Environmental, Water Resources, and Coastal Engineering Graduate Research Symposium

March 1, 2019

Hunt Jr. Library

Department of Civil, Construction, and Environmental Engineering

The EWC faculty and students would like to thank our generous sponsors.

SILVER SPONSORS

AECOM

FREESE AND NICHOLS

Gavel & Dorn Engineering

SMITH+ GARDNER ENGINEERS

Hazen

Geosyntec consultants

BRONZE SPONSORS

EOS Remediation, LLC

25 years EREF

Environmental Research & Education Foundation™

Lighting a path to sustainable waste management practices

JACOBS®

SCS ENGINEERS

Environmental Consultants and Contractors

Contents

Schedule

TIME	EVENT
12:00-1:00 PM	Luncheon
1:00-2:30 PM	Poster Presentations
2:30-2:45 PM	Break
2:45-3:45 PM	Finalists Presentations
3:45-4:00 PM	Break
4:00-5:00 PM	Keynote Speaker
5:00-5:30 PM	Award Ceremony

Keynote Speaker

Janet G. McCabe, J.D.

Janet McCabe is Professor of Practice at the Indiana University McKinney School of Law and Assistant Director for Policy and Implementation at IU's Environmental Resilience Institute. She is also a Senior Law Fellow with the Environmental Law and Policy Center. From July 2013 through January 2017, Janet McCabe was the Acting Assistant Administrator for the Office of Air and Radiation at the United States Environmental Protection Agency. She joined EPA in November 2009, serving as the Principal Deputy to the Assistant Administrator of OAR. Prior to joining EPA in November 2009, Janet McCabe was Executive Director of Improving Kids' Environment, Inc., a children's environmental health advocacy organization based in Indianapolis, Indiana. From 1993 to 2005, Ms. McCabe held several leadership positions in the Indiana Department of Environmental Management's Office of Air Quality and was the office's Assistant Commissioner from 1998 to 2005. Ms. McCabe served as Assistant Attorney General for environmental protection for the Commonwealth of Massachusetts and Assistant Secretary for Environmental Impact Review. Ms. McCabe graduated from Harvard College in 1980 and Harvard Law School in 1983.

THE PAST, PRESENT AND FUTURE OF ENVIRONMENTAL PROTECTION: THREATS AND OPPORTUNITIES

When it comes to environmental rules, the country is in a time of unprecedented deregulatory activity. Almost every one of the public health and climate change regulations adopted during the prior administration is in the process of being reconsidered, delayed or repealed. In addition, the EPA is taking steps to undermine the very pillars of science- and reason-based decision making that have characterized EPA's work under both Republican and Democratic administrations since the 1970s when the environmental movement began. This talk will explore the biggest threats, the near and longer term implications for public health and public policy, and the reactions and responses from many perspectives. It will also discuss the critical need for young scientists, policy analysts, lawyers and others to continue participating in regulatory processes, volunteering for federal advisory committees and task forces, and seeking employment in federal, state and local agencies.

A. Air

No. 1: Public health impacts of intense prescribed burn activity in socially vulnerable communities of the Southeastern U.S.

Sadia Afrin
Fernando Garcia Menendez (Advisor)
Keywords: prescribed burning, hotspot, social vulnerability

Prescribed burning (PB) is an important land management strategy used to reduce wildfire risk. However, assessing the impacts of PB on public health has become important research need due to the practice's potential for high particulate matter emissions and poor atmospheric dispersion. Here, we rely on permit-based PB data to quantify the impacts of burning activity across clusters of vulnerable population in the Southeastern US. We identify statistically significant geographic clustering based on the spatial association between PB and the Centers for Disease Control and Prevention's census-tract-level social vulnerability index. We find several significant PB and vulnerability hotspots, including large spatial clusters in Southwest Georgia, Northwest Florida and the central region of Southern Florida. Additionally, we use base-rate health incident data from the Georgia Department of Public Health and a reduced form air quality model (COBRA) to estimate the impact of PB-specific PM2.5 pollution on an increased rate of different negative health endpoints within these clusters. Finally, we compare the role of PB relative to other major emissions sources, including industrial combustion, vehicles, and wildfires. We find that a significant amount of premature mortality and respiratory disease is attributable to PB and these impacts can be larger than those associated with other important emissions sources, particularly at the social vulnerability and prescribed fire hotspots.

No. 2: Air quality observations from low-cost gas and particle sensor packages deployed in North Carolina and Malawi

Ashley Bittner
Andrew Grieshop (Advisor)
Keywords: ambient air quality, low-cost sensor packages, low-income countries, field measurements

Malawi, like many other Sub-Saharan African countries, is a low-income nation with a near-complete dearth of ambient air quality observations. The lack of continuous observation in rural Africa limits quantitative understanding of regional air quality trends and restricts the evaluation of atmospheric models. To address this gap, in June 2017 we deployed three low-cost, low-power sensor packages (Aerodyne Research Inc.'s 'ARISense') for 13 months to three sites in Malawi (two rural, one peri-urban) to collect data on gases (CO_2, CO, NO/NO_2, O_3), particles (size/count) and meteorological parameters. Before and after deployment to Malawi, the packages were collocated with regulatory monitors in Durham, NC. Temperature, RH, and concentration-span data collected in NC and Malawi suggest the collocation and deployment settings are environmentally similar. We apply a set of hybrid random-forest (RF) and linear regression calibration models to the data and find good agreement between the RF-calibrated ARIsense data and the reference data before and after deployment ($R2=0.9$ and $R2=0.75$, respectively). We apply the calibrations to the ambient data collected in Malawi and find consistent diurnal trends across the two rural village sites (indicative of peak household cooking periods) and similar annual trends across all three sites (indicative of regional agricultural-burning periods).

No. 3: Sensitivity of particulate matter pollution to emissions sector changes in a Latin American megacity

James East
Fernando Garcia Menendez (Advisor)
Keywords: air quality modeling, Latin America, Bogota, particulate matter, emissions

Bogota, Colombia, a city of 8.5 million people, frequently exceeds coarse and fine particulate matter (PM_{10} and $PM_{2.5}$) daily air quality standards, exposing residents to harmful air pollutant concentrations. Using a three-dimensional gridded air quality model, this work evaluates the performance of air quality model simulations compared to observed values and examines the response of PM to changes in emissions of various sectors. Two three-month simulations were performed: a dry season simulation (January, February, March), and a wet season simulation (October, November, December). Model inputs included meteorological simulation data for 2014, chemical boundary and initial conditions derived from global air quality simulations, and a local emissions inventory. The Community Multiscale Air Quality Model (CMAQ v5.0.2) was used to perform the analysis. Model predictions were evaluated against daily air quality observations measured at 14 sites across the city. In the sensitivity analyses, major emissions sectors were perturbed to assess their influence on the modeled pollutant concentrations and determine the contribution of each sector to overall PM pollution. Our results show that model predicts PM_{10} better in the wet season than the dry season, $PM_{2.5}$ is overestimated at high concentrations in both seasons' simulations, and resuspended road dust is the largest contributor to PM pollution in the city.

No. 4: Factors affecting seasonality and inter-location variability in emissions measured in a multi-year cookstove intervention trial in rural India

Maksim Islam
Andrew Grieshop (Advisor)
Keywords: cookstove, emission, regression, PM, variability

Globally over 3 billion people use biomass cookstoves to meet household energy demand. In this study, in-home emission factors (EFs) of various gas- and particle phase pollutants emitted from cookstoves were measured in two rural areas in India: Kullu in Himachal Pradesh and Koppal in Karnataka. The study had three measurement periods (baseline: BL, follow-up-1: F1, follow-up-2: F2) and included a wide range of cookstove models. Here, I discuss traditional stove emission as it displays substantial inter-site and inter-period variability. In Koppal, PM2.5 EF was significantly higher in F2 than BL (mean: 51%) and F1 (32%). In Kullu, it was significantly lower in F1 relative to BL (40%) and F2 (32%). Emission optical properties also showed inter-period variability. Multilinear regression models were used to evaluate how emissions varied by season, location, fuel properties (e.g. fuel moisture content: MC and fuel use), ambient condition (e.g. relative humidity: RH), modified combustion efficiency (MCE) and cooking duration. MC, RH, and MCE appeared to be significant predictors of PM2.5 and OC EF that explain ~25% and ~21% variability respectively. Model predictability was highest for Single Scattering Albedo where ~50% variability was explained by season, fuel use and cooking duration. The result of this study would help understand the factors affecting emission and thus reduce the overall emission.

No. 5: Uncertainty in estimated health and air quality impacts from the 2016 Southern Appalachian wildfires

Megan Johnson
Fernando Garcia Menendez (Advisor)
Keywords: wildfire, health impacts, uncertainty, PM2.5, concentration-response

Wildfire events often lead to elevated concentrations of fine particulate matter (PM2.5) that can be harmful to human health. However, there is considerable uncertainty in estimating wildfire-attributable concentration fields and the associated health impacts. We use the 2016 Southern Appalachian wildfires as a case study to evaluate the uncertainties in estimating wildfire air pollution and health outcomes for the population of North Carolina. Using multiple spatially- and temporally-resolved concentration fields, this work compares the uncertainty associated with fire-attributable $PM_{2.5}$ estimation methods to the uncertainty related to the use of concentration-response functions and epidemiological studies in smoke impacts analyses. Multiple fire-attributable $PM_{2.5}$ concentration fields were created using monitor data, satellite aerosol optical depth retrievals, and a model-based smoke forecast product. Differences in these concentration fields and in health impacts estimated from them are evaluated and compared. Uncertainty in health outcomes due to increased $PM_{2.5}$ is quantified using various concentration-response functions for multiple health endpoints including mortality, work loss days, respiratory-related hospital admissions, and non-fatal heart attacks. Estimated premature mortalities range from tens to hundreds. By contrasting major sources of uncertainty, this work helps identify the largest research needs to achieve improved estimates of wildfire-attributable impacts on public health.

No. 6: Optimal use of grid-connected energy storage to reduce human health impacts

Qian Luo
Fernando Garcia Menendez (Advisor), Jeremiah Johnson (Advisor)
Keywords: energy storage, air quality, human health

Grid-connected energy storage can perform a variety of applications, yielding benefits to power system operations and costs. Current applications for energy storage, however, do not explicitly consider its potential to reduce adverse human health impacts from power generation. In this study, by taking advantage of energy storage's ability to shift both the time and location of power sector emissions based on their charging and discharging strategies, we propose a method that enables energy storage to cost-effectively reduce human health impacts from power sector. To do this, we determine the hourly health damage cost for each electricity generating unit. We then internalize these health damage costs in power plant dispatch decisions, re-optimizing the unit commitment and economic dispatch in light of these costs. We introduce two factors, energy storage and health damage cost, and our preliminary results show that both can contribute to a health impact reduction: a reduction in human exposure was achieved through changes in the commitment and dispatch of existing generators in the absence of energy storage; energy storage allowed further reducing health damages by adding more flexibility to the system. With a higher energy storage capacity in the grid, a greater health damage reduction can be realized.

No. 7: Comparison of methods based on portable emission measurement systems for evaluation of a diesel locomotive retrofitted NO_x emission control system

Nikhil Rastogi
Chris Frey (Advisor)
Keywords: exhaust after treatment, NOx control, selective catalytic reduction, locomotive emissions

Diesel locomotives used in passenger rail service have a long operational life. To reduce emissions for passenger rail service in populated corridors, it is less expensive to retrofit emissions controls on an existing locomotive than to purchase a new locomotive. However, reference methods for measuring locomotive emissions to validate the effectiveness of an emission control system often require taking the locomotive out of service and sending it to a third-party test facility. A portable emissions measurement system-based (PEMS) method to quantify the effect of a retrofitted emission control technology on NO_x emissions is demonstrated. The reference method is based on gravimetric measurements of fuel consumed and exhaust gas measurements which yields accurate data on emission rates. The PEMS-based method is based on estimating engine air flow using the speed-density method, taking into account airbox pressure, revolutions per minute, intake air temperature, and volumetric efficiency, coupled with measurement of the air/fuel ratio. PEMS-based NO_x emission rates were highly correlated with the reference method. NO_x control efficiencies estimated using the two methods were also comparable to each other. The PEMS-based method can be used later for over-the-rail train operation, for which reference measurements are not feasible.

No. 8: Factor analysis of laboratory aging of organic aerosol emissions from biomass cookstoves

Aditya Sinha
Andrew Grieshop (Advisor)
Keywords: factor analysis, positive matrix factorization, secondary organic aerosol, oxidation flow reactor

Roughly 2.5 billion people burn biofuels in cookstoves to meet their daily needs which have implications on health and climate. Emissions include primary organic aerosol (POA) and gas-phase emissions which undergo conversion to form secondary organic aerosol (SOA) during atmospheric aging. Under ambient conditions, these two components (POA and SOA) are difficult to resolve. However, spectral fragment information from aerosol mass spectrometers used with a statistical approach, positive matrix factorization (PMF), can combine several individual fragments into mass spectral factors or 'fingerprints' for different sources/processes. Here, we adopt this approach in a controlled laboratory environment, where experiments were designed with known sources (three stoves of varying combustion efficiencies and two fuel types) and SOA was generated using an oxidation flow reactor (OFR). Preliminary results indicate a three factor solution – one POA and two SOA (intermediately and substantially aged) with reasonable consistency across repeat experiments/conditions. However, the strength of these factors vary with stove and fuel type along with differences in reactor dynamics of the OFR. For instance, the intermediately aged factor is less dominant in more efficient stoves while reactor dynamics affects both SOA factors. The factors extracted here will be compared to ambient studies under similar conditions from the literature.

No. 9: Quantifying emissions effects of non-ideal field observed practices with Mimi Moto

Kyle Tanner
Andrew Grieshop (Advisor)
Keywords: cookstove, emissions, laboratory, biomass, burning

Globally 40% of people burn solid fuels for cooking daily and household air pollution from solid fuel use accounts for 5.5 million deaths annually. One gasifier stove, the Mimi Moto, burns hardwood pellets and has shown to lower emission factors (EFs) of particulate matter (PM) and carbon monoxide (CO) down to those of a propane gas stove. However, field data collected in Rwanda by the Grieshop Group, occasionally shows EFs closer to those of traditional stoves, suggesting the Mimi Moto is sensitive to operation conditions. To explore contributors of high emission events, 26 WBTs were conducted using varying starting (kerosene vs. kindling) and ending (refueling, smoldering) approaches. Measurements were taken for PM, CO, CO2, and organic and elemental carbon. Our results showed that refueling and using kindling for ignition caused PM EFs to increase to values much closer to what had been recorded during high emissions events in the field. CO EFs were also brought close to those of field tests (~30 g/kg) when smoldering was included. Findings may help inform best use practices for Mimi Moto and other improved cookstove customers.

No. 10: Development of running exhaust emission rate models for transit buses

Tongchuan Wei
Chris Frey (Advisor)
Keywords: transit bus, exhaust emissions, passenger load, MOVES

There are 71,100 transit buses in the U.S. Key factors affecting bus exhaust emission rates have been separately evaluated in prior studies. However, bus emission rates are jointly affected by multiple factors. The objective is to evaluate factors affecting bus emission rates in a systematic framework. To achieve this goal, a transit bus emissions model (TBEM) was developed that takes into account bus size, fuel and powertrain, passenger load, driving cycle, and model year. TBEM is based on adjustments of predictions for generic bus types represented in the MOtor Vehicle Emission Simulator (MOVES). TBEM was developed for eight transit bus types and was calibrated based on over 4,000 empirical data. By evaluating factors in a systematic framework based on TBEM, the largest effect on per mile emission rates is from driving cycle, followed by model year, fuel and powertrain, bus size, and passenger load. The largest effect on per passenger-mile emission rates is from passenger load, followed by model year, fuel and powertrain, driving cycle, and bus size. Bus size, fuel and powertrain, passenger load, driving cycle, and model year should be systematically taken into account when developing strategies to improve energy efficiency and reducing emissions for passenger transport.

No. 11: Low cost analysis for elemental and brown carbon (EC/BrC)

Andrew Whitesell
Andrew Grieshop (Advisor)
Keywords: brown carbon, low-cost sensor, Raspberry Pi

Large uncertainties in estimated influences of elemental carbon EC and organic carbon OC as drivers of degraded air quality and climate change drive a need for improved EC and OC in source and ambient measurements. However, analysis of EC and OC using reference instruments is expensive and unrealistic in many areas where biomass combustion can be an issue (e.g., Africa, South Asia, Central America). In this study, the measurement of light absorption by EC and brown carbon (BrC) using a custom low-cost tool was investigated. The low-cost (<$100) absorption apparatus (LCAA) uses a Raspberry Pi computer, Pi Camera, and LED/UV light controlled by a Python script. Transmission of red light through quartz filter samples was used to calibrate a double exponential relationship between absorption and EC concentrations. When fitting absorbed red values and EC to a double exponential model, it was possible to estimate EC from samples of low to medium loadings (1.0 to 10.0 ug/cm^2) with a root mean square error (RMSE) of 2.97 ug/cm^2. Current work is being done to predict BrC concentrations through similar method of comparing absorbed UV light ($\lambda = 365$ nm) and OC within the LCAA.

No. 12: Quantification of energy saving potential for a passenger train based on inter-run variability in speed trajectories

Weichang Yuan, Nikhil Rastogi
Chris Frey (Advisor)
Keywords: train energy consumption, variability, speed trajectory, simulation, eco-driving

Passenger train energy consumption is dependent on speed trajectories. Empirical fuel use data from a portable measurement emission measurement system (PEMS) and empirical speed trajectories measured using a Global Positioning System (GPS) receiver were used to verify and quantify real-world energy consumption variability and variability in empirical speed trajectories, respectively. To identify potential realistic speed trajectories that can lead to energy saving (i.e. eco-driving), a Markov-Chain based speed trajectory simulator was developed. An energy index model (EIM) was used to compare energy consumption among different speed trajectories. Results show inter-run variability in fuel use associated with inter-run variability in empirical speed trajectories. There is also inter-segment variability in fuel use related to segment length and grade. The Markov-Chain based speed trajectory simulator can simulate realistic inter-run variability in speed trajectories based on calibration using empirical speed trajectories. The EIM provides accurate estimation of empirical fuel use. Eco-driving, such as lowering peak speed, can reduce energy consumption without compromising travel time. For example, peak speed reduction on average leads to an energy saving potential of 18% for the Raleigh to Cary segment. The methodology shown in this study is not system-specific and can be applied to other passenger train systems.

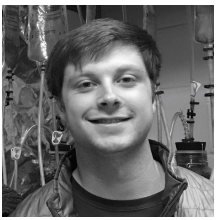
B. Solids

No. 13: Heat generation and accumulation in municipal solid waste landfills

Zisu Hao
Morton Barlaz (Advisor), Joel Ducoste (Advisor)
Keywords: elevated temperature landfills, heat generation, municipal solid waste, temperature, finite element model

Elevated temperatures have been reported in some municipal solid waste (MSW) landfills in North America and require increased monitoring and management. A number of exothermic reactions occur when MSW and other non-hazardous wastes are buried in landfills, including both aerobic and anaerobic biodegradation, anaerobic metal corrosion, acid-base neutralization, ash hydration/carbonation, and possibly thermochemical (pyrolytic) reactions. Demonstrated by a batch reactor model, anaerobic Al corrosion and ash hydration/carbonation were predicted to significantly increase landfill temperatures. However, a batch reactor model does not allow landfill temperatures and waste concentrations to vary spatially, which is not representative of actual landfills. In this work, a 3D transient finite element model was developed to incorporate gas-liquid-heat reactive transfer in a landfill with biological and chemical reactions. The heat balance equation considered the effects of heat generation from abiotic and biotic reactions, conduction, evaporation and condensation, and liquid and gas convection. For the MSW only case, the simulation results illustrate that the maximum temperature of ~55 °C occurred at the center of the landfill. The impact of waste disposal strategy was explored by varying the disposal location of an ash layer and new insights were revealed to reduce heat accumulation from those wastes.

No. 14: Impact of vegetation on the disposal of coal combustion residuals



Logan Herman, Ben Miller, Addie Nixon
Florentino De la Cruz (Advisor), Morton Barlaz (Advisor)
Keywords: coal ash, combustion residuals, landfill, subtitle D

About 66 million tons of coal combustion residuals (CCR) is being disposed annually. The new CCR rule has provisions on management and disposal of CCR to protect air, water, and the impacted communities. These requirements have been finalized under the solid waste provisions (subtitle D) of Resource Conservation and Recovery Act (RCRA) covering siting of new landfills and surface impoundments, liner design, operations, and closure criteria. While landfilling can be considered a "mature" disposal technology, co-disposal of organic matter such as vegetation with CCR presents uncertainties as to the overall behavior of a landfill. This would in turn affect operational decisions relating to the extent and timing to which gas collection system should be installed, settlement and leachate quality. The overall objective of this study is to determine the impact of organic matter (vegetation) on chemical and biochemical processes in conditions representative of landfills. Representative CCR and vegetation samples were collected from the study site. Chemical and biochemical characterization of samples were conducted. Initial results suggest that CCR are methanogenically active and that methane production is limited by the presence of degradable organic matter. This work is being conducted concurrent with geotechnical evaluation of the CCR and vegetation mixture.

No. 15: Exploring alternative methods of achieving policy goals: Impacts of solid waste policy and management choices on the flexibility of solid waste management alternatives

Megan Jaunich
S. Ranji Ranjithan (Advisor), Joseph DeCarolis (Advisor), James Levis (Advisor), Morton Barlaz (Advisor)
Keywords: LCA, SWM, MSW, policy analysis, decision support

Combinations of solid waste management (SWM) collection and treatment processes have been identified to achieve various objectives (e.g., minimum cost, maximum landfill diversion) using the Solid Waste Optimization Life-cycle Framework (SWOLF) for a large, real-world SWM system. Although such models are useful tools to support local and regional decision-making, implementation of "optimal" SWM strategies is challenging because the nature of these systems is complex; hence, it is difficult to entirely represent all considerations within the modeling framework. As such, an optimal solution based on one objective may not represent the most preferable or practicable SWM approach. Rather than identifying a single "best" solution, an approach that explores different ways to meet policy goals is necessary to identify SWM alternatives that may better satisfy non-modeled objectives (e.g., practical limitations, social preferences, political considerations). This study presents results from a systematic exploration of near-optimal solutions using modeling to generate alternatives (MGA). SWM alternatives are generated for several plausible scenarios that meet all modeled objectives and constraints while being maximally different from each other in terms of waste flows. The authors present solutions to county officials and elicit expert feedback, which is used to characterize additional SWM strategies that address possible implementation challenges.

No. 16: Development of test methods to measure heat released from ash hydration and carbonation in landfills

Asmita Narode
Morton Barlaz (Advisor)
Keywords: landfills, reactor, isothermal calorimeter, ash hydration, ash carbonation

In recently published work, a landfill heat accumulation model identified several reactions as significant sources of heat in landfills. There is limited quantitative data on the hydration and carbonation of calcium-containing wastes such as ash from municipal solid waste (MSW) and coal combustion. The objective of ongoing research is to develop methods to measure heat released by ash hydration and carbonation under conditions found in landfills using a reactor system and an isothermal calorimeter (more economic and faster) and to find a correlation between the two methods. Initial tests compared the heat released by calcium oxide (CaO) and hydroxide $Ca(OH)_2$ with theoretical values. Known quantities of CaO and water were added to 20 mL vials for hydration. To measure carbonation, known quantity of $Ca(OH)_2$ was added with gaseous and aqueous CO_2 using sodium bicarbonate. After completion of the reaction, the presence of calcium carbonate (the product of $Ca(OH)_2$ carbonation) was verified by thermogravimetric analysis (TGA). In the calorimeter, measured heat of hydration is ~85% of the theoretical amount. Moreover, data shows formation of crust on product carbonate. Work is in progress to understand how crust formation can be eliminated to reach theoretical values of heat release for the carbonation reaction.

No. 17: Environmental life-cycle assessment of integrated organics management strategies

Mojtaba Sardarmehni
James Levis (Advisor)
Keywords: life cycle assessment, gasification Fischer-Tropsch, municipal solid waste, modeling, organic waste

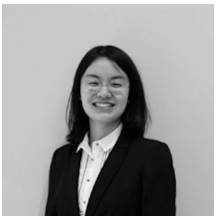
Over 40 million tons of food waste are generated each year in the U.S., and over 75% of this material is disposed at landfills where it is the leading source of fugitive methane emissions. Recovering food waste from municipal solid waste (MSW) can conserve the resources and generate renewable fuels and electricity while reducing environmental impacts. However, increasing source separation and separate collection can add costs and energy use to the waste collection process. The objective of this study is to compare the life-cycle impacts associated with management alternatives for recovering energy and/or nutrients from the organic fraction of MSW. Considered treatment alternatives include landfilling, mass burn waste-to-energy, gasification and syngas combustion, gasification Fischer-Tropsch (GFT), composting, and anaerobic digestion (AD). Results indicate that the gasification and syngas combustion scenario resulted in the least environmental impacts, while landfilling and GFT have the greatest impacts. Separating out the organics for composting or AD generally increased environmental impacts compared to gasification and combustion. The GFT typically performed worse than the other waste-to-energy processes primarily due to the level of compression required for the syngas. The greenhouse gas intensity of the electricity grid was found to be the most important factor affecting the results.

No. 18: The effect of temperature on methane generation from solid waste excavated from landfills with elevated temperatures

Sierra Schupp
Morton Barlaz (Advisor)
Keywords: landfill, elevated, temperature, methanogenesis

Landfills are the predominant disposal method for solid waste globally. Although there are a limited number of elevated temperature landfills (ETLFs), they require intensive monitoring and management as they represent a threat to a landfill's infrastructure (i.e. gas and leachate collection and liner system). At this time, the underlying mechanisms are not well understood. It is hypothesized that microbial communities are able to adapt and sustain methanogenesis as temperatures rise from the mesophilic to thermophilic range and potentially higher. This research aims to determine if and to what extent methanogenesis is possible under ETLF conditions. Samples cultured from a currently operating ETLF were utilized as inoculum in a BMP assay and lab-scale bioreactors. Results to date show that substantial methane production is possible up to at least 62.5°C (145°F). It appears that a smaller population of methanogens capable of enduring elevated temperatures may be responsible for reduced methane generation. Future work will characterize the microbial community present in ETLFs and how they may impact biological processes associated with anaerobic degradation. The results of this research will provide an understanding of methane production potential in landfills at elevated temperatures.

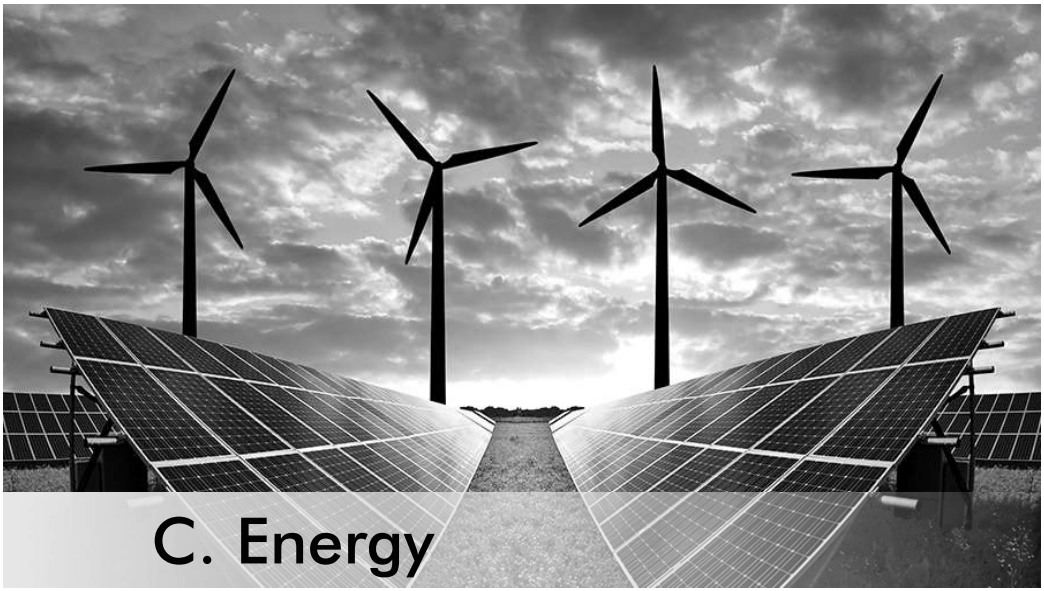
No. 19: Identifying critical impacts and flows in life-cycle assessments of municipal solid waste systems



Yixuan (Wendy) Wang
James Levis (Advisor)

Keywords: life cycle assessment, life cycle impact assessment, municipal solid waste management, principal component analysis

Life-cycle assessments (LCAs) of municipal solid waste (MSW) systems are time and data intensive. Reducing the time and data required for the inventory and impact assessment will facilitate the wider use of LCAs during project, system, or policy planning. Therefore, the objective of this study is to identify the most critical impacts and flows based on their contributions to the final impacts as well as their mutual correlations using principal component analysis. Five treatment process were considered: landfills, waste-to-energy, single-stream recycling, anaerobic digestion, and composing). The scenarios were assessed using 1752 flows of resources and emissions, nine impact categories, three impact assessment methods, and seven weighting schemes. The results show that human health, ecotoxicity, eutrophication, global warming, and fossil fuel depletion contribute 83 to 99% to the total impacts, regardless of weighting schemes. Of the 1752 flows included in the inventory, 29 flows accounted for over 92% of each impact across all the scenarios. It was also found that 92% of variance among the impacts could be explained solely by ecotoxicity and respiratory effects impact categories. The results will be used to develop and evaluate recommended sets of flows and impacts.



C. Energy

No. 20: Environmental life-cycle modeling and assessment of microalgae-to-biofuel systems

Sarang Bhagwat
James Levis (Advisor), Ranji Ranjithan (Advisor)
Keywords: biofuels, algal biofuels, LCA, impact assessment, kinetic model

There is increasing interest in microalgae-based biofuels, given their potential for reduced greenhouse gas (GHG) emissions and resource use compared to conventional fossil fuels and currently prevailing biofuels. However, given the complexity of potential microalgae-to-biofuels processes and systems, implementation of largescale production facilities will require systematic life-cycle assessments of economic viability and environmental performance. Previous assessments of production technology combinations have focused on traditional drying and extraction technologies. This study aims to evaluate and compare the potential environmental and resource impacts of several unique production chains that use a variety of contemporary technologies. The microalgae-to-biofuel system consists of the following sequential processes: algae cultivation, harvesting, dewatering/drying, lipid extraction, and fuel conversion. We developed life-cycle models of multiple alternatives for each process to determine critical processes and input parameters. Drying generally contributed the most to each of the environmental impacts, followed by algae cultivation, fuel conversion, and lipid extraction. However, cultivation reduces GHG emissions due to the uptake of CO_2. Compared to traditional hexane extraction, osmotic lysis reduced GHG emissions but significantly increased freshwater use. This study and the tool developed provide a framework for evaluating and comparing resource use and environmental impact associated with current, largescale microalgae-based fuel production technologies.

No. 21: Environmental and economic impacts of solar powered integrated greenhouses

Joe Hollingsworth
Joseph DeCarolis (Advisor), Jeremiah Johnson (Advisor)
Keywords: sustainable agriculture, organic solar photovoltaics, life cycle assessment, emerging technologies, agrivoltaics

As land becomes more constrained, food demand increases, and climate extremes become more common, controlled agricultural environments will become an increasingly viable option for supplying food to growing communities. Although greenhouses allow for high crop productivity and extended growing seasons, optimal environmental control comes with additional energy demands and costs compared to open field crops. Our research investigates how organic solar photovoltaic (OPV) technology can be integrated into greenhouses to reduce the need for existing infrastructure and reduce environmental impacts associated with crop production. OPVs have the potential to selectively capture infrared wavelengths used for electricity production, while transmitting wavelengths needed for plant growth. The application of OPVs onto greenhouses shows value in the ability to self-supply electricity demands while maintaining plant productivity. Our research is built on the concept of a Solar PoweRed INtegrated Greenhouse (SPRING) system. We conduct a regional environmental LCA and economic analysis to compare the SPRING system with a conventional greenhouse. Our research also incorporates a solar plus battery storage optimization model to determine the feasibility of self-sustaining greenhouses. To best understand these integrated impacts, our analysis relies on an interdisciplinary research team with scholars in plant biology, physics, chemistry, mechanical engineering, and environmental engineering.

No. 22: Buildings as batteries: an experimental investigation into energy efficiency impacts of demand response

Aditya Keskar, David Anderson, Ian Hiskens, Johanna Mathieu
Jeremiah Johnson (Advisor)
Keywords: energy efficiency, commercial building HVAC, building controls, demand response

There is an increasing need for flexible resources to maintain reliable power grid operation due to the combined effect of reduced grid inertia and the addition of supply-side stochasticity caused by renewables. Commercial building heating ventilation and air conditioning (HVAC) systems are attractive candidates for load shifting due to their large thermal inertia and inherently sophisticated building controls. Recent work has suggested potential adverse impacts on energy efficiency associated with such demand response activity. To explore this phenomenon, we conducted over one hundred experiments on three university buildings. We perturb the building temperature setpoints in predefined patterns (that emulate energy neutral demand response events), causing the building to change its power consumption over and below its baseline power use, thereby acting like a battery from the grid's perspective. We present results from the experiments and quantify the efficiency of building response by focusing on the round trip efficiency as well as the additional energy consumed by the building while providing this demand response service. The three buildings respond with mean roundtrip efficiencies ranging from 34% to 81%, with individual tests yielding efficiencies far outside that range. Our findings offer new and practical insights into the impacts of demand response on building operations and potential challenges needed to be overcome to achieve commercial viability.

No. 23: Effect of air-conditioning on light duty gasoline vehicles fuel economy

Tanzila Khan
Chris Frey (Advisor)
Keywords: fuel economy, air-conditioning, real-world, MOVES2014a, driving cycles

With more stringent U.S. fuel economy (FE) standards, the effect of auxiliary devices such as air-conditioning (AC) has received increased attention. AC is the largest auxiliary engine load for light duty gasoline vehicles (LDGVs). However, there are few data regarding the FE penalty from AC usage for LDGVs based on real-world measurements, especially for recent model year vehicles. The Motor Vehicle Emission Simulator (MOVES) is a regulatory model for estimating on-road vehicle energy-use and emissions. MOVES adjusts vehicle energy-use rates for AC effects. However, MOVES-predicted FE with AC has not been evaluated based on empirical measurements. The research objectives are to quantify the LDGVs FE penalty from AC and assess the accuracy of MOVES2014a-predicted FE with AC. The AC effect on real-world fleet-average FE was quantified based on 78 AC-off vehicles versus 55 AC-on vehicles, measured with onboard instruments on defined study routes. MOVES2014a-based FE penalty from AC was evaluated based on real-world estimates. Among a wide range of driving cycles, the real-world FE penalty ranges between 1.3%-7.5% with 2% on average, while that from MOVES estimates ranges between 13.5%-18.5%. Thus, MOVES overestimates the real-world fleet-average FE penalty from AC usage and MOVES AC adjustment factors need to be updated.

No. 24: Cell disruption of marine microalgae, *Dunaliella viridis*, using hydraulic cavitation

Yi-Chun Lai
Joel Ducoste (Advisor), Francis de los Reyes (Advisor)
Keywords: marine microalgae, *Dunaliella viridis*, hydraulic cavitation, lipid, chlorophyll

The use of the microalgal species *Dunaliella viridis* as a potential source of lipids for biofuel production, is especially advantageous because *D. viridis* does not compete for freshwater resources and it has no cell wall. The absence of a cell wall could potentially reduce the cost of extracting lipids for biodiesel production. The harvesting and dewatering steps represent about 30% of the cost of biomass production, and is thus crucial in realizing the economic feasibility of microalgal biodiesel production. Hydraulic cavitation is formed by vapor pressure reduction of the fluid in a constricted pipe. The sudden collapse of numerous microbubbles from the return to higher pressures mechanically disrupts the microalgal membranes and release their intracellular components. Here, we evaluate the efficiency of microalgal cell disruption through hydraulic cavitation by quantifying biomass and chlorophyll concentration. Initial results suggest that the cell disruption rate was high in the first ten minutes but subsequently leveled off. Since hydraulic cavitation can quickly disrupt the cells, we believe it is more energy efficient and has great potential to be applied in full scale. Possible mechanisms and challenges associated with cell disruption using hydraulic cavitation will also be discussed.

No. 25: The potential for emissions reductions with residential demand response

Madeline Macmillan
Jeremiah Johnson (Advisor)
Keywords: demand response, emissions reductions

The primary goal of demand response (DR) is to reduce peak electricity demand. In this study, we examine an alternative goal of using DR to reduce air emissions. For the US, we estimate the diurnal and seasonal demand profiles for suitable residential end uses including air conditioning, electric heating, and water heating. We assume that the DR events are load-neutral and test a range of tolerances for demand deferral. We develop an emissions minimization model that utilizes hourly marginal emissions factors for 22 grid regions to show significant potential to reduce CO_2 emissions through DR approaches. Our results show the magnitude of the benefits is limited by the length of the demand deferral and DR adoption rate. With participation and high tolerance for load shifting, we estimate up to 15%, 12%, and 13% decreases in CO_2 emissions from electric heating, air conditioning, and electric water heating applications, respectively. The potential varies across regions and the regions with high residential demand and high variance in marginal emissions factors yield the greatest potential to reduce CO_2 emissions. This study shows the magnitude of emissions reduction is sufficiently large and these emissions reductions can be met without significant loss of energy services.

No. 26: Simulating a decentralized peer-to-peer electricity market using an agent-based modeling approach

Jacob Monroe
Emily Berglund (Advisor)
Keywords: agent-based modeling, peer-to-peer energy trading, decentralized electricity markets, solar energy, electric distribution

The global diffusion of distributed energy resources pressures grid stakeholders to rethink the historical business model of electric power distribution systems and the roles that major utilities play in their daily operation. An increase in microgeneration of electricity at the grid edge allows for a new system of peer-to-peer electricity trading among end-users. This research develops an agent-based modeling framework for simulating electricity trades between heterogeneous households in a decentralized peer-to-peer electricity market. The framework is applied to a simple low-voltage sub-network filled with single-family residential households to analyze the average price of exchanged electricity that emerges based on agent decisions and environmental conditions. The market is represented as a real-time bilateral exchange system where buyers bid for their upcoming demand and sellers bid their forecasted excess solar power production for the upcoming trade interval. Multiple forecast models are simulated for several trade interval lengths. A utility manager is modeled to sell electricity to households when excess solar power is unavailable and buy excess solar power that is not exchanged in the market. The agent-based peer-to-peer electricity market model is simulated for several cities across the United States, and results are evaluated for market performance.

No. 27: Electrochemical Characterization of the Electricity-Generating Bacterium *Geobacter sulfurreducens* Under Nitrogen Gas Fixation Conditions

Mark Poole, Fausto Ortiz, Dr. Amy Grunden, Dr. Michael Hyman
Douglas Call (Advisor)
Keywords: microbial fuel cell, nitrogen fixation, electrochemical respiration

Nitrogen gas (N_2) conversion to ammonia (NH_3) is an essential but cost- and energy-expensive process, with the Haber-Bosch method constituting the major form of artificial N_2 fixation implemented today. Recently we showed that a microbial consortium can fix N_2 gas into ammonium (NH_4^+; the dissolved form of NH_3) when an applied voltage drove their respiration in microbial electrolysis cells (MECs). High-throughput sequencing of the consortium revealed that the nitrogen-fixing soil bacterium *Geobacter sulfurreduences* was highly abundant. We suspect that this microorganism was the main driver of N_2 fixation in the MEC, but the presence of other microorganisms in that system complicates this conclusion. Accordingly, the objective of this study is to investigate the electrochemical properties of a pure culture of *G. sulfurreducens* under N_2 fixation conditions. MECs containing either NH_4^+ or N_2 will be compared for differences in reactor startup time, cell respiration rate, biofilm thickness, and cellular morphology. Electrochemical techniques, including cyclic voltammetry, will be used to detect shifts in redox peaks indicative of metabolic changes associated with the activation of unique pathways. Electronic impedance spectroscopy will be performed to determine biofilm thickness and resistance along with charge transfer differences. We expect that our results will broaden our understanding of N_2 fixation by *G. sulfurreduences* during electrode respiration and provide insight into the electrochemical triggers associated with the process.

No. 28: Energy storage options for North Carolina

Danny Sodano
Joe DeCarolis (Advisor), Jeremiah Johnson (Advisor)
Keywords: optimization, energy systems, modeling

Retirement of coal generation and rapid renewable energy adoption makes North Carolina a unique candidate for investigation of energy storage benefits. Under HB 589, the NC Policy Collaboratory produced a report on the value of storage to NC customers. The Civil, Construction, and Environmental Engineering subgroup focused on two services storage can provide: energy arbitrage and peak capacity deferral. Using Tools for Energy Model Optimization and Analysis (Temoa), we developed scenarios for the future of the NC grid and modeled yearly capacity expansion and hourly operations. These scenarios include a high natural gas price, electric vehicle adoption, and an expanded renewable portfolio standard. One conclusion from the report was, though some site-specific storage technologies are already cost-effective for some services, storage costs are decreasing so rapidly that even services which are not cost-effective today may be by 2030, according to breakeven analyses. The report was submitted to the NC General Assembly with various policy options detailed. One follow-up project is developing a Python script to continuously run the capacity and operational models, assembling a curve visualizing the trend in storage cost-effectiveness over time. This will make Temoa more user-friendly and will provide more pinpointed and accurate future analyses.

D. Coastal

No. 29: A case study in using remote sensing to quantify motu morphometrics

Faith Johnson
Alejandra Ortiz (Advisor)
Keywords: remote sensing, atoll, Google Earth Engine, Landsat, climate change

Motu (reef islands) are the inhabitable and populated sub-aerial land on an atoll. Atolls are low lying with mean elevations of 2-3 m. Atolls may be particularly vulnerable to climate change (including sea level rise, increasing ocean temperatures, and ocean acidification) because they are composed primarily of unconsolidated carbonate sediments eroded from reefs. Recent research has found that certain atolls may be resilient to climate change. However, we lack comprehensive understanding about the primary processes driving motu evolution. Motu may self-organize and reach an equilibrium reef-flat width in response to a particular wave climate suggesting that exterior forcings (wave climate) may be the primary control on motu evolution. For Katiu and Fakarava, French Polynesia, our case study, I created Landsat composites, categorized each component of the atoll (water, reef flat, or motu), and calculated morphometrics (e.g. atoll size and shape, the width of the reef flat, and the individual motu size and shape) using Google Earth Engine and Python. Local wave and storm climate will be compared to the calculated morphometrics. The methodology will be applied globally in the future in order to test if external forcings are the primary drivers of the evolution of atoll motu.

No. 30: Impact of marine hydrokinetic devices on the wave field and sediment transport

Hanieh Mohamadi Moghadam
Alejandra Ortiz (Advisor)
Keywords: renewable energy, marine hydrokinetics, numerical modeling, SNL-SWAN, Delft3D

Marine Hydrokinetic (MHK) devices provide an opportunity to expand renewable energy by harnessing waves and currents power and converting it to electricity. However, most MHK devices are in the developmental stage requiring research to understand their impacts on the environment, including the abiotic processes such as the wave field and sediment transport. We must understand how the ocean sediments will be moved around these devices to minimize installation and maintenance costs. We need to know whether these devices will be buried or excavated over time and the impact of the MHK devices on the hydrodynamics (the wave and current) and morphodynamics (the ocean floor evolution) to minimize operational costs. In this study, we use SNL-SWAN model to investigate the wave field response to various MHK devices and then couple the MHK module from the SNL-SWAN model into Delft3D to obtain MHK impact on wave, flow, and sediment conditions driving long-term morphologic evolution. The results indicate significant decrease in wave height locally (decreases of 25% or more within several kilometers) and 1-5% decrease further downstream.

No. 31: Development of dune impact forecasting system for NC 12 Highway along Pea Island, North Carolina

Russell Nasrallah
Elizabeth Sciaudone (Advisor)
Keywords: coastal, modeling, xBeach, dunes, highway, prediction

Extreme storms along the coast of North Carolina have significant impacts on infrastructure, economics, and public safety of the region. The North Carolina barrier island chain known as the Outer Banks is especially vulnerable to storm surge and high ocean waves accompanying these storms. Highway NC 12 is one such piece of vulnerable infrastructure, extending along the narrow barrier Hatteras Island. It serves as the only terrestrial evacuation route for the 4000 year round resident's people who reside on the island and the 50,000 weekly visitors during the tourist season. This project's aim is to develop a forecasting system to predict adverse roadway conditions due to storms along NC 12 on Hatteras Island. The eXtreme Beach (xBeach) model is used to simulate storm impacts along the coast by modeling hydrodynamic and morphological processes. Boundary conditions for the XBeach model are developed using the National Oceanic and Atmospheric Administration (NOAA)'s detailed ocean condition predictions derived from the WaveWatch 3 (WW3) model. This poster describes validation of a 1-D XBeach modeling system for the area using Hurricane Sandy as a test case.

No. 32: Atoll reef flat excavation pit influence on wave energy

Johnathan Woodruff, Carter Rucker
Alejandra Ortiz (Advisor), Casey Dietrich (Advisor)
Keywords: atoll, excavation, pit, wave, energy

The shorelines of atolls are often exposed to high energy wave climates. These wave climates have the potential to wreak havoc on coastal structures. Luckily, atolls have a natural defense, a fringing reef flat which serves to attenuate wave energy as the waves propagate overtop of them. Unfortunately, as demand for construction materials increases, reef flats have been excavated. The excavation appears in the form of pits, which dot the coasts of many atolls. This study seeks to understand how the presence of excavation pits on reef flats increase wave energy at an atoll's reef island. A one-dimensional XBeach model is used to analyze the wave energy present at the shoreline of the reef island. The excavation pits located off Majuro Atoll in the Marshall Islands are being used as examples for this project. We have found that the presence of an excavation pit significantly increases the wave energy at the reef island. With more wave energy reaching the reef island, more erosion will likely take place as erosion is dependent on the wave height squared. This is important for atoll municipalities to consider when trying to create construction regulations.

E. Water Treatment

No. 33: Occurrence of pesticides in private well water in North Carolina and point-of-use treatment options

Nancy Lee Alexander
Detlef Knappe (Advisor)
Keywords: pesticides, high resolution mass spectrometry, drinking water quality, untargeted analysis, liquid chromatography

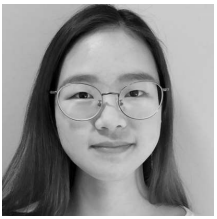
In North Carolina (NC), nearly 35% of residents rely on private well water as their primary drinking water source. There is little information on occurrence of pesticides and other pollutants in private wells because private wells fall outside the purview of the Safe Drinking Water Act. The first goal of this research is to assess pesticide occurrence in private well water across NC. The second goal is to evaluate the effectiveness of point-of-use (POU) treatment options for well users affected by pesticide contamination. To accomplish the first goal, 150 private wells in five NC counties will be sampled and analyzed for a suite of contaminants including pesticides, volatile organic contaminants (including the pesticide impurity 1,2,3-trichloropropane), and total coliforms. To identify a wide range of pesticides, high resolution quadrupole time-of-flight mass spectrometry (QTOF-MS) will be used. For the second goal, a range of POU treatment devices will be tested to identify those effective in removing pesticides and other contaminants identified in objective one. This research has the opportunity to directly impact the public health of the private well community in NC. The data obtained in this research will serve county health departments and equip private well users with valuable knowledge.

No. 34: The effect of electrode orientation on salt removal in flow-through capacitive deionization

Yazeed Algurainy, Shan Zhu
Douglas Call (Advisor)
Keywords: capacitive deionization, flow-through, electrode orientation, Faradaic reactions

Capacitive deionization (CDI) is an emerging desalination technology that may provide a low-energy alternative to pressurized-membrane processes. In CDI, a voltage is applied across a pair of porous electrodes, and ions from the feedwater are removed via electrosorption onto the electrodes. The feedwater can be directed either between the electrodes or through them. Flow-through configurations are asymmetrical; the cathode or anode can be positioned as the upstream, or influent-receiving, electrode. As such, electrode orientation may yield differences in salt removal performance due to the sequential nature that capacitive and/or faradaic reactions occur. Our results show that salt removal and charge efficiency increased by up to 28.9% (6.5 ± 0.2 mg-NaCl/g-AC) and 21.8% (26.4 ± 0.7%), respectively, in the upstream cathode (UC) configuration compared to the upstream anode (UA). Effluent pH dropped sharply to 3.7±0.1 in UC and increased gradually to 9.7±0.1 for UA. These pH changes suggested that faradaic reactions were occurring, but that the reaction type and/or rate was electrode orientation dependent. Much larger effluent hydrogen peroxide concentrations (69±0.2 μM) were recorded in UA compared to UC (26±0.9 μM). In summary, electrode orientation in flow-through CDI affects the extent and rates of faradaic reactions, which in turn has an appreciable impact on CDI performance.

No. 35: Predicting PFASs removal by ion exchange resins with rapid small-scale column tests



Lan Cheng
Detlef Knappe (Advisor)
Keywords: PFASs, ion exchange resins, RSSCTs, drinking water treatment

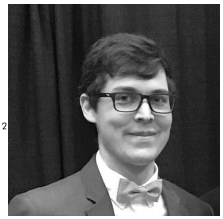
Per- and polyfluoroalkyl substances (PFASs) are persistent contaminants with adverse environmental and public health effects. For drinking water, the EPA issued a health advisory level for the combination of PFOA and PFOS at 70 ng/L. Furthermore, the North Carolina health goal for the emerging PFAS GenX is 140 ng/L. Conventional drinking water treatment processes are ineffective for PFAS removal. Ion exchange (IX) resins have gained attention as a treatment alternative for PFAS removal because they are regenerable materials and may exhibit a long service life. To date, there are no published studies that have identified suitable approaches for the scale-up of bench-scale IX data. To fill this knowledge gap, I will conduct rapid small-scale column tests (RSSCTs) to simulate PFAS removal observed in a recently completed pilot study. RSSCTs are based on principles of similitude and are conducted with crushed IX resin. In my research, I will evaluate whether PFAS diffusion inside of IX resin varies with particle size. Furthermore, I will investigate the effect of IX resins properties, coexisting PFASs, background water matrix, and empty bed contact time on PFAS removal by IX, aiding the design of future full-scale treatment systems.

No. 36: Novel water desalination filter utilizing granular activated carbon

Geoffrey Fylak[1]
Douglas Call[2] (Advisor), Shan Zhu[2] (Advisor)
Keywords: desalination, granular activated carbon, capacitive deionization
[1]North Carolina School of Science and Math, [2]North Carolina State University

As the human population continues increasing, so does the demand for freshwater resources. The scarcity of freshwater will likely impact one third of the world's population within the next decade. While there are many proven methods of water desalination, most are cost and energy intensive. Our research seeks to improve upon a novel desalination technique, which would expand available drinking water sources on a global scale. The technique investigated is capacitive deionization: an emerging, yet proven, scalable method of desalination that removes charged species from water using low levels of electricity. The filter utilizes granular activated carbon (GAC), an affordable, naturally abundant material commonly used in industrial Brita water filters to remove uncharged contaminants. We anticipate that GAC's electrically conductive properties will enable the material to adsorb sodium chloride. Our goal is to determine and enhance the performance capabilities of GAC by altering operational parameters and system design. Initial tests demonstrated low performance due to inadequate operational parameters and design flaws. Through systematic improvements, researchers have increased adsorption capacity from 10.3 μg/g to 452.0 μg/g for a 4,288% increase. Due to success removing sodium chloride, our filter's application may extend to remove more harmful charged contaminants in the future.

No. 37: Factors affecting activated carbon adsorption of recently discovered per- and polyfluoroalkyl ether acids



Zachary Hopkins[1], James McCord[2], Mark Strynar[2], Andrew Lindstrom[2]
Detlef Knappe[1] (Advisor)
Keywords: surface water, drinking water treatment, per- and polyfluoroalkyl substances, granular activated carbon
[1]North Carolina State University, [2]U.S. Environmental Protection Agency

Health implications associated with long-chain per- and polyfluoroalkyl substances (PFAS) have caused a shift in PFAS manufacturing and usage towards shorter-chain PFAS and fluorinated alternatives. Fluorinated alternatives include perfluoroalkyl ether acids (PFEA), in which ether oxygen atoms are incorporated into the perfluoroalkyl chain. PFAS contamination of drinking water sources is a concern because conventional and many advanced treatment processes do not effectively remove PFAS, including PFEA. Our research aims to 1) identify granular activated carbon (GAC) properties that enhance PFAS removal and 2) develop structure-property relationships to predict PFAS removal by GAC. Rapid small-scale column tests (RSSCTs) were conducted to assess PFAS removal from surface water and groundwater by three GACs. Samples were analyzed by liquid chromatography – tandem mass spectrometry for 21 PFAS, including 10 PFEA. PFAS adsorbability increased with chain length and incorporation of ether oxygen atoms. Linear PFAS were more adsorbable than branched PFAS of equivalent chain length. Dissolved organic matter content of the water matrix strongly affected PFAS removal. E.g, 25% PFBA breakthrough was reached after treating 6,900 and 19,400 bed volumes of surface water and groundwater, respectively. Findings are expected to aid water purveyors in selecting the most effective GAC to treat for PFAS.

No. 38: Electrically-assisted sorption and desorption of per- and polyfluoroalkyl substances (PFAS) using activated carbon (AC) electrodes

Elvin Hossen, Shan Zhu
Detlef Knappe (Advisor), Douglas Call (Advisor)
Keywords: capacitive deionization, PFAS, electrosorption, desorption

Per- and polyfluoroalkyl substances (PFAS) are contaminants of emerging concern in water. Activated carbon (AC) can remove PFAS, but is challenged by limited adsorption capacity, lack of cost-effective regeneration options, and inability to adsorb short-chain species. Electrically charging AC, as practiced in capacitive deionization technologies, increases the adsorption of charged species when voltage is applied between two AC-based electrodes. Reversing voltage releases the electro-adsorbed ions back into solution, regenerating AC without needing chemicals. Numerous studies on the electrosorption of small inorganic ions but our knowledge of PFAS is still limited. Accordingly, we investigated the effectiveness of electrical assistance to improve adsorption/desorption of PFAS. We examined three PFAS: perfluorooctanoic acid (PFOA), perfluorooctanesulfonic acid (PFOS), and perfluorobutanesulfonic acid (PFBS) at applied voltage of 1.0 V and in a system without voltage. Our results show that applying voltage for 200 minutes increases adsorption capacity of PFOA by 142%, PFOS by 39%, and PFBS by 138%, relative to no-voltage control. We also explored different electrochemical techniques to desorb PFAS from AC. Applying alternating $\pm$1.0 V to PFOA-saturated AC electrodes increased PFOA recovery by 47% relative to physical desorption. These findings suggest that electrically-assisted AC may provide sustainable alternative for enhanced treatment of PFAS-contaminated water.

No. 39: Evaluation of light modeling approaches for estimating light attenuation during microalgal cultivation

Amanda Karam, Yi-Chun Lai
Francis de los Reyes III (Advisor), Joel Ducoste (Advisor)
Keywords: microalgae, growth modeling, light attenuation, chlorophyll

Capturing the effect of light in kinetic models that predict the growth of microalgae in photobioreactors (PBRs) is challenging due to the dynamic changes in light intensity over space, and the interactive impacts of algal growth and algal biocomponents. This challenge is further complicated by the inconsistent and wide-ranging modeling approaches used to estimate light. The goal of this research was to evaluate many of these various modeling approaches, specifically those that use the Beer-Lambert law, by calibrating and validating these models using a continuous, in-situ photosynthetically active radiation (PAR) light sensor within a flat-plate PBR. *Dunaliella viridis* microalgae was grown under various light and nitrogen conditions and measurements of biomass and pigments were used, as needed, for calibrating and validating seven different light models. Overall, light models that included the absorbance of both biomass and chlorophyll pigments had better predictive power (5-6% error) than models that included only biomass (30% error) or only pigments (23-26% error). These results suggest that current light modeling approaches for estimating light within microalgal systems should shift towards models where both chlorophylls and biomass absorbing constituents are consistently included.

No. 40: Cometabolism of 1,4-dioxane using locally enriched cultures at drinking water relevant concentrations

Amie McElroy
Detlef Knappe (Advisor), Michael Hyman (Advisor)
Keywords: biological treatment, biofiltration, emerging contaminants

1,4-Dioxane is a likely human carcinogen that occurs widely in drinking water. In the US, drinking water health goals are as low as 0.25 μg/L. Biological treatment is a promising alternative for 1,4-dioxane control, but its effectiveness has not been established at low μg/L concentrations. Objectives of my research are to (1) develop and characterize enrichment cultures that cometabolically degrade 1,4-dioxane at low μg/L concentrations and (2) identify impacts of sorptive capacity of filter media, empty bed contact time (EBCT), and primary substrate on 1,4-dioxane removal in biofilters. Cultures were enriched from North Carolina rivers and (waste)water treatment plants using isobutane as the primary substrate. Enrichments rapidly degraded 1,4-dioxane from 100 μg/L to $<$0.25 μg/L. Based on 16S-rRNA amplicon sequencing data, commonly enriched taxa included *Mycobacterium* and *Variovorax*. Activity-based protein profiling (ABPP) results suggest all enriched cultures expressed a similar polypeptide, likely linked to short-chain alkane monooxygenase (SCAM). To determine the impact of design and operating parameters on biofiltration effectiveness, 1,4-dioxane removal in inoculated filters receiving butane or a food-grade additive as primary substrate will be compared to non-inoculated controls. Three filter media with different 1,4-dioxane capacities will be evaluated, and four EBCTs will be considered.

No. 41: NMR analysis of dissolved organic matter isolated from landfill leachate

Jacob Nelson
Florentino De la Cruz (Advisor)
Keywords: dissolved organic matter, landfill leachate, UV254 absorbance, solid phase extraction, NMR

Over 60% of active landfills discharge leachate to municipal wastewater treatment plants (WWTPs). Dissolved Organic Matter (DOM) in landfill leachate poses treatment challenges as it resists traditional biological treatment and absorbs UV254 impacting UV disinfection at WWTPs. While on-site treatment such as reverse osmosis is available, it is economically prohibitive for some landfills. Past research has detailed molecular characterization of DOM, but little is known about the molecular structure of DOM in landfill leachate. The objective of this project is to characterize DOM for evaluation of landfill leachate treatment alternatives. Landfill leachates were collected at different points in study landfill's on-site treatment. DOM was isolated by solid phase extraction (SPE) into methanol extracts. Each extract was further processed to dissolve DOM in DMSO-d_6 for Nuclear Magnetic Resonance (NMR) spectra acquisition. The NMR spectra: ^{1}H, ^{13}C, $^{1}H - ^{13}C$ Heteronuclear Single Quantum Coherence (HSQC), and Homonuclear Multiple Bond Correlation (HMC), allowed for structural elucidation and comparison of DOM from different leachates as well as to DOM from untreated municipal wastewater. Initial results suggest that leachate DOM is characterized by small, oxidized molecules and while there are similarities, there are pronounced differences in DOM chemical signatures when leachate and wastewater is compared.

No. 42: Effect of Food Waste Diversion on Leachate Quality

Addie Nixon, Ben Miller, Logan Herman
Florentino De la Cruz (Advisor)
Keywords: leachate treatment, landfill, wastewater, food waste

Approximately 19,500 million gallons of landfill leachate was estimated to have been sent to wastewater treatment plants (WWTP) in the U.S. in 2013. Whether treatment is on-site or in a publicly-owned WWTP, landfill leachate can be problematic because it contains high levels of refractory organic matter (ROM) and ammonia that could impact WWTP operations. ROM (i.e. lignin-derived humic- and fulvic-like substances) in leachate reduces the effectiveness of UV disinfection systems, the use of which in wastewater treatment plants continues to increase. As a result, WWTPs are increasingly refusing to accept landfill leachate, putting pressure on landfill owners to explore costlier leachate treatment alternatives. Thus, an understanding of the nature, characteristics, and sources of ROM would allow for a better understanding of the effects of leachate components on treatment processes. The objectives of this research are: (1) To determine the effect of removing food waste from municipal solid waste (MSW) on leachate quality, during waste decomposition under simulated landfill conditions; (2) To characterize the compounds/moieties that absorb UV254 in samples of leachate produced in systems with and without food waste. Initial results suggest that different types of food waste affect leachate quality differently.

No. 43: Nitrogen gas fixation and conversion to ammonium using microbial electrolysis cells

Fausto Ortiz
Douglas Call (Advisor)
Keywords: ammonium production, *Geobacter*, Haber-Bosch, microbial electrolysis cell, nitrogen fixation

Ammonia (NH_3) is an important industrial chemical that is produced using the energy- and carbon-intensive Haber-Bosch process. Nitrogen gas fixation (N_2) may provide a sustainable alternative because specialized microbial enzymes, called nitrogenases, reduce N_2 to ammonium (NH_4^+) without needing high temperature and pressure. This study explored the possibility of NH_4^+ production using microbial electrolysis cells (MECs). In an MEC, applying a voltage between two electrodes drives the microbial conversion of organic matter into electrical current. N_2 fixation rates of a microbial consortium in the MEC increased significantly when the applied voltage increased from 0.7 V to 1.0 V. Dissolved NH_4^+, which inhibits nitrogenase, did not significantly reduce N_2 fixation rates. By adding methionine sulfoximine, an NH_4^+ uptake inhibitor, NH_4^+ was recovered at rates approaching 5.2×10^{-12} mol NH_4^+ s^{-1} cm^{-2}. Production of energy-rich methane gas via methanogenesis helped offset the electrical energy demand, resulting in total demands as low as 24 MJ mol^{-1} NH_4^+. *Geobacter* species predominated in the anode biofilm, suggesting that these bacteria are essential for current generation and N_2 fixation. These results show that MECs offers a new route for generating NH_4^+ from nitrogen-deficient wastewaters, such those produced in the pulp and paper industries.

No. 44: Exploring the conversion of tertiary denitrification to mainstream deammonification: Pilot scale filter results and challenges

Eric Polli[1,2], Katya Bilyk[2], Wendell Khunjar[2], Erika Bailey[3]
Tarek Aziz[1] (Advisor), Francis de los Reyes[1] (Advisor)
Keywords: Anammox, mainstream, deammonification, nitrogen removal, pilot-scale
[1]North Carolina State University, [2]Hazen & Sawyer, [3]City of Raleigh

This research presents a novel alternative to mainstream biological nutrient removal (BNR) - mainstream deammonification utilizing a two-stage system of an activated sludge process, operating in a partial nitritation mode, and tertiary anammox filters. Mainstream deammonification is still an emerging technology with many challenges. The two-stage system promises to reduce chemical costs while minimizing infrastructure costs of operating the BNR process. Despite these potential benefits, there are key questions that need to be answered: if anammox filters can meet necessary TN limits, how diurnal nitrogen loading impacts performance, and understanding the impacts of backwash on performance recovery. Our results show the anammox filter is achieving low effluent ammonia and nitrite values (<0.3 mg/L for both). However, nitrate production from the anammox reaction is hindering meeting a 2 mg/L TIN limit. A diurnal NLR experiment showed the clean media filter beginning to adjust to a higher peaking factor after a short period. Filter recovery is quick after a backwash and a more extensive backwashing experiment on a 72-hr filter run time is to be conducted.

No. 45: Dissolved organic matter processing and enhanced photodegradation of emerging contaminants in treatment wetlands

Arpit Sardana
Tarek Aziz (Advisor)
Keywords: treatment wetlands, emerging contaminants, photochemistry

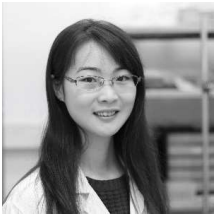
Free-water surface constructed wetlands exposed to sunlight have been shown to photo-chemically degrade a range of contaminants of emerging concern (CECs) recalcitrant to conventional wastewater treatment. Photo-degradation kinetics in wetlands are dependent on effluent photochemistry, dissolved organic matter (DOM) composition, irradiation intensity, and CEC reactivity. While DOM composition can result in enhanced CECs photodegradation, the role of engineering design on photochemically-favorable DOM is not well understood. To evaluate the photoreactivity of wastewater in constructed wetlands we have collected field samples from wetlands across North Carolina and are conducting microcosm experiments wherein we explore the role of wetland plant senescence in enhancing photodegradation. We hypothesize that the indirect photodegradation rates of CECs are enhanced by DOM processing in treatment wetlands. The DOM composition of effluent samples from field wetlands and laboratory microcosms was characterized using fluorescence spectroscopy. Due to leaching of terrestrial DOM from plants, both sets of samples were observed to have significant concentrations of humic acid-like and fulvic acid-like substances. Furthermore, pseudo-first order photodegradation rates of selected CECs were estimated for the collected wetland waters using an open source photochemical model – APEX. The model incorporates both direct and indirect photodegradation pathways and assists in designing wetlands for CECs removal.

No. 46: What determines the microbial community in aerobic wastewater treatment and what that means for design and operation.

Joseph Weaver
Francis de los Reyes (Advisor)
Keywords: wastewater treatment, microbial ecology, community assembly, metagenomics

An activated sludge basin's microbial community directly affects its performance; so a central question that needs to be answered is: "What drives community assembly towards desired populations?" Metagenomic 'snapshots' of single, established reactor populations give only partial answers. We had an opportunity to fill this gap by comparing changes in initially identical microbial communities between two different plants, one of which was undergoing startup and inoculated with sludge from the other. Our goals were to observe if the communities converged or diverged, determine which assembly processes dominated, and identify differences in assembly between microbial community subpopulations. We found that communities converged and were more influenced by the inoculum than the influent. Random selection (aka neutral processes) dominates when the entire microbial community is considered. A differential abundance analysis (deseq2) attributes this to generalist heterotrophs. Meanwhile, functionally categorized subpopulations (such as autotrophs) identified through the MiDAS database appear more divergent and driven by niche-based selection. Such analyses quantitatively support and extend engineering common sense: both a 'good start' and good operation are critical. General plant performance benefits most from selecting a good inoculum, but proper basin design and operation are essential for promoting desired specialist communities.

No. 47: Fate of per- and polyfluoroalkyl ether acids in the total oxidizable precursor assay



Chuhui Zhang[1], Zachary Hopkins[1], James McCord[2], Mark Strynar[2], Andrew Lindstrom[2]
Detlef Knappe[1] (Advisor)
Keywords: perfluoroalkyl ether acids, total oxidizable precursor assay, UV/H2O2, PFASs
[1]North Carolina State University, [2]U.S. Environmental Protection Agency

Per- and polyfluoroalkyl substances (PFAS) are widely used anthropogenic chemicals. The PFAS class includes almost 5,000 registered compounds, and analytical methods are lacking for the vast majority of compounds. The total oxidizable precursor (TOP) assay was developed to estimate concentrations of precursor compounds that may degrade in the environment to commonly measured PFAS. To date, little information is available about the fate of recently discovered per- and polyfluoroalkyl ether acids (PFEA) in the TOP assay. The aims of this research are to (1) determine the fate of eight perfluoroalkyl ether carboxylic acids (PFECAs), including GenX; four polyfluorinated ether acids; and one chlorofluoroalkyl ether sulfonic acid (F-53B) in the TOP assay; and (2) determine the role of hydroxyl and sulfate radicals in the TOP assay. The eight tested PFECAs and F-53B were stable in the TOP assay and thus represent new dead-end products that need to be added to the list of target analytes for the TOP assay. In contrast, polyfluorinated ether acids were oxidized during the TOP assay. Results of this study are expected to provide an enhanced TOP assay that will capture a larger fraction of oxidizable precursors that may be present in environmental samples.

F. Water Resources

No. 48: Multi-decadal assessment of nutrient loading and water quality change in Jordan Lake

Matthew Aupperle, Jonathan W. Miller, Kimia Karimi, Dario Del Giudice, A. Sankarasubramanian
Dan Obenour (Advisor)
Keywords: water-quality, Jordan Lake, eutrophication

Jordan Lake is an important water supply and recreational reservoir in North Carolina, and high levels of nutrient loading and algal productivity have demanded attention from water quality managers. Prior efforts have made it clear the Jordan Lake Nutrient Management Study requires a broader understanding of the lake and its surrounding watershed. A preliminary evaluation was performed on a dataset representing the lake and its nutrient loadings. Tributary nutrient loading growth and decline over space and time were analyzed using the USGS modeling algorithm Weighted Regressions on Time, Discharge, and Season (WRTDS) for comparison with Lake Jordan water quality data. Small tributaries experienced gradual nutrient loading decline from 1980 to 2016, with a nitrogen spike in 2000. Haw River nutrient loading remained stable during the period. The lake was analyzed as a series of basins which showed nutrient reduction capability as minor inflows progress towards the outflow and before joining the Haw River. This preliminary data collection and analysis paves the way for deeper scrutiny of both the lake and its surrounding watershed as linked systems, considering land-use and within-lake nutrient dynamics.

No. 49: Trend analyses of IDF curves across the coterminous US

Chandramauli Awasthi
Sankar Arumugam (Advisor)
Keywords: stationarity, extreme value distribution, IDF curves

Traditionally, precipitation Intensity-Duration-Frequency (IDF) curves used in the design of urban storm water systems have been developed under the assumption of stationarity. However, changing climatic conditions challenge this assumption of stationarity. Few recent studies have found non-stationarity in precipitation extremes suggesting that current IDF curves might be underestimating the changing extremes. In the present study, daily precipitation dataset at 1/16 degree is analyzed across the coterminous US (CONUS). We systematically show how the IDF values have changed over a 90-year period across the CONUS. We find about 76% of grid points across the CONUS exhibit significant trend, both increasing and decreasing, in the IDF value. The strong presence of trends show the need for updating the IDF curves with precipitation across various return periods should be estimated by non-stationary extreme value distributions.

No. 50: Developing an agent based model from novel water column reactor results to forecast harmful algal bloom (HAB) formation

Monica Camacho
Tarek Aziz (Advisor), Emily Berglund (Advisor), Daniel Obenour (Advisor)
Keywords: HABs, agent-based-modeling, phytoplankton, lake-mixing

Harmful algal blooms (HABs) appear in reservoirs worldwide, impairing our waters and hindering drinking water treatment. A key component of HABs is a sub-group of phytoplankton called cyanobacteria, which can produce toxins. Population-averaged equation-based models (EBMs) are currently used to predict algal bloom dynamics, but EBMs do not consider the stochasticity or track life-histories of individual organisms, which may better explain the collective behavior of phytoplankton. Agent-based models (ABM) are increasingly being used to simulate microorganism populations because they model individuals and their interactions to provide more realistic representations of natural biological systems. This research focuses on creating an ABM to better predict HABs under various engineered and natural conditions. Water column reactor (WCR) experiments will be used to study the impact of vertical mixing and light exposure on algal communities. Algal community analysis from the WCRs will then be used to calibrate our ABM framework. The ABM will be validated by future WCR experiments and case studies. Its performance will then be compared to conventional EBMs. The goal of this research is to create a tool for engineers and researchers to help predict, prevent, and remediate water bodies impaired by HABs and to forecast bloom formation as climate changes.

No. 51: Tropical storm contribution to seasonal streamflow in the southern United States

Dol Raj Chalise
Sankar Arumugam (Advisor)
Keywords: hurricane, tropical cyclone, streamflow

Every year, tropical cyclone (TC) strikes coastal states of the Gulf of Mexico, the North-South Atlantic states, brings heavy rainfall on time scale of a few days, causes floods resulting in tremendous economic and property losses. Recent studies have focused on identifying the contribution of heavy rainfall associated with tropical cyclones in the south-eastern U.S. However, no comprehensive study is available to characterize the contribution of TC to seasonal streamflow, in the southern US. This paper examines the fractional contribution of 71 TC-events to seasonal streamflow and annual maximum streamflow at 467 long-term U.S. Geological Survey (USGS) virgin streamgages with 20 years of daily discharge data from 1998 to 2017. The tropical system contributes on average 12% of the total seasonal (June to November) streamflow. For TCs making landfall, the tropical cyclone streamflow contribution could be locally up to 38% on monthly basis. The highest fractional contributions to annual daily maxima by these storms (>30%) are found in Florida and North Carolina. Nearly 70% of the streamflow gages experiences one annual maximum that was generated by TC event.

No. 52: An investigation into the impact of multiple drinking water source use in low- and middle-income countries: a systematic review

Sean Daly, Jeremy Lowe
Angela Harris (Advisor)
Keywords: low-income, middle-income, drinking water, multiple water sources, systematic review

The Joint Monitoring Programme 2017 Update and SDG Baselines report classified 71% of the global population as having access to 'safely managed' drinking water. However, standard data collection practices focus on primary water sources accessed, while there is evidence that a variety of sources are used to meet water needs in many low-income settings. To address this discrepancy, an ongoing systematic review has been established to answer the following primary research questions: 1) What is the extent that multiple household drinking water sources are used in low- and middle-income countries? 2) What factors (cost, distance, etc.) influence these behaviors? Target databases, keywords and search terms, and inclusion/exclusion criteria were all established prior to review. The abstract/title screening process is ongoing in the beta web-application, Abstrackr, from Brown University, which will be followed by full-text review. Once the review processes are completed, conducting a meta analysis will also be considered. The desired outcomes from this systematic review are: to synthesize the current understanding on the stated topic, to identify common themes/factors that influence multiple water source use, and to create a new research question and develop a study that can offer insight into discovered gaps in knowledge.

No. 53: Rapid response data collection about social media use in Hurricanes Florence and Michael

Morgan DiCarlo
Emily Berglund (Advisor)
Keywords: Hurricane Florence, social media

During hurricanes, information about flooding hazards, rescue operations, evacuation routes, shelter, and supplies is critical. Through social media platforms and crowdsourced websites, the public can rapidly contribute to and access information as impacts are unfolding. In Hurricane Florence, people sought and received aid using social media and websites like CrowdRelief.net, which is a crowdsource network launched by a volunteer rescue organization known as the Cajun Navy. Sponsored by the Department of CCEE, our research objective was to develop a dataset about social media use in recent Hurricanes Florence and Michael through mining online social media posts and conducting surveys. Data collection methodologies for Twitter, CrowdRelief.net and the survey instrument will be discussed. The web-based survey, which received more than 400 responses, is a novel dataset describing mandatory evacuations, compliance with evacuations, and attempts to seek aid via social media. The survey results are presented in detail. Future work includes developing an Agents-Based Model (ABM) to understand the diffusion of information over social media during a water-related crisis like flooding.

No. 54: Geostatistical synthesis of *in situ* and remote sensing data to improve harmful algal bloom estimation

Shiqi Fang
Dan Obenour (Advisor)
Keywords: geostatistics, cokriging, harmful algal bloom, remote sensing, western Lake Erie

Harmful algal blooms (HABs) of cyanobacteria have returned to western Lake Erie over the past decade. Several agencies have made efforts to monitoring HAB using remote sensing and shipborne (in situ) samplings. However, atmospheric conditions (e.g., clouds) have limited remote sensing temporal coverage, whereas operating costs have largely restrained in situ sampling spatial and temporal coverage. Consequently, HAB estimates based on a single data type could be incomplete or biased. In this study, we applied a space-time geostatistical cokriging framework to improve the spatio-temporal HAB estimation using in situ Chlorophyll a concentrations as a primary predictand and remote sensing Cyanobacterial Index as the secondary covariable. Compared with estimates using in situ data only, cokriging reduced HAB estimation uncertainties by 31% in regions with sparse in situ measurements (e.g., Canadian side), and 19% for periods with less frequent cruises (e.g., late September). Moreover, in contrast to conventional remote sensing estimates, our model provides continuous daily estimates and corresponding uncertainties over each summer (2008-2017). Our model can predict a short-term HABs estimation using the latest remote sensing alone, which can be applied to improve decisions for shipborne sampling locations.

No. 55: Climate-Water-Energy Nexus: An integrated modeling framework to analyze water and power systems under a changing climate

Lucas Ford
Sankar Arumugam (Advisor)
Keywords: water management, reservoirs, energy, modeling, climate

Assessing the impacts of climate variability and change on water and energy infrastructures requires the study of these interconnected systems in a seamless manner. In this context, hydroelectric power generation is one of the critical connections between water management and electricity generation systems as hydropower has low marginal cost and can be used to meet the peak power demand. These systems also depend on climatic factors, precipitation and temperature, which underlines the importance of managing these two systems together. To accomplish this goal, a single integrated modeling framework was developed that utilizes the Generalized Reservoir Analysis using Probabilistic Streamflow (GRAPS) model for reservoir simulation and the Tools for Energy Model Optimization and Analysis (TEMOA) model for energy system optimization. To improve the usability of this framework, a graphical user interface was developed that streamlines reservoir network creation. The utility of this modeling framework is currently being tested on Tennessee Valley Authority's (TVA) electricity generation system from 2004 to 2015. The developed framework will also be utilized to operate TVA's water and electricity generation systems based on sub-seasonal to seasonal forecasts of streamflow and energy demand to better understand the vulnerability of water and power systems under a changing climate.

No. 56: Probabilistic forecasting of Neuse Estuary hypoxia using a Bayesian mechanistic approach

Alexey Katin
Dan Obenour (Advisor), Dario Del Giudice (Advisor)
Keywords: hypoxia, Neuse Estuary, Bayesian, forecast

Hypoxia or bottom water layer dissolved oxygen (BLDO) depletion below 2 mg/L frequently occurs in the Neuse River Estuary (NRE). Hypoxia can negatively affect estuarine ecosystems, causing fish kills and habitat loss. Here, we develop a novel modeling approach to predict BLDO, accounting for the complex interactions of hydrometeorologic and anthropogenic influences, which control development of hypoxia in the NRE. A process-based model is calibrated using Bayesian framework, which allows for probabilistic estimation of uncertain parameters based on prior scientific knowledge within a mechanistic framework. The resulting model is beneficial in several ways. First, it provides a means for assessing the response of BLDO to various nutrient loading scenarios relevant to water quality management, accounting for rigorous uncertainty quantification. Second, the model can make short-term forecasts of BLDO (up to 3 months ahead), which can inform fisheries and estuarine managers of expected upcoming July-August conditions. Last year, experimental summer forecasts for 2018 predicted severe hypoxia in the NRE due to low Neuse River flow during the preceding winter and expected elevated summer flows and nutrient loadings. Observed BLDO values were generally within the forecasted intervals, while hindcasting captured elevated BLDO due to tropical storms.

No. 57: Hierarchical model for empirical crop yield estimation across CONUS

Hemant Kumar
Sankar Arumugam (Advisor)
Keywords: crop yield, hierarchical model

The cropping pattern and associated crop yields across the CONUS vary with changes in technology, water availability and climate. An empirical model for yield prediction has many applications especially in studying the historical trends as well integration into larger complex models. The following variables have been identified as key predictors for estimating yield per unit area: harvested area, Palmer Drought Severity Z-Index (PDSI-Z), chronological trend, and irrigated acreage. However, the information available for different predictors varies in spatial and temporal resolution. For instance, yield and area are available at county level, PDSI-Z is available at climate division level, and irrigated/rainfed information is available only at state level. To address these varying spatial levels in predictors, we consider a hierarchical model (also called mixed linear model) for yield per unit area estimation in place of simple linear regression. We explore the variable intercept (VI) and variable intercept and slope (VIS) models. We also consider localized regression to consider the dependence between neighboring spatial units. The split sample and short-term forecast validation tests exhibit the underlying reasons for the hierarchical models' predictability.

No. 58: Reducing the formation and adhesion of Fat, Oil and Grease (FOG) deposition on sewer line surfaces

Samrin Ahmed Kusum
Mohammad Pour-Ghaz (Advisor), Joel Ducoste (Advisor)
Keywords: FOG, SSOs, calcium leaching, collection system, SCM

The accumulation of FOG in sewer pipes reduces its carrying capacity and results in Sanitary Sewer Overflows. FOG deposits are formed from a saponification reaction between calcium and long chain free fatty acids. Previous research showed that concrete corrosion is a source for calcium ion that participates in FOG deposit formation. Concrete made with blended Supplementary Cementitious Materials (SCMs) and cement decreased the calcium leaching under corrosive media. Hence, this study aims to reduce the contribution of concrete corrosion on FOG deposit formation by applying Fly Ash (FA) as the SCM. Two High Volume FA portland cement samples were cast using 50% and 75% cement replacement. After 90 days of leaching under corrosive media, 50% and 75% FA replaced samples showed 75% and 86% reduction in calcium leaching, respectively. Samples were also tested for FOG formation and deposition under synthetic wastewater. After 18 days, 75% FA replaced samples showed 76% reduction in FOG deposition. The results of this study suggest that a significant decrease in calcium release can be achieved by using FA as cement replacement and lead to reduced FOG deposit formation in collection systems.

No. 59: Climate-informed optimal operation for multipurpose multi-reservoir system in Tennessee

Sudarshana Mukhopadhyay
Sankar Arumugam (Advisor)
Keywords: optimum reservoir management, multipurpose multi-reservoir system, water allocation, climate forecast, linear programming

While improved predictability and forecast skill are critical to hydro-meteorological applications, one can unequivocally say that translation of these forecast products to the end-users pose a similar challenge to the researchers as system constraints could limit their potential utility. There is a need for reliable monthly to seasonal streamflow forecast among water resources practitioners as this is the period over which crucial operational decisions – short term water release, water allocation during droughts, alteration in hydropower generation to meet peak energy demand, maintaining end-of-the-season target storage – must be taken. We investigate the applicability streamflow forecast for multi-purpose multi-reservoir system analysis using probabilistic streamflow forecasts developed for the Tennessee Valley Authority (TVA) system. This study is carried out in two steps: first, monthly precipitation and temperature forecasts are translated into natural inflows to the reservoirs by developing probabilistic streamflow forecasts. Total precipitation forecast and reforecast products from NCEP and ECMWF models of WWRP/WCRP S2S Project are used as different potential predictors. Next, a multi-reservoir network model is developed, calibrated and validated for the entire TVA system where water allocation among multiple uses – flood control, hydropower generation and water supply – follows a predefined reliability. We focus on different historical drought episodes as well as flood events to understand the utility of streamflow forecast in a multipurpose multi-reservoir system under different operating policies using iterative linear programming for simulation based optimization.

No. 60: Decision tree ensemble models to predict water lead levels in private well water

Jorge, Pesantez, Mohammad Ali Khaksar Fasaee
Emily Berglund (Advisor)
Keywords: lead, water quality, machine learning, decision trees

Drinking water from private groundwater wells may be at risk of water quality issues, because utilities and governing agencies are not responsible for monitoring or treating water within private systems. The presence of metals, including lead, in well water can cause long-term health effects, and tools that can predict the presence of contaminants are needed to protect public health of residents. This research develops a machine learning modeling approach to explore interactions among household characteristics, geological conditions, water quality parameters, and water lead levels in tap water at private wells. The Virginia Household Water Quality Program (VHWQP) collected water samples and conducted household surveys at 2146 households in Virginia between 2012 and 2013. An ensemble of decision tree models is developed to explore the predictability of lead for other metals and chemicals in water samples, plumbing characteristics, observed water quality perceptions, and physiographic region. Results demonstrate that ensemble modeling improves prediction performance, and that copper is a significant predictor for water lead levels.

No. 61: Capturing Irrigation Dynamics in a Groundwater Model Using Remote Sensing Data

Elizabeth Ramsey
Emily Berglund (Advisor)
Keywords: remote Sensing, groundwater modeling, irrigation, data scarcity

The use of groundwater for crop irrigation creates a feedback loop that is not often captured in traditional groundwater flow models because of the difficulty inherent in data collection on individual irrigation behaviors. This research presents an approach for capturing these dynamics by using remotely sensed soil moisture, precipitation, and temperature data from the Global Land Data Assimilation System to estimate irrigation quantities. These irrigation estimates will be used to calibrate a 2-dimensional discretized groundwater flow model. The regional scale groundwater model is delineated by the Khabour River sub-basin in Syria and Turkey, where data availability has been impacted by social unrest and uprising. This research develops and demonstrates a new methodology to capture irrigation in a groundwater model at the sub-basin scale in areas where data is unavailable or unattainable.

No. 62: Dynamic modeling of *Dunaliella viridis* growth and storage molecule production under various light and nitrogen conditions

Diyuan Wang, Yi-Chun Lai, Amanda Karam, Francis de los Reyes
Joel Ducoste (Advisor)

Keywords: mathematical models, microalgae, neutral lipids, biofuel, MCMC

To aid the large-scale biofuel production, mathematical models have been developed to facilitate a better understanding of the algal growth and lipid production in response to different operational conditions. Yet, most prior models lack regulatory mechanisms to dynamically characterize the photosynthesis and carbon allocation processes. In this work, we established a new dynamic model to characterize and predict the behaviors of *Dunaliella viridis* cultivated under wide-ranging light and nitrogen conditions in a lab-scale photobioreactor (PBR). We simulated the concentrations of functional biomass, carbohydrates, neutral lipids, chlorophyll a, and extracellular nitrate, as well as the time-changing light intensities inside the PBR. We used eleven experimental sets to calibrate and validate the proposed model using 65% and 35% of total data, respectively. We conducted the identifiability, uncertainty, and sensitivity analyses to demonstrate the model reliability. The posterior distributions of estimated model parameters as well as the credible and prediction intervals of model outputs were obtained using the Markov Chain Monte Carlo (MCMC) method. Our modeling results demonstrated good agreement with the experimental data. Compared to prior literature, our proposed work offers a more comprehensive modeling strategy for simulating the dynamics of the underlying algal bioprocesses under various light and nitrogen conditions.

G. Global WASH

No. 63: Biochar adsorption of per and poly-fluorinated alkyl substances (PFASs) and using PARAFAC to establish fluorescence spectroscopy as real-time PFASs breakthrough monitoring

Myat Aung
Joshua Kearns (Advisor)
Keywords: PFAS, biochar adsorption, RSSCT, PARAFAC, fluorescence spectroscopy

Per/polyfluoroalkyl substances (PFAS) are widely detected in the environment and biota, and have gained attention due to their persistence and potential health impacts. Well waters were collected from 28 handpumps across three residential shanty communities within Shwe Pyi Thar Industrial Zone, Yangon during Nov-2017. Samples were pushed through solid phase extraction (SPE) cartridges and analyzed by high-resolution mass spectrometry (HRMS) for PFAS. PFBA was detected in 13 wells with concentrations at 180-128,000ng/L(avg 22,000ng/L); PFPeA in 4 wells at 420-5,800ng/L(avg 1,700ng/L); PFOA in 1 well at 50ng/L; PFHxA in 8 wells at 380-6,100ng/L(avg 1,400ng/L); and GenX in 8 wells at 700-8,900ng/L(avg 2,400ng/L). These values are significantly higher than previously reported for other SE Asian countries. Hardwood biochar has shown to effectively remove emerging organic contaminants and gained the interest of this research for PFAS removal. This study aims to develop biochar water treatment systems designed after rapid small-scale (RSSCT) and pilot-column scale studies for PFAS breakthrough and to establish the breakthough correlation between fluorescent dissolved organic matters and PFAS using Parallel Factor Analysis (PARAFAC) modeling for a low-cost and simple real-time monitoring proxy.

No. 64: Meeting a global sanitation challenge: mechanized pit latrine emptying with trash exclusion

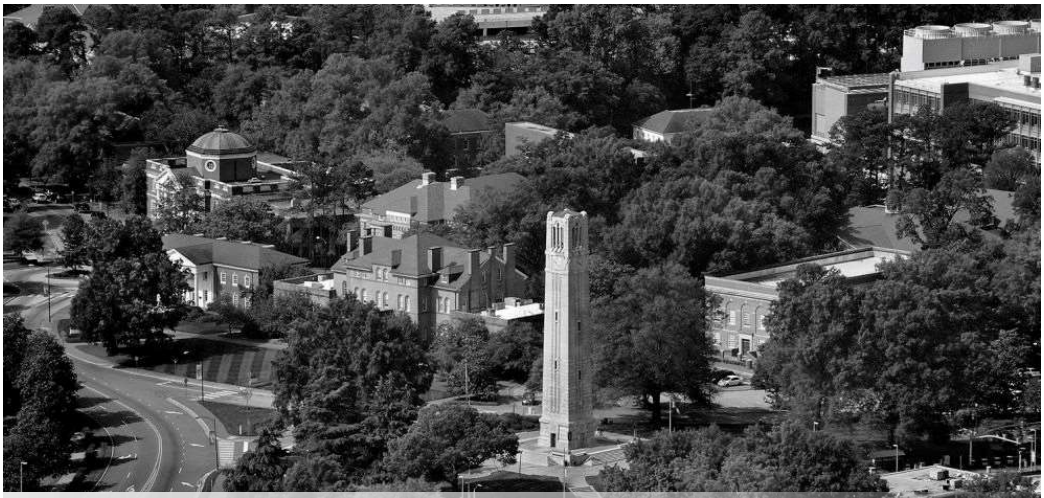
Giovanna Portiolli
Francis de los Reyes III (Advisor)
Keywords: sanitation, pit latrine emptying, trash exclusion, Flexcrevator

More than 2 billion people in the world lack access to adequate sanitation, and the poor management of human excreta is a health hazard in these underserved communities. One of the biggest challenges in emptying pit latrines is dealing with the high amount of trash mixed in with the faecal sludge. This research project involved the optimization of the Flexcrevator, a vacuum system with simultaneous trash exclusion for emptying pit latrines. Three main trash exclusion mechanisms were explored: (1) screening- preventing large trash items from entering the system; (2) deflection- forcing trash away from the vacuum zone of influence; (3) clearing- actively clearing any trash items that attach to the inlet surface. Features such as hole diameters, pipe lengths, and auger rotation direction were evaluated in wet and dry pit scenarios. Through continuous rapid prototyping, a combination of the screening and clearing mechanisms proved the most efficient. This design successfully excluded high trash content in wet pits and achieved a flow rate range of 3 to 4 lps. Remaining challenges involve thicker sludges and fibrous material clogging the system. Fluidization of the sludge and continuous optimization of the excluder head will address these issues and provide an efficient and safe emptying solution for a wide range of pit latrines.

No. 65: Rapid small-scale column development for fluoride control using bone-char sorbents

Maggie Thompson
Joshua Kearns (Advisor)
Keywords: RSSCT, fluoride, bone-char, groundwater, Mexico

Millions of people worldwide are exposed to harmful levels of fluoride (F) by consuming groundwater exceeding the WHO Guideline value of 1.5 mg/L. Many affected live in low resource settings including dispersed rural settlements lacking infrastructure and rely on groundwater requiring point-of-use treatment as their main source of drinking water. One such region is Guanajuato state, central Mexico, where F levels in community wells can exceed 20 mg/L and values ranging from 2-8 mg/L are common. Bone-char (BC) produced locally from cow bones has shown promise as a low-cost sorbent for uptake of F from groundwater. Pilot tests have been conducted but are costly, time consuming, and require large amounts of water from water-scarce areas. Rapid small-scale column tests (RSSCTs) require significantly less water and can be completed over less time. This research aims to develop a bench-scale method to quantify F removal by BC sorbents from groundwater specific to central Mexico. Phase I of this project will develop and optimize an RSSCT approach for F removal using BC. Phase II will quantify F uptake by BC sorbents modified to enhance sorption, and under different water chemistry and fixed bed operational regimes, following the methods developed in Phase I.



Judges

Our gratitude to the following judges for their time and expertise.

Susan Auten
Black & Veatch

Steven Bolyard
NCDOT

Katie Finegan
Moffatt & Nichol

Kenneth Hunu
Atkins

Frank Lopez
NC Sea Grant

Frank Lopez
NC Sea Grant

Beth Smyre
Dewberry

Robert Vinay
Freese & Nichols

Joy Das
EOS

Ken Bannister
Draper Aden

John Classen
NCSU BAE

Scott Haberstroh
Freese & Nichols

Matt Jenny
Geosyntec

Dan Loughlin
EPA

Dan Loughlin
EPA

Joan Smyth
Smith Gardner

Kenneth Waldroup
City of Raleigh

Katya Bilyk
Hazen & Sawyer

Pete de Haven
Geosyntec

Bob Hall
AWMA, Wood

Ozge Kaplan
EPA

TJ Lynch
City of Raleigh

Narayan Rajbhandari
NCDEQ DWR

Ross Stroud
CDM Smith

Lauren Wellborn
Geosyntec

Stephanie Bolyard
EREF

Jason Dorn
Gavel & Dorn

James Harrington
RTI

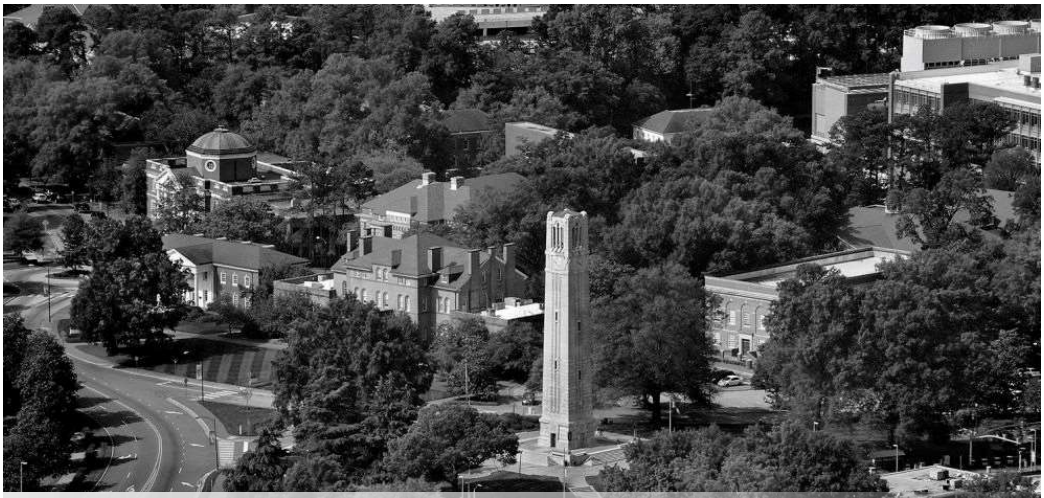
James Law
SCS

Anne Mikelonis
EPA

Chuck Riley
McKim & Creed

Dahman Touati
EPA/Jacobs

Hong Zhao
Veolia



Sponsors

The Environmental, Water Resources, and Coastal Engineering (EWC) Graduate Research Symposium 2019 is sponsored by the NC State Engineering Foundation.

The EWC faculty and students would like to thank our generous sponsors for making this symposium possible:

SILVER SPONSORS:

AECOM; Freese & Nichols; Gavel & Dorn; Geosyntec; Hazen & Sawyer; Smith Gardner

BRONZE SPONSORS:

EREF (Environmental Research and Education Foundation); Jacobs Engineering; EOS Remediation

EWC 2019 Committee

Committee Chair
Shiqi Fang

Program
Eric Polli Nancy Lee Alexander Sierra Schupp
Myat Aung Maggie Thompson Qian Luo

Logistics
Alexey Katin Jorge Pesantez Sadia Afrin
Dol Raj Chalise Alireza Gharagozlou Aditya Sinha
Chandramauli Awasthi

Transportation
Joe Hollingsworth Asmita Narode Faith Johnson
James East Delandra Clark Danny Sodano
Mojtaba Sardarmehni

Food
Russell Nasrallah **Autumn Poisson** Poorva Mokashi
Maksimul Islam Monica Camacho Carter Rucker
Johnathan Woodruff

Prospective Students
Megan Johnson Morgan DiCarlo Ashley Bittner
Stephanie Parsons Giovanna Portiolli Aditya Keskar
Hemant Kumar

Publicity
Austin Burke **Casey Dolan** Fausto Ortiz
Hanieh Moghadam

Faculty Advisors
Daniel Obenour Jeremiah Johnson Joshua Kearns
Andrew Grieshop Francis de los Reyes

PUBLISHED by EWC, March 2019, Raleigh, NC