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FEBRUARY 2, 2018 · PURDUE UNIVERSITY · WEST LAFAYETTE, INDIANA

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PURDUE ENGINEERING

ENVIRONMENTAL AND ECOLOGICAL ENGINEERING

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KEYNOTE SPEAKER

PEDRO J. ALVAREZ

PH.D., P.E., BCEE

RICE UNIVERSITY

2:30 P.M.
FOWLER HALL, STEWART CENTER

BIOGRAPHY:

Pedro J. Alvarez is the George R. Brown Professor of Civil and Environmental Engineering at Rice University, where he also serves as Director of the NSF ERC on Nanotechnology-Enabled Water Treatment (NEWT). His research interests include environmental implications and applications of nanotechnology, bioremediation, fate and transport of toxic chemicals, water footprint of biofuels, water treatment and reuse, and antibiotic resistance control. Pedro received the B. Eng. Degree in Civil Engineering from McGill University and MS and Ph.D. degrees in Environmental Engineering from the University of Michigan. He is the 2012 Clarke Prize laureate and also won the 2014 AAEES Grand Prize for Excellence in Environmental Engineering and Science. Past honors include President of AEESP, the AEESP Frontiers in Research Award, the WEF McKee Medal for Groundwater Protection, the SERDP cleanup project of the year award, and various best paper awards with his students. Pedro currently serves on the advisory board of NSF Engineering Directorate and as Associate Editor of Environmental Science and Technology.

Nanotechnology-Enabled Water Treatment:
A Vision to Enable Decentralized Water Treatment and Address Growing Challenges of the Water Energy Nexus

Through control over material size, morphology and chemical structure, nanotechnology offers novel materials that are nearly "all surface" and that can be more reactive per atom than bulk materials. Such engineered nanomaterials (ENMs) can offer superior catalytic, adsorptive, optical, quantum, electrical and/or antimicrobial properties that enable multi-functional technology platforms for next-generation water treatment. This presentation will address emerging opportunities for nanotechnology to improve the selectivity and efficiency to remove priority pollutants, decrease electrical energy requirements, and meet a growing need for safer and more affordable decentralized water treatment and reuse. Because water is by far the largest waste stream of the energy industry, we will also discuss technological innovation to enable produced water reuse in remote (off-grid) oil and gas fields, to minimize freshwater withdrawal and disposal challenges. Examples of applicable nano-enabled technologies include fouling-resistant membranes with embedded ENMs that allow for self-cleaning and repair; capacitive deionization with highly conductive and selective electrodes to remove multivalent ions that precipitate or cause scaling; rapid magnetic separation using superparamagnetic nanoparticles; solar-thermal processes enabled by nanophotonics to desalinate with membrane distillation; disinfection and advanced oxidation using nanocatalysts; and nanostructured surfaces that discourage microbial adhesion and protect infrastructure against biofouling and corrosion. We envision using these enabling technologies to develop compact modular water treatment systems that are easy to deploy and can treat challenging waters to protect human lives and support sustainable economic development

CONFERENCE SCHEDULE

TIME	Event	
9:00 - 9:30 am	Registration *Ross Ade Pavilion 1st floor – Lobby* *(850 Steven Beering Drive, West Lafayette, IN 47906)*	
	Parallel Presentation Session: Sustainability and Energy-Water Nexus *Ross Ade Pavilion 3rd floor North - Shively Club* *Moderator: Dr. Gamini Mendis*	**Parallel Presentation Session: Endocrine Disrupting Compounds** *Ross Ade Pavilion 5th floor North - Buchanan Room* *Moderator: Ms. Alysha M. Helmrich*
9:30 – 9:50 am	Sustainable Manufacturing **Dr. John W. Sutherland**	Poly/Per-fluoroalkyl Substances: Highlights on Source, Fate and In-situ Potential **Dr. Linda S. Lee**
9:50 – 10:10 am	Analyzing the Energy-Water Nexus in the Built Environment **Dr. Ashlynn S. Stillwell**	Brief Overview on the Endocrine Disrupting Toxicity of Per/polyfluoroalkyl Acids **Dr. Maria S. Sepulveda**
10:10 – 10:30 am	The Role of Phosphorus Recovery in Advancing FEW System Resilience in Corn Belt Watersheds **Dr. Roland D. Cusick**	Developmental Origins of Toxicity of the Endocrine Disrupting Herbicide Atrazine **Dr. Jennifer L. Freeman**
10:30 – 10:40 am	Break	
	Parallel Presentation Session: Stormwater and Environmental Quality *Ross Ade Pavilion 3rd floor North - Shively Club* *Moderator: Dr. Gamini Mendis*	**Parallel Presentation Session: Wastewater Treatment** *Ross Ade Pavilion 5th floor North - Buchanan Room* *Moderator: Ms. Alysha M. Helmrich*
10:40 - 11:00 am	Stormwater Biogeochemistry in Urban Stream Networks **Dr. Sara McMillan**	Adopting Innovative Stormwater Treatment Practices through Computational Fluid Dynamics (CFD) Simulation **Dr. David Spelman**
11:00 – 11:20 am	A Soft-sensor Software Application for Environmental Data: Examples from Water Resources **Dr. Junjie Zhu**	Renewable Enzyme Biocatalysis for Treating Emerging Contaminants in Water Reclamation and Reuse **Dr. Na Wei**
11:20 – 11:40 am	Catalyzed by Citizen and Practitioner Requests: Water Pipe Repairs Bring Public Health and Occupational Exposure Risks **Dr. Andrew J. Whelton**	Solar-TiO_2 Nanoparticles Enabled Degradation of Carbamazepine: An Energy Efficient Immobilization Technique **Dr. A. G. Agwu Nnanna**
11:40 am – 12:30 pm	Lunch *Ross Ade Pavilion 3rd floor South - Shively Club*	
12:30 – 2:00 pm	Poster Session *Ross Ade Pavilion 5th floor South - Mingling area*	
2:00 – 2:30 pm	Free Shuttle Bus Transportation to Fowler Hall at the first floor of Stewart Center *(128 Memorial Mall, West Lafayette, IN 47907)*	
2:30 – 3:30 pm	**KEYNOTE PRESENTATION: NANOTECHNOLOGY-ENABLED DECENTRALIZED WATER TREATMENT AND ADDRESS GROWING CHALLENGES OF THE WATER ENERGY NEXUS** **DR. PEDRO ALVAREZ**	
3:30 – 3:40 pm	Q & A	
4:00 – 4:30 pm	Free Shuttle Bus Transportation Back to Ross Ade Stadium	

ABSTRACTS OF PARALLEL PRESENTATION SESSIONS

Parallel Presentation Session: Sustainability and Energy-Water Nexus

Sustainable Manufacturing

9:30 – 9:50 AM ***Ross Ade Pavilion 3rd floor North - Shively Club***

Dr. John W. Sutherland, Professor and Fehsenfeld Family Head
Environmental and Ecological Engineering, Purdue University

Environmental engineers have historically been asked to clean up the problems created by other engineering disciplines. While such efforts serve to protect the environment and human health, they often do so at great cost. A better approach is to not create the problems in the first place. Sustainable manufacturing seeks to create products with processes and production systems that minimize negative environmental impacts and require a minimum of amount of energy and natural resources. This presentation will examine the origin of sustainable manufacturing and discuss several real-world examples.

Analyzing the Energy-Water Nexus in the Built Environment

9:50 – 10:10 AM ***Ross Ade Pavilion 3rd floor North - Shively Club***

Dr. Ashlynn S. Stillwell, Assistant Professor
Civil and Environmental Engineering, University of Illinois at Urbana-Champaign

Energy and water resources are closely related, especially in urban environments. The urban water cycle requires energy for disinfection and distribution of drinking water, end-use water heating, and treatment of wastewater. Similarly, providing energy for urban environments requires water for thermoelectric power plant cooling and extracting, processing, and refining conventional and unconventional liquid fuels. This work explores the urban energy-water nexus at both the city scale and within the residential household. Results are pertinent for advancing toward the goal of water and energy sustainability via large-scale benchmarking and small-scale investments.

The Role of Phosphorus Recovery in Advancing FEW System Resilience in Corn Belt Watersheds

10:10 – 10:30 AM ***Ross Ade Pavilion 3rd floor North - Shively Club***

Dr. Roland D. Cusick, Assistant Professor
Civil and Environmental Engineering, University of Illinois at Urbana-Champaign

Grain production in Midwestern states that make up the Corn Belt is reliant on highly interconnected food (F), energy, (E) and water (W) systems. Grain production practices and subsequent utilization for animal production, food processing and ethanol production have pervasive effects on water quantity and quality in downstream environments, both locally and nationally. Nutrient loads accelerate vegetative growth, disrupt ecosystems, and increase water treatment costs. Recent increases in corn-based ethanol production in the Corn Belt has spurred much needed economic development in rural areas but also exacerbated existing regional resource constrains. Extracting phosphorus (P) from grain processing facilities and wastewater treatment plants through chemical precipitation could reduce point source pollution while providing a renewable supply of slow-release fertilizer to local producers. While the potential of P recovery is clear, several challenges remain to realizing the benefits of circular P flows in the Corn Belt. Challenges to P recovery from waste streams include understanding how solution chemistry can influence the rate of P removal and recovery, mineral phase of recovered P, and plant specific benefits associated with precipitation. Fostering reuse of recovered P fertilizers for grain production will require a detailed assessment of the agronomic value, and pollution reduction benefits, of waste derived slow-release products.

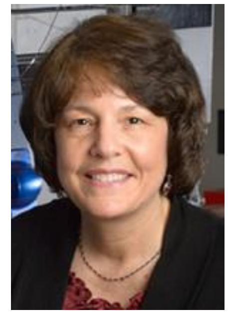
Parallel Presentation Session: Trace Organics and Toxicity

Poly/Per-fluoroalkyl Substances: Highlights on Source, Fate and In-situ Potential

9:30 – 9:50 AM ***Ross Ade Pavilion 5th floor North - Buchanan Room***

Dr. Linda S. Lee, Professor and Associate Head, Courtesy appointment in Environmental and Ecological Engineering and Program Head of Ecological Science and Engineering Interdisciplinary Program

Agronomy, Purdue University



Per/polyfluoroalkyl substances (PFASs) have been widely used as commercial or industrial products. The heat stability PFASs and their ability to block oxygen and suppress volatile vapors from flammable solvents resulted in their common use in aqueous film-forming foams (AFFFs) amenable to fighting even the toughest fires. Training with AFFFs at military fire-fighting training areas for more than 30 years has resulted in repeated short-term releases of AFFFs at nearly 600 military sites in the United States. Per/polyfluoroalkyl acids (PFAAs) such as of perfluorooctane sulfonate (PFOS) and perfluorooctanoic acid (PFOA) are being found in groundwater associated with military fire-fighting as well as in potable water groundwater sources from multiple sources globally at levels above USEPA Provisional Health Advisory values. Suspected PFAS sources in water supplies range from land applied biosolids, storm runoff, leaky landfills, public fire-fighting activities, and industrial spills and dumping. Many PFAAs are terminal end products of microbial degradation of precursor PFASs present in commercial products and AFFFs, thus biodegradation-enhanced remediation of legacy contaminants at military sites subsequently can lead to increase concentrations of PFAAs. Traditional abiotic technologies do little to nothing to reduce PFAAs, particularly PFOS, especially technologies most amenable to in-situ remediation. A brief overview of PFAS sources and biotransformation pathways of PFASs to PFAAs will be presented along with highlights from our recent work in evaluating abiotic in-situ remediation technologies of PFAAs.

Brief Overview on the Endocrine Disrupting Toxicity of Per/polyfluoroalkyl Acids

9:50 – 10:10 AM ***Ross Ade Pavilion 5th floor North - Buchanan Room***

Dr. Maria S. Sepulveda, Professor and Associate Head for Research

Forestry & Natural Resources, Purdue University

Per/polyfluoroalkyl acids (PFAAs) are an emerging group of organic pollutants. Widespread use along with volatility of some PFAAs has led to global distribution in soils and surface waters. The chemical stability of these compounds assures persistence in the environment, with unknown effects to much of the chronically-exposed biota. Many toxicology studies implicate PFAAs in disruption of thyroid hormone, which is also known to play a major role in control of metamorphosis in amphibians. Thus, amphibians represent a class of organisms that may be susceptible to sub-lethal effects due to PFAA exposure. In this study, we examined the effects of aqueous exposure of four different PFAAs at environmentally-relevant doses (ranging from 10-1000 ppb) on larvae of three species: northern leopard frogs (*Rana pipens*), eastern tiger salamanders (*Ambystoma tigrinum*) and American toads (*Anaxyrus americanus*). The OECD amphibian metamorphosis assay (Test 231) was used as a guideline for these experiments. Tadpoles were exposed for 10 days of accumulation followed by a 22-day chronic exposure. Length, mass, and time to metamorphosis were compared between control and treatment groups. In addition, histopathology of the thyroid glands of control and treatment animals from both species were examined at the conclusion of each experiment. Of the chemicals tested, perfluorooctane sulfonate (PFOS) was found to accumulate to the highest levels (peak bioconcentration factor, BCF, values ranging from 58.5 to 240.9, depending on exposure concentration) and had the highest half-life (t1/2) of 3.08 d. Similar patterns were seen with perfluorooctanoic acid (PFOA) and perfluorohexane sulfonate (PFHxS), but BCF values were < 10 followed by depuration during the exposure phase (BCF < 1) and rapid clearance of the chemicals during the depuration phase (t1/2 ≈ 0.25d). 6:2 fluorotelomer sulfonate (6:2FTS) was found to accumulate to similar levels compared to PFOA and PFHxS (peak BCF = 7.62), but had a half-life similar to that of PFOS (t1/2 = 4.28 d). Importantly, delayed development and decreased body condition were observed in salamanders and frogs, starting at the lowest concentration tested. Overall, these results mirror patterns seen in other studies with other model species: PFOS body burdens reach much higher levels than other PFAAs. The mechanisms behind the delayed growth are being investigated using a battery of tools including thyroid histopathology, thyroid hormone levels and changes in expression of thyroid-related genes.

Developmental Origins of Toxicity of the Endocrine Disrupting Herbicide Atrazine

10:10 – 10:30 AM ***Ross Ade Pavilion 5th floor North - Buchanan Room***

Dr. Jennifer L. Freeman, Associate Professor
Health Sciences, Purdue University

It is now well accepted that there are windows of enhanced susceptibility to environmental chemical exposures during critical periods of development and that developmental chemical exposure can influence the onset of adult disease and dysfunction. Ongoing studies are defining the genetic and epigenetic mechanisms of toxicity of an embryonic exposure to the herbicide atrazine and assessing the later in life adverse health outcomes from this developmental chemical exposure using the zebrafish model system. Atrazine is a herbicide commonly applied to agricultural areas throughout the Midwestern United States and is a common contaminant of potable water supplies. Atrazine is regulated by the United States Environmental Protection Agency with a Maximum Contaminant Level (MCL) of 3 ppb (Âµg/L) in drinking water. Atrazine is implicated as an endocrine disrupting chemical and there are questions on health hazards at concentrations near the MCL. For this study, zebrafish, a common biomedical research animal model system, were exposed to 0, 0.3, 3, or 30 ppb atrazine shortly after fertilization through the end of embryogenesis. Transcriptomic profiles immediately following the embryonic atrazine exposure identified expression alterations in genes associated with neuroendocrine function, cell cycle regulation, and carcinogenesis with morphological alterations observed in larvae from all three atrazine treatments. Using this transcriptomic data as a guide, various endpoints along the hypothalamus-pituitary-gonadal axis were evaluated in adults exposed to atrazine only during embryogenesis and in their progeny. This study supports atrazine as an endocrine disrupting chemical causing reproductive dysfunction; behavioral changes; and molecular, pathological, neurotransmitter, and hormonal alterations in adult zebrafish exposed only during embryogenesis coupled to morphological alterations in their offspring.

Parallel Presentation Session: Stormwater and Environmental Quality

Stormwater Biogeochemistry in Urban Stream Networks

10:40 – 11:00 AM ***Ross Ade Pavilion 3rd floor North - Shively Club***

Dr. Sara McMillan, Assistant Professor
Agricultural and Biological Engineering, Purdue University.

Urbanization reduces infiltration and efficiently routes excess precipitation to receiving streams, resulting in elevated peak flows and lower residence times in river networks. Nutrient loads from urban areas and piped collection systems often bypass riparian zones leading to even greater nutrient export. Changing climate regimes are expected to change precipitation patterns resulting in higher peak flows leading to increased streambank erosion and channelization, and decreased residence times. Together, these reduce the capacity for biologically active headwater streams to attenuate nutrient loads. Stormwater control measures (SCMs, e.g., ponds & wetlands) have the potential to improve these conditions through reduction of scouring peak flows and changing water chemistry. Because performance monitoring typically ends at the outlet, the impact on ecosystem structure and function within the river network remains unknown. To address this gap, we monitored four small urban watersheds to quantify patterns of nutrient export during a range of storm sizes and measured denitrification as an indicator of ecosystem function. In all watersheds, SCMs were transformers of stream water chemistry. In the two urban sites, lower solute concentrations in SCM outflow reduced instream concentrations below the stream-SCM confluence. However, in the suburban watersheds, we were unable to empirically separate the effects of impervious surface runoff and mitigation because an increase in developed/impervious area coincided with addition of SCMs. We observed longitudinal increases in denitrification, which coincided with inputs of additional SCMs along the stream reach. Further, denitrification measurements showed that SCMs have greater potential to enhance rates at low levels of total imperviousness. Our results suggest that particularly in watersheds with low TI, SCMs may act synergistically to reduce runoff and pollutant loads within the watershed as well as enhance in-stream processes.

A Soft-sensor Software Application for Environmental Data: Examples from Water Resources

11:00 – 11:20 AM ***Ross Ade Pavilion 3rd floor North - Shively Club***

Dr. Junjie Zhu, Adjunct Assistant Professor

Civil, Architectural and Environmental Engineering, Illinois Institute of Technology

Although data acquisition is critical to provide an effective process controls in water and wastewater treatment industries, much of the required information is difficult or expensive to measure by conventional hard sensors. To address this issue, we have been investigating an alternative data acquisition method based on soft sensors, which can be used to predict needed information based on historical data and easily-acquirable real-time information. Advantages of soft sensors include low cost, fast response times, and the ability to work in parallel or integrated with hard sensors to enhance process control reliability. Soft sensors also have other advantages that conventional hard sensors do not have, including the ability to predict future information, the ability to detect measurement errors, and adaptive learning. Proper management of missing data is critical to soft-sensor applications, but current data management methods can affect covariance and correlation (such as replacement methods) and some of them typically require intensive computations (such as imputations). We developed a simple and effective approach, iterated stepwise multiple linear regression (ISMLR), to evaluate and retain appropriate data for use in an MLR prediction model. From that initial work, a MATLAB-based ISMLR software application was recently developed, featuring reduced computation time and options that allow users to adjust parameters for different conditions. This presentation features one example for predicting the current day's influent ammonia ($R^2 = 0.84$) at the MWRDGC Calumet WRP, and one example to predict future UVA ($R^2 \sim 0.94$) in the Illinois Fox River.

Catalyzed by Citizen and Practitioner Requests: Water Pipe Repairs Bring Public Health and Occupational Exposure Risks

11:20 – 11:40 am ***Ross Ade Pavilion 3rd floor North - Shively Club***

Dr. Andrew J. Whelton, Assistant Professor

Environmental and Ecological Engineering and Civil Engineering, Purdue University

Sanitary sewer and storm sewer water pipe repairs are increasingly being completed with cured in place pipe (CIPP) technology. CIPPs are plastic pipes chemically manufactured inside existing damaged pipes. CIPPs are being installed by municipalities nationwide because it helps avoid costly pipe replacement activities (i.e., road closures, building repairs). Reports have shown that this practice can release chemicals into the air at the worksite and into nearby buildings including day care centers, schools, office, and residential buildings. For some incidents, the administration of medical care, building evacuations, and building decontamination has been needed. At present, little information is available about chemical emission into air and water by CIPP installation activities. Results of two nationally significant CIPP chemical emission studies will be presented. One RAPID National Science Foundation funded study and another study supported by six state transportation agencies. Recommendations for the public, health officials, worker safety agencies, municipalities, regulatory agencies, and researchers will be provided.

Parallel Presentation Session: Wastewater Treatment

Adopting Innovative Stormwater Treatment Practices through Computational Fluid Dynamics (CFD) Simulation

10:40 – 11:00 AM ***Ross Ade Pavilion 5th floor North - Buchanan Room***

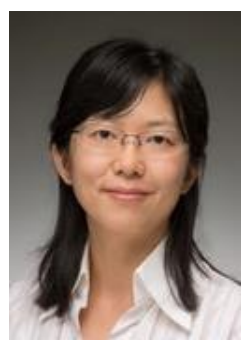
Dr. David Spelman, Assistant Professor
Civil Engineering and Construction, Bradley University

Stormwater runoff and nonpoint source pollution have the potential to cause harm to human health and receiving water body ecology due to associated nutrient, metal, and organic loads. The transport of sediment in stormwater flows is of particular concern given that particulate matter acts as a mobile substrate for constituents through partitioning. The design and regulation of engineered systems to store and treat runoff, largely through separation of suspended particulate, is challenged by a lack of predictive capability in comparing design alternatives for effectiveness in reducing effluent loads. Further complication is embedded in the variety of environmental conditions under which treatment systems such as sedimentation basins are implemented, resulting in the necessity of unique solutions in different geographic regions. A study of the environmental conditions that affect unit operation performance was performed alongside the development of novel modeling methods, which allow for the prediction of long-term effluent loads. Computational fluid dynamics simulation was used to analyze the interaction between internal basin hydrodynamics and particle transport. By normalizing basin behavior to hydrologic, granulometric, and temperature conditions, particulate matter separation efficiency was demonstrated to be portable for individual treatment systems. Stepwise-steady modeling methods show promising utility and accuracy in efficiently modeling long-term unit operation behavior. Large detention basins and small unit operations were found to require different modeling considerations and methods, with additional research needed in the simulation of large systems. The results of this study demonstrate an encouraging outlook for the use of novel modeling methods including computational fluid dynamics in the design, analysis, and regulation of stormwater sedimentation basins. Continued application of the presented models as well as integration into hydrologic software packages has the potential to revolutionize the treatment of runoff.

Renewable Enzyme Biocatalysis for Treating Emerging Contaminants in Water Reclamation and Reuse

11:00 – 11:20 AM ***Ross Ade Pavilion 5th floor North - Buchanan Room***

Dr. Na Wei, Assistant Professor
Civil and Environmental Engineering and Earth Sciences, University of Notre Dame



Enzymes, which are natural, highly efficient biological catalysts that can degrade toxic compounds to environmentally benign products, are a promising platform for the development of advanced treatment technologies for water reclamation and reuse. However, using enzymes in solution as additives for water treatment is not suitable and economical due to short enzyme lifetimes, non-reusability or renewability, and high cost of single use. Conventional enzyme immobilization has critical drawbacks including potential conformational changes of the enzyme that result in loss of enzyme functionality, and costly and time-consuming protein purification. Using synthetic biology and protein engineering approaches, we develop a new type of surface-display enzyme biocatalysts that have unique advantageous features to overcome the above-mentioned drawbacks. We have shown that surface display of fungal laccase on Baker's yeast cells can ensure the enzyme functionality while enhancing stability and enabling reuse. More importantly, the biocatalyst can be easily regenerated through cell cultivation, without need for time-consuming and expensive protein purification. *Renewability* is assured by the ability to generate and automatically localize the enzyme of interest on the surface of biological cells through engineered biological machinery. Furthermore, we have demonstrated the fabrication of biocatalytic membranes using ink-jet printing technology that deposits the surface display biocatalysts on membranes in a rapid and controllable manner while retains cell viability and functionality. Being at the interface of fundamental science and applied technology, the research will potentially lead to an efficient, robust and renewable biocatalytic technology as an innovative advanced treatment alternative for treating persistent organic contaminants in water reclamation and reuse. It is worth noting that the cell surface display platform system is highly modular: by changing the target enzymes for expression, renewable biocatalysts with different new functions of interest would be created and applied for many beneficial biotransformation purposes relevant to other components at food-water-energy nexus.

Solar-TiO_2 Nanoparticles Enabled Degradation of Carbamazepine: An Energy Efficient Immobilization Technique

11:20 – 11:40 am ***Ross Ade Pavilion 5th floor North - Buchanan Room***

Dr. A. G. Agwu Nnanna, PE, Professor and Head

Purdue Water Institute and Department of Mechanical and Civil Engineering, Purdue University Northwest

Under ultraviolet (UVC) irradiation conditions, TiO_2 nanoparticles in suspension has potential to degrade pharmaceutical contaminants in water. The major drawback in this approach is that it requires expensive filtration techniques to separate the suspended nanoparticles from the treated water. To avoid this challenge and improve recoverability or reusability of the catalyst, TiO_2 has been immobilized on different types of supports. TiO_2 immobilized on substrates requires high temperature for adhesion which could affect the catalyst crystalline structure and photo-activity. The aim of this study is to develop an energy efficient technique for immobilization of catalyst TiO_2 on a low cost Polymethylmethacrylate (PMMA) substrate for the degradation of a recalcitrant Carbamazepine in a batch reactor. Here, we immobilized the TiO_2 at low temperature hence preserving the catalyst crystalline structure, photo-activity, recoverability, and reusability. The immobilized photocatalyst was characterized using EDS, AFM and SEM. The TiO_2 film was observed to be evenly distributed with an average thickness of 14μm after the third coating. The effects of natural organic matter (NOM) using actual waste water effluent matrix, catalyst structure and immobilized surface areas were studied under UVC irradiation. Reaction Kinetics of the photodegradation was also studied and a correlation between reaction rate constant and immobilized surface area was obtained. Catalyst film stability and reusability were assessed by running a series of experiment. The immobilized catalyst activity was tested by degrading a recalcitrant pharmaceutical (carbamazepine) in a batch reactor under UVC irradiation. Experimental evidence shows that the reaction followed pseudo first order kinetics and that complete (100%) degradation of carbamazepine was achieved after 3 hours irradiation. Comparison study of reaction kinetics performed with other works indicates that the technique is a potential candidate for treating waste water. NOM in tertiary and secondary waste water effluents resulted in 16 and 33% decrease in reaction rate constant. Increase in number of substrates resulted in an increase in photodegradation rate constant and a correlation was obtained between reaction rate constant and immobilized surface area. The results also indicate that the photocatalytic efficiency of the catalyst film on Acrylic Glass is in the order of P25>Anatase TiO_2>P25/AC. The film catalyst was also found to be highly stable, self-regenerating and reusable after an additional 3 cycles of experiment.

ABSTRACTS OF POSTER PRESENTATIONS

1) Albraa Alsaati
Purdue University
Energy Efficient Membrane Distillation through Localized Heating

Among the promising membrane-based technologies for water treatment is Membrane Distillation (MD) where temperature gradient across membrane induces vapor pressure difference driving pure water vapor molecules across hydrophobic membrane pores. Even though MD yields higher water purity compared to Reverse Osmosis (RO), still conventional MD configurations are energy intensive. To reduce energy consumption while maintaining mass flux rate, localizing heat generation at the liquid-membrane interface is analyzed. Localized heating also allows membrane distillation method to be used in miniature and modular design fitting wider range of pervaporation applications in addition to desalination. In this study, a novel MD configuration has been evaluated analytically and experimentally. Measured mass flux rates match analytical mass flux limits incorporating diffusive and advective mass transport mechanisms. Further, thermally-stable silver nanoparticles-based membrane demonstrates similar mass flux rate compared to conventional polymer-based membranes. Below boiling temperature, Localized membrane heating demonstrates 75% energy reduction over direct contact and air gap membrane distillation configurations.

2) Helena Avila-Arias*,[1,2] Loring F. Nies,[3] Marianne Bischoff Gray,[1] and Ronald F. Turco[1]*
[1]College of Agriculture − Laboratory for Soil Microbiology, [2]Ecological Sciences and Engineering Interdisciplinary Graduate Program, [3]School of Civil Engineering & Environmental and Ecological Engineering, Purdue University, West Lafayette, Indiana 47907
Soil Response to Metal Oxide Engineered Nanomaterials

Engineered nanomaterials entering the soil directly (e.g., nanoagrochemicals) or indirectly (released during all life cycle phases) may become the next emerging category of environmental contaminants. Following up on previous work, we aim to further investigate soil toxicity of nano-Li_2O and both bulk and nano forms of MoO_3, NiO, and ZnO, by answering the following: i. Is there a size (bulk vs nano form) effect to the toxicity of metal oxides?; ii. How do these metal oxides affect soil microbial biomass and diversity?; iii. How are soil microbial dynamics altered due to metal oxide exposure?; and, iv. Are there any microbial species essential for stability, activity and resilience of the soil system? In general, soil responded to metal oxide effect rather than a size effect. The most notable soil response was to nano-Li2O, which decreased soil enzyme activity and microbial biomass while also increased soil basal respiration and pH. Other metal oxides affected a select few measured variables: MoO_3 decreased acid phosphatase activity and total DNA, NiO decreased pH, while ZnO decreased soil basal respiration and increased pH. Response to size effect was observed only in microbial biomass analyzed by total phospholipid phosphate: nano-MoO_3 produced a lower response, while bulk NiO and ZnO responses were lower. Soil microbial structure analyzed by phospholipid phosphate fatty acids (PLFAs) abundance, was disturbed by nano-Li_2O, bulkMoO3, nano-NiO and bulk ZnO. Soil microbial PLFAs abundance immediately increased on day 1 after bulk MoO_3 exposure. On day 14, nano-Li_2O increased both total and bacterial PLFAs while also decreased Fungal:Bacteria (F:B) ratio. In contrast, nano-NiO and bulk ZnO decreased total and fungal PLFAs, with no effect on F:B ratio. The effect of metal oxides on soil bacterial, archaeal and eukaryal diversity still requires investigation. 16S rRNA and ITS amplicons are currently being sequenced and will be analyzed using QIIME2.

3) Margaret Busse
Purdue University
Utilizing Solar UV for Drinking Water Disinfection in Developing Countries

In many developing countries, solar ultraviolet (UV) radiation is abundantly available and can be used to accomplish disinfection of drinking water by processes that involve no electrical power, such as solar water disinfection (SODIS). Conventional SODIS systems are limited by batch processing and exclusion of UVB radiation, the most germicidally-active portion of the solar UV spectrum. To address this limitation, a continuous-flow solar UV disinfection system has been developed that allows amplification of ambient solar UV radiation, including UVB. Laboratory experiments and a coordinated set of models were applied to

analyze the performance of this system. The laboratory experiments involved measurements of the action spectra of two bacteria (*Salmonella typhi* LT2, *Vibrio harveyi*) and *Cryptosporidium parvum*. The bacteria were selected as surrogates for the organisms that cause typhoid fever and cholera, respectively. *C. parvum* was selected because it is known to account for a large fraction of illnesses associated with drinking water. The Tropospheric Ultraviolet and Visible Radiation Model (TUV) was used to simulate incident, ambient solar spectral irradiance at locations corresponding to planned implementation of the reactor. Simulations with the TUV model were also conducted for West Lafayette, IN because it has been the site of field testing with the CPC reactor conducted to date. This is also the location of a station within the USDA UVB monitoring network. Data from this station were used to compare with results of TUV modeling. Collectively, the results of the action spectrum and spectral irradiance modeling efforts indicated peak antimicrobial effectiveness at around 320 nm. A ray-tracing program (Photopia, LTI Optics) was then used to simulate and optimize amplification of solar spectral irradiance by the reactor. Integration of these results with the action spectra of the target microbes allowed predictions of the inactivation responses of each, ultimately informing the setup of system process controls.

4) Ran Chen
Purdue University
<u>Effect of Carbon Nanotube on Horizontal Gene Transfer in Microbes</u>

Because of the unique chemical and physical characteristics, the application of carbon nanotubes (CNTs) in wastewater treatment has been widely studied. However, CNTs could leak into the natural environment and pose potential health risks. Previous studies have shown that CNTs can negatively affect metabolic processes and bacterial morphology, facilitate direct interspecies electron transfer, and inhibit generation of extracellular vesicles. However, no previous studies have been reported on the effects of CNTs on horizon gene transfer, which is an important biological process for the development of antibiotic resistance. The objective of this study was to evaluate how CNTs affect horizon gene transfer. Erythromycin-resistant E. coli with erm gene was used as donor, and erythromycin-sensitive Bacillus sp. without erm80 was used as recipient. These strains were cultured separately in 37 ℃ for one day and then mixed to get an initial concentration of 106 cells/ml. Then different concentrations of CNTs were added in the mixture and cultured in 37 ℃ and counted in agar plates supplied with 0.2 mg/L erythromycin. During the first seven days, there was no significant difference among the groups with different concentrations of CNTs. But after nine days of incubation, the number of colonies in agar plates inoculated from the mixture exposed with 0.5 g/L CNTs was 5.7-fold higher than those from the mixture exposed with 0.05 g/L CNTs, suggesting that high concentrations of CNTs may promote horizontal gene transfer. Additional experiments are needed to confirm the successful transfer of resistance genes, and the potential health risks of CNTs on horizontal gene transfer needs further investigation.

5) Sruthi Dasika
Purdue University
<u>Development of an Effective Chlorine Residual Test Kit for Schools in Kenya</u>

Chlorination is the most prevalent way of disinfecting drinking water in the United States. When chlorine is added to water, some of it reacts with materials in the water (i.e., bacteria, iron species, etc.) reducing its concentration. Hence, it is important to measure the final concentration of residual chlorine to ensure that the water is safe to drink. The DPD (N,N diethyl-1,4-phenylenediamine) method is EPA-approved and is the most commonly used method in the U.S. for measuring residual chlorine. Other reported methods for analyzing residual chlorine include: amperometric titration, a leucocrystal violet method, a methyl orange method, as well as over a dozen different other photometric methods. Commercial DPD kits for measuring chlorine cost approximately $0.20 USD per analysis. The goal of this research is to develop a much less expensive kit for measuring chlorine in developing countries. As a start, we have examined ABTS (2,2-azino-bis-(3-ethylbenzothiazoline)-6-sulfonic acid) as a possible chemical reagent to measure chlorine species. Through a literature review and initial experiments, ABTS reacts with free chlorine (under acidic conditions) to form a stable bluish-green product that absorbs visible light with maximum intensities at 405 and 728 nm. To perform a chlorine analysis with ABTS, the chemical cost for reagent grade ABTS is approximately $ 0.012 USD, with this cost potentially decreasing as we develop the method further. From our initial studies, ABTS appears to be a promising indicator for routinely testing chlorine concentrations in drinking water in low income schools and communities.

6) Mackenzie Davies
Purdue University
The Fate of Lead (Pb) in Residential Storage Tank Water Heaters

Lead (Pb) has been a primary constituent of potable water distribution systems for centuries. Leaching from old pipes and solder in joints are the primary methods of lead contamination in distribution systems today. Over the past several decades, lead has also been identified as a health risk, a neurotoxin and renal toxin. As a result of these effects, the EPA established the Lead and Copper Rule (LCR), 1991, which disallowed the installation of lead pipes and limited the allowable lead concentration in brass fittings and solder. Literature has shown that lead can form numerous complexes with ligands present in water – carbonates, hydroxides, and oxides, primarily. One well-documented contaminant is lead dioxide, PbO_2, which is a solid formed in highly oxidized conditions. The issue under inspection is determining the effects that residential water heating systems have on the chemical interactions with lead. The primary purpose of this research is to answer the following questions: (1) what chemical interactions occur with lead due to the unique water heater reservoir, and (2) how do these differ from a cold-water premise plumbing system? We predict that increasing temperature out of standard ranges (up to 55°C) will affect the reaction constants of the aforementioned complexes, but solubility may also be affected. Solubility of metals in drinking water can have an acute effect on human health, especially in children.

7) Martina del Cerro
University of Illinois at Urbana-Champaign
Enhancing Counter-ion Adsorption Efficiency in Capacitive Deionization with Charged Polysaccharide Binders

Capacitive deionization (CDI) is an electrochemical desalination technology in which low voltage (~1.2 V) is applied between two porous carbon electrodes. Ions in solution migrate under the effect of the electric field and are adsorbed on the polarized electrodes' surfaces. The electrodes are regenerated through short-circuiting the cell (0.0 V), discharging adsorbed salt to a brine stream. One of the major challenges in the design of CDI electrodes is improving charge efficiency (CE) (amount of ions removed per electrical charge applied). Fixed charge addition through the incorporation of ion-exchange membranes or electrode surface modification are known to achieve this by mitigating co-ion repulsion and providing ionic selectivity. In this work, we present a method to introduce fixed charge in the macroporous electrode structure by replacing the traditionally used, petrochemically-derived, polyvinylidene fluoride (PVDF) binders with chitosan (CS) and carboxymethyl cellulose (CMC), two biodegradable polysaccharides with fixed positively (CS) and negatively (CMC) charged functional groups. When CS and CMC are utilized as anodic and cathodic electrode binders, respectively, salt adsorption capacity (SAC) and charge efficiency reached peak values of 14.1 mg/g and 91%, compared to 5.1 mg/g and 31% obtained with PVDF binders. Surface-modified carbon electrodes with PVDF binders were also synthesized and used for comparison. Using modified carbons, SAC and CE reached values of 16.2 mg/g and 87%, illustrating that incorporation of charged binders is a viable method for performance improvement. Sensitivity of the binders' charge density to pH was also assessed, demonstrating the need for an anodic binder with a higher pKa than chitosan to maintain enhanced performance at higher pH. Finally, we propose a mechanism for the enhanced system's operation which takes into consideration the bare carbon's surface characteristics and the addition of charge in the electrode's macrostructure.

8) *Ukoha E. Emekwo*[1,2] *A. G. Agwu Nnanna[1,2], John D. Vargo[3] and Nicholas Baumhover[3]*
[1]Purdue Water Institute, and Department of Mechanical and Civil Engineering, [2]Purdue University Northwest, Hammond, IN, [3]State Hygienic Laboratory, University of Iowa, Coralville, IA.
Rapid Preparation of $BiOCl_x/BiOI_{(x-1)}$ for Degradation of Tartrazine and Pharmaceuticals under Simulated Solar and Visible LED Light Irradiation

In this study, flowerlike $BiOCl_x/BiOI_{(x-1)}$ was rapidly prepared at room temperature and dried under microwave irradiation. The prepared photo-catalysts morphology were observed using SEM. Photo-catalyst experiment performed in degrading Tartrazine reveals that BiOCI/BiOI composite with molar ratio of 0.85 to 0.15 exhibited the highest photo-activity and achieved 100% degradation of 20mg/l of Tartrazine in 60mins and 140mins under simulated solar light and visible LED light irradiation respectively. Results also show that the photo-catalysis followed pseudo first order reaction mechanism with kinetic rate constants of 0.097min^{-1} and 0.048 min^{-1} for $BiOCl_{0.85}/BiOI_{0.15}$ under simulated solar light and visible LED light irradiation respectively. $BiOCl_{0.85}/BiOI_{0.15}$ was also found to be 5 time better than TiO_2 (P25) and 14 times better than BiOI. The high catalyst activity experienced by $BiOCl_{0.85}/BiOI_{0.15}$ is attributed to reduction in electron-hole recombination rate, high surface area for adsorption and harnessing of visible light photons by BiOI in the composite. Furthermore, a novel photocatalytic continuous flow reactor with large immobilized catalyst area was designed and fabricated for degrading Emerging Contaminants (Pharmaceuticals) in water. The results obtained from these research work will both proffer an energy efficient method in preparing highly active photo-catalyst and a cost-effective technique for degrading contaminants in water.

9) Mary Foltz
University of Illinois at Urbana-Champaign
Influence of Precipitation and Irrigation on Nitrous Oxide Flux Predictions from US Corn

The Denitrification Decomposition (DNDC) model is used to simulate agricultural systems and predict trace gas emissions, such as nitrous oxide (N_2O), which contribute to global climate change and stratospheric ozone destruction. In this study, the DNDC model was evaluated for prediction of N_2O fluxes from two corn-field sites in the United States (Colorado and Minnesota) that simultaneously considered multiple field managements, including fertilizer application rate, tillage, and crop rotation. Model evaluation was completed by comparing DNDC model predictions to published N_2O measurements. Then, the model was calibrated by parameter optimization of soil parameters. In addition, correlation statistics were used to determine parameters that influence model performance, which will inform future model improvements. We found that DNDC did not consistently predict daily-scale N_2O fluxes. Cumulative growing season N_2O fluxes were significantly under-predicted in Colorado and were both under- and over-predicted in Minnesota. In addition, model calibration did not consistently improve N_2O emission predictions at either time scale. Overall, model predictions were poor in years with high frequency and magnitude precipitation, especially after several years of drought. Furthermore, model error was strongly correlated with precipitation, but only when fields under drought conditions were unirrigated. Despite discrepancies at the daily and annual scale, DNDC could consistently identify managements that significantly influenced N_2O fluxes, suggesting the model can be used to predict general environmental shifts from changes in field management. In future work, model improvements to decrease model error for corn cropping systems in temperate climate zones should focus on the influence of precipitation on model processes, such as nitrification and denitrification.

10) Gary Hoover
Purdue University
Examination of the Sub-lethal Effects of Four Per/polyfluoroalkyl Substances (PFASs) on Two Species of US-native Amphibians

Per/polyfluoroalkyl substances (PFASs) are an emerging group of organic pollutants. Widespread use along with volatility of some PFASs has led to global distribution in soils and surface waters. The chemical stability of these compounds assures persistence in the environment, with unknown effects to much of the chronically-exposed biota. Many toxicology studies implicate PFASs in disruption of thyroid hormone, which is also known to play a major role in control of metamorphosis in amphibians. Thus, amphibians represent a class of organisms that may be susceptible to sub-lethal effects due to PFAS exposure. In this study, we examined the effects of aqueous exposure of four different PFASs at environmentally-relevant doses (ranging from 10-1000 ppb) on larvae of two species: eastern tiger salamanders (*Ambystoma tigrinum*) and American toads (*Anaxyrus americanus*). The OECD amphibian metamorphosis assay (Test 231) was used as a guideline for these experiments. Larval salamanders were exposed for 10 days of accumulation followed by a 22-day chronic exposure. Measurements of length and mass were compared between control and treatment groups. Toad tadpoles were exposed from Gosner stage 26-28 through climax of metamorphosis, defined as Gosner stage 43-44. Length, mass, and time to metamorphosis were compared between control and treatment groups. In addition, histopathology of the thyroid glands of control and treatment animals from both species were examined at the conclusion of each experiment. Alterations in morphology of thyroid follicular cells, colloid deposition, and overall architecture were noted. This study presents the first in-depth look at potential effects of PFASs on growth, development, and endocrine disruption at environmentally-relevant doses on US-native amphibians.

11) Stephanie Houser

University of Illinois at Urbana – Champaign

Navigating Environmental, Economic, and Hydraulic Trade-offs in the Design of Green Infrastructure for Stormwater Management in Urban Settings

The implementation of green infrastructure in urban settings to help manage stormwater is a growing trend in cities worldwide. Many studies have been carried out to analyze the life cycle impacts of green infrastructure; however, the general approach to comparatively analyze a small set of static designs has limited researchers' ability to draw generalizable conclusions relevant to policy makers, engineers, and the general public as they seek to develop more sustainable stormwater management solutions. The goal of this study was to enumerate the decision space of gray and green infrastructure to understand tradeoffs between technologies and across individual design decisions. A total of seven categories of green infrastructure were evaluated against gray infrastructure alternatives using the National Green Infrastructure Certification Program's list of green infrastructure technologies: bioretention basins, infiltration trenches, rain gardens, green roofs, rain barrels, dry wells, and permeable pavement. Design decisions for each technology were identified (layer thicknesses, porosity, hydraulic conductivity, etc.) and implemented in a quantitative sustainable design framework linking life cycle assessment (LCA), life cycle costing (LCC), and hydraulic modeling in EPA SWMM 5. The integrated model was run in a Monte Carlo framework using Latin hypercube sampling and a sensitivity analysis was performed on all input parameters. Results demonstrate tradeoffs among green infrastructure technologies and between green and gray infrastructure. Gray infrastructure had a lower cost, but in most scenarios higher emissions than green counterparts, particularly for eutrophication potential due to the increased infiltration by green infrastructure. The study also identified the most meaningful design decisions for lowering cost, lowering environmental emissions, improving human health, and increasing infiltration of stormwater. These critical design components allowed for a greater understanding of how to navigate designs decisions to identify the best option based on stakeholder objectives.

12) Kun Huang

Purdue University

Polyamide Membrane Monomer Degradation Kinetics and Mechanisms during Chlorination of Halide-impacted Waters

Polyamide-based thin film composite membranes are the most widely used reverse osmosis and nanofiltration membranes for water desalination and reuse due to their excellent selectivity. A drawback of using these membranes is that they can undergo biofouling over time, and can subsequently degrade and fail when treated with free chlorine. The mechanisms between polyamide surface and chlorine have been proposed, including chlorination of amide N, direct ring chlorination by Cl_2 or indirect ring chlorination through intermolecular rearrangement from N-chloroamide, followed by amide link scission. This study is intended to evaluate the polyamide-based membrane degradation kinetics and pathways during chlorination of waters impacted by halides. The role of halides is usually overlooked in previous research, but it is important because many of the waters that are treated by RO and NF contain significant high concentrations of halides. To initiate this study, the polyamide monomer, benzanilide, was exposed to excess free chlorine in the presence of varying concentrations of chloride or bromide under different pH conditions (6-9). The decay of benzanilide and formation of by-products were monitored. Results indicated that in the absence of halides, the apparent constants (kapp) of benzanilide decay were in the range of 10^{-2} $M^{-1}s^{-1}$, and the main product formed was an N-chlorination product. The presence of halides (e.g. Cl^- and Br^-) during chlorination also formed secondary chlorinating/brominating species including Cl_2, Cl_2O, HOBr, Br_2, Br_2O, BrCl, and BrOCl which exhibited higher reactivity towards benzanilide than HOCl. In this case, the species-specific constants were orders of magnitude higher (10^2-10^4 $M^{-1}s^{-1}$) than with HOCl alone (10^{-2} $M^{-1}s^{-1}$). In addition, the dominant products formed were instead chlorinated or brominated on the ring. Overall, these results derived a better understanding of how the water chemistry affects the polyamide membrane degradation mechanisms during chlorination.

13) Enze Jin

Purdue University

An Integrated Sustainable Model for Bioenergy System: Forest Residues for Electricity Generation

In the U.S., bioenergy accounts for about 50% of the total renewable energy that is generated. Biomass may be used as a source of energy in a variety of ways. Using forest residues, which would normally be treated as waste, in a co-firing power plant application is one strategy for utilizing biomass. Every stage in the life cycle of using forest residues (e.g., growing biomass, harvesting biomass, transporting biomass, and co-firing with coal) has consequences in terms of the three dimensions of sustainability: economy, environment, and society. An integrated sustainability model (ISM) using system dynamics is developed for a bioenergy system to understand how changes in the bioenergy system influence environmental measures, economic development, and social impacts. Exogenous factors such as population growth, land-use change (LUC) patterns, and renewable energy policy are considered by the ISM. Predictions, such as soil carbon sequestration, greenhouse gas savings, monetary gain, and employment, can be made for a given temporal and spatial scale. Different policy scenarios varying the bioenergy share of the total electricity generation were identified and examined via the ISM. The results of the scenario analysis indicate that an increase in the bioenergy share of the total electricity generation will stimulate the bioenergy market for bio-power. Model projections provide comprehensive insights to key stakeholders and policy makers for supporting decision-making regarding bioenergy development.

14) Indran Kamalanathan

University of Illinois at Urbana-Champaign

Biocatalysis with Chlorite Dismutase Attached to Resin Beads

Emerging contaminants present a challenge to drinking water treatment and public health because these contaminants are toxic at concentrations below a part per million, especially amongst vulnerable populations. Biocatalysis, using enzymes to degrade contaminants, can selectively degrade emerging contaminants to nontoxic byproducts and can be applied to a variety of contaminants; however, for cost-effective treatment the enzymes must be retained or recovered for reuse. This research investigates the impact of attachment on the activity of the biocatalyst chlorite dismutase. Chlorite dismutase was attached to resin beads so it could be retained in a column. Activity assays were conducted with free enzyme and attached enzyme in a batch system and with attached enzyme in a column setup, over a range of initial chlorite concentrations. As expected, the activity of the free enzyme was the highest, followed by the attached enzyme in the batch and column setups, respectively. The activity of the attached enzyme in batch tests agreed well with expected mass transfer limitations imposed by the larger size. While the activity is reduced, it is still sufficient to treat chlorite concentrations relevant to environmental engineering applications. Calculations based on column experiments of 1mg L-1 chlorite estimate greater than 1,000 bed volumes could be treated, exceeding the reuse threshold needed for the biocatalytic approach to be economically and environmentally viable relative to existing technologies.

15) Junyeol Kim

University of Notre Dame

Time-Resolved In-Situ ATR-FTIR Investigation of Macromolecular Corona Formation and Transformation on Nanoparticles upon Environmental Perturbations

Engineered nanomaterials (ENM) entering the aqueous environment interact instantaneously with the macromolecules forming layers (corona) on the surface of the ENMs. Due to the new identity of the ENMs generated by the macromolecular corona, studies on the behavior and transport of ENMs, based on the physicochemical properties of the pristine ENMs, have limitations to accurately predict the behavior of ENMs. For more accurate ENM behavior studies that consider macromolecular corona formed on the surface of nanomaterials, we investigated corona formation and transformation caused by environmental factors (e.g., various macromolecules) using time-resolved in-situ ATR-FTIR spectroscopy. Using ATR-FTIR, we studied the adsorption / desorption / transformation of macromolecules that occur when the surface of nanomaterials interact sequentially with macromolecules in the environment such as BSA and oxalate. As a result, at neutral pH, oxalate was covalently adsorbed on the surface of the used TiO2 ENMs, and then BSA was adsorbed by displacing pre-formed oxalate at the TiO2 (photocatalytic P90 and food-grade E171) adsorption site when BSA was added. Additionally, BSA showed different adsorption and desorption behaviors depending on the presence or absence of oxalate. Also, oxalate had a greater impact on BSA corona formation in P90 than in E171 in primary and secondary structures of BSA. Finally, the order of BSA adsorption on P90 and E171 surfaces varied according to the presence or absence of already adsorbed oxalate. Consequently, the results from this study will help to better understand the behavior of ENMs that react with various macromolecules in complex natural environments. In addition, the results of this study will contribute to the study of safer ENMs design that can minimize the environmental impact of ENMs by studying more practical behavior of ENMs in the aqueous environment.

16) Wo Jae Lee
Purdue University
<u>Fusion of Multi-sensor Data for a Tool Condition Monitoring (TCM) System Using Machine Learning Techniques</u>

Historically, technological and economic issues are the biggest interest for the manufacturing enterprise. However, with the increasing awareness on the environment, the concept of sustainable manufacturing is now receiving considerable attention. Before a manufacturing process planning, a variety of analyses are performed in the early stages of part/product design. However, manufacturing process analyses, including environmental analyses, are often overlooked during in the early product design stages. Part/product design decisions greatly impact environmental, productivity, and financial manufacturing process metrics. The proposed research is developing models to analyze manufacturing operations during the design process to optimize part and process metrics. The models and analyses will be validated on a selected part/product.

17) Lei Li
Purdue University
<u>Low Carbon Manufacturing for Metal Forming Equipment- Energy-saving Strategies in Use</u>

As it is urgent to implement low carbon manufacturing for hydraulic presses, life cycle oriented low carbon manufacturing and operation were proposed to navigate the reduction of carbon emission from the levels of machine, process and workshop, based on the summarization of existing researches. Carbon emission models in manufacture and use were first established to find the potentials of carbon emissions reduction. When focusing on the potentials identified by employing the model in the operation stage, energy matching method for the drive unit at machine level and a group of hydraulic presses in manufacturing system at workshop level were presented to match the output power of the drive with the needed power of the load, so as to reduce carbon intensity and improve energy efficiency. And when focusing on forming at process level, the process parameters were optimized without sacrificing the forming quality, aiming to reduce the deformation energy. The proposed methods, which show significant low carbon effect, can provide useful guidelines to minimize carbon emission and maximize production efficiency in manufacturing and operation of a hydraulic press.

18) Bolin Li
Purdue University
<u>The Possible Role of Different Aggregates in Nitrogen Removal in Single-stage Autotrophic Nitrogen Removal Process</u>

In recent years, anaerobic ammonium oxidation (ANAMMOX)-based single-stage autotrophic nitrogen removal has been developed into a hot research top due to its high treatment efficiency and cost-effectiveness. Granule sludge was the desirable aggregate morphology in such a process due to its high settling velocity and long sludge retention time. Previous studies have revealed that aggregates in different sizes played diverse roles in nitrogen removal, but limited studies have been done to study the mechanisms of the effects of aggregates on nitrogen removal. The objective of this study was to investigate the role of different aggregates in nitrogen removal in a hybrid reactor combined with flocs (＜200μm) and granules (＞200μm). The relative contribution of anaerobic ammonia oxidation bacteria (AAOB) and heterotrophic denitrification bacteria (HDB) was calculated based on nitrogen mass balance, and the community compositions were analyzed with high-throughput sequencing techniques. The reactor was operated for 73 days, which were divided into three phases with different aeration rates (0.6, 0.4 and 0.5 L/min). In phase

III, the maximum nitrogen removal efficiency (NRE) and nitrogen recovery rate (NRR) were up to 92.0% and 0.498 kgN/m3/d, respectively. The proportion of nitrogen removal by HDB increased with increased aeration rate, which was different from the variation of AAOB. Batch tests were carried out on day 72. A high specific anammox activity of 227.4 mgN/gVSS/d was observed in granules, which were the main contributor for nitrogen removal. The specific denitrification activity in flocs was higher than that in granules. The high-throughput sequencing demonstrated that AAOB was enriched in granules, whereas HDB was dominant in flocs. These results suggested that granules played an important role in nitrogen removal via nitritation-anammox, which accounted for the majority of nitrogen removal in this study, and heterotrophic denitrification mainly occurred in flocs.

19) Mengfei Li
University of Notre Dame
<u>Mechanical Properties of Pseudomonas aeruginosa Biofilms: Effects of Shear Stress, Water Chemistry and Dissolved Oxygen on the Spatial Distribution</u>

The understanding of biofilm mechanical properties is critical to the removal of detrimental biofilms and to the accumulation of beneficial biofilms in engineering systems. Due to the variability and heterogeneity of biofilm, it is difficult to obtain representative data of biofilm mechanical properties. In this study, we used magnetic tweezers to perform in situ mapping of the elastic compliance of a Pseudomonas aeruginosa biofilm, and then used modeling to explore its impacts on biofilm deformation. Biofilms were grown under fluid flows ranging from 0.1 mL/h to 5 mL/h (Reynolds number 0.28-13.9), dissolved oxygen concentrations of 8 mg/L and 1 mg/L, and calcium ion concentrations of 0 and 100 mg-CaCl2/L in bulk liquid. Results show that higher flow rate increased the averaged stiffness due to mechanical adaptability and the addition of calcium generated more uniform biofilms than in the absence of calcium, depending on the limitation of chemical penetration. Using fluid-structure interaction modeling, we explored the impact of the spatial compliance variability on the deformation of both a biofilm colony and a mushroom-like tower structure in fluid flow. For biofilms with a large variability in compliance, i.e., those grown under low-flow conditions, the impact of neglecting heterogeneous properties depended on the biofilm morphology. For the biofilm colony, the predicted deformations were 64% greater for biofilm with heterogeneous properties, as compared to the same structure assuming uniform compliance distribution. For the mushroom structure, the deformation was 22.8% greater for the uniform distribution. These results increased the understanding of biofilm mechanical properties and the impacts on biofilm control in engineering systems.

20) Mustafa Lokhandwala
Purdue University
<u>Ride Sharing, An Agent Based Modeling Analysis</u>

Individual mobility known to be highly inefficient in operation. The average occupancy of personal vehicles in New York City is 1.6 according to a NTHS survey. Additionally, in 2014 the transportation sector accounted for 26% of all greenhouse gas emissions in the United States. In the previous few years there has been a considerable growth in transportation technologies (for example, electric vehicles, autonomous vehicles and ride sharing) which have the potential to improve transportation sustainability and reduce carbon dioxide emissions. The growth of these technologies will necessitate new policy implications for cities. We have studied and quantified the environmental and efficiency gains of these emerging transportation technologies using agent-based models. We have found that using a combination of ride sharing and autonomous vehicles New York City has the potential to reduce CO_2 emissions by 725 metric tons per day and increase average vehicle occupancy from 1.2 to 3.

21) Xiangxing Long
Purdue University
<u>Geospatial Analysis of Ecosystem Services on Purdue University Campus</u>

The goal of this project is to examine the economic value of ecosystem service (ES) provided by trees on Purdue campus. We used tree data from Purdue Arboretum as the basis for estimation of ecosystem services (ES) using the I Tree Streets model, designed by USDA Forest Service. ES calculations were based on tree genus and size, which were obtained from the Purdue Arboretum database. I-Tree Streets estimates ES values by calculating energy savings, CO2 sequestration, air quality improvements, stormwater interception, and aesthetic value of urban trees. The model relies on regionally averaged utilities prices, current market prices for treating CO2 emission and air pollutants, the cost of stormwater interception, average home resale value, tree health condition, various city characteristics, as well as maintenance costs associated with the trees themselves. Because all benefits of ES are assigned in dollars, I Tree Streets estimates the economic value of ES provided by trees in dollars. Based on currently available data, we estimate that trees on Purdue's West Lafayette campus generate ES $397,920 annually (gross) and $148,000 (net) after accounting for the $249,899 that Purdue Physical Facilities spends on tree maintenance each year. We conducted a geospatial analysis of ES provisioning across the Purdue Campus to identify and map hotspots, areas of high ES provisioning that can be used to inform campus tree maintenance efforts.

22) Qi Lu
Purdue University
The Construction of a Design Framework in Support of Low-carbon Design Flow

Low-carbon design is an effective measure to cut carbon emissions for manufactured products. This paper is aiming to construct a design framework to support the low-carbon design process. There are three levels in the framework. Then, crucial low-carbon design technologies are studied. Finally, an example of supporting components validates the feasibility of the proposed low-carbon design framework and key technologies. The method provides a theoretical basis for low-carbon design flow and technologies from a lifecycle perspective of manufactured products.

23) Xiaona Luan
Purdue University
Trade-off Analysis of Tool Wear, Machining Quality and Energy Efficiency of Alloy Cast Iron Milling Process

For many manufacturing companies, maximizing profit is a primary goal. However, the environmental impact of the manufacturing process should be considered due to government and public pressure. Cutting tool costs and electricity costs are the two main costs of manufacturing process. Tool wear conditions can be used to measure the cutting tool cost indirectly. The objective of this research is to increase the profit of an industry by identifying trade-offs between cutting tool cost, electricity cost, and machining quality. First, an on-line tool wear prediction model was designed to study the change in cutting power due to the change in tool wear. Experimental data were collected to examine the relationships between tool wear, cutting power and surface roughness. Second, multi-objective optimization functions were established to solve trade-off analysis problems. Real-time cutting power data, surface roughness, and flank tool wear data from the experiments were analyzed in the models. Finally, grey relational analysis was applied to obtain the grey relational grade of the cutting parameters on the three optimization objectives. The relationships between these parameters were evaluated using trade-off analysis. The tool wear-cutting power-surface roughness trade-off surface was used to visualize the trade-offs among the parameters. The results of this work can help decision makers or operators design cutting parameters for different goals.

24) Randal Marks
University of Notre Dame
Time Resolved in-situ ATR-FTIR Monitoring of Nitrite Sorption on Supported Metal Catalysts

Nitrite (NO_2^-) is a ubiquitous contaminant of drinking water that requires advanced treatment processes prior to delivery to tap. Catalytic and photocatalytic methods have been explored as low-energy methods to drive the removal of nitrite from source water. Major challenges preventing adoption of this technique include difficulty in controlling by-product selectivity (N_2 vs NH_3) and low rates of catalytic activity. Supported metal catalysts show promise for both tuning by-product selectivity and driving rapid catalytic activity. Previously, we have shown that Ag-TiO_2 can drive photocatalytic reduction of nitrate. However, nitrate reduction by-product selectivity is governed by pH, and reduction past nitrite was not observed at neutral or basic pH. This study uses time resolved in situ ATR-FTIR (TRIS-ATR-FTIR) to observe the sorption of aqueous nitrite on the surface of TiO_2 supported monometallic catalysts and elucidate the effects of pH on the molecular interactions at the solid-liquid interface. Nitrite sorption on P90 (commercial TiO_2), as well as silver loaded and platinum loaded P90, was observed over the pH range 2-6 using TRIS-ATR-FTIR. The results suggest that nitrite sorption on the catalysts is governed by nitrite speciation. At neutral pH, physisorption of NO^{2-} to the catalyst surface is primary pathway of nitrite sorption. However, at acidic pH, HNO_2 predominates in solution as nitrite is protonated. HNO_2 sorption on the catalyst surface occurs through a slower chemisorption process that is dependent upon the metallic nature of the catalyst surface. Our results suggest that chemisorption of nitrite to the catalyst surface only occurs through the HNO2 species at acidic pH, and further that the chemisorption pathway is necessary for catalytic activity in these materials.

25) Nehika Mathur
Purdue University
Industrial Symbiosis: Biomimicry in the Photovoltaic Industry

As society works towards mitigating its reliance on fossil fuels, the demand for renewable energy has grown rapidly in recent years. The Solar Photovoltaic (PV) industry is one such source of renewable energy and has witnessed a significant rise since the 1990s. The average lifespan of a multi-Silicon PV module is about two decades and the first generation PV modules are nearing the end of their life around now. While PV waste volumes remain relatively small at this time, cumulative PV waste is estimated to grow substantially within the next decade. This raises concerns about the safe disposal of PV waste at the end of life (EoL). Effective dismantling and disposal methods need to be aggressively developed and implemented in order to prevent a potential e-waste like situation where large volumes of hazardous wastes are being disposed in landfills subsequently contaminating the air, water and soil. Our research proposes the circularization of the PV industry using the notion of Industrial Symbiosis (IS). The fundamental idea behind IS is promoting closed-loop thinking within networks by identifying waste streams that may have value as potential raw material/ feedstock through the development of collaborative business interactions between a diverse set of organizations. We have applied IS in the context of EoL PVs to a hypothetical eco-industrial network and have demonstrated the environmental benefits of developing symbiotic relationships. Additionally, it should be noted that an IS network can be represented as a naturally occurring ecological network. Ecological Network Analyses allows for holistic analysis of interactions within complex networks. In the context of the PV industry and the given hypothetical industrial network, the use of ENA aims to identify and quantify potential opportunities in an industrial network and also the potential risks and barriers that may compromise the efficiency, sustainability and resilience of this network.

26) Kyle McLaughlin
Purdue University
Persistence of Biosolids-Borne Contaminants in Urban Garden Soils

While commercial biosolids-based fertilizers can provide a valuable source of nutrients and organic matter when applied to urban and suburban soils, they also have the potential to introduce pharmaceuticals and personal care products (PPCPs) to the soil ecosystem. The potential for ecological disruptions, such as phytotoxicity and the spread of antibiotics-resistant genes, due to PPCPs necessitates a thorough understanding of their environmental fate. We hypothesized that recalcitrant fractions would persist and degradation would be limited by desorption from the biosolids matrix. This study observed aerobic degradation of three model biosolids-borne (indigenous) PPCPs present in the biosolids product OCEANGRO®: triclosan, carbamazepine, and miconazole. Biosolids were added to aerobic microcosms using soil collected from community gardens in the Greater Lafayette region. Over a period of 180 days, microcosms were sacrificed in triplicate using solvent extraction at approximately 30-day intervals. Surrogate and internal standards were used to determine recovery and matrix effects. Compound detection was performed on a liquid chromatograph tandem triple quadrupole mass spectrometer. Preliminary results showed that the three model biosolid-borne PPCPs were relatively persistent in soils with half-lives of carbamazepine > miconazole > triclosan. Carbamazepine and miconazole loss was also more limited in high organic matter soils. The possibility of recalcitrant fractions of PPCPs in soils could have profound implications for micro and macroscopic organisms and warrants further investigation.

27) Mahsa Modiri Gharehveran
Purdue University
Investigating the Photochemical Pathways of Organic Sulfur in forming COS and CS_2 in Natural Waters

COS and CS_2 in natural waters are abundant volatile low-molecular weight sulfur compounds which are critical precursors to sulfate aerosols, which are known to counteract global warming by reflecting solar radiation. One major source of COS and CS_2 stems from the ocean. While previous studies have linked COS and CS_2 formation in ocean waters to the indirect photolysis of organic sulfur compounds such as cysteine, a clear understanding of the precursors, reactive intermediates, and photolytic transformation pathways involved is still needed. This is especially true given that COS and CS_2 formation is likely induced by sunlight-generated reactive intermediates (e.g. 3DOM•, $1O_2$, Br•, and $CO_3•^-$) that are produced from various water quality constituents such as dissolved organic matter (DOM), O_2, halides, and HCO_3^-/CO_3^{2-}. However, these water quality constituents vary strongly depending on water type when considering waters ranging from freshwater to seawater. The objectives of this work were thus to derive a more comprehensive understanding of the fundamental processes that govern COS and CS_2 formation in these various natural water types. Preliminary experiments were performed at the bench-scale in which three Chesapeake Bay (Maryland, US) waters including a freshwater, brackish water, and seawater were additionally spiked with cysteine and exposed to simulated sunlight. Results indicated up to a 20-fold increase in COS and CS_2 formation after seven hours of sunlight exposure, but the kinetics and response to water type were found to differ significantly between COS and CS_2. Following this work, future experiments will be used to explore a larger number of water types, various other spiked organic sulfur compounds, and system conditions (e.g. temperature). Additional experiments will also test synthetically prepared waters containing various sensitizers and individual sulfur compounds to further probe the important reaction pathways involved in COS and CS_2 photochemical production.

28) Robert Nunoo
Illinois Institute of Technology
Human and Ecological Risk-Based Margin of Safety Estimation for TMDLs

The margin of safety (MOS) is one of the three mandatory terms of the standard equation that defines Total Maximum Daily Load (TMDL) (U.S. EPA 1999). The MOS accounts for uncertainties and also represents the degree of protection of a waterbody. Events and characteristics such as rainfall, impairment type, and land use characteristics play major roles in TMDL development. Watershed modelers incorporate a margin of safety to help evaluate and resolve the problem of uncertainty to achieve the required performance and to protect water bodies. The probability of these events is obtained from historical data, environmental evidence, and scientific theories. According to the National Research Council (NRC, 2001), uncertainty must be explicitly acknowledged both in the models selected to develop TMDL and in results generated by those models. This study, we focused on review existing TMDLs to identify those that explicitly-defined margin of safety (MOS), in an attempt to identify correlation that might exist between MOS values and human population density (ρ), human population of watershed(p), impairment type (I), and designated use of waterbody (d). We also proposed an estimation method that is based on a Bayesian approach that incorporates human and ecological factors. Tying the MOS value in a TMDL with the human population, impairment type and designated use of a waterbody will allow watershed managers to factor in the human and socioeconomic damages that could occur in the unfortunate case of a violation of a water quality standard.

29) Renee Obringer
Purdue University
Applying Machine Learning Techniques to Predict Urban Droughts

Urban water supplies are critical to the growth of the city and the wellbeing of its citizens. However, these supplies can be vulnerable to hydrological extremes, such as droughts and floods, especially if they are the single source of water for the city. Maintaining these supplies and preparing for future conditions is a crucial task for water managers, but predicting hydrological extremes is a challenge, especially in urban watersheds. This study tested the abilities of eight statistical learning techniques to predict reservoir levels, given the current hydroclimatic conditions. The results showed that random forest, an ensemble, tree-based method, was the best algorithm for predicting reservoir levels. We initially ran the models using Lake Sidney Lanier (Atlanta, Georgia) as the test site; however, further analysis demonstrated that the random forest algorithm was transferable to other reservoirs, specifically Eagle Creek (Indianapolis, Indiana) and Lake Travis (Austin, Texas). Additionally, we found that although the models for each reservoir were affected differently by the various predictors, the streamflow, city population, and El Niño/Southern Oscillation (ENSO) index were repeatedly among the most important variables. These are critical variables which can be used by water managers to recognize the potential for a change in reservoir level.

30) Shunlong Pan
Purdue University
Decomposition of Pb-EDTA and Subsequent Adsorption of Pb(II) with Yolk-shell Fe_3O_4@$Zr(OH)_x$

Water purification from heavy metal-organic complexes is a crucial but still challenging task. Here, this study proposes yolk-shell Fe3O4@Zr(OH)x sphere (YHZOs) to remove the EDTA-chelated Pb(II) (Pb-EDTA) from aqueous solution. Specifically, the Fe3O4 core of YHZOs is served as Fenton-like catalyst for decomplexation of Pb-EDTA, and the Zr(OH)x shell of YHZOs is used as adsorbent to remove the free Pb(II) generated during the decomplexation. The total Pb removal efficiencies of YHZOs towards 0.1 mM Pb-EDTA was determined to be 88.7% at pH 7. Meanwhile, 63.3% of total organic carbon was eliminated. The major intermediates of decomplexation, including Pb-NTA (nitrilotriacetic acid), Pb-ED3A/ED3A (ethylenediaminetriacetic acid), Pb-ED2A/ED2A (ethylenediamine-N, N'-diacetic acid), IDA (iminodiacetic acid), Pb-EDA (ethylenediamine), acetic acid, formic acid, oxalic acid, ammonia, and nitrogen were identified. The adsorption of Pb(II) ions on the Zr(OH)x shell was confirmed by scanning transmission electron microscopy (STEM) mapping and X-ray photoelectron spectra (XPS). Moreover, the exhausted YHZOs could be easily refreshed for cyclic runs with less capacity loss. These findings suggest that the YHZOs shows promising alternative for destruction of the heavy metal-organic complexes and decontamination of metal ions.

31) Kyungyeon Ra
Purdue University
Understanding and Reducing Impacts of Storm Water Culvert Rehabilitation Technologies to the Environment

Cured-in-place-pipe (CIPP) technology has been used to rehabilitate sanitary sewer, storm 23 sewer, and drinking water pipes. However, utilities, regulators, and health officials have 24 raised environmental, occupational, and public health concerns regarding chemical emissions 25 into air and water. To better understand emissions into water, available literature was 26 reviewed. Water contamination has been documented in 10 states and Canada due to the 27 release of uncured resin, solvents, manufacturing byproducts, and wastes during and after 28 construction. Odor, fish kill, and drinking water contamination incidents have been reported. 29 The few field- and bench-scale studies available show that a variety of VOCs and SVOCs 30 have been released into water and contamination was detected for several months. CIPP 31 waste was acutely toxic to aquatic organisms. Chemical release is likely influenced by 32 formulation, installation, and environmental conditions. CIPP installation and inspection 33 recommendations were suggested. Studies are needed to develop evidence-based construction 34 and monitoring practices to minimize risks.

32) Raymond RedCorn
Purdue University
Evaluating the Potential of Glycogen Accumulating Organisms to Recycle Waste Carbon

Glucose is an important feedstock in the production of biological fuels and chemicals. However, demand for glucose is largely filled through harvesting starch and cellulose based crops which must be stored to match seasonal harvest with continuous demand. In the present work, we evaluate phenotypic glycogen accumulating organisms (GAOs) for their potential to convert the carbon in municipal waste to glycogen, an analogue of starch. GAOs are currently considered nuisance organisms in wastewater treatment facilities using enhanced biological phosphorous removal. It is envisioned that these organisms could become an asset. Municipal organic waste could be anaerobically degraded to produce mixed volatile fatty acids (VFAs), which are taken up anaerobically by GAOs and then converted to glycogen aerobically. A GAO culture was selected for in a trickling filter reactor through continuous twelve hour cycles which consisted of feeding a model acid phase digestate, followed by three hours of anaerobic conditions and nine hours of aerobic conditions. Following this work, glycogen accumulation will be optimized in the GAO culture at varied pH and temperature conditions. The optimum pH and temperature will be used to evaluate the yield of glycogen per unit carbon fed. The work will inform the potential of GAOs to convert biopolymers, food waste, sewage, paper products, and other waste carbon into a stable year round supply of glucose for biological fuel and chemical production. "

33) Josh Rembusch

Danco - Water Management, Reuse and Conservation Solutions

Membrane-Capacitive Deionization (CapDI©) - tunable, salt-free and chemical-free water softening and desalination

Membrane Capacitive Deionization (CapDI) is a revolutionary tunable water deionization technology that is designed to remove dissolved salts from a variety of water sources ranging from tap water and brackish groundwater to industrial process water. *CapDI achieves this at a lower economic cost and reduced environmental impact than any other available technology*. Voltea's technology treats water types ranging from residential consumer appliances to large-scale industrial plants. Our systems are modular, allowing easy expansion to meet any increased water demands. CapDI is tunable, allowing adjustable TDS reduction between 25 – 95% depending on customer needs, eliminating the requirement for blending to achieve a specific water quality. The customer sets their desired reduction rate and CapDI maintains this level, continually adjusting itself to account for any fluctuations in feed water characteristics. Impacts may include: cost savings, hazardous chemical reduction, waste water discharge reduction and reuse, energy conservation as well as enhanced asset protection. Applications include: Salt and Chemical Free Softening, RO Reject Recycle and Recovery, Wastewater Recycle and Recovery, Water Conservation and Reuse for Cooling Towers/Evaporative Condensers and Polishing and Utilization of Natural Water Sources.

34) Justin Richter

Purdue University

Modeling the Social Impacts of Advanced Manufacturing

People are integral to the success of all products and services, yet how people are affected by those same products and services has largely been a qualitative undertaking. This work seeks to address a quantitative approach to measuring and evaluating the impacts that products and services have on people considering first and second order needs, a la Maslow's hierarchy. The model and data generated come from publicly available data and seeks to create a baseline of understanding for how people are affected by production activities.

35) Maryam Salehi

Purdue University

Investigation on Influence of Polymer Aging and Water pH on Lead (Pb) Deposition onto Polyethylene Surface

The influence of polymer aging, water pH, and aqueous Pb concentration on Pb deposition onto low density polyethylene (LDPE) was investigated. LDPE pellets were aged by ozonation at 85 °C. ATR-FTIR and X-ray photoelectron spectroscopy (XPS) analysis of aged LDPE surfaces showed that a variety of polar functional groups (>C-O<, >C=O, >COO) were formed during aging. These functional groups likely provided better nucleation sites for Pb(OH)2 deposition compared to new LDPE, which did not have these oxygen-containing functional groups. The type and amount of Pb species present on these surfaces were evaluated through XPS. The influence of exposure duration on Pb deposition onto LDPE was modeled using the pseudo-first-order equation. Distribution ratio calculations showed Pb precipitates had greater affinity for the surface of aged LDPE compared to new LDPE. Aged LDPE had less Pb surface loading at pH 11 compared to loading at pH 7.8. Pb surface loading for aged LDPE changed linearly with aging duration (from 0.5 to 7.5 h). Pb surface loading on both new and aged LDPE increased linearly with increasing Pb initial concentration. Greater Pb precipitation rates were found for aged LDPE compared to new LDPE at both tested pH values.

36) Stephanie Schramm
University of Illinois
Lumped Pathway Metabolic Model for Determining Universal Stoichiometric Yield Coefficients of Microalgae

Utilizing algae for biological nutrient removal processes at water resource recovery facilities (WRRFs) has the potential to decrease the amount of nitrogen and phosphorus leaving in the facilities' discharge effluent. In addition to removing undesirable nutrients from wastewater, algae form storage compounds such as lipids and carbohydrates that can be used as bioenergy feedstock and potentially generate an additional revenue stream for water resource recovery facilities. Wastewater is beneficial to use as a medium for algae cultivation, however a significant hurdle to the widespread application of algal technologies at WRRFs is the replication of algae cultivation processes. Due to variability in composition and the inevitable biodiversity of wastewater, achieving an axenic microalgae culture within the system is not practical. To tackle this hurdle, a universal approach for understanding how algae of various species uptake nutrients from wastewater and store energy within the cell is needed. In this study, a stoichiometric lumped pathway metabolic model was created based on the universal metabolic properties of microalgae to determine yield coefficients for microalgae under various energy inputs, nutrient sources, and carbon sources. Universal yield coefficients were developed by simplifying conserved enzymatic metabolic reconstruction data available into lumped stoichiometric equations for the metabolic pathways of interest. The stoichiometric equations were used to develop linear equations and yield coefficients for different algal growth conditions as well as varying extracellular conditions. The yield coefficients include biomass growth on various carbon sources, nutrient uptake under various extracellular conditions, and the accumulation of energy storage compounds. With the developed universal stoichiometric lumped pathway metabolic model, algal technologies can be implemented more widely and operated more efficiently to improve WRRFs effluent quality.

37) Andrew Schranck
University of Notre Dame
Sustainable Treatment of Wastewater and Generation of Electricity using a Solar Photocatalytic Fuel Cell

A visible-light active photocatalyst, bismuth vanadate ($BiVO_4$), was compared to a predominantly UV active photocatalyst, titanium dioxide (TiO2), to compare their effectiveness in a photocatalytic fuel cell. TiO_2 and $BiVO_4$ were identified as promising candidates through literature, synthesized, and then analyzed using light-chopped chronoamperometry. The photoactivity and electrochemical performance of the electrodes in the presence of organic pollutants such as dextrose, urea, and synthetic urine were evaluated to screen for viable photocatalytic degradation candidates. Further, two reactor setups were investigated, single and dual chamber electrochemical cells. By varying operational parameters (e.g., pH, conductivity, and organic concentration) in the case of dextrose, we determined increasing pH linearly improved power output in linear sweep polarization experiments, while increased dextrose concentration still improved power linearly but with limited effect. Both results were attributed to Nernstian behavior, which says pH and chemical species concentrations affect redox potentials and electrochemical cell performance. These insights enhance understanding of photocatalysts for advanced water and wastewater treatment for the field of environmental engineering.

38) Navneet Sharma
University of Illinois at Urbana-Champaign
Evaluating the Potential of Phosphorous Recovery from Side Streams at Corn-ethanol Production Plants using Chemical Precipitation to Enhance the Sustainability of Corn Food-energy-water System

In 2015, 98% of the domestic ethanol production was from corn grain which is about 44% of the total corn production in the United States. Major phosphorous demand is contributed to food production which is dominated by corn production in the United States. The co-products produced during the corn-ethanol production such as distillers grain and corn gluten feed are utilized as animal feed. About 50 - 80 % of the phosphorous in corn is in the form of phytate (inositol hexakisphosphate) which cannot be digested by non-ruminant animal and is released in the environment with animal waste. The corn-ethanol production directly impacts environment due to nutrient pollution from agricultural run-off, wastewater from corn-ethanol plants and animal manure run-off. This is a major source of phosphorous pollution which causes eutrophication of water bodies. Phosphorous flows plays a vital role in defining the sustainability of Food-Energy-Water nexus related to crop production, animal production, water pollution, resource recycling, energy flows and financial flows. Side streams formed during the corn-ethanol production, such as thin stillage and light steep water, contain phosphorus concentrations that are several orders of magnitude greater than wastewater, potentially enabling cost effective recovery, yet precipitation of phytate in these side streams is poorly understood. Our preliminary lab-scale experimental analysis was conducted over a wide range of pH values, with & without enzymatic transformations and metal to phosphorous molar ratios and results have shown substantial potential for chemical precipitation to recover phosphorous from these side streams. Our analysis outlines optimum conditions for phosphorous precipitation and characterize the precipitate formed for evaluating potential reuse. Phosphorous recovery from corn-ethanol production side streams will reduce phosphorous load in wastewater steams from these plants, excess phosphorous in animal feed and subsequent run-off from animal manure thus reducing phosphorous pollution of water bodies.

39) Zhe Sun
Purdue University
Nature-inspired Virus-assisted Lipid Extraction for Efficient Biofuel Production with Microalgae Chlorella sp.

Biofuel production from microalgae has been advocated as one of the potential alternative energy sources that is sustainable and environmental friendly. Lipid extraction has been identified as one of the costliest and energy intensive steps during the production of algal biofuel. Various extraction methods have been developed, but only limited studies have been reported on utilizing viral disruption in microalgal biofuel production. In this study, viral infection of microalgae *Chlorella* sp. was studied as a natural cell disruption method for algal biofuel production. Chlorovirus was isolated from a local river and identified by plaque assay and PCR. Concentrated *Chlorella* suspensions were treated by viral infection and sonication. The effects of virus concentration, infection time, and lipid content on algal cell lysis and lipid yield of *Chlorella* sp. were investigated. Viral disruption with multiplicity of 0.1 disrupted more than 99% of *Chlorella* cells in three days and the disrupted cells reduced more than 50% sonication power for complete lysis as compared to untreated cells. Lipid yield increased from 3 mg/g dry algal biomass (no treatment) to 33.6 mg/g dry algal biomass (viral infection method), while the lipid yield with sonication was 28.7 mg/g dry algal biomass. The results in this study confirmed the feasibility of applying viral infection to extract algal lipids and may provide new insights in the development of nature-inspired lipid extraction method for cost-efficient biofuel production.

40) Mahboobeh Teimouri
Purdue University
Safety Concerns Caused by Cured in Place Pipe installations

Water pipe repairs are increasingly being completed with polymer coatings and cured in place pipes (CIPP). These technologies enable pipe owners to avoid costly pipe replacement activities (i.e., road closures, building repairs) by installing a barrier between the corroded pipe and water that it conveys. CIPP pipes are new pipes chemically manufactured inside an existing damaged pipe in-situ. Today, 50% of all water pipes are repaired by CIPP technology. At present, little information is available about chemical emission into air and water by CIPP installation activities. Results of two ongoing CIPP chemical emission studies will be presented. In 2016, the US National Science Foundation funded a rapid response study to investigate chemical air emissions caused by the CIPP installation processes. In 2016, six US state transportation agencies also funded a project to investigate how to better understand and limit emissions into waterways when CIPP technology is used for storm water culvert repairs. Results showed that chemical air emissions can be high, transient, and contain more than simply styrene. Characterization of installed CIPP materials also has indicated a variety of organic compounds can be released from the CIPP once the contractors leave the worksite. Results in this presentation will be described in the context of workplace safety and environmental toxicity thresholds.

41) Wen Tong

Purdue University

Low-carbon Supply Chain Operation Optimization and Simulation

Carbon cap-and-trade mechanism is a government-mandated, market-based scheme to reducing emissions, which has been implemented in many countries such as Europe, China, Korea and so on. In order to satisfy random market demands which have been impacted by the emission reduction effort level, we develop an Emission Reduction-Production Model which references the joint pricing and ordering decisions in newsvendor model, where a manufacturer produces a single product. This paper derives the production quantity and emission reduction effort. We find that the emission reduction effort level has a significant effect on the optimal solutions, which were independent of the initial allowance. The numerical analysis also shows that that production quantity may be increasing first and then falling in the carbon credit's price. Production quantity is increasing in the emission reduction effort level owing to the effects of the carbon emission reduction investment. In addition, it's interesting that enterprise's profit and the carbon credit cap have a positive correlation. Important managerial insights are discussed.

42) Matt Triebe

Purdue University

Reducing Environmental Impact of Machine Tools through Energy Efficiency

Manufacturing is an indispensable part of the global economy but it also has a large environmental burden. With an increasing awareness of environmental impact, the idea of sustainable manufacturing is receiving much attention. There has been much work in the manufacturing field to reduce energy consumption and environmental impact. This work focusses on the energy consumption of machine tools. In order to reduce the energy consumption, first an understanding of where the energy is consumed is important. Then, investigating opportunities to reduce the energy consumption can be completed. This poster will outline where energy is consumed in CNC machine tools and then provide opportunities for reducing the energy consumption.

43) Ehsan Vahidi

Purdue University

Assessing the Environmental Footprint of Rare Earth Metals Production via Electro-Refining and Manufacturing of Rare Earth Magnets

Due to the importance of Rare Earth Elements (REEs) in many high-tech and clean energy applications, they have received increased attention in recent years. Although production pathway of REEs is known to be environmentally destructive, very limited Life Cycle Assessment (LCA) investigations have yet been conducted. This is particularly true for the electrolysis of the RE oxides in a medium comprising lithium fluoride and RE fluorides, a key step in the high-purity RE metals production pathway as well as manufacturing of NdFeB permanent magnets. In this study, a comparative LCA was carried out on different electro-refining facilities in China using graphite and tungsten as anode and cathode, respectively. Furthermore, cradle to gate LCA models of RE containing magnets using REEs from monazite/bastnasite deposits in Bayan Obo as well as ion adsorption clay in China's southern provinces were developed. In combination with mass/energy balance and stoichiometry, the life cycle inventories were developed using SimaPro 8 software and Ecoinvent 3 database and the life cycle impact was evaluated by TRACI. LCA results were utilized to determine and quantify environmental hotspots of the electro-refining process and manufacturing of RE magnet. Finally, challenges and opportunities for improved environmental performance of the RE elements production and magnet and phosphor manufacturing processes were discussed.

44) Marcela Vega

University of Notre Dame

Chlorate Addition Enhances Perchlorate Reduction and Inhibits Sulfate Reduction in a Perchlorate-reducing Membrane Biofilm Reactor

Microbial reduction is a promising strategy to remediate perchlorate (ClO_4^-), as perchlorate is reduced to innocuous chloride (Cl^-). The process can be problematic, though, as perchlorate is typically in the µg/L range, exerting a weak selective pressure for perchlorate-reducing bacteria. Also, nitrate can inhibit perchlorate reduction, so low nitrate levels are needed in the reactor, which favors sulfate-reducing bacteria. Chlorate (ClO_3^-) is an intermediate in the perchlorate reduction pathway, and we hypothesized it could solve both problems: help select for perchlorate-reducing bacteria and inhibit of sulfate-reducing bacteria. We tested this with two hydrogen-based membrane biofilm reactors (H_2-MBfRS) in three phases. First, Reactors A (control) and B (experimental) were supplied with an influent with 600 µg/L perchlorate, 5 mg-N/L nitrate, 80 mg/L sulfate, and 8.4 mg/L oxygen during 25 days. Then, we continuously added chlorate (5 mg/L) to Reactor B for 30 days. In the last phase, we ran both reactors without chlorate for 15 days. In both H2-MBfRs, nitrate was completely reduced after 5 days, and perchlorate was reduced by 95-100% after 10 days. Sulfate removal averaged 10% on day 20 in both H_2-MBfRS and perchlorate reduction decreased to 77-95%; however, during chlorate addition in Reactor B, sulfate reduction decreased to below 5% and perchlorate reduction increased to >95%. Once we removed chlorate, Reactor B quickly resumed with higher sulfate reduction and had lower perchlorate removals (<95%). qPCR results from the third phase show lower proportion of sulfate reducing bacteria in reactor B (0.063%±0.007) compared to reactor A (0.95%±0.19). Our results suggest that chlorate addition enhances selection for perchlorate-reducing bacteria and inhibits sulfate reduction. The mechanisms are still being investigated.

45) Danielle Wagner
Purdue University
<u>Emission Rate Analysis of Fine and Ultrafine Particle Concentrations Arising from Biomass Burning Stoves in Nandi, Kenya</u>

Lacking access to electricity, 3 billion people across the world use biomass as a fuel for cooking and heating. Recent studies reveal that particle number size distributions of incomplete combustion from these cookstoves are dominated by sub-100 nm aerosols. These nano-sized particles have high diffusivity, and can penetrate each region of the respiratory system, causing preventable chronic diseases. This study is motivated by the goals of a healthcare organization, AMPATH, to design modified kitchens exhibiting reduced indoor air pollution (IAP) for rural women and children in Nandi County, Kenya. Measurements were taken in 3 modified and 6 traditional kitchens, in January and July of 2017. CO, CO_2, and fine and ultrafine particle number concentrations (10 nm to 2.5 µm) were passively sampled at breathing zone height for 3 days, using Pegasor Indoor Air Quality and carbon monoxide sensors. Pressure differentials and flow rates through façade airflow pathways and chimneys were manually logged for 15 minutes. Nonlinear regression of the mass-balance model is used to evaluate the measured concentrations. Stove emission rates (no. particles/ min) and air exchange rates (/hr) elucidated for each kitchen are metrics of the ventilation performance of each kitchen design and womens' exposure to wood smoke. Notable information was collected through daily conversations with women in each kitchen to parallel quantitative data. Preliminary results demonstrate that modified kitchens that preserve cultural features have the ability to reduce exposure to IAP as much as 80%, with air exchange rates around 30-40 /h. A parallel study carried out by the EPICS Global Air Quality Trekkers team is focused on replicating a Nandi kitchen at Purdue University to enable in-depth physicochemical characterization of field-like conditions. The most recently built kitchen in Nandi is currently a demonstration for community members to encourage scale-up.

46) Mian Wang
Purdue University
<u>Selective Pressure of Trace Level Antibiotics on the Development of Antibiotic Resistance and Horizontal Gene Transfer</u>

Antibiotics have been discovered to treat bacterial infections since 1940s, but the increased occurrence and frequencies of antibiotic resistance have endangered the efficacy of antibiotics. Many studies have examined horizontal gene transfer (HGT) of antibiotic resistance genes (ARGs) and focused on antibiotic concentrations at or above the minimal inhibitory concentrations (MIC), which are much higher than those detected in natural environments. However, there are limited studies on the effects of trace level antibiotics on the development of antibiotic resistance. The aim of this study was to evaluate whether ARG transfer can be facilitated by trace levels of antibiotics. We hypothesized that sub-MIC concentrations of antibiotics strongly selected for the dissemination of ARGs. An erythromycin-resistant E. coli and an erythromycin-sensitive Bacillus strain were isolated from the environment and mixed for conjugation experiments to evaluate if erythromycin resistance methylase (erm) gene can be transferred through HGT under the exposure of different levels of antibiotics. Successful conjugation was confirmed with PCR and gel electrophoresis. The results showed that no transconjugant was detected when antibiotic concentrations were above 1 MIC. However, efficiencies of HGT under the exposure of 0.01 MIC and 0.1 MIC erythromycin were 1,351 and 6,532 times higher than that under 1 MIC erythromycin after three days of incubation. The experimental results suggested that sub-MIC concentrations of antibiotics could promote HGT of ARBs and further studies are needed to evaluate microbial dynamics and genetic responses during HGT. Information on conjugation of ARGs will help understand the effects of trace level antibiotics on the spread and propagation of ARGs for the development of effective mitigation strategies to control antibiotic resistance.

47) Tianqi Wang
Purdue University
<u>*Case Study: Management of Plastic Bottle and Filter Waste during the Large-Scale Flint Michigan Contaminated Drinking Water Incident*</u>

When large drinking water systems are unable to deliver safe water, the provision of emergency water supplies becomes a necessity. Depending on the incident scale and duration, this increase could overwhelm a community's waste management capacity. A case study was conducted to understand waste management challenges associated with the large-scale Flint, Michigan drinking water disaster. In October 2015, more than 90,000 people were directed not to use their lead-contaminated water, but instead use emergency drinking water and in-home filters. Results demonstrated that public and private sector partnerships enabled the distribution of water and waste collection/recycling activities. The authors found millions of water bottles were provided to the community, but these amounts may have been less than the calculated estimates for community water needs. During January 2016, the recycling participation rate increased from 13% to 27%. Water bottle and faucet filter recycling was encouraged by the establishment of drop-off locations. The curbside pickup program was expanded to address the added water bottle waste. Tens of thousands of filters were donated to the community, but records found only accounted for about 2,600 filters recycled. Points of distribution (PODs) were established to provide emergency supplies, increase waste management efficiency, and were relocated months after the initial response. A lack of material flows entering and leaving Flint inhibited a better understanding of waste management. Communities seeking to better prepare for large-scale emergencies should: pre-identify the roles of waste management organizations, set up a procedure for documenting emergency water supply materials (bottles, filters) entering and exiting the community, determine where to best site PODs, draft public notifications (print, flyer, radio) about waste management activities, and centralize all data archiving.

48) David Warsinger
Purdue University
<u>*Batch Reverse Osmosis: Time-varying Desalination for Energy Efficiency and Fouling Mitigation*</u>

As reverse osmosis (RO) has proven itself as the most efficient desalination technology, it is paramount to further improve its energy efficiency, and make it applicable to higher salinities to displace less efficient alternatives. A new variant of RO, batch reverse osmosis, has shown to have the potential to make substantial energy improvements, and to also be more resilient to avoiding fouling at high salinity. Here, the energetics of batch RO are modelled in detail. Additionally, Batch RO's potential to reduce membrane fouling through its cycling to lower salinity every batch is also modelled, with experimental validation. Relative to continuous RO, models predict that CCRO and batch RO demonstrate up to 37 % and 64 % energy savings, respectively, for brackish water desalination at high water recovery. Additionally, here, a framework for predicting reverse osmosis fouling is developed by comparing the fluid residence time in batch and continuous (conventional) reverse osmosis systems to the induction times of crystallization for sparingly soluble salts. The methods are applied to key water types (seawater and groundwater), and examined for extending recovery for representative RO brine. Due to batch RO's shorter residence times due to the salinity cycling from low to high each batch, significantly higher recovery ratios and higher salinity were possible in batch RO than in continuous RO for all cases examined. Overall, the induction time modeling methodology provided here can be used to allow RO to operate at high salinity and high recovery, while controlling scaling. The results show that, in addition to its known energy efficiency improvement, batch RO has superior inorganic fouling resistance relative to conventional RO.

49) Yaochun Yu
University of Illinois at Urbana-Champaign
Biotransformation of Carbendazim Exclusively by a Complete Ammonia Oxidizer Nitrospira inopinata among Three Ammonia-oxidizers

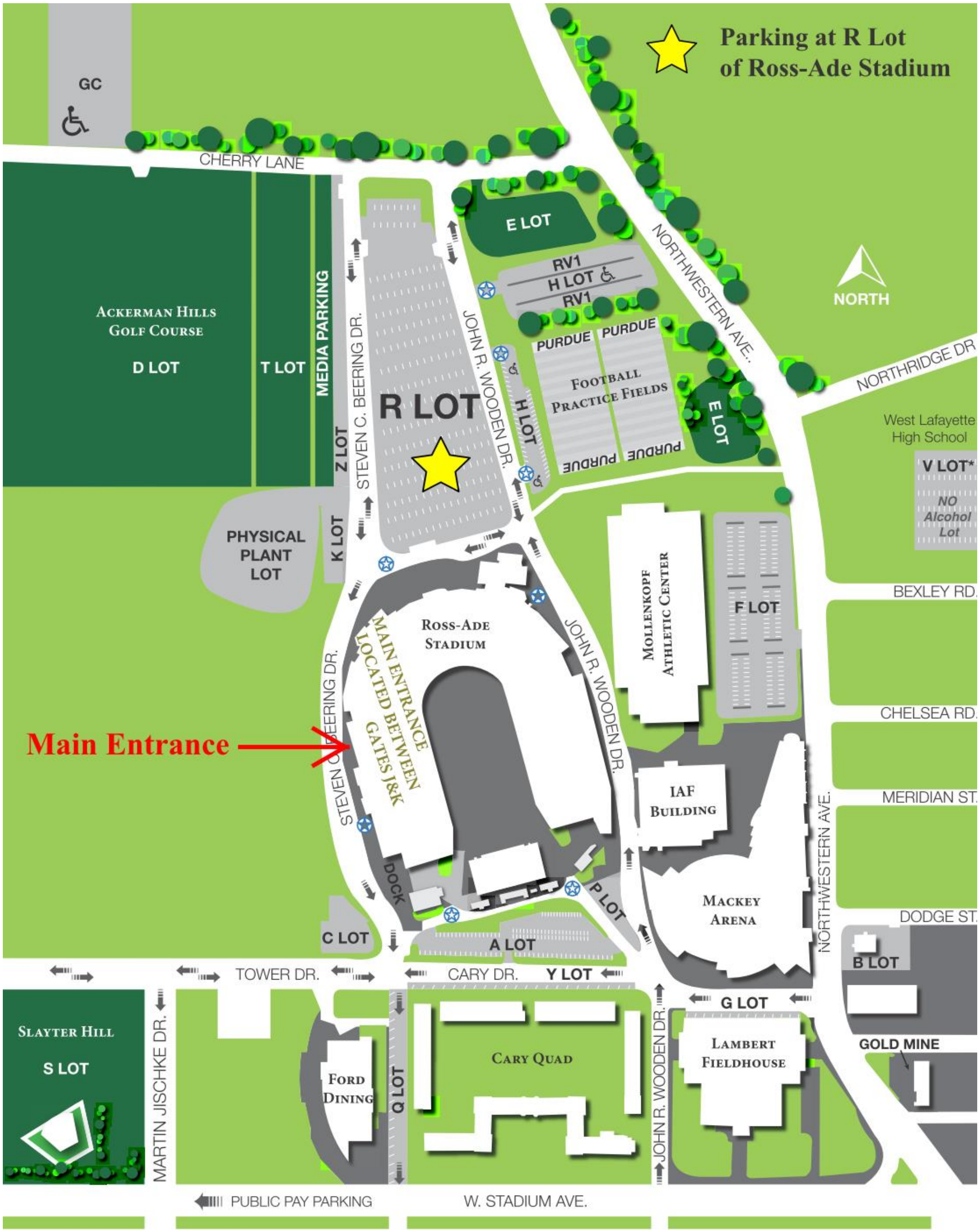
The discovery of previously overlooked complete ammonia oxidizers (comammox) raised research interests of their ecological roles in natural and engineered environments. In this study, we investigated biotransformation capability of the only available comammox isolate so far, *Nitrospira inopinata* for sixteen micropollutants. *N. inopinata* was able to biotransform 5 out of the 16 compounds, four of which were also biotransformed by two other ammonia oxidizers, i.e., ammonia-oxidizing bacteria (AOB): *Nitrosomonas nitrosa* Nm90, and ammonia-oxidizing archaea (AOA): *Nitrososphaera gargensis*. The fifth compound, carbendazim, a benzimidazole fungicide was exclusively biotransformed by *N. inopinata* with ~ 50% removal after 10-day, whereas the removals by the other two ammonia oxidizers were less than 5%. Moreover, the biotransformation of carbendazim only occurred when *N. inopinata* was fed with ammonia but not nitrite as the energy source, indicating ammonia monooxygenase (AMO) was the responsible enzyme during carbendazim biotransformation. Furthermore, one major transformation product (TP) of carbendazim was identified to be a hydroxylation product at the aromatic ring of carbendazim structure, which is consistent with the function of AMO. In addition, TPs identified for the other biotransformed compounds by *N. inopinata* were similar with those formed by the AOA and AOB species, indicating similar biotransformation mechanisms, all likely mediated by AMO. This study, for the first time explored the distinct environmental services of comammox bacteria in terms of micropollutant biotransformation. The findings expand our knowledge of micropollutant biotransformation mediated by different groups of ammonia oxidizers.

50) Xinyi Zhang
University of Illinois at Urbana-Champaign
A Global Sensitivity Analysis in Solar Virus Inactivation Modeling

Enteric viruses pose a substantial threat to human health due to their low infectious dose and long survival in surface water and drinking water. Sunlight is known to be a pertinent contributor to the inactivation of viral pathogens in the environment. Low-cost water treatment technologies, such as solar disinfection of drinking water (SODIS) and waste stabilization ponds (WSPs), rely on sunlight for disinfection. Sunlight irradiation can cause direct endogenous inactivation through absorption of UVB photons by virus components (e.g. DNA, proteins) and indirect exogenous inactivation that involves absorption of UVA or PAR photons by external photosensitizers. Integration of current understandings of the solar inactivation processes into a quantitative framework for mechanistic modelling of solar virus inactivation would allow prediction of disinfection efficiencies and optimization of the design of natural treatment systems. The object of this work is to elucidate the relative importance of environmental, water quality, viral and engineering design parameters in solar virus inactivation in WSPs and natural surface waters. This will be accomplished through a global sensitivity analysis (GSA) in a Monte Carlo framework in python, leveraging the sunlight irradiance model SMARTS and the photochemistry model APEX. Data from WSPs and natural surface waters are used to define water quality. Environmental factors, including irradiance and temperature, are varied using global datasets. MS2, ΦX174 and adenovirus are selected as model viruses based on differences in susceptibility to endogenous (predominant for ΦX174) vs. exogenous (predominant for MS2) inactivation mechanisms. The inactivation rates will be modeled using reaction rate constants (exogenous mechanism), photolysis quantum yields and extinction coefficients (endogenous mechanism) from previous studies. GSA will be performed to determine the relative importance of the abovementioned parameters on virus inactivation rates.

INFORMATION ON PARKING

You can freely park your car in the R Lot (North Stadium Lot) of Ross-Ade Stadium (850 Steven Beering Dr, West Layette, IN 47906), and walk to the main entrance at the west side of the Ross-Ade Pavilion. The conference will be held on the 3rd and 5th floor in the Ross-Ade Pavilion.



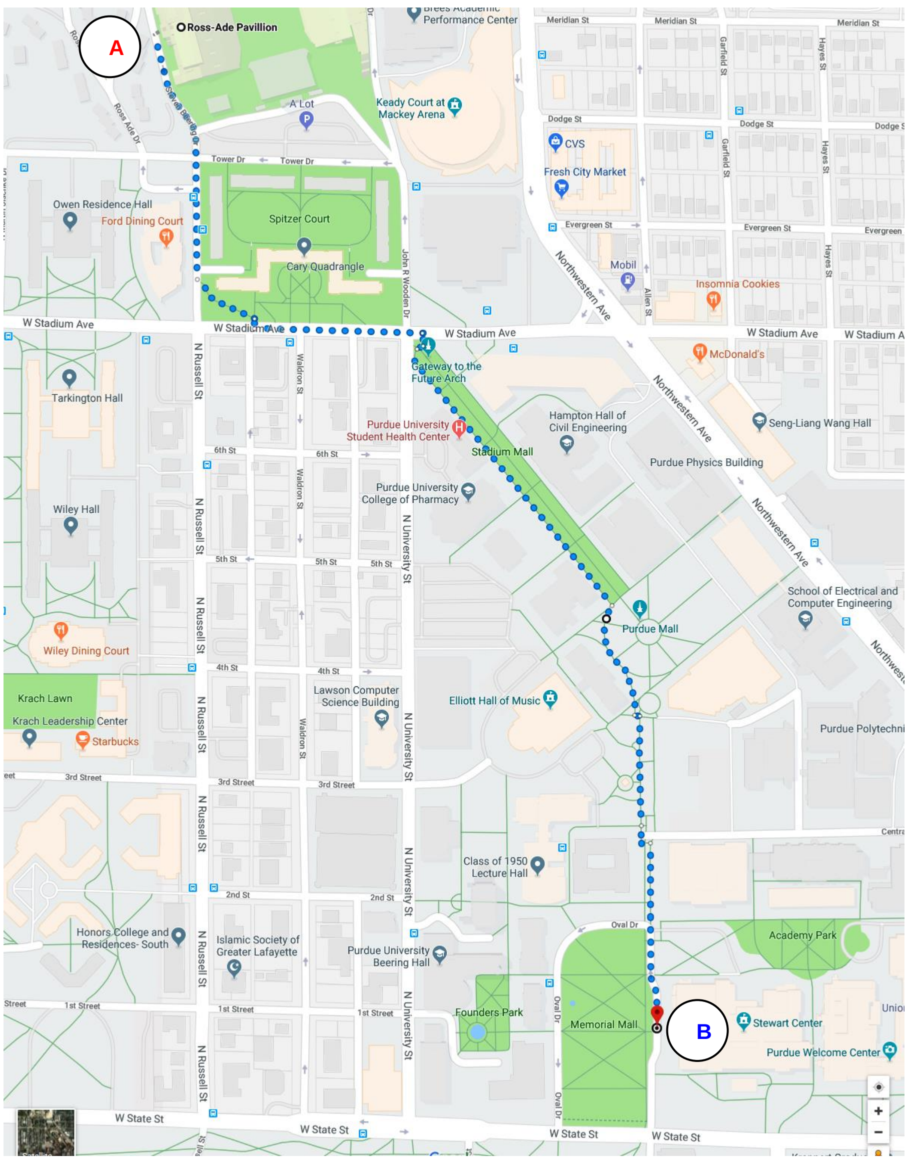
INFORMATION ON COMMUTING BETWEEN ROSS-ADE PAVILION AND FOWLER HALL AT STEWART CENTER

There will be two free shuttle buses to take you from Ross-Ade Pavilion to Fowler Hall at Stewart Center at 2pm and bring you back from Fowler Hall at Stewart Center to Ross-Ade Pavilion at 4pm.

If you miss the two free shuttle buses or choose to walk from Ross-Ade Pavilion to Fowler Hall at Steward Center (0.8 mile, 16 min), you can follow the directions shown below.

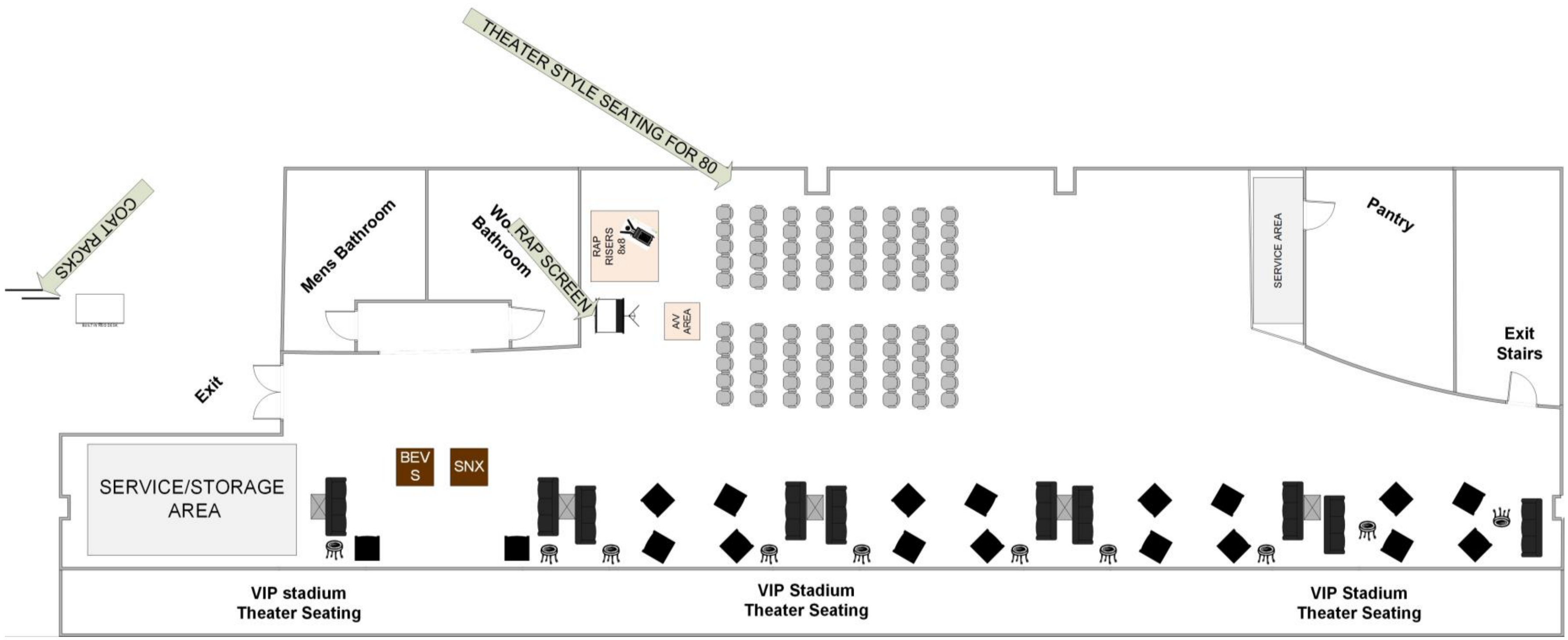
A) **Ross-Ade Pavilion** (850 Steven Beering Dr, West Lafayette, IN 47906)
Depart Steven Beering Dr toward Tower Dr (0.2 mi)
Turn left onto W Stadium Ave (0.1 mi)
Bear right onto Stadium Mall Dr (0.2 mi)
Turn right onto Purdue Mall, and then immediately turn right onto Centennial Mall Dr (0.2 mi)
Road name changes to Memorial Mall (0.06 mi)

B) **Fowler Hall at Stewart Center** (128 Memorial Mall, West Lafayette, IN 47907)



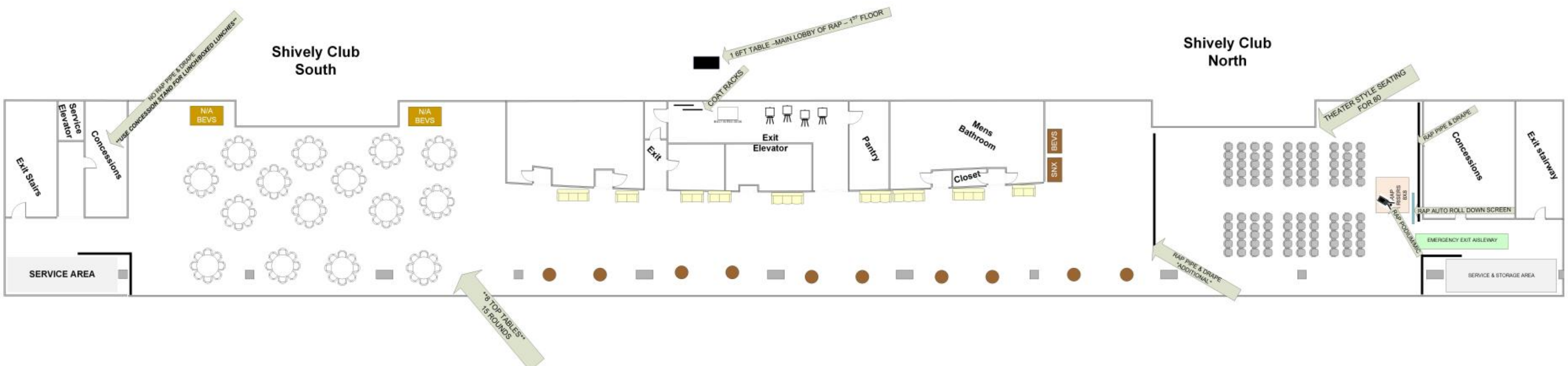
FLOOR PLAN

ROSS-ADE PAVILION - FIFTH FLOOR BUCHANAN CLUB



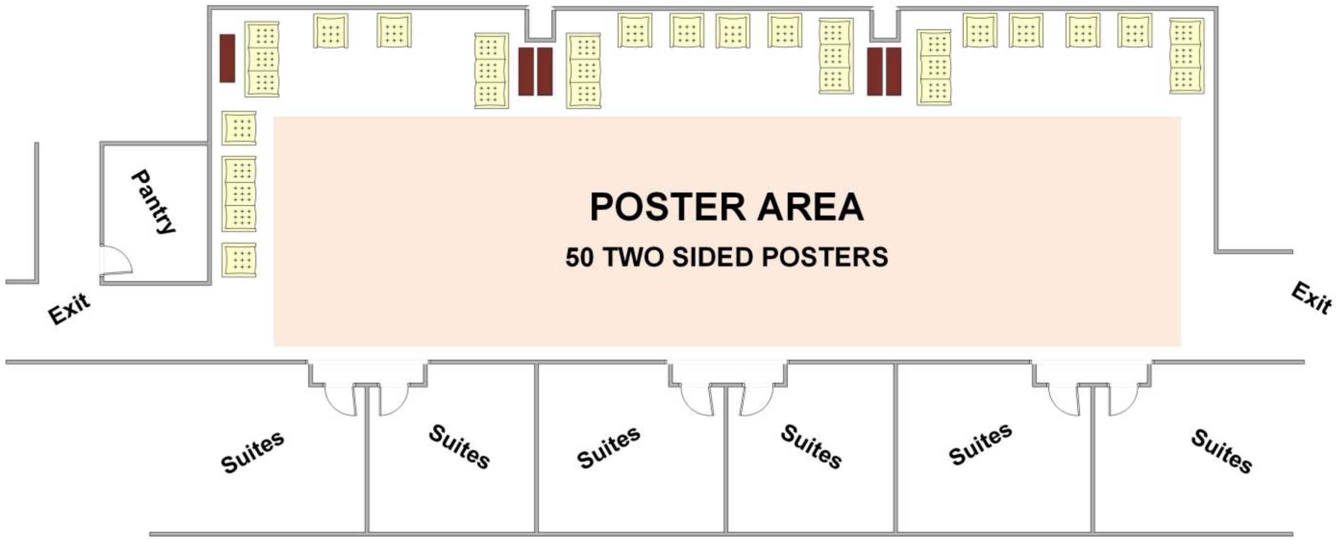
FLOOR PLAN

ROSS-ADE PAVILION – THIRD FLOOR SHIVELY CLUB



FLOOR PLAN

ROSS-ADE PAVILION - FIFTH FLOOR MINGLING AREA



ACKNOWLEDGEMENT

This conference was financially supported by Environmental and Ecological Engineering at Purdue University. Additionally, we acknowledge the following individuals and institutions for their kind support of this conference.

Paul Anderson	Illinois Institute of Technology
Jeremy S. Guest	University of Illinois at Urbana-Champaign
Alysha M. Helmrich	Purdue University
Kenneth (Chris) Holford	Purdue University
Krishnanand Maillacheruvu	Bradley University
Gamini Mendis	Purdue University
Robert Nerenberg	University of Notre Dame
Wei-tsyi Evert Ting	Purdue University

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