NC STATE UNIVERSITY

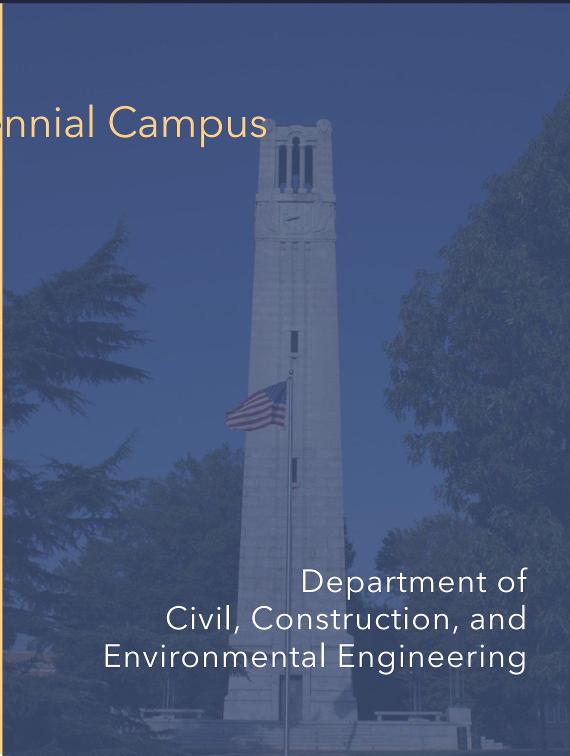
2020 EWC

Graduate Research Symposium

Environmental, Water Resources and Coastal Engineering

March 6th, 2020

Park Alumni Center, Centennial Campus



Department of
Civil, Construction, and
Environmental Engineering

EWC 2020

Symposium Booklet

March 6th, 2020

Park Alumni Center, Centennial Campus

2020 EWC

Graduate Research Symposium

TABLE OF CONTENTS

Environmental, Water Resources and Coastal Engineering

NC State University

Department of Civil, Construction, and Environmental Engineering

EWC 2020

Sponsors

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

Silver

AECOM

Gavel & Dorn Engineering
Full Service Engineering Consultancy

EREF
Environmental Research & Education Foundation™
Lighting a path to sustainable waste management practices

FREESE AND NICHOLS

Hazen

SMITH+ GARDNER ENGINEERS

Geosyntec consultants

Bronze

EOS
EOS Remediation, LLC

Dewberry®

Brown AND Caldwell®

Other Contributions

Air & Waste Management Association RTP

2020 EWC

KEYNOTE SPEAKER

Dr. Kara Nelson

University of California, Berkeley

Dr. Kara Nelson is a Professor of Environmental Engineering and Associate Dean of Equity and Inclusion in the College of Engineering at U.C. Berkeley. She teaches courses on innovation in the water sector, drinking water and wastewater treatment processes, and pathogen detection and inactivation, taking into consideration the wide range of contexts that exist in low to high-income countries. Her research program investigates innovative strategies to improve the sustainability of urban water infrastructure, including practices for water reuse, disinfection, nutrient recovery, and international WASH (water, sanitation, and hygiene). She leads the engineering research thrust at ReNUWIt (Reinventing our Nation's Urban Water Infrastructure), and previously served on the expert panel advising the State of California on criteria to regulate indirect and direct potable water reuse. As Associate Dean, she ensures that equity and inclusion are embedded throughout the College's programming and leads efforts to diversify the College and create a climate in which everyone can reach their full potential. Dr. Nelson is a recipient of the Presidential Early Career Award for Scientists and Engineers (PECASE). She currently conducts research in the United States, India, Bangladesh, Kenya, and Panama.

2020 EWC

KEYNOTE

Wastewater contains valuable resources that can be recovered for beneficial uses, including recycled water, nutrients, and energy. The incentives to recover these resources are growing as human populations increasingly face water scarcity, food insecurity, eutrophication, and rising greenhouse gas emissions. For populations that still lack access to adequate sanitation infrastructure, innovative strategies that integrate resource recovery hold promise to accelerate investment in effective solutions. In this talk, I will discuss two approaches to recover wastewater resources in agriculture, which illustrate the food, energy, water (FEWs) nexus. The first FEWs approach is to irrigate crops with recycled water. While this practice is already ubiquitous in many parts the world, it is often informal and unsafe. I will share research results that quantify the large potential for this practice, and contribute to characterizing the risks to human health. To contrast the context in high- versus low-income regions, I will highlight field work in the US, Ghana, and India. The second FEWs approach is to de-link water and nutrient recovery by concentrating nutrients directly from urine to produce fertilizer. I will share progress we have made developing technologies for nitrogen recovery, and feasibility assessments conducted for San Francisco, CA and Nairobi, Kenya.

2020 EWC

Graduate Research Symposium

AGENDA

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

2020 EWC

List of Posters

AIR

2020 EWC

List of Posters

SOLIDS

2020 EWC

List of Posters

ENERGY

COASTAL

2020 EWC

List of Posters

WATER TREATMENT

2020 EWC

List of Posters

WATER RESOURCES

2020 EWC

List of Posters

2020 EWC

List of Posters

GLOBAL WASH

2020 EWC

Graduate Research Symposium

AIR

Environmental, Water Resources and Coastal Engineering

NC State University

Department of Civil, Construction, and Environmental Engineering

Ambient air pollutant observations in Malawi: separating biomass source-influenced periods from background concentrations

Ashley Bittner
Advisor(s): Andrew Grieshop

No. 1

Malawi, a low-income nation in Southern Africa, has a near-complete dearth of empirical ambient air quality (AQ) observations. To address this gap, since June 2017 we have deployed three low-cost, low-power sensor packages (QuantAQ's 'ARIsense') to three rural sites in Malawi to collect data on gases (CO2, CO, NO/NO2, O3), particulate matter (PM) and meteorological parameters. To better characterize how pollutant concentrations, and thus human exposures to air pollution, vary in Malawi we separate the data set into 'source-influenced' and 'background' periods. The monitors located in rural residential villages are regularly exposed to fresh emission sources, given their proximity to nearby households that rely entirely on traditional biomass-burning (wood & charcoal) cookstoves for all their household energy needs. For example, during morning and evening cooking periods, local concentrations of CO and PM (tracers of biomass burning) may be 50 – 100% higher than overnight concentrations. Our continued analysis investigates how variation in both local residential and regional (e.g. agricultural burning) combustion activity across different seasons (wet and dry) affects local ambient AQ. This work characterizes spatial and temporal variation in exposure to air pollution in Malawi and provides estimates of 'true' background concentrations, which can help to verify global AQ models.

Keywords: ambient air pollution, low-income countries, biomass-burning emissions

Impact of climate sensitivity on projections of US air quality and extreme air pollution

James East
Advisor(s): Fernando Garcia Menendez

No. 2

Uncertainty in the sensitivity of the climate system to increasing greenhouse gas concentrations impacts the predictive capability of simulations of climate change impacts on air quality. Previous studies have identified significant contributions from emissions scenarios and natural variability to uncertainty in projections of climate-induced air quality impacts. However, the role of climate model response remains largely unexplored in air quality assessments. Using a coupled global climate and air quality modeling ensemble, we show that, while smaller in magnitude than uncertainty from natural variability and climate policy, uncertainty in the climate system's response leads to uncertainties of 2 ppb O3 and 1 μg/m3 PM2.5 in the air quality penalty at end century. Projections with high estimates for climate sensitivity lead to increased spread in annual-average impacts, suggesting a greater likelihood for extreme air pollution events at end century. The effect of high climate sensitivity estimates on extreme air pollution events, indicated by the spread of projected impacts, is magnified when the intra-annual extreme events are considered, with increases in the magnitude of extreme air pollution events at end-century and high climate sensitivity.

Keywords: air quality, climate impacts, climate modeling, climate sensitivity, greenhouse gas policy

Study Design for Stochastic Population-Based Air Pollutant Exposure Modeling for Hong Kong

Sailaja Eluri
Advisor(s): H. Christopher Frey

No. 3

Exposure to air pollutants causes adverse human health effects. The U.S.-based stochastic Air Pollution Exposure (APEX) model will be adapted to estimate CO, NO2, O3 and PM2.5 microenvironmental air pollutant exposures in Hong Kong (HK). Microenvironments are locations with relatively homogenous air pollutant concentrations. The four key inputs for APEX are: (1) temporally and spatially variable ambient pollutant concentrations, temperature and humidity; (2) infiltration factors for combinations of pollutants and microenvironments; (3) population census data, including population distribution by age, sex, employment and housing type; and (4) activity data, including daily diary data for individual with time spent in each microenvironment and commuting patterns. The feasibility of using the existing data input structure with HK census data will be determined. Spatial and temporal variation in meteorology and air quality will be readily available from HK collaborators. Infiltration factors will be inferred based on previously conducted HK microenvironmental measurements. The availability and utility of housing, commuting, and activity data will be assessed. The model will be used to estimate inter-individual variability in hourly and daily average air pollutant exposures. The result is a detailed study design for HK population-based exposure simulation.

Keywords: Stochastic Population-Based Exposure Model, APEX

A Low-Cost Black and Brown Carbon Filter Analyzer

Emily Floess, Stephanie Eberly
Advisor(s): Andrew Grieshop

No. 4

Black and brown carbon aerosols from combustion are major contributors to climate forcing and are quantified using their light absorptive properties. Black carbon absorbs light across all wavelengths while brown carbon, light-absorbing organic carbon, absorbs light mainly in ultraviolet (UV) and blue wavelengths. Current methods to measure black and brown carbon are cost prohibitive but more measurements are needed globally, especially in developing countries, to understand their sources and climate forcing role. We are developing a reproducible, open-source, easy to build, low-cost instrument for measuring black and brown carbon, using Raspberry Pi and a UV/IR Pi-camera. UV, infrared and red LEDS are used to quantify light absorption from quartz filter samples. A camera image shows light absorbed through the filter and is compared with a calibrated reference scale. The low-cost instrument is calibrated and evaluated using filter samples from biomass burning emission tests. Instrument results are compared with those from a Magee Scientific Soot Scan Optical Transmissometer and Sunset Lab OC-EC Aerosol Analyzer, to evaluate the accuracy, repeatability, and limits of detection of the low-cost analyzer. Preliminary results show that this instrument can accurately measure UV and IR absorption which can be used to estimate black and brown carbon.

Keywords: Particulate matter, combustion, light absorption, optical properties, aerosols

Analysis of household air pollution personal exposure data in Lusaka, Zambia

Wesley Hayes
Advisor(s): Andrew Grieshop

No. 5

Household air pollution, mainly due to the combustion of solid fuels for cooking or heating, is a serious health concern in lower and middle income countries, including those in Southern Africa. In the summer of 2019, data on carbon monoxide (CO) and fine particulate matter (PM2.5) in households with both traditional and improved cookstoves were collected as baseline data for a cookstove intervention trial. 24-hour personal exposure data were collected for the primary cook in 743 households across 4 compounds in Lusaka, Zambia. After data validation, 496 carbon monoxide tests and 68 particulate matter tests were compiled. Further analysis will compare average concentrations across compounds and stove types to investigate exposure trends. Time series data will be analyzed to explore diurnal patterns in pollutant exposure and separate cooking and non-cooking related exposures of PM2.5 and CO. It is hoped that this research will contribute to the continued investigation of improved cookstove implementation and help to guide future policy decisions on emerging technologies.

***Keywords*:** Household Air Pollution, Carbon Monoxide, Particulate Matter

A comparison of smoke modeling tools used to predict prescribed burning air quality impacts in North Carolina

Megan Johnson, Sadia Afrin, Fiona Tennyson
Advisor(s): Fernando Garcia Menendez

No. 6

Prescribed burning is an important land management technique used by private and public landowners. While this practice is widely beneficial for fuel reduction and ecological purposes, smoke management can be a significant barrier to its use. There are several modeling tools available to predict smoke transport from a prescribed burn; however, these vary in scientific complexity, data requirements, and ease of use, which may impact smoke dispersion predictions and likelihood of adoption. Further, there are few systematic analyses of these tools. Here, commonly used smoke modeling tools are evaluated from the perspective of planning a prescribed burn and estimating smoke impacts. Using prescribed burning data for North Carolina State Parks, we model and compare smoke plumes predicted by the most commonly used tools, HYSPLIT, VSmoke-Web, and the Simple Smoke Screening Model, as well as from the state-of-the-science chemical transport model CMAQ. Model predictions are compared using metrics for spatial overlap, population smoke exposure, and predicted concentrations. The tools are further assessed by considering ease of use for land managers. This analysis provides insight into potential public impacts in areas of frequent prescribed burning, highlights the feasibility of using these simplified models to support fire decision-making, and emphasizes research needs to improve these tools.

Keywords: smoke, prescribed fire, dispersion modeling, CMAQ

Reducing human health impacts from power sector emissions with redispatch and energy storage

Qian Luo
Advisor(s): Fernando Garcia Menendez, Jeremiah Johnson

No. 7

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: internalizing the time- and location- varying health damage costs into the unit commitment and economic dispatch model helps reduce the adverse health impacts from electricity generation and the addition of energy storage to the grid can help reduce additional health impacts when considering health damage costs, while also reducing the electricity generation costs.

***Keywords*:** power system, air quality, human health

The effects on emissions of modified operation of pellet-fed gasifier stoves

Stephanie Parsons, Ky Tanner
Advisor(s): Andrew Grieshop

No. 8

Field tests of biomass pellet-fed stoves in Rwanda found lower emissions compared to other biomass stoves, in many cases approaching that of current "gold standard" technologies such as liquefied petroleum gas. However, emission factors of particulate matter (PM) and carbon monoxide (CO) during high emitting pellet tests overlap with low emitting wood and charcoal tests, emitting the most PM and black carbon (BC) at the startup and the end of cooking (i.e. the burnout phase). We conducted a series of laboratory tests to observe how varying the operation during the burnout phase affects emissions of PM, CO, organic and elemental carbon (OC, EC), and BC. We examined two different factors: fan speed and the height of pellet embers used from a previous cooking event to ignite the next cooking event. Medium and high fan speeds during the burnout phase result in CO emission factors 14% and 30% higher than a low fan speed, respectively. We expect ember heights blocking the gasifier holes (the largest ember heights) to have the largest emission factors as blocking these holes reduces stove efficiency. We will communicate results to the stove manufacturer to possibly influence the stove design and operation specifications to decrease improper use.

Keywords: biomass cookstove, pellet stove, indoor air pollution

Quantifying emission hotspots along a diesel-powered passenger train route

Nikhil Rastogi
Advisor(s): H. Christopher Frey

No. 9

Passenger trains are more energy efficient and low emitters of greenhouse gases compared to other transportation modes. However, emission rates of nitrogen oxides (NOx) and particulate matter (PM) for diesel-powered locomotives are higher. Spatial variability in emission rates leads to emission hotspots and affects human exposure to train-generated air pollution. Identification of hotspot locations is needed to target emission reduction interventions. Existing laboratory-based methods lack spatial resolution needed to identify hotspots. Therefore, emission rates were measured for over-the-rail (OTR) operation on the Amtrak-operated Piedmont passenger rail service. OTR measurements were conducted for 35 one-way trips using a portable emissions measurement system. Segment average NOx and PM emission rates were quantified for 0.25-mile track segments. For each one-way trip and pollutant, hotspots were defined as the segments with the top 20th percentile segment average emission rates. On average, the hotspots comprised 45% and 48% of the trip total NOx and PM emissions. On a per-passenger-mile basis, NOx and PM emission rates were 30 times higher than for light-duty passenger cars. To lower per-passenger-mile emission rates, trains must carry more passengers. Most hotspots were located near populated urban centers. Such hotspots lead to higher pollutant exposure versus other locations

Keywords: emission hotspots, passenger train emissions, spatial variation

Evaluation of the precision and accuracy of cycle average light duty gasoline vehicles tailpipe emission rates predicted by modal models

Tongchuan Wei
Advisor(s): H. Christopher Frey

No. 10

A Vehicle Specific Power (VSP) modal model and the MOtor Vehicle Emission Simulator Operating Mode model have been used to quantify the fuel use and emission rates (FUERs) for on-road vehicles. Both models bin second-by-second FUERs based on factors such as VSP, speed, and others. The objective is to quantify the precision and accuracy of the two modeling methods. Since 2008, NC State University has used Portable Emission Measurement Systems to measure tailpipe emission rates for 214 light-duty gasoline vehicles on 1,677 driving cycles, including 839 outbound cycles and 838 inbound cycles on the same routes. For each vehicle, the models were calibrated based on outbound cycles and were validated based on inbound cycles. The goodness-of-fit of the calibrated models was assessed using linear least squares regression without intercept between model-predicted versus empirical cycle-average emission rates for individual vehicles. The coefficients of determination typically range from 0.60 to 0.97 depending on the vehicle group and pollutant, indicating moderate to high precision, with precision typically higher for higher emitting vehicle groups. The slopes of parity plots for each vehicle group typically range from 0.90 to 1.10 indicating good accuracy. The two modeling approaches are similar at the microscopic and macroscopic levels.

Keywords: precision, accuracy, modal model, exhaust emissions

Evaluation of the effects of cruise control on light-duty gasoline vehicle (LDGV) fuel use and emission rates

Weichang Yuan, Tongchuan Wei
Advisor(s): H. Christopher Frey

No. 11

Cruise control assists drivers to maintain a relatively constant cruise speed, which is a characteristic of eco-driving. However, there is a lack of quantitative evaluation of the effects of cruise control on vehicle fuel use and emission rates (FUERs). The objective is to quantify the differences in FUERs for vehicle operation with versus without cruise control. Vehicle Specific Power (VSP) indicates vehicle engine power demand. VSP modal models were used to estimate vehicle FUERs based on measured speed trajectories and road grade. The models were calibrated and validated to 1 Hz FUERs of 232 light-duty gasoline vehicles (LDGVs) measured in real-world driving. Comparisons of estimated FUERs for trajectories with versus without cruise control were made for three freeway links. Trajectories without cruise control were matched to those with cruise control if their average speed was within ± 5% of the target cruise speed. Approximately 50% of the comparisons are statistically significant. Statistically significant results indicate that cruise control can reduce fuel use and CO2 emission rates by 3% to 10%, CO emission rates by 6% to 39%, hydrocarbons (HC) emission rates by 3% to 13%, and nitrogen oxides (NOx) emission rates by 3% to 22%, depending on links and vehicles.

***Keywords*:** Eco-driving, Cruise Control, Light-duty Gasoline Vehicle, Fuel use, Emissions

Now you see it, now you don't: development of volatility distributions of biomass burning organic emissions

Aditya Sinha, Ingrid George, Amara Holder, Michael Hays
Advisor(s): Andrew Grieshop

No. 12

The volatility distribution of biomass burning organic emissions is important in determining their atmospheric evolution from partitioning and aging. Measurement-model discrepancies for secondary organic aerosol (SOA) has been attributed to the absence of semi- and intermediate volatility organic compound (S/IVOC) measurements. The volatility basis set (VBS) framework can quantify the contribution of S/IVOCs from biomass burning emissions and characterize partitioning between gas and particle phases. However, the amount and composition of S/IVOCs and the influence of factors such as fuel type and combustion conditions are uncertain. We collected sorbent tubes and quartz-fiber filter samples from biomass burning experiments for a range of fuels and combustion approaches. We analyzed samples using thermal desorption gas chromatography-mass spectrometry (TD-GC-MS) for both targeted and non-targeted compounds with a wide volatility range (Saturation concentration, C* ranging 10-3-107 g/m3). We fit these measurements using the VBS; comparisons across sources indicate similar distributions for open and prescribed burns and are consistent with distributions from literature. We noted deviations in distributions for woodstove emissions with 20% in the particle phase at lower OA concentrations (<25μg/m3) compared to ~40% for other fire types. Current work involves validation testing with different classes of compounds (PAHs, methoxy-phenols etc.) to constrain distributions.

Keywords: precision, accuracy, model, exhaust emissions

2020 EWC

Graduate Research Symposium

Solids

Environmental, Water Resources and Coastal Engineering

NC State University

Department of Civil,
Construction,
and Environmental Engineering

The contribution of abiotic cellulose hydrolysis to heat accumulation in landfills

Komal Charania, Zisu Hao, Florentino de la Cruz
Advisor(s): Morton Barlaz

No. 13

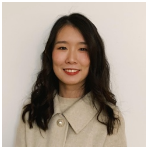
Cellulose is the largest biodegradable component of municipal solid waste (MSW) and is reported to undergo exothermic abiotic hydrolysis. The objectives of this study were to (1) evaluate the potential for abiotic cellulose hydrolysis to occur in landfills that are experiencing elevated temperatures, (2) evaluate the effects of temperature, pH, NaCl concentration and pressure on cellulose hydrolysis, and (3) assess the impact of abiotic cellulose hydrolysis on heat generation in landfills.

Initial work was conducted at the most extreme temperature condition (200°F) to determine if there was evidence of cellulose hydrolysis as an indication to proceed with lower temperature treatments. Under incubation at 200°F, up to 6% of the initial cellulose was hydrolyzed after 2 months in samples buffered at pH 10. In contrast, less than 2% hydrolysis was measured at pH 5 and 7, and no hydrolysis was measured at 100°F. Based on these results, additional tests were initiated at pH 10 and 160°F, 170°F and 180°F.

To evaluate the significance of the measured cellulose hydrolysis, the hydrolysis reaction was added to a previously developed model to estimate the contribution of this reaction to heat accumulation in landfills. Simulations predict that this reaction can increase landfill temperatures by 17.5°F.

***Keywords*:** Landfills, Elevated Temperature, Cellulose Hydrolysis

Promoting VFA production from food waste in anaerobic digesters – the effects of inoculum composition



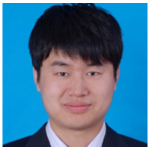
Jenny Ding
Advisor(s): Morton Barlaz, Francis de los Reyes, Douglas Call

No. 14

Anaerobic digestion has been shown to be one of the most sustainable options for managing food waste , whose generation is an increasing global challenge. Volatile fatty acids (VFAs) are products of the anaerobic process, and production of VFAs from food waste can potentially result in higher commercial value than methane production. However, the efficiency of production and VFA profile are highly dependent on the microbial communities present. A preliminary experiment was designed to determine the appropriate inoculum for the anaerobic digester. Four different inocula will be tested for treating food waste composed of proteins and carbohydrates: 1) anaerobic sludge (AS); 2) thickened waste activated sludge (TWAS); 3) AS+TWAS; 4) no inoculum added. Fourteen 250 mL serum bottles will be set up and run under mesophilic conditions (37 °C) for 15 days. VFA concentrations, soluble COD, pH, CH_4 and H_2 production will be closely monitored. We hypothesize that treatment 2 and 3 might be suitable inocula for degrading food waste to VFAs. The findings from this study will provide insights for inoculum selection for further studies on promoting VFA production in anaerobic digesters.

Keywords: food waste, volatile fatty acids, anaerobic digestion, inoculum

Finite element modeling of landfills to estimate heat generation, transport and accumulation



Zisu Hao
Advisor(s): Morton Barlaz, Joel Ducoste

No. 15

In North America, temperatures nearing 100 °C have been reported in several municipal solid waste landfills. However, the temporal and spatial-dependent processes that result in excessive heat accumulation are still not well understood. The objective of this study was to develop a transient finite element three-dimensional model to describe the heterogeneity of landfills, to incorporate the impacts of boundary and initial conditions, and to consider spatially dependent heat transfer mechanisms to better understand heat generation, accumulation, and propagation. The model incorporates gas-liquid-heat reactive transfer with aerobic and anaerobic biological reactions, anaerobic metal corrosion, and ash hydration and carbonation. Increasing boundary temperature, biological reaction rates, and landfill height increases the maximum temperature in the central region of a landfill while the impact of thermal properties of MSW is negligible. Simulation results predict that placement of ash near the corner of a landfill reduces the size of the elevated temperature region relative to placement in the landfill center. Mixing heat-generating wastes (ash or Al) with MSW decreases maximum temperatures but results in elevated temperatures over a larger fraction of the landfill volume relative to segregated ash disposal.

***Keywords*:** Waste management, Landfills, Heat transfer, Solid waste, Modeling

Development of methods to measure heat released from ash hydration and carbonation in landfills

Asmita Narode
Advisor(s): Morton Barlaz

No. 16

A recently published model describing landfill heat accumulation identified several reactions that contribute significant heat to landfills including the hydration and carbonation of calcium-containing wastes such as ash from municipal solid waste (MSW) and coal combustion. The objective of this research is to develop laboratory methods using an isothermal calorimeter to measure heat released by ash hydration and carbonation.

Tests were conducted in a calorimeter to compare the heat released by calcium oxide (CaO) and hydroxide $Ca(OH)_2$ to theoretical values. Known quantities of CaO and water was added to 20 mL vials for hydration. To measure carbonation, known quantities of $Ca(OH)_2$ were mixed with aqueous CO_2 by using $KHCO_3$. After the reaction was completed, the presence of carbonates (the product of $Ca(OH)_2$ carbonation) was verified by thermogravimetric analysis and X-Ray diffraction (XRD). The results show that measured heat is within 90% and 73% of the theoretical amount for hydration and carbonation, respectively. XRD analysis of the carbonated products shows the generation of several carbonates in addition to $CaCO_3$. We suspect that the lower efficiency for the carbonation reaction is due to other reactions. Work is in progress to extend the method to a reactor system that better represents landfill conditions.

Keywords: Landfills, isothermal calorimeter, ash hydration, ash carbonation

What are the environmental implications of using compost as alternative daily cover in a landfill?

Mojtaba Sardarmehni
Advisor(s): Morton Barlaz, Joel Ducoste

No. 17

There is increasing interest in diverting the organic fraction of municipal solid waste (OFMSW) from landfills to biological processes which produce compost. Environmental impacts of managing OFMSW through biological processes and applying compost to land are investigated in literature; however, no one has considered landfilling compost. The objective of this study is to use life-cycle assessment to compare the environmental impacts of compost as a soil amendment with use as an alternative daily cover (ADC) in landfills equipped with energy recovery and leachate treatment systems. Monte Carlo simulation and parametric sensitivity analyses were performed to evaluate the effects of uncertainty in input values on the final results and rankings. The results indicate that the ADC scenario generally outperforms the soil amendment scenario in terms of global warming potential and eutrophication, while the soil amendment scenario is generally better in terms of cumulative energy demand. The acidification impact in both scenarios is relatively small and comparable between scenarios. Policymakers seeking to enact OFMSW management regulations should consider the use of compost as ADC especially when factors such as feedstock contamination, imperfect sorting, or a lack of markets make it difficult to find appropriate applications for compost as a soil amendment.

***Keywords*:** Life Cycle Assessment, Organic waste, Compost, Alternative Daily Cover

The effect of temperature on methane generation from solid waste excavated from landfills experiencing elevated temperatures

Sierra Schupp
Advisor(s): Morton Barlaz

No. 18

A limited number of landfills in the U.S. have exhibited temperatures of 80 – 100 °C. These landfills, referred to as elevated temperature landfills (ETLFs), require intensive management as the elevated temperatures are a threat to a landfill's gas and leachate collection systems, liner integrity, and geotechnical stability. The objectives of this research were to (1) evaluate the extent to which the landfill methanogenic community adapts as temperatures increase from the mesophilic to thermophilic range and (2) determine whether the upper temperature limit of fermentation exceeds that of methanogenesis. Sixteen samples excavated from two ETLFs were utilized as inocula for reactor tests. Results showed that methane production is possible up to at least 65 °C (150 °F) and fermentation up to 77 °C (170 °F). The implication of the higher temperature for fermentation is that its intermediates can accumulate and act as early indicators of an ETLF. It appears that a smaller population of methanogens capable of activity at elevated temperatures may be responsible for reduced methane generation beyond the optimal range of 45 to 55 °C. The results provide an understanding of methane production potential in landfills at elevated temperatures and provide improved data for modeling heat generation.

Keywords: landfill, elevated, temperature, methanogenesis

Identifying critical impacts and flows in life-cycle assessments of municipal solid waste management

Yixuan Wang
Advisor(s): James W. Levis

No. 19

Life-cycle assessments (LCAs) of municipal solid waste (MSW) systems are time and data intensive. Reducing the time and data required for inventory and impact assessments 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 the effect on the final rankings of alternative scenarios. Six treatment processes were considered: landfills, waste-to-energy, single-stream recycling, mixed waste recycling, anaerobic digestion, and composing. Eighteen scenarios were assessed using 1752 flows of resources and emissions, ten impact categories, three normalization references, and seven weighting schemes. The results show that human health, ecotoxicity, eutrophication, global warming, and fossil fuel depletion contribute 81 to 97% to the total impacts, regardless of weighting schemes. However, the normalization references have a similar contribution to the weighted scores as the choice of weighting scheme. It was found that 4% of the life-cycle inventory flows suffice to cover over 99% of the overall environmental burden and provide reasonably accurate impact estimates, compared with the full system. The recommended impact and flow sets could provide useful results in rankings of alternative scenarios.

***Keywords*:** life cycle analysis, simplified life cycle assessment, streamlining, municipal solid waste management

2020 EWC

Graduate Research Symposium

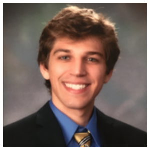
Energy

Environmental, Water Resources and Coastal Engineering

NC State University

Department of Civil,
Construction,
and Environmental Engineering

Energy storage and solar photovoltaic capacity value sensitivity analysis



Danny Sodano
Advisor(s): Jeremiah Johnson, Joseph DeCarolis

No. 20

Ensuring utility-scale solar and energy storage systems operate cost-optimally to provide maximum electric grid benefits has become increasingly important as these resources continue to see rapid growth in deployments. Grid infrastructure must meet peak demand, a role traditionally undertaken by inefficient natural gas peaking plants. Capacity values for thermal generators are high since they're typically only unavailable during scheduled shutdowns. Since solar photovoltaics are non-dispatchable due to variable solar irradiance, utilities assign low capacity values to solar PV. Energy storage can alleviate solar generation variability and shift peak demand but is energy limited. Monte Carlo simulations have demonstrated the sensitivity of solar PV capacity credit under various penetration levels using Equivalent Forced Outage Rate Demand (EFORd) values to determine Loss of Load Probability (LOLP) changes on Duke Energy's balancing territory. Temoa, NC State's in-house energy model, has been used to evaluate cost-optimal storage operational behavior. Early analysis suggests a strong positive correlation between solar and storage penetration, storage duration, and resource reliability. Recent growth in solar generation and winter/duel-peaking grid demand behavior make Duke Energy territory a good test case for reassessing solar and storage capacity value, especially as the utility aims to replace their aging peaking plants.

***Keywords*:** Optimization, energy systems, modeling

Enhancing microalgae-based biofuel production via dynamic control of light variation

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

No. 21

Photosynthetic microalgae are widely studied for biofuel production due to its high lipid yield compared to other biofuel feedstocks. A fundamental challenge in advancing microalgae-based biofuel technologies is to control and optimize the cultivation process. Specifically, many prior studies cultivated microalgae under different constant light intensities to identify the optimal light conditions for algae growth. However, these cultures cannot maintain the maximum photosynthesis rate across the entire growth period due to light attenuation, which inevitably limits the carbon fixation and lipid yield. This project aims to enhance the biomass and lipid production by dynamically varying the light intensities during algae growth. We utilized a mathematical model established on our prior work to simulate and determine the potential light-varying schemes. According to computational analyses, a substantial increase in lipid production (as compared to the optimal constant light conditions) was achieved by strategically increasing the light intensity from low to high. Interestingly, the inhibition effect caused by high light intensities seemed attenuated. Future experiments are being designed to validate the proposed light control strategy. This research will help understand the effect of dynamic light control on microalgae growth to optimize the cultivation process for enhanced biofuel production in large practical scale.

Keywords: Microalgae, Biofuel, Mathematical model, Lipid, Photosynthesis

Stay cool and be flexible: energy-efficient grid services using commercial buildings HVAC systems

Aditya Keskar
Advisor(s): Jeremiah Johnson

No. 22

The thermal inertia of commercial buildings allows us to shift their power consumption on short time scales to provide power grid services while maintaining occupant comfort. Previous experimental research has shown that buildings providing these services may consume more energy than they would under normal operation. I explore this phenomenon by analyzing results from over one thousand experiments conducted on seven buildings at North Carolina State University. In these experiments, we manipulate the buildings' thermostat setpoints using pre-defined setpoint signals that cause the building to shift its power consumption with respect to its baseline. Expanding on my prior research using square-symmetric setpoint signals, I implemented a variety of new signals (e.g., ramping the setpoints) that enable an enhanced understanding of the physics and control response of HVAC systems. I analyze the fan power response and investigate impacts on the building chilled water and hot water systems, incorporating a more holistic energy efficiency impact assessment. Furthermore, I quantify the efficiency of building response using new methods that incorporate both the additional energy consumed and the quality of cooling service provided to the building. This research provides new insights that will help inform the design of building response strategies that mitigate inefficiency.

***Keywords*:** Ancillary services, Energy efficiency, Commercial buildings, HVAC, Demand response

2020 EWC

Graduate Research Symposium

Coastal

Environmental, Water Resources and Coastal Engineering

NC State University

Department of Civil, Construction, and Environmental Engineering

Improving ‘sub-grid’ representation in the SLOSH model (sea, lake, overland surges, from hurricanes)

Autumn Poisson
Advisor(s): Casey Dietrich

No. 23

As our climate continues to change, hurricanes are predicted to become more intense and more frequent, and thus models that predict flooding need to be as accurate as possible. The Sea, Lake, Overland Surges from Hurricanes (SLOSH) model is the operational storm surge forecast model for the U.S government. This model relies on a computational grid to represent the coastal environment. To allow for fast run-times, this grid uses a coarse representation of the continental shelf, coastline, and other large-scale features, and then parameterizes the flow at small-scale features such as channels, bays, and barriers. We propose a method to improve the ‘sub-grid’ features by correcting with information from high-resolution data sets. Our first step is to examine the model performance in a simple grid test case with flow through a small channel in a barrier to a back bay. We wish to understand if using our grid at a coarsened resolution allows for fluid flow to the back bay or if flow gets cut off, and if the coarsened grid still represents the channel or the barrier. Anticipated results will show the need for sub-grid corrections and motivate the rest of our project.

Keywords: storm-surge, SLOSH, resolution, numerical modeling

Improving predictions of coastal flooding via sub-mesh corrections

Johnathan Woodruff
Advisor(s): Casey Dietrich

No. 24

ADCIRC (ADvanced CIRCulation) is a hydrodynamic model used to predict coastal water levels. During storm events, such as hurricanes, ADCIRC forecasts flood levels along the coast, which can be used to advise emergency managers and the general public and prepare them for the storm. Although ADCIRC can be highly accurate, its accuracy depends on its “mesh”, which represents the coastal environment with bathymetric elevations and bottom frictions. Meshes of high resolution and accuracy can predict water levels very precisely; however, this precision comes at a high computational cost, which delays the ability to forecast the storm and advise interested parties. This study aims to incorporate high resolution data on a lesser resolved mesh by incorporating correction factors into the governing equations. These correction factors will maintain model accuracy while also decreasing run time. This concept was applied to both 1D and 2D versions of ADCIRC, and produced stable results that mimicked the traditional version of ADCIRC.

Keywords: storm-surge, correction factors, mesh, forecast

Understanding Global Motu Morphometrics

Faith Johnson
Advisor(s): Elizabeth Sciaudone

No. 25

Atolls are carbonate reef systems found in subtropical and tropical oceans composed of a reef flat, motu (also known as reef islands, cays, and islets), and an inner lagoon. Motu form and respond to changes in the environment quickly, with motu formation on the scale of decades to millennia and evolution of motu on as short a time scale as weeks. They may be particularly vulnerable to climate change including increasing ocean temperatures (causing coral die-off), ocean acidification (decreasing coral resiliency), and increasing sea level rise. We automate the analysis of atolls and apply it globally utilizing open-source cloud-based geospatial analysis coupled with freely-available Landsat satellite imagery. For select atolls, we compare offshore wave conditions to each atoll and its morphometrics, determining if wave climate and storms are the primary driver of motu evolution. Additionally, a global database of atolls and their morphometrics is created and can be used for further analysis. This will increase our understanding of processes driving landscape change on atoll islands (locations highly vulnerable to changing climate impacts). Moreover, it will provide us with the tools to analyze globally which drivers of atoll island evolution dominates.

***Keywords*:** atoll, coral reef, remote sensing

Improving the accuracy of a real-time ADCIRC storm surge downscaling model

Carter Rucker
Advisor(s): Casey Dietrich

No. 26

During major storm events such as hurricanes, emergency managers rely on fast and accurate forecasting models in order to make important decisions concerning public safety. These models are typically computationally heavy and cannot quickly make predictions at high resolution. However, model output can be post-processed to mimic high resolution results at minimal computational cost. This research proposes methods for improvement in the accuracy of downscaling a real-time storm surge forecasting model. Such improvements to the model include 1) expansion in its spatial applicability, 2) accuracy increase using water surface slope extrapolation, and 3) accuracy increase using friction loss across the ground surface.

This research builds upon a model which uses maximum water elevation output from the ADvanced CIRCulation (ADCIRC) model and downscales these results to a finer resolution by extrapolating the water levels to a Digital Elevation Model (DEM). The model was previously only able to run in North Carolina, but improvements have been made to apply the model globally and add simple physics by taking into account the slopes of the water surface and friction due to changes in land cover classifications. These improvements can be used by emergency managers to provide a better estimation of forecasted flooding extents.

Keywords: Storm surge, Forecasting, ADCIRC, Hurricanes, Flooding

The impact of marine hydrokinetic devices on morphodynamics

Hanieh Mohamadi Moghadam
Advisor(s): Alejandra Ortiz

No. 27

Marine Hydrokinetic (MHK) devices provide an opportunity to expand renewable energy by harnessing power from waves and currents and converting it to electricity. However, most MHK devices are in the developmental stage requiring research to understand their impacts on the surrounding environment. The impact of the devices on morphodynamics is of great importance to minimize future operational costs. In this study, we investigate near-field wave conditions and morphology response to MHK devices. Then, we model different MHK arrays to understand their impacts on wave, flow, and sediment conditions driving short-term and long-term morphologic evolution under mean and extreme wave conditions.

The objectives are: wave data analysis and investigation of mean and extreme condition; obtain equilibrium bathymetry under mean condition; the placement of the devices using different methods (static physical lump, energy absorption object, and a combination these two methods) into Delft3d; and sensitivity analysis of sedimentation to different MHK array parameters. Representing the devices as static lumps, the sediment deposition on the downstream decreases 50%. However, adding 30% energy absorption, downstream deposition increases around 100%. Changing MHK deployment array parameters (spacing, size and number) led to a discernible change in the pattern and amount of the sedimentation, as well.

Keywords: Marine hydrokinetics, numerical modeling, sediment transport

2020 EWC

Graduate Research Symposium

Water Treatment

Environmental, Water Resources and Coastal Engineering

NC State University

Department of Civil, Construction, and Environmental Engineering

Determination of pesticide occurrence in private wells by high-resolution mass spectrometry

Nancy Lee Alexander
Advisor(s): Detlef Knappe

No. 28

Approximately 30% of North Carolinians rely on private wells as their primary source of drinking water. Because private wells fall outside of the purview of the Safe Drinking Water Act, occurrence data for pesticides are lacking. To address this challenge, my research aims to 1) develop robust non-targeted acquisition and data analysis workflows for identifying pesticides and pesticide degradates and 2) investigate the occurrence of pesticides, as well as other common contaminants, in private wells across North Carolina. A liquid chromatography – quadrupole time-of-flight mass spectrometry system was used to develop a large volume injection workflow. Pesticide mixtures containing a total of 31 compounds were used to develop 4 acquisition methods each in both positive and negative electrospray ionization (ESI) modes. Following data acquisition, MS data were analyzed using Agilent identification algorithms and an online WebApp developed by the US EPA while MS/MS data were analyzed using Agilent identification algorithms as well as Competitive Fragmentation Modeling for Metabolite Identification. Both MS and MS/MS outputs were then paired and analyzed using a Python script developed by the US EPA to determine confidence of tentative identifications followed by Agilent's Mass Profiler Professional to analyze significance and sample uniqueness.

Keywords: pesticides, high resolution mass spectrometry, drinking water quality, nontargeted analysis

Enhancement of salt ions removal during desalination using capacitive deionization

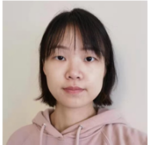
Yazeed Algurainy
Advisor(s): Douglas Call

No. 29

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 carbon electrodes and ions (e.g., Na+, Cl-) from the feedwater are removed via electrosorption. Most CDI designs are based on a 1:1 mass ratio of electrodes (symmetric CDI). The conventional assumption in CDI is that Na+ and Cl- are removed in a 1:1 symmetry on the electrodes. When oxygen gets reduced to H2O2 or OH- in the negatively charged electrode (cathode), Na+ adsorption can be affected because both processes compete over the adsorption cites in cathode. In a previous work, we showed that the oxygen reduction reactions (ORRs) had a strong impact on Na+ removal. In this study, we are studying how the ratio of electrodes affects the competing processes, with a hypothesis that ORRs become dissolved oxygen (DO) concentration limited when the mass of positively charged electrode (anode) is greater than cathode (asymmetric CDI). Measurements of pH, DO and H2O2 indicated that ORRs were DO limited in asymmetric CDI. This in turn enhanced Na+ adsorption. The adsorption capacity of Na+ increased from 59.4±14.5 μmol/g-C in symmetric CDI to 110.8±6.1 μmol/g-C in asymmetric CDI. Our results demonstrate how the mass ratio of electrodes can affect Na+ removal during desalination using CDI.

Keywords: desalination, capacitive deionization, asymmetric electrodes

Rapid small-scale column tests to predict PFAS removal by anion exchange resins



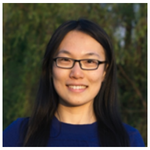
Lan Cheng
Advisor(s): Detlef Knappe

No. 30

Per- and polyfluoroalkyl substances (PFASs) are persistent contaminants with adverse environmental and public health effects. Conventional drinking water treatment processes are ineffective for PFAS removal. Ion exchange (IX) resins have gained attention as a treatment alternative for PFAS because they can more effectively remove short-chain PFAS than granular activated carbon. To date, suitable approaches for the scale-up of bench-scale IX data have not been developed. The rapid small-scale column test (RSSCT) is a bench-scale test that can significantly reduce the time required to determine effective IX design and operating parameters. We explored alternative RSSCT designs (constant diffusivity, proportional diffusivity) to simulate PFAS removal observed in a pilot study conducted in Wilmington, NC. RSSCTs were designed based on principles of similitude and conducted with crushed IX resin. Excellent agreement between RSSCT and pilot-scale data was obtained with the constant diffusivity RSSCT design. Moreover, this study reveals that longer-chain PFAS were more effectively removed than shorter-chain PFAS and that PFAS with a sulfonic acid head group were more effectively removed than those with a carboxylic acid head group. This research will support the design of future IX treatment processes in the contexts of remediation and drinking water treatment.

Keywords: PFAS, Ion Exchange Resin, Rapid Small-Scale Column Test

Biological activated carbon system harboring microorganisms that exchange electrons with activated carbon



Qiwen Cheng, Juan Fausto Ortiz Medina
Advisor(s): Douglas Call

No. 31

Pyrogenic carbonaceous materials (PCMs), such as biochar and activated carbon, are widely used to adsorb contaminants from water. Recent research has shown that they can also be redox mediators that drive contaminant biotransformations (e.g., denitrification, dehalogenation). PCMs can serve as electron acceptors/donors for pure-culture Geobacter and Shewanella species to degrade contaminants. However, little is known about whether or not microorganisms present in environmental systems, especially where PCMs have been already applied, can reduce/oxidize PCMs. The objective of this study was to identify microorganisms from a PCM-amended system that can exchange electrons with PCMs, and to explore electron exchange mechanisms. We sampled a native microbial community from a biological activated carbon (BAC) filter, and provided granular activated carbon (GAC) as the electron acceptor and ozonation by-products (acetate, formate) as the electron donor. Our results indicated that the BAC community could oxidize acetate (but not formate) by reducing GAC. Geobacter species were specifically enriched, with a relative abundance of up to 96%. GAC's electrical properties could be responsible for electron exchange between microorganisms and GAC. Our work suggests that providing GAC as the electron acceptor might enhance PCM-mediated contaminant degradation pathways in full-scale water treatment systems.

Keywords: PCMs, electron exchange, BAC filter, Geobacter, electrical properties

Adsorption of PFAS by granular activated carbon: Scale-up of bench-scale data and factors controlling GAC use rates

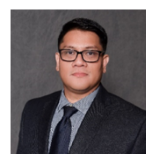
Zack Hopkins
Advisor(s): Detlef Knappe

No. 32

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/PFEA. One treatment option considered effective is granular activated carbon (GAC) adsorption. Our research aims to 1) compare rapid small-scale column test (RSSCT) design [e.g. constant diffusivity (CD), proportional diffusivity (PD)] to predict field-scale GAC performance, 2) elucidate PFAS properties controlling adsorbability to GAC, and 3) identify GAC properties that enhance PFAS removal. RSSCTs were conducted to assess PFAS removal in surface water and groundwater. Samples were analyzed by LC-MS/MS for 24 PFAS, including 13 PFEA. Bed volumes to 10% breakthrough were ~3 times greater for most PFAS for the PD-RSSCT compared to the CD-RSSCT. PFAS adsorbability increased with chain length. Linear PFAS were more adsorbable than branched PFAS of equivalent chain length. Reagglomerated, sub-bituminous coal-based GAC was more effective than enhanced coconut GAC, likely due to the larger mesopore volume.

***Keywords*:** Per- and polyfluoroalkyl substances, granular activated carbon, drinking water treatment, surface water

A modelling approach to understand the mechanisms of per- and polyfluoroalkyl substance removal on electrically charged activated carbon electrodes



Elvin Hossen
Advisor(s): Douglas Call

No. 33

Per- and polyfluoroalkyl substances (PFAS) are contaminants of emerging concern in water. Activated carbon (AC) can remove some PFAS, but is challenged by limited adsorption capacity, lack of cost-effective regeneration options, and inability to adsorb certain species. Recent study on electrically charging AC has shown that applying voltage to AC electrodes can increase PFAS removal by up to 2.5 times relative to physical adsorption. However, little is known about electrosorption mechanism of large organic ions such as PFAS on AC. Studies on electrosorption of small inorganic ions (e.g. Na+, Cl-) found that constant electrostatic with ion volume interactions theory can accurately predict ion concentration stored in micropores of the electrodes at equilibrium. But state-of-the-art electrical double layer (EDL) theory has yet to explain the observed phenomena in PFAS electrosorption. This study proposed modelling approach to describe the mechanism of PFAS adsorption onto micropores EDLs. Two equation-of-state models were investigated to explain interactions in EDLs containing PFAS: (1) Boublik-Mansoori-Carnahan-Sterling-Leland (BMCSL) and (2) Non-spherical Hard-Convex Bodies (NSHCB). We tested our model with experimental results from our previous studies on 6 different PFAS species for model validation. Ultimately, an accurate model for electrosorption could serve as a predictive tool for optimized PFAS removal.

Keywords: PFAS, Electrosorption, EDL theory, Equation-of-State

Design considerations for rapid small-scale column tests to elucidate effects of dissolved organic matter on PFAS adsorption by granular activated carbon

Yoko Koyama
Advisor(s): Detlef Knappe

No. 34

The rapid small-scale column test (RSSCT) is an efficient bench-scale approach for estimating contaminant breakthrough in full-scale granular activated carbon (GAC) adsorbers. The overarching goal of this research is to elucidate effects of dissolved organic matter (DOM) on the adsorption of short-chain perfluoroalkyl acids (PFAA) with appropriately designed RSSCTs. RSSCTs are designed based on the principle of similitude, keeping dimensionless parameters constant between small- and large-scale adsorbers. An initial objective of the study is to determine an RSSCT design that minimizes water usage while assuring that the same mass transfer mechanisms are rate limiting in both small- and large-scale adsorbers. Dimensionless parameters were obtained through modeling pilot-scale data, and the same parameters were used to predict the performance of an ideal bench-scale column. Non-ideal RSSCT designs, for which some dimensionless parameters deviated from those of the large column, were then explored to lower water consumption while maintaining the same rate controlling mass-transfer mechanism. The resulting column design will be used to evaluate the effects of DOM on PFAS adsorption. For example, adsorption competition among PFAAs will be evaluated in water with a range of DOM levels typically encountered in drinking water sources.

***Keywords*:** RSSCT, breakthrough, PFAA, DOM, competition

Sodium hydroxide induced flocculation of marine microalgae *Dunaliella viridis*: Efficiency, mechanism, and media recycling potential

Yi-Chun Lai
Advisor(s): Joel Ducoste, Francis de los Reyes

No. 35

Biofuel from extracted lipids of marine microalgae, *Dunaliella viridis* (*D. viridis*), is a promising replacement for fossil fuels because: (1) microalgae grow fast and have high lipid content; (2) seawater is used for cultivation, minimizing the need for freshwater; and (3) the lack of a cell wall potentially simplifies lipid extraction process. However, a cost-effective harvesting method is still needed to make microalgal biofuel production economically feasible. Flocculating *D. viridis* by sodium hydroxide has been shown to be effective; however, comprehensive research on the mechanisms and the use of recycled media are lacking. In this study, we examined sodium hydroxide induced flocculation at six pH levels (10, 10.5, 11, 11.5, 12, 12.5). The flocculation efficiency was evaluated using cell number recovery rate. The flocculation mechanism was elucidated by analyzing the intracellular and extracellular protein and carbohydrate concentrations, zeta potential, and supernatant cation concentration before and after treatments. The supernatant after flocculation was neutralized and used as recycled media for growing *D. viridis* cells. This research allowed determination of the ideal pH for sodium hydroxide induced flocculation of *D. viridis*, elucidation of actual mechanisms, and showed the reusability of neutralized used media.

Keywords: marine microalgae, *Dunaliella viridis*, flocculation, sodium hydroxide, media recycling

How are microbial communities assembled in bioengineered systems? A review and experimental approach for anaerobic food waste digesters

Savanna Smith
Advisor(s): Francis de los Reyes

No. 36

Understanding how complex microbial communities are assembled in engineered bioreactors is a fundamental requirement for gaining deeper insights into microbial ecology and function of waste treatment and conversion processes such as activated sludge systems and anaerobic digesters. Microbial community assembly theory posits that abiotic and biotic factors influence how microbial community structure is developed. Deterministic influences are imposed by the abiotic environment, while stochastic influences are due to unpredictable disturbances - chance, immigration, and birth-death events. However, there is not yet a universal framework explaining the dominant assemblage processes in different bioreactor systems at different conditions. Using previous studies, we compare stochastic versus deterministic influences in relation to the thermodynamic potential of the system. It is expected that the dominant assembly process is driven by thermodynamics, and that the higher the thermodynamic potential of a system, the more dominant deterministic processes are. Experimentally, the community assemblages of anaerobic co-digesters operated under different feeding conditions (high protein, carbohydrate, or fat waste) will be analyzed to determine the contributions of deterministic and stochastic factors. It is expected that the reactor fed with high fat waste will be largely deterministic because of higher thermodynamic potential compared to the high carbohydrate and protein reactors.

***Keywords*:** community assembly, anaerobic co-digestion, wastewater

Sunlight-mediated removal of emerging contaminants in treatment wetlands and surface waters

Leah Weaver, Arpit Sardana
Advisor(s): Tarek Aziz

No. 37

Contaminants of emerging concern (CECs) are known to photodegrade in constructed wetlands treating wastewater effluent, but the effect of dissolved organic matter (DOM) on the kinetics of their photodegradation is complex and not fully understood. The DOM quantity and quality crucially determines what species of photoproduced reactive intermediates are formed or inhibited, affecting indirect photodegradation pathways of CECs. The lack of understanding of DOM transformation and the impact of that transformation on photodegradation within a wetland inhibits our ability to optimally design open-water treatment wetlands for CEC removal. To examine how DOM-mediated photodegradation reactions are coupled to wetland processing of wastewater, we characterized wetland DOM using spectrophotometry techniques and performed photo-decay experiments of target CECs in real and simulated wetland water samples under simulated sunlight. Target CECs included four pharmaceuticals: cimetidine, amoxicillin, 17α-ethinylestradiol, and atenolol. Our results show that wetlands process microbial-like DOM characteristics of wastewater to a humic terrestrial composition, influencing the ability of wetland DOM to phototransform organic micropollutants. These photoreactivity trends and treatment wetland environmental variables can then be linked, improving the prediction of photochemical fate of wastewater derived CECs and thus treatment wetland design.

Keywords: constructed wetlands, photodegradation, DOM, emerging contaminants

Tertiary partial denitrification-anammox (PANDA) filters for sustainable nitrogen removal

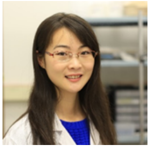
Anthony Young
Advisor(s): Tarek Aziz, Francis de los Reyes

No. 38

Concentrated discharges of nitrogen into our waterways have led to serious environmental impacts, such as eutrophication and algae blooms. Due to these discharges, stringent total nitrogen (TN) discharge limits have been placed on Water Reclamation Facilities (WRFs). Mainstream deammonification offers a solution to improve nitrogen removal at these facilities through the use of anaerobic ammonia oxidizing bacteria (Anammox). However, the success of this process has been limited. Previous research at NC State explored the conversion of tertiary filters into mainstream deammonification filters which were capable of an average total inorganic nitrogen (TIN) removal rate of 91%, with effluent TIN reaching below 2 mg/L-N. However, this research suggested that nitrate loading was a key limiting factor in meeting rigorous effluent limitations. Incorporating partial denitrification (PdN) into this process offers a promising solution. The goal of this research is to explore the TN removal capability of a PdN-Anammox (PANDA) filter. Utilizing pilot scale filters, we will compare efficiencies of carbon loading strategies and will identify the microbes involved within the PANDA process. It is expected that this treatment technique will provide improved TN removal efficiencies and an opportunity for stable TN removal at WRFs, as well as the possibility of substantial savings.

***Keywords*:** wastewater, nitrogen, anammox, filters

Fate of Per- and Polyfluoroalkyl Ether Acids in the Total Oxidizable Precursor Assay and Implications on Analysis of Impacted Water



Chuhui Zhang, Zachary Hopkins, James McCord, Mark Strynar
Advisor(s): Detlef Knappe

No. 39

Per- and polyfluoroalkyl substances (PFASs) are widely used anthropogenic chemicals. The PFAS class includes almost 5,000 registered compounds, but analytical methods are lacking for most PFASs. The total oxidizable precursor (TOP) assay was developed to indirectly quantify unknown PFASs that are precursors to commonly measured perfluoroalkyl acids. To understand the behavior of recently identified per- and polyfluoroalkyl ether acids (PFEAs), including fluorinated replacements and manufacturing by-products, we determined the fate of fifteen PFEAs in the TOP assay. Ten perfluoroalkyl ether acids and a chlorinated polyfluoroalkyl ether acid (F-53B) were stable in the TOP assay and represent terminal products that are likely as persistent as historically used PFASs. Adding perfluoroalkyl ether acids and F-53B to the target analyte list for the TOP assay is recommended to capture a larger percentage of the total PFAS concentration in environmental samples. In contrast, polyfluoroalkyl ether acids with a -O-CFH- moiety were oxidized, typically to products that could not be identified by liquid chromatography-high resolution mass spectrometry. Application of the TOP assay in its proposed enhanced form revealed high levels of PFEAs, presence of precursors that form perfluoroalkyl carboxylic acids, and absence of precursors that form PFEA in surface water impacted by PFAS-containing wastewater discharges.
Keywords: per- and polyfluoroalkyl ether acids, total oxidizable precursor assay, PFASs, Cape Fear River water

Implementation of CRISPR-Cas9 system in Geobacter sulfurreducens to enhance the release of fixed ammonium

Mark Poole
Advisor(s): Douglas Call

No. 40

Nitrogen gas (N2) conversion to ammonium (NH4+) is an essential but cost- and energy-expensive process, with the Haber-Bosch method constituting the major form of artificial N2 fixation implemented today. Biological nitrogen fixation (BNF) is a more efficient process that has seen significant barriers to commercial implementation. Geobacter sulfurreducens is a nitrogen-fixing soil bacterium also known to respire using electrodes. Recent evidence has indicated that the metabolic rate of G. sulfurreducens while respiring in microbial electrochemical cells (MECs) is connected to nitrogen fixation. However, NH4+ is not secreted from cells due to tight regulatory control. The CRISPR-dCas9 system is a robust method for offsetting undesirable regulatory control. In Geobacter, the DraT gene inhibits the function of nitrogenase in response to high extracellular ammonium, preventing efficient ammonium secretion. In this study, the CRISPR-dCas9 system was implemented in G. sulfurreduencs to target DraT, ensuring continued function of nitrogenase with high extracellular ammonium. This system paves the way for future work in G. sullfurreducens and a more economical BNF process.

***Keywords*:** CRISPR, ammonium, genetic engineering, Geobacter

2020 EWC

Graduate Research Symposium

Water Resources

Environmental, Water Resources and Coastal Engineering

NC State University

Department of Civil, Construction, and Environmental Engineering

Multi-decadal assessment of within-lake nutrient cycling via Bayesian mass-balance modeling

Matthew Aupperle, Dario Del Giudice
Advisor(s): Daniel Obenour, Sankar Arumugam

No. 41

Nutrient recycling from bottom sediments can exceed external watershed loads. However, lack of sediment nutrient flux measurements leads many studies to ignore or oversimplify these fluxes. We seek to understand internal cycling in Jordan Lake using a mass-balance model combined with Bayesian inference to rigorously estimate nutrient flux parameters. Jordan Lake is a major water supply reservoir and has been eutrophic since impoundment in 1983. We simulate monthly nitrogen and phosphorus dynamics in the water column and sediment layer of four longitudinal reservoir segments, forced by watershed flows, nutrient loads, and meteorology. We compare multiple model versions to assess the importance of prior information, calibration data, and mechanistic formulation on performance. Overall, the model explains 59% of the variability in observed nutrient concentrations. Phosphorus recycling rates were found to be higher than expected a priori, particularly in the summer. Combination of the phosphorus model with parallel models for Nitrogen and Chl-a show how nutrients stored in lacustrine sediment dampen the effects of external watershed loading reductions such that a 50% reduction only leads to a 15% Chl-a reduction. To better quantify potential time scales for reservoir recovery, we report future simulations over a multi-decadal period and characterize forecast uncertainties.

***Keywords*:** nutrient cycling, Bayesian modeling, lake management, phosphorus

Bayesian approach to predict changing floods under climate change

Chandramauli Awasthi
Advisor(s): Sankar Arumugam

No. 42

Many past studies have challenged the idea of stationarity in hydrologic extremes. Trends have been observed in annual maximum flood (AMF) series across the coterminous US (CONUS). The presence of non-stationarity in AMF has outdated the existing conventional methods of estimating floods for various water infrastructure designs. An increasing trend in AMF poses higher risk to those hydrological structures which are designed using conventional flood estimation methods. The present work provides a new approach to estimate the future floods which takes into account the projected future changes in AMF. In the developed Bayesian framework, posterior is formulated such that likelihood is assigned weights based on a defined kernel. Then, the weight kernel parameter is tuned to estimate the marginal parameters of extreme value distributions such that the risk on water infrastructure is equal to what is expected under non-stationary conditions.

Keywords: floods, non-stationarity, climate change

Developing an agent based model from novel water column reactor results to forecast harmful algal bloom (HAB) formation

Monica Camacho
Advisor(s): Tarek Aziz, Emily, Berglund, Daniel Obenour

No. 43

Cyanobacteria harmful algal blooms (HABs) appear in reservoirs worldwide, impairing our water supplies with a range of problems including taste, odor, and the presence of dangerous cyanotoxins. Conventional modeling of HABs is performed using population-based models (PBMs), but PBMs do not consider the 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 the behavior and interaction of individuals to more realistically represent natural biological systems. This research focuses on creating an ABM to better predict HABs under various engineered and natural conditions. Here we present our results from an ABM developed in NetLogo and compare simulated results to data collected from experimental water column reactors (WCRs) designed to study phytoplankton behavior in shallow turbid reservoirs. Once calibrated to the reactors, the model's parameters, such as turbidity, diffusion, and temperature, will be altered to explore how other environmental scenarios—like climate change—can impact phytoplankton community structure. The goal of this research is to create a tool for engineers and scientists to help explore phytoplankton community dynamics to predict and prevent the challenges associated with HAB formation.

Keywords: HABs, agent-based modeling, phytoplankton, lake-mixing

Reservoir operation considering ecological release in Lake Lanier, Georgia

Dol Raj Chalise
Advisor(s): Sankar Arumugam

No. 44

Conventional reservoir management typically optimizes water and energy needs and produces economic benefits. Reservoir management considers downstream release to be an environmental constraint where a minimum flow value must be met. However, such minimum flow value may not meet the environmental flow requirement. In this paper, we assess how a reservoir modifies the flow by comparing with the in-flows. Additionally, we develop a reservoir optimization model that minimizes the upstream to downstream flow alteration by modifying the release. Our initial results demonstrate that reservoir optimization framework could be a very useful tool in minimizing flow alteration in highly regulated basin in the U.S.

Keywords: reservoir, environmental flow, simulation, optimization

Agents-based model of social media behaviors during Hurricanes Florence and Michael

Morgan DiCarlo
Advisor(s): Emily Berglund

No. 45

Recent Hurricanes Florence and Michael both are designated by the National Oceanic and Atmospheric Administration as billion-dollar weather disasters. Social media is a developing platform by which people are self-organizing in response to extreme weather, to both seek help and respond to help requests. It is important to better understand communication during hurricanes, in order to better allocate resources and improve disaster resilience. We conducted a social media user survey of 434 people affected by Hurricanes Florence and Michael and used Theory of Planned Behavior concepts (TPB) to identify the predictors of two types social media behaviors that occurred during the hurricanes: help-seeking and help-responding. Then, an agents-based model (ABM) is developed to simulate help-seeking and responding behaviors during hurricanes of varying severity on a virtual social network. The ABM is tested under a Design of Experiments set-up and four scenarios of social network structure are presented: (I) a small number of agents in a poorly connected network; (II) a small, well-connected network; (III) a large, poorly connected network and (IV) a large, well-connected network. Results demonstrate the dynamics in the number of social media users that receive help given different settings of network structure and hurricane severity.

***Keywords*:** hurricanes, social media, agents based modeling

Assessing and predicting microcystin dynamics in western basin of Lake Erie

Shiqi Fang
Advisor(s): Daniel Obenour

No. 46

Cyanobacterial harmful algal blooms (HABs) have become prevalent worldwide and pose threats to ecosystem and human health, particularly due to the production of cyanotoxins. The most ubiquitous cyanotoxins in freshwater are microcystins (MCs), which caused the Toledo drinking water crisis in 2014. Despite intensified research into HABs in the last decade, the causal relationships and mechanisms leading to high MC events still remain unclear. With a space-time geostatistical approach, we elucidate inter- and intra-seasonal dynamics of MC from 2008-2017 over the western basin of Lake Erie. Using statistical variable selection, we develop two predictive regression models for mean MC concentration dynamics: model 'A' establishes relationships influencing MC using in-lake observations, and model 'B' predicts MC using mechanistic eutrophication model estimates when in-lake measurements are not available. The selected variables of model A and B explain 75% and 73% of MC variability, respectively. In model A, 42-day-lagged water temperature, chlorophyll-a, ammonia, and total nitrogen concentration are the most influential variables. In model B, simulated chlorophyll-a, 32-day-lagged water temperature, and riverine total nitrogen concentration are the most important predictors. These models indicate that lagged water temperature and nitrogen concentrations are key factors that influence MC production when algal blooms occur.

Keywords: microcystin, HABs, water temperature, nitrogen, Lake Erie

Assessing the importance of nutrients, light limitation and vertical mixing on algal productivity in a shallow turbid reservoir

Yue Han
Advisor(s): Tarek Aziz, Daniel Obenour

No. 47

Harmful algal blooms are increasingly recognized as a threat to the integrity of freshwater reservoirs, which serve as water supplies and recreational attractions. While the formation of harmful algal blooms is controlled by many environmental factors, the leading factors are continuously debated, particularly for turbid eutrophic systems. Here we develop and compare two modeling approaches to test the relative importance of biophysical drivers in limiting algal productivity in a shallow turbid reservoir. One is a multiple linear regression (statistical) model and the other is a process-based (mechanistic) model. Both models are calibrated using a multi-decadal data record (2003-2018) for the cyanobacteria dominance period from June to October. The mechanistic model is calibrated using Bayesian inference, which enables us to incorporate prior knowledge on biophysical rates. Both models show that chlorophyll-a is much more responsive to nutrient variability than light and temperature. Moreover, we incorporate vertical mixing and cyanobacteria buoyancy into the mechanistic model, but find these factors have minimal influence. While both models explain approximately two thirds of the variability in chlorophyll-a concentrations, the mechanistic model is more robust in cross-validation. The mechanistic model also allows us to more comprehensively analyze the relative importance of environmental drivers on algal productivity.
Keywords: cyanobacteria, eutrophic reservoir, biophysical factor, modeling

Contrasting nutrient management implications from chlorophyll a modeling for the Neuse River Estuary

Alexey Katin
Advisor(s): Daniel Obenour

No. 48

The Neuse River Estuary, NC, USA, has been experiencing eutrophication symptoms including algal blooms, hypoxia and fishkills for decades. These problems are attributed to high anthropogenic nutrient loadings, which doubled since the 1960s as a result of agricultural and urban watershed development. The objectives of this study include development and comparison of statistical and mechanistic predictive models to understand how environmental factors control chl-a concentrations and to test the system sensitivity to nutrient loading variations. Both types of models are calibrated to a multi-decadal dataset within a Bayesian framework, which accommodates previous knowledge about parameters and allows for obtaining probabilistic predictions. All models explain over a third of chl-a variability and indicate that flow variability is an important driver of phytoplankton accumulation. Results of nutrient perturbation scenarios differ by a factor of two between modeling approaches. However, mechanistic models integrate over a wider range of biogeochemical processes and are simultaneously calibrated to nutrients, which allows for obtaining more realistic responses to changes in the system and for potential chl-a forecasting. Additionally, in contrast to previous studies performed in early 2000s, simulations demonstrate that 30% nutrient loading reductions would facilitate compliance with state water quality standards.

Keywords: phytoplankton, nutrient management, Bayesian modeling

Hydroeconomic model for multiobjective optimization in Flint River Basin, USA

Hemant Kumar
Advisor(s): Sankar Arumugam

No. 49

Climate change is expected to increase water loss through evapotranspiration in the southeast US resulting in a decrease in total streamflow, groundwater recharge, flow rate, and regional water supplies. It will impact agriculture in the Flint River basin which is highly dependent on irrigation, especially on groundwater withdrawals. We plan to develop a hydroeconomic model based on Positive Mathematical Programming (PMP) framework to model the agricultural output. The model links the available agricultural inputs: land, labor, water (surface water and groundwater), fertilizers, etc. to agricultural yield through a crop growth simulation model called AquaCrop. The model decision variables will be crop acreage and irrigation depth. This model will help in developing a relationship between the economic value of the output and the inputs. We will use the model to generate alternatives for multiobjective optimization: maximize regional production and farmers' incomes, maintain high groundwater levels. These alternative scenarios can be used by the decision-makers for water allocation and selecting the best crop portfolio during water scarcity.

Keywords: hydroeconomic model

Evaluating the adhesion phenomena of fat, oil, and grease (FOG) deposits on different sewer line surfaces

Samrin Ahmed Kusum
Advisor(s): Mohammad Pour-Ghaz, Joel Ducoste

No. 50

According to the USEPA, around 25% of the Sanitary Sewer Overflows (SSOs) are due to sewer line blockages related to fat, oil, and grease (FOG) deposits. Research shows that FOG deposits are formed from a saponification reaction between calcium and long chain free fatty acids (LCFFAs). Although the FOG formation mechanism is well studied, the FOG deposit adhesion phenomena on sewer line surfaces has not been investigated. Hence, in this study we aim to evaluate the FOG deposit adhesion phenomena on vitrified clay pipes, PVC pipes and three high volume fly ash (FA) concrete surfaces made by replacing cement with FA. After 30 days of FOG deposit formation test, results show 55% and 67% reduction in FOG deposit adhesion on 50% and 75% FA replaced concrete samples when compared to 0% FA replaced concrete. When all sample surfaces were exposed under same synthetic wastewater, similar FOG deposit adhesion trend was observed for concrete samples; however, no FOG deposit was found on PVC and Vitrified clay pipes surfaces. Therefore, we hypothesize that the adhesion phenomena is controlled by the pipe material's surface properties in addition to the availability of calcium and LCFFA. Pipe surface images and proposed mechanisms will be presented.

Keywords: FOG, SSOs, adhesion, saponification, fly ash

Pilot-scale biofilters for the cometabolic treatment of 1,4-dioxane at drinking water-relevant concentrations

Amie McElroy
Advisor(s): Michael Hyman, Detlef Knappe

No. 51

1,4-Dioxane is a likely human carcinogen and occurs widely in drinking water. Conventional drinking water treatment processes do not remove 1,4-dioxane, but cometabolic biodegradation represents a promising alternative. Using an enrichment culture derived from NC surface water, pilot-scale biofilters were inoculated and operated to determine effects of filter media type, empty bed contact time (EBCT), and primary substrate (e.g. n-butane) on 1,4-dioxane cometabolism. In addition, I am evaluating whether the abundance of short chain alkane monooxygenase in filter backwash water is a reliable indicator of biofilter effectiveness for 1,4-dioxane biodegradation. Three filter media [2 granular activated carbons (GACs), 1 carbonaceous resin] were evaluated at four EBCTs. 1,4-Dioxane removal in biofilters was compared to non-inoculated controls. 1,4-Dioxane removal was maintained for >3 months in biofilters, while 1,4-dioxane removal in control GAC filters quickly ceased. At an EBCT of 30 minutes, 1,4-dioxane removal averaged 87% at steady state in one GAC biofilter. Reducing the hydraulic loading rate by 50% increased removal to >92%. In control filters, the carbonaceous resin removed 1,4-dioxane more effectively than GAC. 1,4-Dioxane removal was higher in biologically active resin filters than controls. Early evidence suggests that backwash water from biofilters capable of 1,4-dioxane degradation contained short-chain alkane monooxygenase.

Keywords: cometabolism, drinking water, emerging contaminants

Groundwater model development in irrigated data-scarce environments using remote sensing data

Elizabeth Ramsey
Advisor(s): Emily Berglund, Kumar Mahinthakumar

No. 52

Groundwater flow models typically require extensive local data, and the expense and challenges of obtaining the requisite data often limit the development of groundwater models in poor regions. In particular, obtaining accurate data on groundwater pumping for irrigation is difficult because it requires extensive monitoring infrastructure. Irrigation is the primary driver of groundwater over-abstraction and is consequently a crucial input for groundwater modeling. This research presents an approach for developing a 2-dimensional discretized groundwater flow model that incorporates irrigation estimates using publicly accessible global datasets. Irrigation is calculated based on the soil moisture balance equation using remotely sensed soil moisture, precipitation, and temperature data from the Global Land Data Assimilation System (GLDAS). Satellite data from the Gravity Recovery and Climate Experiment (GRACE) is used to determine the change in hydraulic heads at the center of 1o by 1o grid cells over time. A simulation-optimization based inverse modeling approach is applied to estimate hydraulic conductivity values in the Khabour River sub-basin in Syria and Turkey. This research develops and a new methodology to use global datasets in the construction of groundwater models at the sub-basin scale in irrigated areas where data is unavailable or unattainable.

Keywords: groundwater, remote sensing, irrigation, data scarcity

2020 EWC

Graduate Research Symposium

Global WASH

Environmental, Water Resources and Coastal Engineering

NC State University

Department of Civil, Construction, and Environmental Engineering

Rapid small-scale column test development for fluoride control using bone-char sorbents

Maggie Thompson
Advisor(s): Joshua Kearns

No. 53

Millions worldwide are exposed to harmful levels of fluoride (F) by consuming groundwater (GW) exceeding the World Health Organization guideline value of 1.5 mg/L. Many affected live in low-resource settings including dispersed rural settlements that rely on wells requiring point-of-use (POU) treatment. Community wells in central Mexico have been measured above 20 mg/L F. Cow bone-char (BC) produced locally utilizing waste material from beef processing has shown promise as a low-cost sorbent for uptake of F from GW. Traditionally, pilot tests have been conducted but are costly, time consuming, and require large amounts of water from water-scarce areas. Therefore, a bench scale method applying a rapid small-scale column test (RSSCT) approach was developed to quantify F removal by BC sorbents from GW specific to central Mexico. Preliminary kinetic tests were used to design constant (CD) and proportional (PD) diffusivity RSSCTs with crushed BC for comparison with pilot columns using full size BC granules. CD and PD-RSSCT breakthrough curves were fit with the HSDM to determine the best approach for predicting F breakthrough from actual treatment systems. This RSSCT approach will save time, labor, and experimental resources, and support the implementation of affordable POU water treatment in low resource regions.

Keywords: RSSCT, Fluoride, Bone-char, Groundwater, Mexico

Assessing the design and operation and maintenance of community toilet blocks in Mumbai, India

Pradnya Latkar
Advisor(s): Francis de los Reyes

No. 54

Sustainable Development Goal 6 (SDG 6) defines "safely managed sanitation service" as one in which the population uses improved sanitation facilities that are not shared with other households. This goal thus excludes community sanitation systems which are most prevalent in urban areas. Many people regularly rely on these community toilet blocks (CTBs) which are found to be more suitable given the space constraints and high density of population. However, it is not clear if these systems are delivering safe sanitation services to its users.

The objective of this study is to assess the design and operation and maintenance characteristics of existing community toilet blocks in Mumbai, India. Site visits and surveys of >45 CTBs in city and suburban areas in Mumbai were conducted. The data collected include daily usage, design aspects, and the role of caretakers in maintaining the toilets. The data were analyzed to identify specific factors that lead to better practices in design and O&M, that can be used to pragmatically make these systems more human-centered and effective.

Keywords: Community Toilet Block, Design, Operation and Maintenance

Modeling exposure to fecal contamination in drinking water due to multiple water source use

Sean Daly
Advisor(s): Angela Harris

No. 55

The Joint Monitoring Programme estimated that 71% of the global population had access to 'safely managed' drinking water in 2017. However, standard data collection practices focus only on primary water sources accessed, ignoring exposures from supplemental water sources. A recent systematic review revealed evidence that multiple water source use (MWSU) is globally prevalent among households in low- and middle-income countries. Additionally, the practice of supplemental unimproved source use (SUSU) was reported globally, representing households with 'improved water access' that also access unimproved water throughout the year. To assess potential exposure to fecal contamination due to this behavior, an exposure model was created using Monte Carlo simulations and previously published water ingestion and quality data. A statistically significant (α=0.05) increase in total exposure to fecal contamination and portion of year exceeding the WHO standard for drinking water (i.e., 0 E. coli/100mL) was found for individuals practicing SUSU as compared to sole-use of improved sources for drinking. These results suggest that the practices of MWSU and SUSU serve as a neglected pathway of exposure, revealing implications for current monitoring techniques and global progress on safe water access. These practices should be considered to accurately classify access to safe drinking water globally.

***Keywords*:** drinking water, multiple water source use, Monte Carlo simulations, global water monitoring, LMIC

Optimization and validation of poultry-specific microbial source tracking fecal marker LA 35 in North Carolina

Michaela Hill, Tanvir Pasha
Advisor(s): Angela Harris

No. 56

In North Carolina, commercial poultry operations (CPOs) in industrial poultry production have increased significantly. There is limited research on the environmental effects of these CPOs within the state. A poultry-specific marker, LA35, must be validated in North Carolina before implementation. We will focus on environmental safety from CPOs, detecting sources of pollution, and adopting the technique of Droplet Digital PCR (ddPCR). ddPCR has the potential for identifying this marker more effectively than qPCR because it assesses the fluorescence in each sample droplet, not the entire sample. This assay will be optimized to obtain maximum droplet separation and minimum droplet rain by varying cycling parameters including annealing temperatures, denaturation times, thermocycler, and the total number of cycles. For validation, DNA will be extracted from various fecal samples and ddPCR will be performed. Animal fecal controls will be included in order to evaluate the marker's specificity and environmental samples will be used to test the sensitivity of the marker. Expected results include minimizing droplet rain and maximizing droplet separation and the LA35 marker will be sensitive and specific to poultry feces. This research will provide the scientific community with an accurate method of detecting poultry feces in environmental samples in North Carolina.

Keywords: ddPCR, Validation, Optimization, Poultry

Tracking the sources of fecal contamination in surface water after Hurricane Dorian in coastal North Carolina

A B M Tanvir Pasha, Jacob Rudolph
Advisor(s): Christopher Osburn, Angela Harris

No. 57

Extreme flooding events can mobilize contaminants and thereby negatively impact surface water quality. To understand how flooding influences levels of microbial contamination in surface water bodies, a microbial source tracking (MST) study was performed at four points along the Neuse River for eight weeks after Hurricane Dorian made landfall, representing upstream and downstream sites of large-scale industrial agriculture land uses. Total coliforms (94% positive) and E. coli (93% positive) were measured in the samples, and molecular MST targets of human (HF183), swine (Pig2Bac) and poultry (LA35) will be used to identify host-specific contamination. In addition, carbon isotope measurements will be compared to the molecular MST measurements to compare the effectiveness of these two source tracking tools. We observed low (20%) to moderate (38%) positive correlation of E. coli concentrations to discharge measured at the Neuse River USGS stations at Kinston and Fort Barnwell ($p<0.03$) suggesting storm drain water is influencing microbial water quality. Spatial distribution of E. coli showed a decreasing concentration with distance downstream, highlighting the surface washed microbial loading near Kinston. Results from this work will inform methods for source tracking in the watershed based on the correlation between molecular and isotopic measurements and identify the profile of sources after an extreme flooding event.

***Keywords*:** Hurricane, Flood, Bacterial Outbreaks, MST

Judges

John Kiviniemi
City of Raleigh

Mark McIntire
Duke Energy

Anne Mikelonis
EPA

Tom Nangle
Brown & Caldwell

Tom Pace
AWMA

Jason Patskoski
Summit Design

Angela Poore
Jacobs

Khalil Porter
NCEMCS

Narayan Rajbhandari
NCDEQ DWR

Randy Boyd
Scenic Consulting Group

Beth Smyre
Dewberry

Joan Smyth
Smith Gardner

Ross Stroud
CDM Smith

Robert Vinay
Freese & Nichols

Ken Walsh
AWMA, Leidos

Lauren Wellborn
Geosyntec

Bilgen Yuncu
Draper Aden

Matt Zenker
AECOM

Ken Bannister
Draper Aden

Katya Bilyk
Hazen & Sawyer

Stephanie Bolyard
EREF

Steven Bolyard
NCDOT

Alessa Braswell
Geosyntec

Alex Travaglia
Black & Veatch

Mark Cooney
Scenic Consulting Group

Jason Dorn
Gavel & Dorn

Leigh-Ann Dudley
Dewberry

Bob Hall
AWMA, Wood

James Harrington
RTI

Kenneth Hunu
Atkins

Jenny Padgett
Geosyntec

Ayse Karanci
Moffat & Nichol

EWC 2020

Committees

Faculty Advisors

Dr. Jeremiah Johnson
Dr. Fracis de los Reyes
Dr. Daniel Obenour

Committee Chair

Johnathan Woodruff

Symposium Logistics

Matthew Apperle
Shiqi Fang
Dol Chalise
Poorva Mokashi
Nilay Warkhedkar
Faisal Alghamdi
Jorge Pesantez

Publicity

Yoko Koyama
Brooke Rumbaugh
Seiji Nyamadi

Visiting Student Logistics

Megan Johnson
Russell Nasrallah
Autumn Poisson
Haofan Li
Ashley Bittner
Stephanie Parsons
Savanna Smith
Komal Charania
Temi Ibitoye
Mohammad Khaksar
Monica Camacho
Faith Johnson
Morgan DiCarlo
Breon Henley
Leah Weaver

Food

Ajimon Thomas
Asmita Narode
Carter Rucker
Hanieh Moghadam
Aditya Keskar

Abstracts/Booklet

Danny Sodano
Jenny Ding
Elvin Hossen
Emily Floess
Amanda Mattingly

Environmental, Water Resources and Coastal Engineering

NC State University

Department of Civil, Construction, and Environmental Engineering

2020 EWC

Graduate Research Symposium

Environmental, Water Resources and Coastal Engineering

NC State University

Department of Civil, Construction, and Environmental Engineering

EWC 2020

Graduate Research Symposium

Environmental, Water Resources and Coastal Engineering

Designed by Jenny Ding

NC State University

Department of Civil, Construction, and Environmental Engineering