reducing environmental impact, not only because people can directly affect their environment in a positive or negative way, but also because it is still a hard task to commit to by most people. Working in a community in order to achieve a better life for future generations (though it is a moral issue for many), still requires extra effort, and in people’s busy lives, it is practically impossible to put time and effort into solving a problem that is often being managed by large companies and governments. With this in mind, it is not surprising that many individuals do not feel it is necessary to participate in activities such as recycling, and/or water and energy conservation. The lack of commitment by most of the people is a critical component to any waste management approach that depends on community participation and response.

The overall objective of this project is to examine the impacts to recycling in public areas in response to a combination of technological and psychological stimuli. More specifically, the objectives are to:

1. Evaluate the impacts to recycling from the placement of a public ‘smart’ recycle bin engineered with eco-feedback technology.
2. Promote public awareness of smart-bin recycling activities by designing a web portal that aggregates and visualizes recycling data wirelessly collected from deployed smart-bins.
3. Increase public recycling accessibility and encourage recycling by creating a mobile device application that facilitates locating a public recycling bin to deposit a recyclable container or paper.

The research and technology proposed here is very different from the Dream Machine (by Pepsico) concept. This research proposes more flexible, less expensive and customizable (to produce, install and operate) smart bins that will include eco-feedback technology. Instead of a single bin that is the same nationwide, the proposed bin can be made from a current bin that is used at any public location (a bin that the public already recognizes). This means that any solid waste management structure (from collection through disposal), public or private, and any entity can utilize the proposed technology. In addition, this research proposes to encourage and facilitate recycling (using any type of bin) through a mobile application. The nature of this research is very practical and applied, so that a new product would be created and released at the end of the project to *immediately* impact the solid waste industry and the public it serves. •

Scholar Updates

Jooyoung Park
Yale University
EREF Scholar 2010



Waste as Resources: Utilization of Coal Combustion By-products in the United States

Since the past academic year, Jooyoung has been working primarily on two projects related to her doctoral dissertation research.

For her first project, she develops alternative interpretations of waste to promote waste reuse. The current use of the term "waste" imposes negative perceptions on materials even though they can actually be reused, and information about reusability of the material is lacking. New terminology could embody an idea that all materials have inherent value with a possibility of reuse. Recognizing that what realizes the value of a material is the knowledge on how and where to use it, Jooyoung devised a new indicator termed as "reuse potential," which measures the extent of technological development, or how "resource-like" the secondary material is. Based on this research, she created a poster presentation, titled "Re-defining the Concept of Waste for Closed-Loop Material Economies," for the International Conference on Industrial Ecology held in Berkeley, California, in June 2011.

Jooyoung's second project deals with an evolutionary process of waste – how waste materials are transformed into valuable resources with the advance of knowledge. With coal combustion by-products as case materials, she analyzed various patterns for reusing them by examining patent records and exploring underlying causes and effects of technological innovation. The result of this study was presented in the World of Coal Ash Conference, held in Denver, Colorado in May 2011. The title of the presentation was "From Waste to Resource: Examining the Pattern of U.S. Patents for Technologies Reusing Coal Combustion By-products," and the presentation won the best WOCA student poster award.

In addition to these two studies, Jooyoung completed a study on analyzing environmental benefits of reusing coal combustion by-products instead of discarding them in a landfill, based on a life-cycle analysis approach. This study was presented at the Gordon Conference of Industrial Ecology that was held in New London, New Hampshire, in August 2010. With her advisor, Professor Marian Chertow, Jooyoung also performed a meta-analysis that reviewed all documentations on reusing waste and sharing residual heat and secondary effluent among industries in 13 industrial clusters around the world. This phenomenon of inter-firm waste exchanges

Scholarships are awarded by EREF to recognize excellence in master's, doctoral or post-doctoral waste management research and education. Awards to doctoral students are given in memory of Francois Fiessinger, P.E., Ph.D., a graduate of Rutgers University, who was a founding director of the foundation; and by the Environmental Research and Education Foundation. Awards to master's students are given by Robert P. Stearns, P.E., DEE/SCS Engineers, former Chairman of EREF; and by Robert J. Riethmiller/-PTR Baler and Compactor, current Chairman of the Scholarship Committee. More information can be found at www.erefndn.org/index.php/scholarships.

and reuse is known as "industrial symbiosis." By exploring patterns of industrial symbiosis, this study addresses questions regarding what kinds of industrial waste have been reused, how frequently each waste exchange has been observed, and by which industrial sectors each waste has been reused. Understanding such patterns of industrial waste reuse helps to plan and promote further waste reuse practices. This study was published in Chapter 14 of "A Handbook of Waste Management and Recycling," titled "Reusing Non-hazardous Industrial Waste across Business Clusters." Jooyoung will present the result of this research at the 6th International Conference on Industrial Ecology.

Jooyoung is truly grateful to EREF for its financial support to perform these studies.

Carrie Harns
University of Wyoming
Stearns/SCS Scholar 2010



Mechanistic Assessment of the Mobility of Titanium Dioxide and Cerium Oxide Nanoparticles through Municipal Solid Waste Landfill Clay Liners

Nanoparticles contain some fraction of manufactured nanomaterials and are expected to penetrate a wide range of commercial markets, such as electronics, health and fitness, construction and pharmaceuticals. The increased production and use of nanoparticles indicates that manufactured nanomaterials will become prevalent in municipal solid waste (MSW). The overall goal of this project is to determine the ability of existing MSW land-

fills to serve as containment systems for nano-waste products. The objectives of this project are: 1) assess the interfacial interactions between two types of commercial nanoparticles [titanium dioxide (TiO_2) and cerium oxide (CeO_2)] and montmorillonite clay in order to understand the mobility of these materials through landfill liners of similar composition; 2) characterize the modification of montmorillonite clay liner properties following exposure to pristine nanoparticles; 3) characterize the adsorption of heavy metals to the nanoparticles under simulated low redox (landfill) conditions to evaluate their ability to serve as transport vectors across landfill containment systems.

To date, efforts have centered on reviewing the available literature and setting up experimental apparatuses. The focus has been on becoming familiar with nanotechnology in general, and more specifically, the physical and chemical properties of TiO_2 and CeO_2 nanoparticles and their use in consumer products. TiO_2 is photocatalytic, so these nanoparticles have been used in self-cleaning, or anti-fouling, coatings and paints as well as in cosmetics and sunscreens. CeO_2 is used as a catalyst, fuel cell electrolyte, and in polishing agents. Additionally, time has been spent reviewing the literature pertaining to the landfill environment, including leachate characteristics and MSW landfill liner systems. The landfill environment itself (pH, ionic strength, etc.) will likely influence the behavior and mobility of the nanoparticles in these systems. MSW landfills are designed with liner systems (geosynthetic and compacted clay liners) to prevent contamination of soil and groundwater by landfill leachate. While the geosynthetic liner provides an effective barrier to leachate, leaking does occur through defects (seams, punctures, etc.). The compacted clay liner is therefore the final barrier preventing groundwater contamination caused by leaking landfill leachate. Dynamic light scattering (DLS) has been used to determine the size and zeta potential (charge) of the TiO_2 nanoparticles under a variety of solution chemistries (pH, ionic strength and composition). Based on the data collected to date, the average diameter of these nanoparticles was found to be 55.68 nm, and the isoelectric point (pH_{iep}) of these nanoparticles is just slightly above pH 3. Characterization of the CeO_2 nanoparticles has just now commenced.

The experimental work for this project will be in full swing this summer. Sorption isotherm experiments will be conducted to determine the affinity of the nanoparticles for the montmorillonite clay particles. Packed column tests will be used to determine how various concentrations of clay affect the mobility of the nanoparticles through clay-sand mixtures (5, 10, 20, and 25% w/w). Franz cell tests will also be completed to determine the ability of the nanoparticles to diffuse through clay samples. Nanoparticle-humic acid solutions will also be used to determine the effect humic acids (humic and fulvic acids are predominant in landfill environments) have on the size of the nanoparticles (aggregation, stability), as the nanoparticles will likely encounter these substances in

landfill leachate. These studies, along with compaction permeameter tests, will be used to accomplish objective 1.

Paige Griffin
Colorado State University
EREF Scholar 2010



Anaerobic Digesters for Treatment of the Organic Fraction of MSW

Colorado State University has recently developed an innovative, multi-stage approach to anaerobic digestion. As hydrolysis is the rate-limiting step of the digestion process for a number of substrates, optimization of hydrolysis has the potential to radically increase the economic profitability of anaerobic digestion. Currently, there is little understanding of the impact of operating conditions (eg. temperature, ammonia concentrations) on hydrolysis. Paige's research focuses on designing a rapid and cost-effective system to determine hydrolysis rates to ultimately identify optimal operating conditions for reactors. Current efforts are focusing on determining hydrolysis rates for the following operating conditions: temperature, ammonia and total dissolved solids concentrations.

Paige has developed a small-scale batch reactor system that allows for simple anaerobic sampling of liquid and biogas. 140-ml syringes are inoculated with nutrients, digester sludge, and substrate under the appropriate testing conditions. Biogas is collected at constant pressure, and samples are measured for methane content. Liquid samples are extracted via three-way valves and analyzed for total and dissolved chemical oxygen demand, as well as adenosine triphosphate concentration. Hydrolysis rates are determined from these analyses using a first-order kinetic model with an experimental biomass concentration factor.

Batch studies have been conducted using manure as a substrate and inoculum from a wastewater treatment plant anaerobic digester. Kinetic rates with a high coefficient of determination have been obtained for "baseline" conditions (eg. no additional ammonia or salt, native temperature) and varying concentrations of added biomass. Cultures are currently acclimating to the test conditions, as preliminary results showed a need for acclimation to higher concentrations of ammonia and total dissolved solids. To determine rates for thermophilic conditions, Paige has obtained sludge samples from an anaerobic digester operating at 55°C for use as an inoculum. Batch studies will be conducted for each of the specified operating conditions using manure as substrate, and additional studies may be conducted in the future using varying sources of substrate.

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Project Updates

The Fate and Transport of Nanoparticles in Municipal Solid Waste Landfills

Debra Reinhart

University of Central Florida

With the rapid advancement of nanotechnology, there is an exponential growth in manufacturing consumer products containing nanomaterials (NMs). This is due to the fact that NMs exhibit unique properties (physical, chemical, electronic etc.) and behavior that are absent in their bulk 'non-nano' counterpart materials. As the number of consumer products containing NMs increases, so will the quantity of these products being disposed of at landfills at the end of their useful life. An inventory completed by the Project on Emerging Nanotechnologies (Nanotech-Project, 2011) reported that 1,317 nanotechnology consumer products were available in 2010, of which more than 55% products are cosmetics and personal care related. While the nanotech industry is rapidly expanding, the ultimate fate of NPs in the environment (soil, water, air) is largely unknown, thus demanding a thorough investigation of the impact on NPs on the environment.

This research focuses on understanding the fate of NMs within waste environments. The effect on landfill biological processes and fate of NMs upon exposure to leachate is being evaluated. The overall goal of this research is to provide valuable information concerning any potential risks associated with the disposal of NM containing products in landfills.

Zinc oxide (ZnO), nano silver (Ag), and titanium dioxide (TiO₂) were selected based upon their common presence in consumer products currently on the market. This study involves characterization of landfill leachate in the absence and presence of these NMs using standard methods such as 5-day biochemical oxygen demand (BOD₅) and the Standard Test Method for Determining Anaerobic Biodegradation Potential of Organic Chemicals Under Methanogenic Conditions, or BMP test. Decreases in BOD₅ and BMP relative to control samples without NPs would suggest inhibition.

The effect of Zinc Oxide (ZnO) nanoparticles added to leachate at concentrations of 0.1 to 100 mg/L was studied in two different landfill leachates which represent different stages of waste degradation: (a) one classified as middle aged (BOD:COD=0.54), and (b) the other characterized as mature (BOD:COD=0.11). The BOD₅ after

exposure to ZnO nanoparticles was analyzed to determine the rate of disappearance of biodegradable matter. The biodegradation rate for organic materials exposed to each NM concentration was compared statistically, and it was concluded that the biodegradation rates were not dependent on NM concentration. Secondly, overall biogas production and composition produced from BMP tests did not vary substantially over a 90-day period. Therefore, it can be concluded that ZnO, added to both middle aged and mature leachate, does not have inhibitory effects on either anaerobic or aerobic processes. This result may be attributed to the low concentration of dissolved/soluble zinc.

Particle sizes were also evaluated in an attempt to differentiate complexed zinc aggregates and soluble (non-aggregated) zinc. The concentration of zinc by size fraction was completed at Days 7, 30, and 60 for mature leachate containing 100 mg/L ZnO particles. Over time there was an increase in the concentration of zinc present in the fraction less than 200 nm. This fraction may reflect the presence of zinc that is soluble. The increase in the soluble fraction over time can be a result of the wetting properties of ZnO nanoparticles changing as a result of direct interaction with humic and fulvic acids.

Basic studies to understand interaction of humic acid (a major organic component of leachate) with the ZnO nanoparticles is important for the assessment of NM mobility and fate in leachate. Several material characterization techniques

such as high-resolution electron microscopy (HRTEM), fluorescence spectroscopy and FT-IR spectroscopy techniques have been used. The interaction of middle aged leachate and ZnO nanoparticles was characterized through HRTEM, as shown in Figure 1A.

This work, along with systematic fluorescence and FT-IR spectroscopy studies suggest:

- Humic acid is able to strongly adhere to the ZnO nanoparticle surface upon incubation for 7 days.
- Humic acid tends to interact with ZnO nanoparticles to facilitate aggregation of NMs.

The above results suggest that humic acid could mobilize ZnO nanoparticles in leachate, thus making them more susceptible to transport.

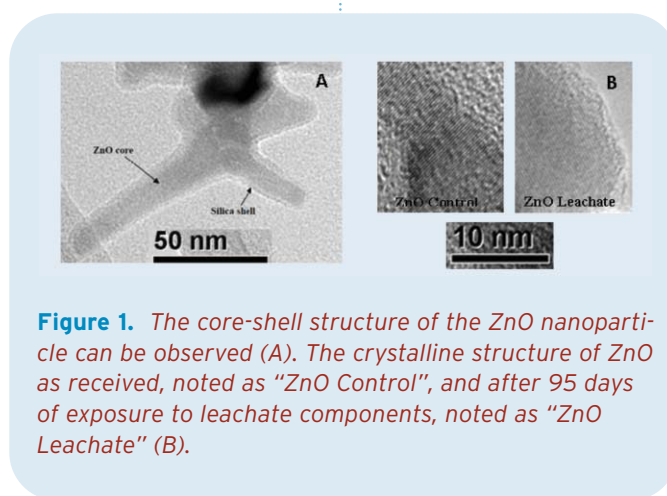


Figure 1. The core-shell structure of the ZnO nanoparticle can be observed (A). The crystalline structure of ZnO as received, noted as "ZnO Control", and after 95 days of exposure to leachate components, noted as "ZnO Leachate" (B).

Development and Application of a Tracer Gas Correlation Technique to Determine Whole Landfill Rates of Methane Emission and Oxidation

Dr. Jeffrey Chanton
Florida State University

Nathan Swan
Cygnus Environmental

It is important to conduct accurate reliable measurements of methane emission from landfills. Default values for fugitive methane emissions that are based upon assumptions that are not based on measured field data, which may result in landfills being categorized as more significant contributors to greenhouse emissions than they actually are.

The objectives of this research project are to:

1. Determine the optimum weather/environmental conditions for employing the tracer gas correlation technique used to measure fugitive emissions. The tracer gas technique was identified as the optimal technique compared to other potential measurement methods in a prior EREF-funded study.
2. Employ the technique to examine methane emissions from landfills in different stages of development specifically focusing on the goals below:
 - a. Newly constructed sites prior to gas collection (if possible to find one without interference from other landfill cells**)
 - b. Large regional facilities with active gas collection and waste collection
 - c. Closed facilities without gas collection

d. Closed facilities with final cover and gas collection

3. In conjunction with the tracer gas technique, collect plume samples for isotopic analysis to determine landfill cover methane oxidation.

Based on this research, it has been determined that environmental conditions impact the quality of measurements made, and that early mornings are the best time to employ the tracer gas technique before the surface of the landfill warms to the extent that fugitive emissions begin to radiate upwards. On hot sunny afternoons, it has been determined that emissions are carried upwards and do not migrate horizontally, which affects measurements made since the instrumentation is on the ground. The optimum wind speeds over which to apply the technique have also been determined.

At large regional facilities, the tracer gas technique is very applicable and agrees well the earlier measurements utilizing a tunable diode laser (TDL) approach as identified in the US EPA's OTM-10 method. However the tracer gas technique is much easier to apply than TDL-based OTM-10. It takes less man-power and gives a whole landfill estimate instead of an estimate for selected cover types only, which has been a criticism of the OTM-10 method. At closed facilities without gas collection, it has been found that methane emission rates are roughly one-half of the EPA default values. In addition, methane oxidation results based on the stable isotope approach consistently indicates methane oxidation through landfills soils averages 30%, which results in 3 times less methane emissions when compared to the 10% default methane oxidation value recommended by the EPA. ●

Significance: The understanding of NP fate and behavior in leachate will aid in developing any necessary approaches in the management of nanoparticle containing leachate. Additional data from this research will help regulatory agencies addressing any potential nanotoxicological issues. ●

Integrated Solid Waste Management and Its Environmental Sustainability in a Carbon Constrained Environment

Ranji Ranjithan, Joe DeCarolis and Morton Barlaz
North Carolina State University

It is expected that some form of climate change mitigation policy will be enacted in the near future. As a result, the cost of energy (e.g., electricity, gasoline, and diesel) will increase and this has implications for the economics of solid waste management. Analysis of the effects of alternate climate change mitigation policies is

required to determine the most cost effective way to manage solid waste in the future.

The goal of this research is to develop a life-cycle assessment (LCA) model capable of analyzing solid waste management performance – at both the individual process (e.g., collection, landfill) and integrated system levels – taking into account implications of greenhouse gas (GHG) mitigation policies and competing objectives of solid waste management (e.g., costs, emissions, and diversion targets). The LCA model will allow users to estimate the costs, energy use, emissions, and environmental impacts associated the processes (e.g., collection, separation, waste-to-energy, composting, anaerobic digestion, landfilling) that make up the solid waste management system. Furthermore, an integrated life-cycle optimization model is being developed that will allow a user to determine the best way to manage

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waste in order to minimize the costs, energy use, emissions, or environmental impacts associated with the entire integrated waste management system.

These optimization models, in the form of stand-alone Excel spreadsheets, are being developed for each solid waste process. Each spreadsheet relates the emissions (e.g., CO₂, CH₄, NO_x, SO_x, CO, particulate matter, etc.) associated with a process to the waste quantity and composition. These spreadsheets will make it possible to study how changes to a process can alter the environmental performance. For example, what is the savings in CO₂ emissions for a more efficient collection vehicle? Ultimately, these spreadsheet models will be combined into a complete solid waste systems model in which a user can search for management strategies that minimize cost or a specified environmental impact such as global warming potential.

The first of the spreadsheet models are nearly complete (recycling, composting, anaerobic digestion) and will be posted on a project web site by the end of 2011. Future plans are to use the model to address the following issues:

1. Quantify the increased costs associated with various solid waste management processes due to different GHG mitigation policies, including anticipated policy-induced energy price changes.
2. Evaluate changes in integrated waste management strategies (i.e., waste flows and process choices) that most effectively respond to different GHG mitigation policies.
3. Quantify the effects of GHG mitigation policies and related energy price changes on other solid waste related environmental impacts (e.g., smog formation and acidification).

Quantifying Capture Efficiency of Gas Collection Systems with Gas Tracers

Byunghyun Han, Ramin Yazdani, Paul Imhoff, and Don Augenstein
University of Delaware

There is a critical need for methods to quantify methane capture efficiency from landfill gas (LFG) collection systems. The primary objective of our work is to develop a new approach that directly quantifies the gas collection efficiency of particular well designs and/or landfill management practices.

A field test site was established at Yolo County Central Landfill (Woodland, CA) to develop this method. A plan view of the test region and a cross-sectional view of the tracer injection wells are shown in Figure 2. A known amount of a gas tracer is injected at any of the monitoring wells near a standard vertical LFG collection well in a region with an intermediate soil cover (~ 1 ft of soil). The gas extracted from the LFG well is sampled automatically using a field-portable gas analyzer to quantify concentrations of the injected tracer. A typical breakthrough curve is shown in Figure 3. The amount of gas tracer collected is determined and collection efficiency is determined by

Modernizing Models and Data on Methane Production from Landfills

Morton A. Barlaz
North Carolina State University

There have been changes in both the operation of landfills and in waste composition since the EPA developed default model parameters for its landfill gas emissions model (LandGEM). The accuracy of this model is important as it guides landfill owners on appropriate investments in gas recovery equipment, and is also used to estimate greenhouse gas emissions. The objective of this project is to develop an improved data set and model to predict methane production from U.S. landfills. It is thought that by the acquisition and analysis of current data on landfill gas, improved estimates for the decay rate (*k*) and methane yield (*L₀*), two key input parameters that are used in LandGEM, can be provided. In addition to improved estimates of *k* and *L₀*, whether or not alternate model formulations provide improved predictability will be considered.

To date, 5 landfills have been visited and data analysis is in progress and the process of identifying landfills for data analysis is ongoing. As such, inquiries for potential site visits are welcomed as efforts are made to identify landfills with the highest quality data sets. Data requirements include:

1. Records of gas volume and methane composition for at least 5 years,
2. The mass and types of waste received, which can broadly be classified as containing significant biodegradable material (e.g., residential, commercial, institutional waste) as opposed to inert material (e.g., ash, contaminated soil), and
3. The history of cover type and gas well installation that will be used to estimate gas production rates from gas collection data.

Finally, uncertainty in model predictions will be characterized such that the results can be used to predict how much gas can be generated with a particular degree of certainty, such as noting there is an 80% chance that a landfill will generate for example, 4000 cfm, and a 90% chance that the landfill will generate 3200 cfm. Ultimately, the project will provide a more robust way to analyze landfill gas generation. •

comparing the known injected tracer mass with the amount of gas collected.

A series of tests were conducted to determine the LFG collection efficiency based on the distance from the extraction well and suction measured at the point of injection. Regardless of distance from LFG extraction well,

if suction at the injection point was measurable, LFG collection efficiency averaged 95%. The excellent gas collection was likely due to the high water content of the soil cover (measured in the field) that hindered upward gas movement. Collection was poor only in regions where gas pressures were above atmospheric, which was attributed to perched water in the refuse that hindered gas flow to the extraction well.

Significance: These results suggest that if the cover has low gas permeability, as likely occurred here because of high water contents, LFG collection efficiency is near 100% in regions with measurable gas suction. This field testing system may be employed to directly measure LFG collection efficiency at other landfills with other well designs or management practices. ●

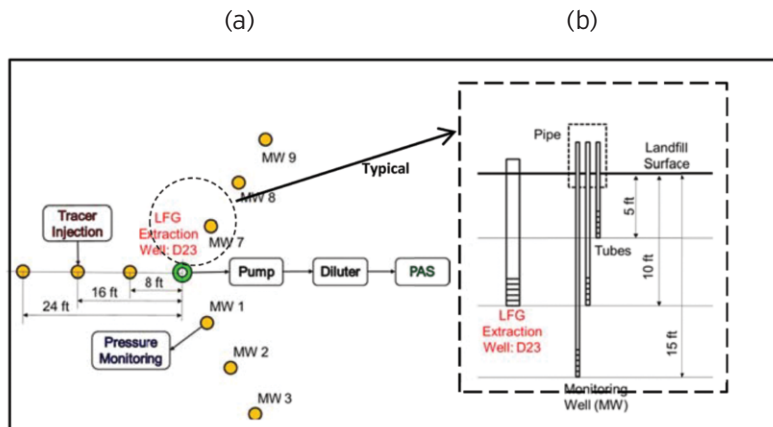
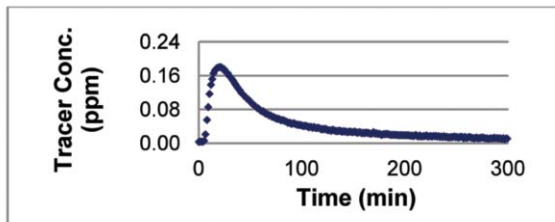


Figure 2 (above). Layout of field site: (a) plan view showing location of gas extraction well (center) and monitoring wells, and (b) cross section illustrating nested tubes for pressure measurement and tracer injection at each monitoring well.

Figure 3 (left). Tracer concentrations measured in the LFG extraction well as a function of time. The area under this curve \times gas flow rate = tracer mass collected.

Scholar Updates (continued from page 15)

James Levis
North Carolina State University, Ph.D.
Francois Fiessinger Scholar 2009



The Effects of Climate Change Legislation on Solid Waste Management Operations

The award of the Fiessinger Doctoral Scholarship has provided Jim with great opportunities over the course of the last year to further his research. His time has been productive and he is pleased to report that he has authored three manuscripts published in various peer-reviewed journals. The first entitled "Assessment of the state of food waste treatment in the United States and Canada" was published in *Waste Management* in August 2010 and evaluated current food waste treatment infrastructure in the U.S. and Canada. The second, entitled "Quantifying the Greenhouse Gas Emission Reductions Associated with Recycling Hot Mix Asphalt" describes life-cycle assessment research of waste hot-mix asphalt and was published in *Road Materials and Pavement Design* in April. Finally, a paper entitled "Is Biodegradability a Desirable Attribute for Discarded Solid Waste? Perspectives from a National Landfill Greenhouse Gas Inventory Model" describing the global warming impacts of discarding biodegradable materials in landfills was published in *Environmental Science & Technology* in May. An additional manuscript describing a life-cycle assessment of food waste management alternatives is currently under second revision with

Environmental Science & Technology.

In addition to working on publications, during the past year Jim presented his research at the Global Waste Management Symposium in October 2010 and at EREF's Regional Summit in April. He also prepared two presentations for the Environmental and Water Resources Institute Congress in May. The first presentation described a solid waste life-cycle optimization framework, and the second presentation reviewed the greenhouse gas emissions associated with composting and landfilling yard wastes. Earlier this month he presented additional life-cycle optimization work at the 2011 Association of Environmental Engineering and Science Professors (AEESP) Education & Research Conference.

In December 2010, Jim passed his preliminary examinations for his Ph.D., allowing him to continue his research focusing on further development of a mixed-integer linear programming modeling framework for multi-stage optimization of solid waste management systems. Additional research time has been spent developing life-cycle process models, as well as a comprehensive model interface. Jim feels very fortunate to have been awarded this scholarship which has greatly benefitted his research and helped him make considerable progress towards the completion of my Ph.D. He intends to continue this scope of research with hopes to graduate next May. ●