GRADUATE RESEARCH SYMPOSIUM

NC STATE UNIVERSITY

2022 EWC

Environmental, Water Resources and Coastal Engineering

Friday, March 4, 2022

Fitts-Woolard Hall & Hunt Library on Centennial Campus

Department of
Civil, Construction, and
Environmental Engineering

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The environmental, water resources, and coastal engineering (EWC) group holds an annual research symposium every spring semester. This student-organized symposium features research poster presentations by graduate students to highlight some of the current research conducted by this group, as well as a keynote speech by an invited speaker. The symposium provides an opportunity for students to gain experience in preparing and delivering presentations of their research.

CONTENTS

Julian D. Marshall

University of Washington

Associate Chair for Diversity, Equity, Inclusion, and Climate
Professor of Civil & Environmental Engineering

"My research is in exposure assessment: understanding how much pollution people breathe, and how to reduce those exposures. My specific areas of focus are (1) Air pollution impacts of urban form; (2) Air pollution and health impacts of transportation energy consumption, including alternative fuels (biofuels, electric vehicles) and active travel (walking, biking); (3) In situ measurement of fine particles in developing countries.

Two core themes underlying those areas are modeling and measuring spatiotemporal variability in pollution concentrations; and environmental justice: understanding who is more exposed or less exposed to air pollution, how exposures correlate with attributes such as race or income, and how changes in emissions might shift existing exposure gaps."

Education

Ph.D., Energy & Resources, UC Berkeley, 2005

M.S., Energy & Resources, UC Berkeley, 2002

B.S.E., Chemical Engineering, Princeton University, 1996

Honors & awards

John R. Kiely Professorship, University of Washington, 2016 - present

Charles E. Bowers Teaching Award, University of Minnesota (UMN), 2014

C. Eugene Allen Award for Innovative International Initiatives (awarded to the Acara program), UMN, 2014

KEYNOTE ABSTRACT

Decades of research provide substantial evidence that in the United States, communities with a greater portion of low-income households and people of color often experience higher-than-average levels of air pollution. These disparities are not accidental; they reflect systemic racism and other historical factors extending far into the past. Societal goals for air pollution include not only reducing population-average exposures, but also addressing exposure inequities. This talk will summarize evidence of existing disparities, highlight scientific approaches for addressing those disparities, and discuss implications for future research.

AGENDA

Time	Event	Location
11:30 - 1:00	Lunch and Poster Session	Duke Energy Hall

Note: poster presenters will be at their posters from 11:30-12:30 and will be eating lunch 12:30-1:00

1:05 - 1:40	**Oral Presentation Session I**	
	Environmental Process Engineering	FWH 2336
	Water Resources	FWH 2331
	Air Quality	FWH 2341
1:45 - 2:20	**Oral Presentation Session II**	
	Global WaSH	FWH 2336
	Coastal Engineering	FWH 2331
	Energy, Modeling, and Systems	FWH 2341
2:40 - 3:45	Networking, Poster Viewing, Finalist Videos	Duke Energy Hall
3:45 - 4:45	Keynote - **Julian D. Marshall**	Duke Energy Hall
4:45 - 5:00	Awards and Close	Duke Energy Hall

Virtual AGENDA

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	Thursday, Martch 3rd	
5:00 - 6:30	EWC Program information Meet and Greet Faculty	Zoom Link
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All day	Poster Session	Link to Posters
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1:45 - 2:20	Talks - Breakout Session II Global WaSH Coastal Engineering Energy, Modeling, and Systems	 Zoom Link Zoom Link Zoom Link
After 2:40	Finalist Videos	Finalist Videos
3:45 - 5:00	Keynote **- Julian D. Marshall** Awards and Close	Zoom Link

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1:05 – 1:40

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Inferring air pollutant emissions using satellites

1

Presenter: James East

Co-author(s): B. H. Henderson, S. L. Napelenok, S. N. Koplitz, D.Q. Tong, R. B. Pierce, A. Lenzen, R. Gilliam, G. Sarwar, F. Garcia Menendez

Research Question: How do international emissions of NOx impact pollution transported to the U.S.?

The long record of nitrogen dioxide (NO2) viewed from space by the Ozone Monitoring Instrument (OMI) has aided advances in the understanding of global emissions of oxides of nitrogen (NOx) through emissions inversion experiments. The more recent overlap of the data record between OMI and the TROPOspheric Monitoring Instrument (TropOMI) since the launch of TROPOMI provides the opportunity to compare emissions inferred using NO2 columns from each instrument. To compare the capabilities of OMI and TropOMI NO2 observations in NOx emissions estimations, we introduce a satellite 3D-variational data assimilation system for inverse modeling of northern hemispheric NOx emissions. The system can provide estimates of NOx emissions in China, India, Europe, US, and the Middle East based on a finite-difference mass balance inversion. We assimilate data from OMI and TropOMI separately in the Community Multiscale Air Quality (CMAQ) model for 2019 over the northern hemisphere and perform NOx emissions inversions for each assimilation. We compare NOx emissions estimated with observations from each satellite instrument and analyze model performance: (1) without any satellite derived information, (2) with assimilated NO2, and (3) with satellite derived emissions updates, for each satellite. Results show large NOx emissions biases in India and China, and smaller biases in the US and Europe compared to satellite-inferred estimates. Assimilating NO2 and using satellite-inferred emissions both improve ozone and NOx model performance.

Keywords: *air quality emissions satellites pollution models*

Characterizing southeastern populations impacted by wildland fire smoke: implications for land management practices

2

Presenter: Megan Johnson

Co-author(s): H. McTernan, F. Garcia Menendez

Research Question: Are there population subgroups that are disproportionately impacted by wildland fire smoke in the Southeastern U.S.?

Smoke from wildland fire (wildfire and prescribed fire) is one of the largest sources of fine particulate matter (PM2.5) in the U.S. Declining contributions from other anthropogenic sources of PM2.5, increasing populations in the wildland urban interface (WUI), and projected increases in climate-driven fire activity mean that residents may experience wildland fire smoke PM2.5 more frequently. While wildfire is a concern for much of the Western U.S., prescribed fire is used extensively in the Southeast to reduce wildfire risk, manage wildlife habitat, and support fire-dependent species. The human populations experiencing wildland fire smoke in the Southeast are not well characterized, especially when considering the distinction between wild- and prescribed fire. Using spatial analysis of publicly available smoke products, satellite fire detections, prescribed burning records, census demographic data, and indices of existing social and environmental stress, we identify the populations in the Southeast that most frequently experience wildland fire smoke. By examining demographic variables such as socioeconomic status, race, and age, this analysis further highlights whether particularly vulnerable subgroups are disproportionately impacted by smoke in the Southeast. Inclusion of U.S. EPA environmental justice indices in this analysis allows us to determine whether this environmental stressor is adding further strain to groups that are already stressed. The analysis shows that wildland fire smoke can disproportionally affect specific population groups in the region and coincides with exposures to other environmental stressors.

Keywords: *wildland fire, smoke, environmental justice*

3

Impacts of a cookstove intervention in urban Zambia on cooks' personal exposure to carbon monoxide and particulate matter

Presenter: Stephanie Parsons

Co-author(s): W. Hayes, J. Pedit, A. Grieshop

Research Question: How do cleaner cookstoves impact cooks' personal exposure to air pollution?

62% of households in Zambia lack electricity access, requiring solid fuel use for cooking and resulting in poor indoor air quality. A 2-year stove intervention trial was undertaken in Lusaka, Zambia. Local stove distribution companies selected four neighborhoods, two with existing use of alternative stoves (Matero, Kamanga) and two with traditional stoves and planned marketing of alternative stoves between baseline and endline (Kalingalinga, Ngombe). We measured carbon monoxide (CO, 496 baseline, 271 endline) and particulate matter (PM2.5, 68 baseline, 31 endline) personal exposure of cooks in these neighborhoods. Cooks wore Lascar, MicroPEM (baseline), and Atmotube (endline) PM2.5 monitors at breathing height for 24 hours. Endline pollutant exposures were approximately 50% of baseline exposures, with Matero cooks having the lowest 24-hour CO exposure (4 ppm) of all neighborhoods in both phases. 24-hour PM2.5 exposures were relatively consistent, but above health guidelines, for all neighborhoods both during baseline (97 +/- 61 µg m-3) and endline (41 +/- 28 µg m-3). Diurnal trends of pollutants were similar across neighborhoods but differed between pollutants. CO peaked at mealtimes while PM2.5 peaked in the morning and evening; this trend was less dramatic at endline. Diurnal PM2.5 exposure was similar to ambient trends from PurpleAir monitors in Kabwe (baseline) and Lusaka, Zambia (endline), suggesting exposure is dominated by regional sources rather than cooking. The differences in CO and PM2.5 exposure by intervention stove adoption status will also be examined to evaluate the net impact of adoption of two alternative stoves on air pollution exposures.

Keywords: *cookstove, intervention, exposure, household air pollution*

4

Operating the Power System in China for Climate and Public Health Benefits with Economic Dispatch

Presenter: Qian Luo

Co-author(s): J. Lin, J.X. Johnson, F. Garcia-Menendez

Research Question: What are the impacts of the power sector transition in China on climate and public health?

Due to its reliance on coal, the power sector in China has significant adverse impacts on both climate and public health. The power system in China is highly regulated and uses an "equal shares dispatch system." However, market mechanisms are being introduced in an effort to improve system safety, reduce generation costs, and promote energy efficiency. Our study quantifies the climate and public health impacts brought about by this transition, projecting adoption of unit commitment and economic dispatch (UC/ED) in China's power system and simulating the associated air pollution changes with a reduced-form air quality model. We observe that significant reductions in CO2 emissions (7%) and air pollution mortality (18%) can be attained through improved efficiency of coal-fired generators compared with the equal share dispatch approach. In addition, we examine the impact of explicitly considering climate and health damages in power system operations, which yields benefits that far exceed the additional costs required to implement this strategy. However, the health benefits are unevenly distributed, and health damages may increase in some regions in China due to the spatial distribution of power plants and population. Our results quantify the benefits of adopting economic dispatch and considering emission externalities in electricity generation decision-making, providing useful insights into effective emissions mitigation policies for China.

Keywords: *economic dispatch, climate change, PM2.5, public health*

5

Developing high yield and resilient anaerobic co-digestion of alternative wastes

Presenter: Emma Guertin

Co-author(s): M. Barlaz, F. de los Reyes

Research Question: What mixtures of various food waste types lead to optimum methane production and what are the effects on the microbial communities?

Growing populations and energy demands require progress towards a circular economy where wastes are transformed into resources. About 30 to 40% of the US food supply is wasted (USDA), mostly ending up in municipal landfills. This food waste can be used as a substrate in anaerobic co-digestion (AcD) to increase biogas production from reactors and reduce greenhouse gas emissions from landfills. However, AcD of food waste requires process optimization. This project aims to identify mixtures of food wastes that result in optimum methane production and understand how microbial communities respond to shifts in mixtures of food waste types. Initially, 18 reactors were loaded with one food waste type, either cellulosic, proteinaceous, or fat-rich (lipid) waste, in a unique simplex centroid mixture design. The experimental design includes three loading stages where reactors are introduced to different mixtures of food waste. At the end of each stage, replicate reactors are destructively sampled for microbial community analysis. The cellulosic- and lipid-based reactors showed similar peak methane production rates to prior substrate shifts, while proteinaceous-based reactors exhibited significantly lower peak production rates. These results suggest microbial communities were able to shift between substrate types, and that the pre-existing community was important in responding to shifts in waste type. Molecular microbial community analyses of reactor samples to observe the shift in communities attributable to substrate shifts are ongoing. This study provides insight into microbial adaptation to substrate changes and informs the development of operational procedures to optimize AcD of food waste.

Keywords: *anaerobic co-digestion, food waste, simplex centroid design*

6

Thermal Hydrolysis and Anaerobic Co-Digestion of Biosolids and Grease Interceptor Waste: Approaches for Higher Methane Production

Presenter: Seraphim Daniel Falterman

Co-author(s): E. Bailey, F. de los Reyes

Research Question: How to intensify methane production in anaerobic co-digestion by incorporating grease interceptor waste and applying thermal hydrolysis

"Intensifying methane production during anaerobic digestion (AD) is a key factor in making anaerobic digestion economically feasible. We explore two key ideas in biomethane production: using thermally hydrolyzed (TH) biosolids, and co-digestion with grease interceptor waste (GIW). Anaerobic digestion of GIW generates substantial methane yields, but has long lag periods and limits to loading. TH breaks down cells, solubilizing chemical oxygen demand (COD) and volatile solids (VS), increasing biodegradability and degradation rate. We used modified biochemical methane potential (BMP) tests to assess TH processes and GIW co-digestion combinations. BMP testing was performed in several rounds in triplicate: the first investigated the optimal COD-based substrate to inoculum (S/I) ratio for mono-digestion of TH biosolids and GIW, the second investigated co-digestion.Application of a TH pretreatment increased the percentage of soluble to total COD from 1.3 to 53%. Fitting BMP results with a Modified Gompertz model identified maximum methane potential (MMP) and maximum daily methane production rate (MDMPR). GIW digestion has a MMP 6.5 times that of TH biosolids but has a lag period that is more than 25 times longer. TH pretreatment increased biosolids MDMPR from a range of 2.0 - 4.2 to 16.3 mLCH4/gVS*day. Testing is ongoing: co-digestion is expected to increase methane generation while allowing microorganisms to degrade GIW with easily accessed, solubilized VS from TH biosolids. The results of this study will inform design and operation of intensified anaerobic digestors with higher methane production."

Keywords: *Thermal Hydrolysis, Anaerobic Co-Digestion, Methane*

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Removal of per-and polyfluoroalkyl substances (PFAS) by ion exchange resins: Effects of PFAS, water matrix, and resin properties

Presenter: Lan Cheng

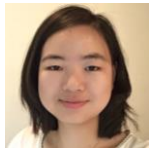
Co-author(s): D. Knappe

Research Question: PFAS removal by anion exchange resins

"Per- and polyfluoroalkyl substances (PFAS) are persistent contaminants with adverse environmental and public health effects. Concerns about the presence of PFAS in drinking water have led to a demand for effective PFAS treatment methods. Anion exchange (AIX) is a readily implementable treatment method that can remove many PFAS, including poorly understood fluoroethers. In this research, the removal of 23 PFAS by two AIX resins was investigated using rapid small-scale column tests (RSSCTs) to quantify factors affecting AIX resins use rates.Breakthrough curves of the 23 studied PFAS, including legacy and fluoroether compounds with 3 to 9 fluorinated carbons, were described with the pore-surface diffusion model to estimate partition coefficients (KAIX), which ranged from 10.5 to >1700 L/g. To predict KAIX from PFAS properties, a group contribution method was developed, with relative contributions of -CF2-, -O-, -SO3, >CF-CF3, -CFH-, and -CH2- being 1.0:0.35:4.0:1.45:0.0:-2.0. Regarding water characteristics effect, KAIX decreased with increasing dissolved organic carbon (DOC) concentration. Nitrate adversely impacted PFAS removal, while chloride, sulfate, and bicarbonate at concentrations up to 3 meq/L had negligible effects on KAIX. Normalized breakthrough curves were independent of the influent PFAS concentration within the tested concentration range of 30 to 300 ng/L. We developed a multiple linear regression model to predict log KAIX from PFAS structural fragments, DOC, UV254, PFAS polarizability, and nitrate concentration. This research will support the design of future AIX treatment processes in the context of remediation and drinking water treatment."

Keywords: *PFAS Treatment, RSSCT, Anion Exchange Resin*

Life Cycle Greenhouse Gas Emissions of CO2-enabled Sedimentary Basin Geothermal



8

Presenter: Lily Liu

Co-author(s): J. Bielicki, B. Ellis, M. Miranda, J. Johnson

Research Question: How frequently do chronic coastal flooding events occur, and what drivers contribute to these events?

There are several technological options to decarbonize the power sector, including the expansion of renewable energy and the large-scale deployment of carbon capture and sequestration. However, to date, carbon capture and sequestration remains uneconomical. One way to mitigate this challenge is the co-production of geothermal energy using the sequestered CO2 as a working fluid. Sedimentary basin CO2-enabled geothermal extracts geothermal heat from naturally permeable sedimentary basins and produces electricity. In this study, we conduct an attributional life cycle assessment (LCA) to determine the greenhouse gas impacts of CPG systems. Adopting the LCA techniques developed to access the potential environmental consequences of emerging technologies, we analyzed the impacts associated with several CO2 feedstocks for these geothermal systems after being retrofitted for CO2 capture, identified the key parameters that contribute the greatest influence on the life cycle emissions, and estimated the potential emissions reductions associated with various designs. We consider CO2 feedstocks from one of the six sources and operating in two geological settings. Using the ReciPe impact assessment method, we found BECCS and ethanol at biorefineries CO2 feedstocks have the lowest carbon footprint per kg CO2eq per kWh CPG electricity. We also found sedimentary basin CO2-enabled geothermal systems can reduce the overall GHG emissions when compared against CO2 sources coupled only with CO2 capture and storage; however, the potential emissions reductions are relatively low and are sensitive to geological locations. We also evaluated the sensitivity of our results by testing the identified key parameters in the LCA.

Keywords: *Geothermal, CCUS, Life cycle assessment (LCA)*

Solar water pumping in India: investigating farm-level impacts and the potential to provide flexibility to the power grid

9

Presenter: Aditya Keskar

Co-author(s): J. X. Johnson

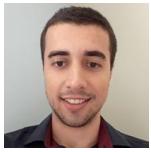
Research Question: Through grid interconnection and off-grid use with energy storage, how can solar water pumping systems provide flexibility to utilize variable renewable energy and reduce power system emissions?

Solar water pumps mitigate multiple irrigation challenges faced by the agriculture sector in India. They reduce the farmer's dependence on unreliable grid electricity, supplied by a coal-dominated power grid, and also reduce the need to rent diesel pumps that incur pollution impacts and recurring fuel costs. The central Indian state of Chhattisgarh has been the leading state in India in solar pump deployment, having installed approximately 90,000 pumps across the state. In this study, we examine the impacts these systems have had at the farm-level and investigate the potential for these systems to provide flexibility to the Indian power grid. We conducted surveys of over 200 farmers across the state and collected pump operational data of farmers to analyze the daily and seasonal pump usage patterns, offering insights into underutilization of solar PV output. We also conducted an educational intervention that assesses the impact of providing farmers with information on the operational practices that will improve the system performance, including operating the manual solar tracker and proper solar panel cleaning. Using the pump operational data, we are able to estimate the power system flexibility that could be provided through grid-connected solar irrigation systems or off-grid use with other farming equipment. In addition, we show the impacts of the educational intervention and estimate the potential for increased solar generation and water pumping through improved operations. We consider future scenarios where the pumps could be used as a flexible grid resource, increasing their potential to serve both the farmers and the broader power system.

Keywords: *Solar Water Pumps; Renewable Energy; Distributed Energy Resources*

10

Travel Route Planning Under Stochastic Flood Inundation Conditions



Presenter: Victor A.D Faria

Co-author(s): A.R. de Queiroz, R. Ranjithan, S. Arumugam

Research Question: How to identify optimal, i.e., short/fast and safe, travel routes prior to, during and after a flooding event?

Finding optimal vehicle routes, considering travel time and safety, under anomalous conditions, such as flooding, is of extreme importance to many, including people in and around affected areas, emergency managers, and utility operators who have to deploy repair crew and equipment. On average, the U.S faces more than 3000 flash floods per year. Floods are the leading cause of weather-related deaths in the U.S.; about 63% of the fatalities during floods are associated with vehicles. Floods are also associated with substantial economic losses due to traffic delays and vehicle damage. Furthermore, the frequency of floods and their impacts are rapidly increasing due to factors such as urbanization, population growth, and climate change. This work addresses the problem of vehicle routing under flood conditions by considering inundation levels and their effects on road conditions and travel speeds. A suite of models that integrate weather and precipitation forecasts, hydrologic flow simulations and stormwater routing is used to forecast spatio-temporal inundation levels, which are then used to forecast travel speeds on the road network, in pre-flooding, flooding and post-flooding phases. The temporal forecasts of road speeds are fed into a route optimization algorithm, which considers time-dependent travel times, to identify alternative travel routes between any origin-destination pair. This procedure is extended to consider forecast uncertainties and their effects on road travel-speed variabilities, and generate a set of efficient routes that represent the tradeoff between minimizing expected route travel times and minimizing variability in route travel times, i.e., risk of delays.

Keywords: *Optimization, Routing, Flood Forecasting, Risk Minimization*

11

Social Equity in Water Distribution Systems

Presenter: Jennifer Zhong

Co-author(s): R. Ranjithan, J. Lewis, K. Mahinthakumar, E. Brill

Research Question: What is the equality level in water distribution system services in dynamic scenarios?

Public water distribution systems (WDSs) are facing challenges such as aging pipes, natural hazard-driven power outages, diminishing water quality, and demand-supply uncertainties that may affect service. These issues in conjunction with social issues such as redlining and gentrification can widen service availability and quality gaps among different social groups. However, systematic approaches are not commonly available to quantify and understand whether and what inequities exist in WDS services provided to different socioeconomic and demographic groups. Thus, this study aims to develop a model-based quantitative approach to simulate water service levels and integrate them with a variety of socioeconomic attributes of the customers to identify and understand service inequities that may exist. WDS hydraulic simulation models (e.g., WNTR and EPANET) were used to estimate water service attributes, including but not limited to water pressure and water quality, under various system operation scenarios (e.g., normal operations and emergency operation under natural disasters). Then Geographic Information System (GIS) and data analysis packages (e.g., ArcPy, Pandas and NumPy) were used to integrate the hydraulic modeling results with socioeconomic and demographic attributes using publicly available data for a large metropolitan area. Ongoing work is investigating ways to visualize the data, analyze the correlations among the attributes, and identify potential inequities in the water service.

Keywords: *Water distribution system, social equality, system modeling*

Climate & Health Implications of Adopting Modern Cooking Fuels

12

Presenter: Emily Floess

Co-author(s): K. Landesman, R. Bailis, E. Puzzolo, D. Pope, A. Grieshop

Research Question: What are the climate and health impacts of transitioning to Liquified Petroleum Gas (LPG) and electricity as cooking fuels?

2.8 billion people in low- and middle-income countries (LMICs) cook and heat using solid fuels, resulting in 2.6 million deaths annually from illnesses related to poor household air quality driven by particulate matter (PM). Combustion of solid fuels also emits short-lived climate forcers (SLCFs) and greenhouse gasses which contribute to climate change. Liquified Petroleum Gas (LPG) and electricity are cleaner alternatives to traditional cooking fuels. We compare the emissions and climate impacts of residential cooking fuel adoption based on business as usual (BAU) and full transition (FT) projections for countries with greater than 1 million solid fuel users. We calculate climate benefits using a reduced form global climate model to calculate temperature differences associated with different scenarios. A FT to LPG and electricity results in significant health benefits with a 3.47 Mt (94%) reduction of PM2.5 by 2040. The. reduction in climate forcers by 2040 results in a 6 milli C global temperature reduction compared to the projected 1.5 degrees C increase. Shifting from biomass-heavy to fossil fuel-heavy cooking fuels results in a large decrease of SLCFs and PM2.5 and a more moderate decrease in CO2 emissions due to the relatively high CO2 upstream emissions. The biggest reduction in pollutants in a FT is for Sub-Saharan Africa, due to the high projections of charcoal use in the BAU scenario. These results help quantify the impacts of rapid scaling LPG, and can help to inform policy decisions supporting access to clean modern household energy as outlined in the Sustainable Development Goal number 7.

Keywords: *Household energy, energy transition, LPG, climate mitigation, air quality*

Analysis of SARS-COV-2 RNA variability in sub-sewershed and hospital wastewater to predict citywide covid-19 outbreaks.

13

Presenter: A B M Tanvir Pasha

Co-author(s): N. Kotlarz, J. Kays, Y. Lai, S. Daly , S. Palani, J. Hoppin, H. Mitasova, F. de los Reyes, A. Harris

Research Question: Sub-sewer and Septic system wastewater testing to predict citywide covid-19 outbreak.

Wastewater-based epidemiology provides an efficient and economical way to understand the outbreaks of pathogens in a community by testing the primary influent from a wastewater treatment system. Sampling within sewer lines and septic systems for cluster housing could be an efficient approach to identify smaller geographic areas of concern; however, sampling at this scale present challenges related to sensitivity, variability, and processing challenges. We collected wastewater samples over a nine months period in 2020 from four sub-sewershed sites: a septic system near a mobile home community (72 households), 2 pump stations along a municipal sewer lines servicing neighborhoods (51 households and 150 households each), and a hospital discharge point. The objectives were to (i) develop methods to concentrate and detect viruses in the sewer lines and septic systems, (ii) identify the potentiality of using sewer lines and septic tanks for epidemiological study, (iii) and assess the correlation with the clinical data from a mobile home neighborhood. We targeted the N gene of the virus in a one-step RT ddPCR duplex assay developed by Bio-Rad Laboratories. BCOV was used as a surrogate virus to measure the recovery efficiency of an RNA virus while processing the sample. The N1 target was detected over the entire time period within the septic system influent. The pump station sites only had target detection in 11% of samples, but the time of detection corresponded with confirmed clinical cases in the serviced neighborhoods. Further comparisons with clinical data will be reported to identify the potential of sub-sewershed monitoring for early warning detection of community infection dynamics.

Keywords: *SARS-COV-2, Septic System, Wastewater based epidemiology*

14

Microbial Source Tracking and Enteric Pathogen Detection in Urban Kenyans and Domestic Animals

Presenter: Sean W. Daly

Co-author(s): A. Pickering, J. Swarthout, A. Harris

Research Question: What are the sources of fecal contamination in urban Kenyan drinking water and what pathogens are present in the fecal contamination?

Diarrheal illness remains a predominant contributor to the global disease burden and preventable death. Various bacteria, viruses, protists, and helminths cause diarrhea, and can interact with humans through various environmental pathways, with a common pathway being drinking water. Human feces, domestic animal feces, and source and stored drinking water samples were collected in low-income areas near Nairobi, Kenya in 2019. Nucleic acid from these samples were extracted and then analyzed using both microbial source tracking (MST) qPCR assays and enteric pathogen TaqMan Array Cards (TAC). MST indicators for human, ruminant, and avian feces were used to identify the source of fecal contamination in drinking water. TACs are a 384-well singleplex real time PCR technology which allows for simultaneously detecting up to 48 enteric pathogens via PCR amplification. More than one enteric pathogen was detected in all human and animal feces. The most common pathogen detected in chicken, dog, and duck feces was E. coli O157:H7, the most common pathogen detected in cow and goat feces was Entamoeba histolytica, and the most common pathogen detected in human feces was Dientamoeba fragilis. Using TACs provides information regarding specific pathogen density in environmental samples, relieving some of the limitations of using more conventional FIB methods. This work will be helpful in identifying the health risks associated with different host feces, and when coupled with environmental surveillance and observational data, it can inform the dominant transmission pathways for pathogens in these settings. These results will be presented in full following completion of laboratory analysis.

Keywords: *microbial source tracking, TaqMan Array Card, drinking water quality, enteric pathogen detection*

15 Application of machine learning models for leak detection in water distribution systems

Presenter: Lochan Basnet

Co-author(s): R. Ranjithan, K. Mahinthakumar, J. Levis, E. Brill

Research Question: How to improve water distribution systems resilience through leak detection?

Water distribution systems (WDSs) face a major challenge in the form of pipe leaks. They inhibit WDSs from meeting the daily functional requirements as well as reduce their potential to perform adequately in the face of disruptions (i.e., reduce their resilience). Locating pipe leaks has been a constant challenge for water utilities and stakeholders due to the underground location of most pipes. Small undetected pipe leaks can turn into major breaks over time. In recent years, there has been a growing interest in applying deep learning techniques, machine learning models in particular to address the challenge of detecting pipe leaks in WDSs. Several studies have applied machine learning models to detect leaks and have shown good potential for a few select leak scenarios. However, there is a huge room for improvements for enhancing accuracy (related to predicting leak locations and sizes) and expanding to other real-life scenarios. Our study explores the use of two different machine learning models namely the Multilayer Perceptron (MLP) and the Convolutional Neural Network (CNN) and compares their performance in predicting leak location and sizes for multiple leak scenarios. The two models are trained using model-generated pressure readings from a few selected nodes representing pressure sensors. Preliminary results of the application of MLP and CNN to the L-Town (model network) network for 10 and 33 potential leak locations show good accuracies for both models, with CNN outperforming MLP in some instances. We plan to expand the scope of the application of the two models by incorporating uncertainties associated with water network model parameters and sensor precision into the data. We also plan to explore the prospect of using other types of readily available data such as water flow rate and water quality in conjunction with pressure to improve prediction accuracy.

Keywords: *Water Distribution Systems, Resilience, Leak Detection, Machine Learning*

16 Data-driven Generalized Release Policies for Reservoirs in the Tennessee River Basin

Presenter: Lucas Ford

Co-author(s): S. Arumugam

Research Question: Can reservoir release policies be generalized using data-mining methods to better characterize human impacts on stream flow in hydrologic models?

In highly regulated river basins, reservoir operations, rather than precipitation or snowmelt, tend to dictate streamflow. These operations are driven by anomalies in inflow, such as droughts or floods, seasonal changes in inflow or demand, varying storage rule curves, and the multi-purpose nature of the allocation. Though it is a challenge to include all information that influences release decisions into a generalized modeling framework, such a framework could help incorporate the release policies into distributed hydrologic models. This work leverages general reservoir characteristics, such as residence time, inflow sources, and the nature of the system - run-of-the-river or storage reservoir - to classify reservoirs and then develop several release parameterizations based on physical variables, such as storage and inflow, using hierarchical regression and regression trees. These parameterizations are trained and evaluated with reservoirs in the Tennessee River Basin and can predict daily reservoir release with a Nash-Sutcliffe Efficiency (NSE) greater than 0.65 for all reservoirs. Additionally, this work illuminates important aspects and relationships that may be useful in future efforts. For example, for periods of low release, the average release over the past week is an important predictor for day-ahead release but has a much smaller effect during periods of high release. Though parameterizations developed here produce accurate day-ahead release predictions for untrained reservoirs in the Tennessee River Basin, they may not translate perfectly to other river basins. Thus, there is a need to generalize reservoir operations in the form of simple equations for incorporating them into distributed hydrologic models.

Keywords: *reservoir operation, statistical modeling, stream flow prediction,*

17

Assessing controls on watershed nutrient loading through GIS-enabled data-driven modeling

Presenter: Kimia Karimi

Co-author(s): C. White, H. Mitasova, D. Obenour

Research Question: How much do different nutrient export contribute and how they vary by precipitation?

Nutrient pollution is a widespread environmental problem that degrades water quality in North Carolina and much of the world. It can result in hypoxia and harmful algal blooms, which jeopardize water supplies and public recreation. Implementing effective nutrient management action calls for understanding and quantifying various loading sources and stormwater management practices. However, loading rates from various nonpoint sources remain uncertain, and studies evaluating the effectiveness of stormwater management mainly focus on short time scales and small catchments. To improve the characterization of nonpoint sources and management practices efficacy, we developed a mechanistically parsimonious watershed model calibrated within a data-driven Bayesian framework. Our approach incorporates inter-annual changes in land use and precipitation as temporal drivers of nutrient loading and transport. Importantly, it also includes a detailed representation of stream buffers, urban canopy, and post-construction stormwater control measures (SCMs) over time (1982-2017). Spatially, the study covers the Jordan and Falls Lakes watersheds of the NC Piedmont. Benefiting from over 20 long-term flow and nutrient monitoring locations, Bayesian inference systematically updates prior information to reduce uncertainties in key rates controlling nutrient export and the removal efficacy of management practices. Results indicate that the combined effects of vegetated stream buffers and SCM are associated with 64% and 70% reductions in phosphorus and nitrogen export, respectively. At the same time, canopy cover over urban areas did not have a statistically credible effect. This study was funded by the WRRI.

Keywords: *Bayesian modeling, temporal variability, watershed, nutrient loading, stormwater management*

18

Detecting changes in design flood across the U.S.

Presenter: Chandramauli Awasthi

Co-author(s): S. Archfield, B. Reich, A. Sankarasubramanian

Research Question: How have flood estimates used for designing water infrastructures changed over time?

Global-scale climate change and watershed-scale anthropogenic disturbances are expected to change stationary design flood estimates over time. We propose a hypothesis testing framework to detect a significant change in post-1970 design flood (i.e., 1971-2015) from its pre-1970 design flood estimates. The post-1970 design flood is estimated from log-Pearson type-III (LP3) distribution based on non-stationary marginal moments estimation technique. We applied the hypothesis testing framework on 31 river basins across the U.S. Our analysis found that design floods of selected return periods have increased significantly for most of the basins from the northeastern region, while they have decreased significantly for basins located in southeastern temperate and arid climate. We also noted that presence of a significant trend in the flood time series during design period did not reflect changes in design flood quantiles. The proposed framework may assist water infrastructure designers in revising old design flood estimates for any basin.

Keywords: *Design flood estimation, non-stationary flood process*

Data from the Drain: Assessing the drivers of chronic coastal flooding

Presenter: Thomas Thelen

Co-author(s): A. Gold, M. Hino, A. Whipple, R. Neve, K. Anarde

Research Question: How frequently do chronic coastal flooding events occur, and what drivers contribute to these events?

As local sea-level rise, land subsidence, and heavy rainfall events increase, so does the frequency of flooding in low-lying coastal areas. The tidal cycle now takes place on higher average sea levels, resulting in "sunny-day" flooding of roadways during high tides. Because sea water infiltrates drainage systems at even low tidal levels, ordinary rainstorms can now cause flash floods. For instance, one of the novel sensors that our group developed to track water levels in coastal stormwater infrastructure captured 24 discrete flood events in five months at a single catch basin in Beaufort, NC. Here we present new tools developed in partnership with the towns of Beaufort and Carolina Beach, NC to identify the causes and frequency of chronic floods and inform adaptation decisions that incorporate chronic flood hazards. First, we developed a web app that displays real-time water level data at stormwater catch basins that chronically flood. We supplement this data with real-time photographs capturing the spatial extent of flooding. In Carolina Beach, alerts triggered when water levels approach flooding thresholds allow for proactive implementation of flood management measures. Second, we develop a numerical model of chronic flooding, validated by the in-situ sensors. This model will be used to test different adaptation scenarios for managing chronic floods, with modelled strategies dictated through engagement with community working groups. Because coastal communities from Florida to Alaska are already actively investing in reducing their risk from sea-level rise, these tools could be widely applied to leverage climate science in coastal adaptation.

Keywords: *sunny day flooding, sensors, adaptation*

Subgrid Corrections in Finite-Element Models of Storm-Driven Coastal Flooding

Presenter: Johnathan Woodruff

Co-author(s): JC Dietrich

Research Question: How can we increase the efficiency of storm surge models by running on coarsened domains?

Coastal flooding models based on the numerical solution of the 2D shallow water equations are widely used to predict the timing and magnitude of inundation during storms, both in real-time forecasting and long-term design. Constraints on computing time, especially in forecasting, can limit the level of spatial resolution of the models and hence their accuracy. Fast flooding predictions that also include the highest-resolution datasets to represent flow pathways and barriers at the scales of critical infrastructure are therefore highly desirable. This need can be addressed via subgrid corrections, which use information at smaller scales to 'correct' the flow variables (water levels and current velocities) averaged over the model scale. Recent studies have shown a decrease in run time by 1 to 2 orders of magnitude, with the ability to decrease further if model time step were also increased. In this study, subgrid corrections have been added to the ADvanced CIRCulation (ADCIRC) model, a widely used, continuous-Galerkin finite-element based, shallow water flow model. The benefits of the subgrid corrections are demonstrated on regional and ocean-scale test cases with hurricane strength forcing to provide a realistic storm surge scenario. This study is both the first to apply hurricane strength forcing to a subgrid model, and the first to run on ocean-scale domains. It is shown that subgrid ADCIRC can match the accuracy of the traditional model, while offering a 10 to 50 times increase in speed.

Keywords: *storm surge; subgrid; ADCIRC; wetting and drying; shallow water equations*

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P1

Expanding stationary and mobile PM2.5 measurement capabilities near fire disasters

Presenter: Ashley Bittner

Co-author(s): M. Arashiro, A. Holder, W. Mitchell, B. Gullett, A. Grieshop

Research Question: How can we use low-cost air sensor technology to inform emergency response following a fire disaster?

"This study used two easily deployable lower-cost air sensor systems to collect high-frequency measurements of fine particulate matter (PM2.5) near fires. The data collection systems include (1) portable, solar-powered backpack monitors equipped with a PurpleAir (PA-II-SD) sensor and (2) a mobile monitoring system equipped with a pDR-1500 (Thermo Scientific). During a fire event, the backpack monitors are deployed as temporary fixed-site monitors to capture longer-term temporal variation, while the mobile monitoring system is driven along routes to characterize spatial variation upwind and downwind, including higher-concentration smoke pulses near the burn.This monitoring approach was tested during prescribed burns in Tall Timbers, FL and Konza Prairie, KS and during the Monument wildfire in Humboldt County, CA. We present these examples to demonstrate the ability of this monitoring approach to improve the spatiotemporal resolution of PM2.5 measurements compared to the nearest regulatory air quality monitoring network site. The results show that both prescribed fire and wildfire plumes can have localized impacts while also contributing to widespread elevated PM2.5 concentrations. Additionally, we explore alternative applications of this technology, including evaluating predictions from commonly used smoke dispersion models, assessing real-time local air quality impacts from the burning of spilled oil, and mobile deployments on all-terrain vehicles and helicopters. The views expressed in this abstract are those of the authors and do not necessarily represent the views or policies of the U.S. Environmental Protection Agency. The mention of trade names does not constitute endorsement."

Keywords: *low-cost sensors, air quality, fire disasters, emergency response*

P2

Quantification of Inter-Home Variability in PM2.5 Air Pollution Infiltration Factors

Presenter: Sailaja Eluri

Co-author(s): H. Christopher Frey

Research Question: What are the factors affecting variability in PM2.5 infiltration factors?

Exposure to air pollutants causes adverse human health effects. Hong Kong residents spend about 60% of their time in homes. Indoor air pollution is caused by infiltration of ambient air pollution indoors and indoor generated sources (e.g., cooking). Infiltration of ambient air pollution depends on type of home, pollutant, and type of ventilation, either natural or mechanical. Stochastic exposure models quantify variability in air pollutant exposures for a microenvironment based on probabilistic inputs of pollutant infiltration factors. The objective of this work is to quantify inter-home variability in air pollution infiltration factors for PM2.5 for various combinations of ventilation behaviors (e.g., window open/close with air conditioner on/off). Infiltration factors will be estimated based on linear regression of simultaneous indoor and outdoor concentrations for each home individually. Indoor and outdoor pollutant concentrations were obtained from measurements done by collaborators in Hong Kong. Effect of home area, floor of the home and type of housing will be analyzed. This work will help in quantification of air pollution infiltration factor distributions for input to stochastic exposure models.

Keywords: *Infiltration Factors, Inter-Home Variability*

P 3

Evaluation of the effect of landfill cover soil on volatile per- and polyfluoroalkyl substances (PFAS) attenuation.

Presenter: Silas Buckner

Co-author(s): M. A. Barlaz, F. B. De la Cruz

Research Question: Is there attenuation/transformation of volatile PFAS in LFG passing through landfill cover soil?

Per- and polyfluoroalkyl substances (PFAS) is a class of contaminant which, due to its high thermal and chemical stability, accumulates in the environment. While the release of PFAS in landfill leachate is well-documented, there is little understanding of the fate and transformations of volatile PFAS in landfill gas (LFG). The objective of this study is to evaluate the transformations/attenuation of volatile PFAS in LFG as it passes through biologically active cover soil. Information on the attenuation of PFAS in LFG is important in evaluating the contribution of landfills in the overall mass release of PFAS into the environment. A static chamber was used to measure the flux and capture samples of LFG passing through the cover soil. LFG within the waste mass was collected using a soil gas probe, which was buried at a depth of two meters and located 15 cm from the chamber. The PFAS concentration profile in the chamber will be compared with that within the waste mass. Changes in PFAS concentration profile will indicate evidence of attenuation. Initial results showed detectable levels of PFAS in both the chamber and the waste mass. In both samples, fluorotelomer alcohols (FTOHs) were the dominant species with lower levels of fluorotelomer olefins (FTOs).

Keywords: *PFAS, Landfill gas, PFAS attenuation, Volatile PFAS*

P4

Fungal Bioremediation of Stormwater: Suspended and Attached Growth Systems for Imidacloprid Removal

Presenter: Leah Weaver

Co-author(s): N. L. Alexander, T. Aziz

Research Question: Can fungus *Phanerochaete chrysosporium* effectively remove imidacloprid from stormwater?

Neonicotinoids, a widely used class of pesticides, enter surface waters through stormwater runoff and threaten the health of our aquatic ecosystems. Imidacloprid is the most commonly used of these neonicotinoids. White-rot wood decay fungi can degrade these compounds, and their natural ecology make them well suited to passive fungal bioremediation applications. However, there is limited research on the viability of fungal bioremediation for treatment of stormwater. In this study, we investigated the rate and extent of imidacloprid degradation by the fungus Phanerochaete chrysosporium. Batch reactor experiments included both suspended and attached growth in synthetic stormwater, and imidacloprid and biomass were measured regularly over four weeks. Transformation products were also identified. Our findings show >99% imidacloprid removal in three weeks. Similar removal results were observed in preliminary experiments with attached fungal growth on wood chips. In this presentation, we will describe the promises and challenges of fungal bioremediation as a tool for preventing ecological damage from pesticides and other emerging contaminants present in stormwater runoff.

Keywords: *Neonicotinoids, fungal bioremediation, stormwater, imidacloprid*

P5

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

Presenter: Asmita Narode

Co-author(s): H. Steffens, M. Barlaz, J. Ducoste, M. Pour-Ghaz

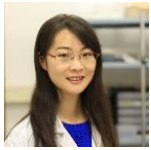
Research Question: Measurement of heat generation of ash going to landfills

A recently published landfill heat accumulation model identified reactions that contribute significant heat to landfills, including the hydration and carbonation of Ca-containing wastes such as ash. Model predictions were based on published information on reaction thermodynamics and kinetics. However, there is limited data on heat evolution from ash. This study aims to develop laboratory methods to measure heat evolution from Ca-containing ash under landfill-relevant conditions. A method is under development to build a semi-adiabatic reactor system. The reactor consists of four major parts: an insulated container (dewar flask), insulation, a sample container, and a center channel to hold a temperature sensor. The temperature sensor is connected to a data acquisition device. The reactor is characterized for heat loss so that temperature data can be used to calculate the rate and extent of heat generation. Reactor characterization involves the determination of two parameters; the coefficient of heat loss and the thermal capacity. Heat evolution from the hydration of pure CaO and the carbonation of pure Ca(OH)2 is being measured. Heat evolution data will be used with a model describing the system to compare measured and theoretical heat. The coefficient of heat loss and thermal capacity was measured to be 120 J.hr-1.K-1 and 1700 J.K-1, respectively. In preliminary work, we encountered k value of 1.61 for hydration of CaO. Once confirmation experiments are complete, heat release and rate from ash samples will be measured. This rate will then be used to better parameterize models of heat generation and accumulation in landfills.

Keywords: *semi-adiabatic reactor, landfills, ash, hydration, carbonation*

P 6

Degradation of Per- and Polyfluoroalkyl Ether Acids by Sulfate and Hydroxyl Radical-Based Advanced Oxidation Processes



Presenter: Chuhui Zhang

Co-author(s): T. Tang, D. Knappe

Research Question: PFAS degradation

Per- and polyfluoroalkyl substances (PFASs) are widely used anthropogenic chemicals and are not destroyed in typical drinking and wastewater treatment processes. Advanced oxidation processes (AOPs) can transform some PFASs, but the fate of per- and polyfluoroalkyl ether acids (PFEAs) is poorly understood. Furthermore, second-order rate constants that describe the oxidation of PFASs by sulfate and hydroxyl radicals are sparse or lacking. In this study, we investigated the degradation of 18 PFASs including 15 novel PFEAs using sulfate and hydroxyl radical based-AOPs. None of the studied PFASs showed measurable degradation by ultraviolet (UV) photolysis up to a UV dose of ~32,000 mJ/cm2. Among the studied PFASs, 6:2 fluorotelomer sulfonate was the only compound that was oxidized by hydroxyl radicals. Using UV photolysis of persulfate (UV/PS), polyfluoroalkyl ether acids with a -O-CFH- moiety degraded more rapidly than perfluoroalkyl ether carboxylic acids and a chloro-perfluoro-polyether carboxylic acid (ClPFPECA). Perfluoroalkyl ether sulfonic acids were not oxidized at any of the tested conditions. In the UV/PS process, PFAS oxidation followed second-order kinetics, and oxidation rates were impacted by solution pH and the presence of matrix constituents such as chloride and natural organic matter. We employed a kinetic model to simulate PFAS destruction and estimate second-order rate constants. For sulfate radicals, second-order rate constants ranged from (0.6–5.0)×10^5 M-1s-1 for perfluoroalkyl ether carboxylic acids and ClPFPECA to (0.7–3.5)×10^7 M-1s-1 for polyfluoroalkyl ether acids. This study provides insight into remediation strategies that include hydroxyl and sulfate radicals as oxidizing agents for the degradation of PFASs.

Keywords: *PFAS, oxidation, kinetics, rate constant*

P 7

Anaerobic Decomposition of Cotton under Simulated Landfill Conditions

Presenter: Sharanya Ananth

Co-author(s): F. B. De la Cruz, J. Kays, M. A. Barlaz

Research Question: What is the rate and extent of anaerobic decomposition of cotton in landfills?

Cotton is one of the leading fabrics used in clothing, and different treatments of cotton continue to emerge due to developments in the textiles field. According to the EPA, around 66.4% of textiles were disposed of in landfills in 2018, with only 14.7% recovered for recycling. Unlike synthetic fabrics such as polyester and nylon, cotton is composed primarily of biodegradable organic material (cellulose) which is known to biodegrade under anaerobic conditions. This project aims to understand the rate and extent of decomposition of cotton fabrics receiving different treatments, including dyed cotton, bleached cotton, cotton with a softener treatment, and cotton with durability treatment. In order to simulate optimal landfill conditions, anaerobic reactors are operated for each type of cotton. Triplicate reactors with each cotton are monitored for both methane generation and leachate composition, including pH, COD, ammonia, and phosphate. The pH and nutrient concentrations are adjusted as needed to maintain optimal conditions for biodegradation. At the end of the decomposition cycle, as evidenced by little to no methane generation, the reactors are destructively sampled to conduct a mass balance to compare cellulose loss and methane generation.

Keywords: *Solid waste, anaerobic decomposition, methane potential, landfills, cellulose degradation*

P8

Properties of activated carbon fiber that contribute to participation in electron exchange reactions with chemical reductants

Presenter: Ethan Quinn

Co-author(s): D. Call

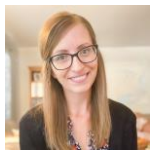
Research Question: What properties of activated carbon fiber contribute to electron transfer?

Pyrogenic carbonaceous materials (PCMs), such as activated carbon (AC) and biochar, can exchange electrons with aqueous contaminants. This reactive behavior may provide new strategies to degrade organic contaminants more quickly and thoroughly. While many studies have examined how PCM synthesis conditions impact resulting electron exchange behavior, there is a lack of information on how post-pyrolysis treatment methods can be leveraged to influence electron exchange. To provide the groundwork for tailoring PCMs for specific contaminant transformations, we are studying a suite of chemical and physical treatment methods. Also, this study, in comparison to past endeavors of this kind, examines the use of AC cloth rather than the conventional granular form. A spectrophotometric method has been utilized to quantify the electrons transferred to the fiber. Initial results show that an oxidative treatment of AC using hydrogen peroxide resulted in the appearance of several functional groups containing C=O and C-H bonds, as revealed by fourier-transform infrared spectroscopy. Initial sodium dithionite-based EAC tests indicate that the hydrogen peroxide-treated AC had a 13.2% larger EAC than untreated AC. Because differences in EAC were noticed when the sodium dithionite starting concentration was increased, an electrochemical method is being examined as a means of comparison to these findings. BET analysis revealed that the total surface area decreased after peroxide treatment, suggesting that the change in EAC was likely due to the chemical functional groups. In future tests, we will study additional chemical and physical treatments of AC and develop relationships between changes in AC properties and EAC.

Keywords: *Pyrogenic carbonaceous materials, activated carbon, redox*

P9

Thermal Reactivation of Spent Granular Activated Carbon (GAC) Containing Per- and Polyfluoroalkyl Substances (PFAS)



Presenter: Stefanie Starr

Co-author(s): D. Knappe, E. Baker, A. Grieshop, H. Liberatore

Research Question: What are conditions that effectively mineralize PFAS during thermal reactivation of PFAS-laden GAC?

Thermal reactivation of spent granular activated carbon (GAC) is a management strategy that permits GAC reuse. The fate of per- and polyfluoroalkyl substances (PFAS) during thermal reactivation of spent GAC from PFAS remediation sites is poorly understood. This study aims to identify conditions that effectively mineralize PFAS during thermal reactivation of PFAS-laden GAC. Thermogravimetric analysis (TGA) experiments with pure PFAS in acid and salt forms as well as PFAS/base (NaOH, Ca(OH)2) and PFAS/salt (NaCl, CaCl2) mixtures were conducted to determine the thermal stability of nine PFAS. Off-gas from the TGA experiments was collected with impingers to trap gaseous compounds soluble in basic water and SUMMA canisters to capture volatile and semi-volatile PFAS that pass through the impingers. Impinger solutions and TGA pan residues were analyzed for fluoride using an ion selective electrode. Targeted PFAS analysis of the impinger solutions was performed with liquid chromatography-mass spectrometry. Results to date show that thermolysis of all tested PFAS was complete at temperatures used to reactivate GAC. In both absence and presence of a base or salt, salt forms of PFAS were more persistent than acid forms, and perfluoroalkyl sulfonates were more persistent than perfluoroalkyl carboxylates. Total fluorine recovery in the absence of a base or salt and in the presence of a salt was <10%. In the presence of Ca(OH)2 and NaOH, total fluorine recoveries increased to >50% with increasing Ca/F and Na/F molar ratios for PFOS salt. Results show that the addition of a base enhances mineralization of some PFAS.

Keywords: *thermal reactivation, PFAS, GAC, mineralization, remediation*

P10

Renewable Resource Adequacy in Energy System Models

Presenter: Jethro Ssengonzi

Co-author(s): J.X. Johnson, J.F. DeCarolis

Research Question: Energy grid planning for implementation of renewable energies

Revamping the electric grid to get to net-zero greenhouse gas emissions by 2050 has become an important international goal to avoid life-threatening environmental damage. The wide scale deployment of variable renewable energy technologies (VREs) offers a pathway to decarbonize the electric grid. Renewable energies are a proven, effective substitute for traditional carbon-dense fuels, but it will require effort and ingenuity to incorporate renewables at a scale that can effectively reduce emissions. One challenge in maintaining the reliable operation of the grid is ensuring that sufficient generating capacity is available to meet demand at all hours; the capacity credit (CC) metric is employed to address this. If renewables are assigned values for CC that are too low, their growth becomes disincentivized. If renewables are assigned values for CC that are too high, energy black outs may occur. The contribution of VRE to resource adequacy as a function of VRE penetration across several technologies is discussed using the effective load carrying capability (ELCC) method to calculate CC values for regions of the contiguous United States. The correlations of plant outages due to events such as extreme temperature, drought, and fuel supply restrictions are also explored, thus yielding more realistic resource adequacy results that can cultivate more economical long-term resource planning for deep-decarbonization.

Keywords: *Capacity credit, effective load carrying capability, loss of load probability, Monte-Carlo simulation*

P11

Developing an integrated hydrology-economics model to simulate food-energy-water nexus in intensive irrigation basin

Presenter: Hemant Kumar

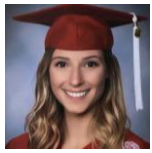
Co-author(s): S. Arumugam

Research Question: How strongly are the production and consumption of food, energy, and water linked to each other?

The concept of the food-energy-water (FEW) nexus has become the preferred framework for resource management policies in the recent decades. The FEW nexus has mostly been studied at the global, regional, or national scales with a water-centric perspective to understand synergies and trade-offs in competing water uses for energy and food production. The decision variables impacting the nexus vary widely across the regions. It is important to quantify the inter-connectedness of nexus components and identify key decision variables. This calls for development of new tools to specifically address nexus linkages in addition to the existing qualitative assessment methods. There has some work in this direction such as development of new economic functions to identify optimal tradeoffs among water, energy, and food production. However, additional tools are required to model the nexus at varying spatial scales. We are developing such quantitative tools using system of systems approach which utilizes transdisciplinary knowledge from hydrology, economics, and agronomy. The developed tools will enable us to design sustainable FEW systems for basins with intensive agricultural water use such as Flint River Basin in Georgia. The proposed model will be used to study the evolution of nexus under changing climate and regional development scenarios.

Keywords: *Food-Energy-Water nexus, irrigation*

Toward deterministic, dynamic model forecasts of storm-driven erosion



Presenter: Jessica Gorski

Co-author(s): R. Luettich, M. Bilskie, D. Passeri, R. Mickey, J. Dietrich

Research Question: Can we deterministically forecast erosion in real time?

The U.S. coast is vulnerable to storm events, which can cause significant erosion of beaches and dunes that protect coastal communities. Real-time predictions of storm-driven erosion are useful for decision support, but they are limited by computational resources and uncertainties in dynamic coastal systems. Current methods for erosion predictions are based on empirical equations for wave run-up, which does not capture dynamic sediment transport, and on surrogate models, which rely on simplified representations of the system. However, with continued advancements in high-resolution input data and computational efficiencies, there is an opportunity to apply morphodynamic models for deterministic predictions of beach and dune erosion in real time. In this study, we apply a morphodynamic model for predictions of coastal erosion during Michael (2018). The coast along the Florida panhandle is represented by several one-dimensional transects, covering the storm's landfall location. The morphodynamic model is initialized with pre-storm digital elevation models, forced with hydrodynamics from wave and circulation models, and validated with a survey conducted directly after storm impact. It is shown that this deterministic framework can provide accurate and efficient predictions of coastal erosion during storms. A key contribution of this study is the automation of the transect development and model simulations, so the framework can be applied to other regions and other storms.

Keywords: *Coastal Erosion, Deterministic Modeling*

P13

Identifying Cyber-Physical Attack Scenarios on Water Distribution Systems using Finite State Processes and Satisfiability Modulo Theory

Presenter: Cade Karrenberg

Co-author(s): J. Benavides, J. Baugh, E. Berglund, E. Kang

Research Question: How can we identify and protect security vulnerabilities in 'smart' water distribution systems?

Modern water distribution systems comprise not only physical infrastructure, but also use smart meters, sensors, and automated control systems to manage hydraulic processes, ensure water quality, and maintain an acceptable level of service. Networked devices create new vulnerabilities to cyber attacks, in which an attacker infiltrates connected devices through internet and network connections with potentially severe consequences, such as creating water supply interruptions and compromising water quality. This research describes a novel approach to modeling water distribution systems to identify vulnerabilities. This research framework couples a process calculus called Finite State Process (FSP) which includes a supporting tool, Labeled Transition System Analyzer (LTSA) for automatically checking safety and progress properties with an open-source toolbox for simulating attacks on water distributions systems, called epanetCPA. Feasible attack scenarios are automatically identified and produced by LTSA, which generates counterexamples to a safety property. To incorporate the physics of water distribution networks into FSP, we discretize and quantize systems and calibrate observable behaviors using WNTR, a Python package that utilizes the EPANET engine to model and analyze water distribution networks. We incorporate another tool that is used in parallel to FSP, NuXmv which is a symbolic model checker that uses Satisfiability Modulo Theory (SMT) techniques to analyze infinite-state transition systems. NuXmv supports unbounded integers and reals, allowing direct use of system equations to relate transition states, further validating the results obtained from FSP. Attack scenarios are simulated with epanetCPA for purposes of validation.

Keywords: *cybersecurity, finite state process, satisfiability modulo theory, formal methods, water resources*

P14

Projecting future phosphorus trends in Jordan Lake under varying climate and management scenarios

Presenter: Smitom Swapna Borah

Co-author(s): D. Del Giudice, D. Obenour

Research Question: How climate change affects the phosphorus trends in Jordan Lake and how different phosphorus management plans are likely to pan out under the changing climate.

Eutrophication in North Carolina's Jordan Lake has been a consistent challenge for its management since its inundation. One of the reasons for this condition is the abundance of phosphorus (P) in the reservoir. As a result, management plans targeting external nutrient loading reduction to the reservoir have been developed in past decades. However, these plans appear to have had limited success, as prior research indicates substantial internal loading of phosphorus from the reservoir's bottom sediments. The sediment flux could potentially increase in the future as reservoir temperature is expected to increase due to climate change. In this study, we applied a mechanistic model within a Bayesian inference framework to simulate long-term P dynamics (1983-2018) in Jordan Lake. Results indicate that the sediment P release could be over 300% of the external P loading in some years, with large seasonal variations (0.1 g/m2/month during Jan-Mar and 0.6 g/m2/month during Jul-Sept). To understand the role of climate change in P dynamics, the model was used to simulate future scenarios under two climate projections (RCP 4.5 and RCP 8.5) from 2019-2099. The simulations indicate a gradual increase in sediment P release, especially under RCP 8.5 in the second half of the century. However, no significant variation in P projections was observed in water column due to rising temperature. Additionally, we applied the model to study long-term P projections under different management scenarios, incorporating the effects of sediment P management strategies such as sediment capping and dredging in conjunction with external P loading reductions.

Keywords: *Eutrophication, Jordan Lake, Climate change, Phosphorus management, Internal phosphorus loading*

Evaluating Subseasonal-to-Seasonal Extreme Precipitation Forecasts

P15

Presenter: Jessica Levey

Co-author(s): S. Arumugam

Research Question: Hydrologic Extremes Forecasting and Water Management.

Climate change is expected to increase the intensity and frequency of extreme precipitation events, which will impact both drought and flooding. This poses challenges for developing accurate and operational forecasts, which are critical for water resource management decisions. There is a need to evaluate precipitation forecasting products' performance for predicting precipitation extremes, and a need to understand if that performance has varied over time and space. To address this, the performance of subseasonal-to-seasonal precipitation forecasts were evaluated. The deterministic forecasts were evaluated based on the Spearman correlation coefficient of the ensemble means and the probabilistic forecast ensembles were evaluated based on a) Brier Score b) Reliability plots and c) Rank Probability Skill Score. Understanding how these forecast products and probabilistic forecasting methods performed over different regions will allow us to assess their utility and improvement in forecasting over the past 10 years. Furthermore, this assessment will provide information on whether extreme precipitation forecasting products are improving over time, as the climate continues to change, and will evaluate any spatial patterns to forecasting skill and improvements. This assessment will address whether we should stick with the 'one size fits all' approach or if forecasting methods should vary across regions to better predict extremes.

Keywords: *Hydrologic Extremes Forecasting, Subseasonal-to-seasonal, Water management*

Flood impact assessment on Water Distribution System Services

P16

Presenter: Qasim Adegbite

Co-author(s): J. Levey, S. Fang, R. Ranjithan, J. Levis, E. Downey, G. Mahinthakumar, S. Arumugam

Research Question: To forecast water service outages given flood inundation forecasts.

The recent increase in the frequency and intensity of precipitation events has resulted in devastating floods that have claimed the lives of people, property, and essential infrastructures. Critical infrastructure systems and lifeline services are vulnerable to floods, potentially causing service outages during and after storm events. Our study focuses on developing a quantitative approach to estimate the implications of flooding on the water distribution system (WDS) services. Direct implications (e.g.pump station or water treatment plant outage) and indirect implications (e.g., WDS service disruptions due to power outages) of flood inundation are represented and simulated via a WDS hydraulic model (e.g., EPANET, WNTR). We estimate the Spatio-temporal water service levels under various hypothetical disruption scenarios using both demand-driven and pressure-driven hydraulic modeling. Ultimately, water service outage forecasts are developed for potential use by the utility managers, emergency personnel, and citizens. Our study is based on a WDS for a large, real metropolitan area, for which the vulnerability of the current system and its critical components are explored. The results and analyses compare the service outage forecasts under numerous scenarios, considering the nodal level and weighted average pressures at the census block group level. This enables us to investigate any correlation between water service delivery and socio-economic attributes.

Keywords: *Water distribution networks, flood, service outage forecast, resilience*

P17

Survey Exploring Water Utility Approaches to Smart Technologies and Customer Complaint Management

Presenter: Morgan DiCarlo

Co-author(s): E. Z. Berglund, N. Kaza, A. Grieshop, L. Shealy, A. Behr

Research Question: How are US water utilities handling customer complaints and implementing smart technologies?

Sociohydrology relies on the collection of data about both human decision-making and water systems, including managerial decisions. Many studies focus on eliciting public perceptions of water delivery and water use behaviors. For example, a recent study indicates as many as 60 million Americans do not drink their water because they do not trust its safety, increasing alarmingly from 2017 to 2018. High profile water quality events, including the Flint Lead in Water Crisis, contribute to a decline in customer trust in their water utilities. Survey techniques can capture the utility perspective in this complex issue of trust and customer complaint management. This presentation will explore the development, implementation, and results of a survey instrument distributed to 504 water service providers across the United States. Survey questions explore the existing tools that utilities use to collect customer complaints, the adoption of smart technology by utilities, and characteristics of customer complaints. This research will assess capabilities to detect issues from customer complaints trends and the level of smart technology integration in United States water systems. We assess differences in complaint reporting and management system by utility size, urbanization, and socioeconomics of their service area. This research will develop new insight about the types of tools that utilities need and are willing to adopt to receive, analyze, and report customer complaints.

Keywords: *Water Utilities; Survey; Smart water; Customer complaints*

Identifying per- and polyfluoroalkyl substances, pesticides, and pesticide transformation products in North Carolina surface and groundwater with nontargeted analyses

Presenter: Nancy Lee Alexander

Co-author(s): J. N. Dodds, N. DeStefano, C. LePrevost, E. S. Baker, D. Knappe

Research Question: What organic contaminants related to agricultural production impact North Carolina water quality?

North Carolina (NC) is a national leader in agriculture with over 16% of the gross state product ($92.7 billion) attributed to food, fiber, and forestry. Intensive agricultural production relies heavily upon the use of pesticides and other agrochemicals, leaving NC water sources vulnerable to impacts from pesticides, pesticide transformation products, pesticide adjuvants, and per- and polyfluoroalkyl substances (PFAS). Recently, PFAS have been found in pesticide products, pesticide packaging containers, and land-applied biosolids. The primary objective of this research is to develop nontargeted analytical approaches to assess the impact of agrochemical and biosolid applications on surface and ground water quality. Initially, 228 pesticide and PFAS standards were analyzed using reversed-phase liquid chromatography, ion mobility spectrometry, and quadrupole time-of-flight mass spectrometry (LC-IMS-MS) to develop a multidimensional database containing retention time, exact mass, fragmentation, and IMS collision cross section (CCS) information. Following database development, 13 surface water samples taken near biosolid application sites and 80 groundwater samples from private wells were analyzed using both LC-MS and LC-IMS-MS methods. Data produced from LC-MS analysis was screened using a nontargeted workflow developed by the US EPA. LC-IMS-MS analysis was then performed, and the collected data were assessed using the multidimensional library. Various identifications were made, including imidacloprid, imidacloprid urea, atrazine, and numerous PFAS, in the surface and groundwater samples. Samples taken near biosolid application sites contained the highest summed PFAS concentration with one sample containing over 1,800 ng/L. Results show that advanced analytical approaches improve our understanding of water quality.

Keywords: *mass spectrometry, organic contaminants, water quality, agriculture*

JUDGES

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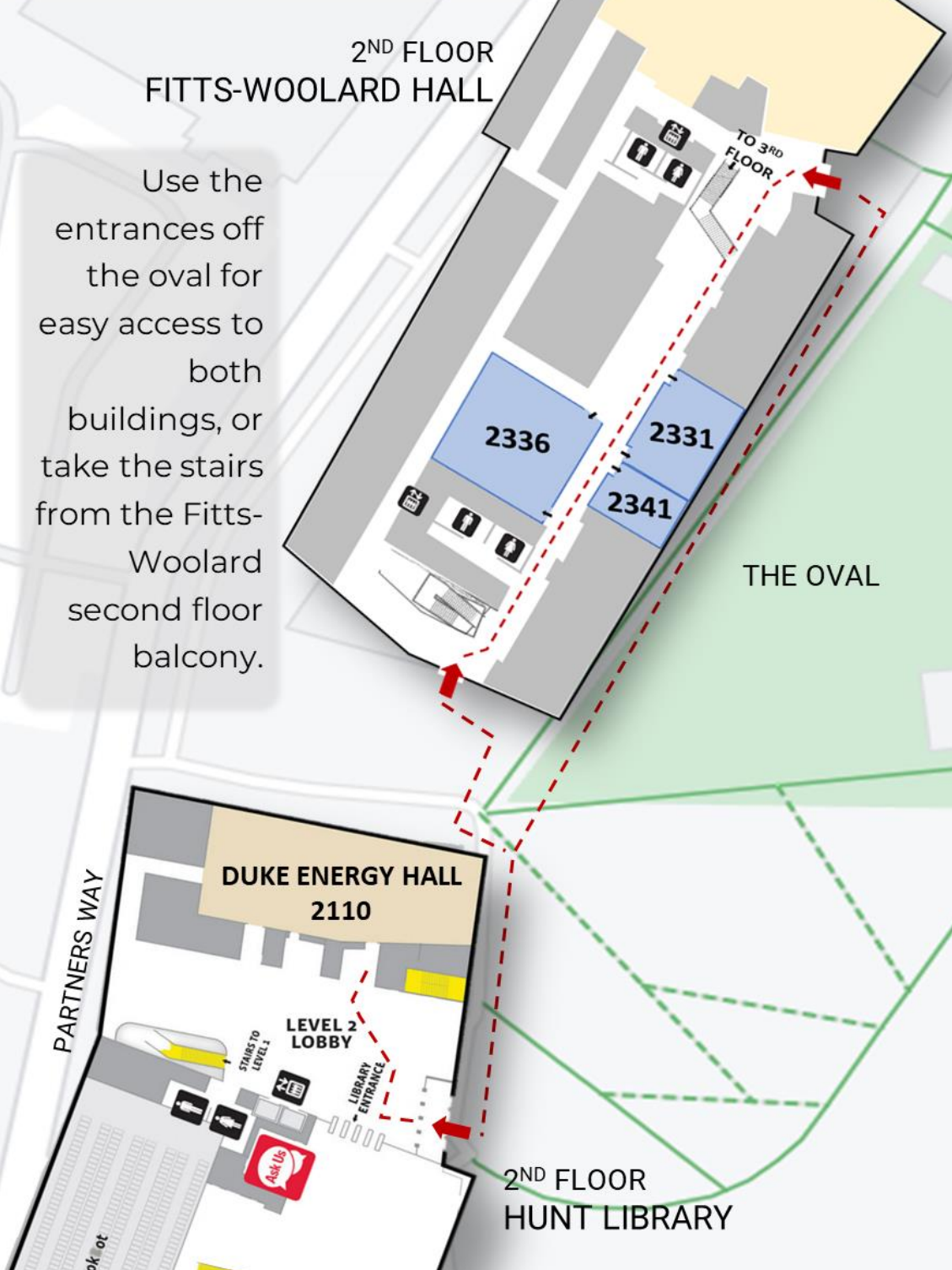
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