# Research Highlights from the North East Graduate Student Water Symposium

A report prepared for USGS

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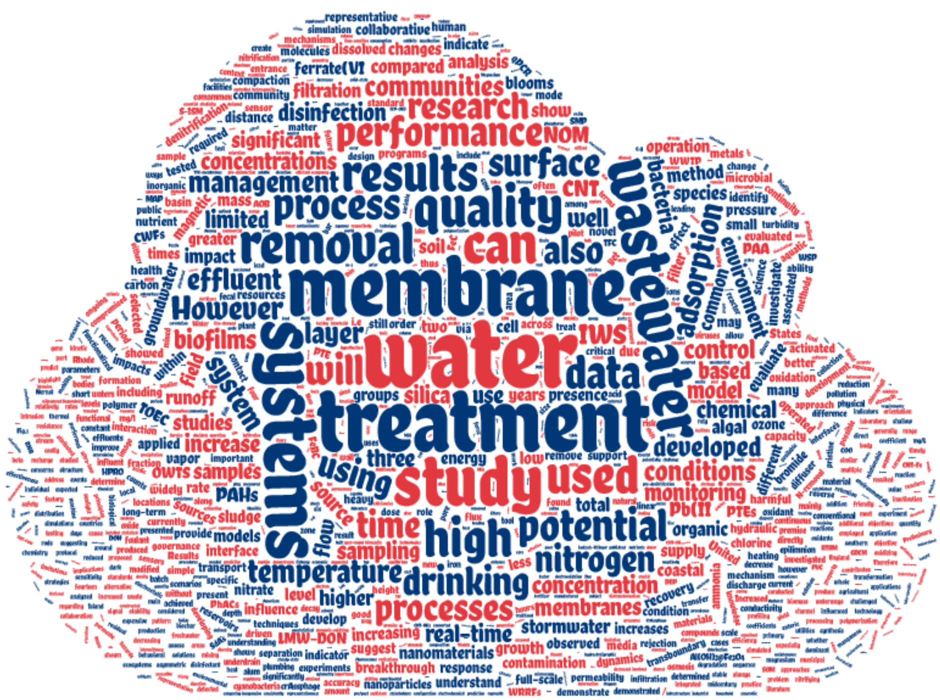

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# I. Introduction

The North East Graduate Student Water Symposium (NEGSWS) is an annual conference that is hosted at the University of Massachusetts Amherst. The purpose of NEGSWS is to provide an affordable conference opportunity in the greater Northeast region for graduate students in water-related disciplines. The symposium is centered around the theme of research advances in water engineering, resources, science, and policy. Organized and hosted primarily by graduate students, it is an opportunity for graduate student researchers to present current research, exchange ideas, network, and interact with industry and government professionals in the water sector.

This report summarizes key research topics that were presented at the 2019 NEGSWS conference and highlights talented researchers and presenters. The report is based upon work supported by the U.S. Geological Survey under Grant/Cooperative Agreement No. G16AP00062. The purpose of this report is to help emphasize the role that NEGSWS plays in providing a venue for talented students to present and network. It also serves to help public and private organizations better identify current and future water sector talents in the Northeast area.

Most of the research in this report were presented at the NEGSWS 2019. The presentations were in both oral and poster formats. Summaries are provided in each research category to feature research trends in each specialty areas. Included are also graphics that show the growth in research topics and presenters' demographics at the NEGSWS over the years. Student and research highlights from other universities that wish to provide said information are also reported, including oral and poster presenters winners from the NEGSWS 2019.

NEGSWS is a unique initiative by graduate students who are passionate about our industry, and it presents an opportunity for the Northeast water sector to show its support for the next generation of water industry professionals. Hopefully, this report will help garner more interest and support for the conference.

# II. Water Research in the North East

## *A. Data Science and Modeling*

This section focuses broadly on data-driven and modeling approaches to water research presented at this conference. Again, research ranges across many subfields and scales, from transboundary collaborative governance to ion selective membrane sensors in wastewater. Across multiple scales, many studies focused on the uncertainty within data and models, and used several different approaches to address the uncertainty, whether it be through ensemble approaches, Monte Carlo simulations, or sensitivity analyses. Several studies also focused on how changes in future climate may impact systems, addressing the nonstationarity of climate through incorporating future projections from general circulation models (GCMs) to look at how road salt applications or reservoirs may adapt to varying temperatures. An overlying theme in the research presented was using models to critically evaluate systems or test the significance of model assumptions. For example, some questions that were explored include nuances of the following:

Are sampling programs effective at representing water quality?
Can models be used to extend our time series of streamflow extremes?
Does heterogeneity matter in brine-freshwater interfaces?
Does lateral inflow to rivers change the over discharge significantly?
Can a Density Function Theory explain adsorption sites?

These questions all reveal a critical and creative approach to incorporating models, while taking into account the opportunities and limitations that lie within all models.

*"All models are wrong, but some are useful"* - George Box

### *Presentations:*

**The Role of Collaborative Science in Transboundary Collaborative Governance**

Berdakh Utemuratov*, Christine Kirchhoff
*University of Connecticut, Storrs, CT*

Increased competition for transboundary groundwater resources is leading to increasing conflicts over these shared resources. Managing these resources requires adaptive, collaborative, and scientifically sound approaches; yet, implementing these approaches is challenged by the hidden nature of ground water and modelling uncertainties. And, while there is an emerging inquiry in the literature stressing the importance of scientific data, information and knowledge for good governance, little empirical evidence exists about how collaboration in groundwater science benefits (or not) collaborative governance processes among transboundary stakeholders. This study uses documentary analysis and interviews of participants from three water management districts involved in transboundary water governance to understand the role of collaborative development of science in supporting or hindering the collaborative transboundary aquifer governance. We found that the use of separate models by each water management district resulted in disagreements over management of the shared resource. The shift to collaborative science development built trust between the three water management districts and increased the perceived ownership of the science among

different actors. However, we also found that collaborative science development was not a panacea; collaborative science development does not always mean collaboration in transboundary governance.

### Testing the Effectiveness of Sampling Programs in Representing Distribution System Water Quality

Nelson da Luz*, Emily Kumpel
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Utilities are challenged with deciding where to sample for drinking water quality. There are many approaches for determining sample representativeness and developing sampling programs. Reasons behind these determinations are often not well stated. This study addresses three objectives relating to these concerns: (1) Defining goals of drinking water quality sampling programs; (2) Developing sampling programs for monitoring of chlorine residual that use different sampling frequencies, locations, and times; and (3) Comparing the results of the sampling programs by quantifying the percentage of samples less than target concentration (PLT) and statistical significance of sampling program results. A list of representation cases (i.e. how do we define representative) in the categories of 1) representative of whole system, 2) representative of worst quality, 3) representative of critical users, and 4) representative of real-world practice by utilities is developed.

Sampling programs are developed based on the representation cases. Sample location selection is aided by GIS. The cases are tested based on an EPANET model which models chlorine concentrations for one week. Monte Carlo simulations are used to create 1000 possible outcomes for each sampling program tested. The results show that rotating through the possible sampling locations is preferable to using constant sampling locations, which is the typical practice of many public water suppliers. Results also show that time of day when samples are taken may not always matter. This study has implications for the way in which representativeness is defined by utilities and the way their water quality sampling programs are structured.

### System Visualization Using Real-time Data-Driven Model Derived from High-Resolution Sensor Profiling

Tianbao Wang*, Baikun Li
*University of Connecticut, Storrs, CT*

High-fidelity profiling with real-time data at multiple points and easily-built kinetics data driven model based on simple physical principles were proposed for shock systems with three parameters: conductivity, pH and temperature in water environment. The profiling with high spatiotemporal resolution in a real-time mode accurately captured the heterogeneous status of whole water system under transient shocks (conductivity and pH) and slow lingering shock (temperature), offering an opportunity for optimization of chemical dosage and energy saving in wastewater treatment systems. Three data driven models for three parameters, based on simple transport principles and integrated with real-time profiling data, generated a series of transfer coefficients indicating quantitative transfer patterns of sodium ions, hydroxide ions and heat in continuous stirred reactor. Coefficients coming from three models could also be used for prediction, to reduce disturbance of chemical dosage and for energy saving (~91.3% based on assumption). The comparison with machine learning method (Eureqa) were applied to validate the good regression and physical meaning of simple physical principles based data driven model.

### Innovative Mathematical Way Targeting the Data-Drifting of Solid-State Ion-Selective Membrane in the Wastewater Treatment

Xingyu Wang*, Baikun Li
*University of Connecticut, Storrs, CT*

Data drifting is one of the most serious shortcomings that impairs the long-term accuracy of ion-selective membrane sensors, especially in wastewater. The electrochemical or material ways to deal with this problem are difficult and costly. Here we address the problem by applying the mathematical method concluded from the Nernst Equation (E=E^0-RT/nF ln[a_Red/a_Ox ]). In this equation, the potential E detected on the sensor is mutable and can be influenced by many factors (temperature, electronic double layer).

But the change of potential, $\Delta E/\Delta t$, which is the value of data drifting, is transferred into signal and then dealt with signal process. Long-term sensor batch experimental data (3-6 days) has been used to test the accuracy of the new method. After the processing, the long-term data drift can be controlled in a short time and the outcome potential is stabilized at a constant value in the end. At the same time, the noise of the sensor is also eliminated in the figure of the Time-Open Circuit Potential. The result of calibration curve and Nernst slope indicate that the accuracy will not be influenced by this mathematical method. And the Nernst slope of the outcome potential is much closer to the theoretical value (59 mV). It means the process also contributes to the sensitivity of sensor data.

### Impact of Heterogeneity on the Sensitivity and Stability of Brine-To-Freshwater Interfaces in Density-Driven Flow Systems

Sarah McKnight*, David Boutt, LeeAnn Munk
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Density-dependent flow occurs where high-salinity, denser fluids interact with fresher groundwater to create a brine-to-freshwater interface that variably responds to changes in recharge. Salar de Atacama (SdA) exhibits a shallow interface when compared to the theoretically predicted geometries, suggesting that aquifer properties influence density-driven dynamics. We therefore investigate how subsurface heterogeneity impacts an interface's time-sensitive response to changes in recharge. Site-specific 2-D SEAWAT simulations of the interface in SdA, with interpretations of SdA's hydrostratigraphic framework (HSF), indicate how geologic complexity influences the interface's geometry and dynamics. Expanding sensitivity analyses to heterogeneous continuity, we create three groups of equally probable distributions of hydraulic conductivity based on SdA's core data using a geostatistical approach. Each group has 50 realizations and varies in the length of continuity of hydrostratigraphic units. We change recharge in each realization in SEAWAT and assess the interface's time-sensitive response. Metrics include migration and response rates. SdA's HSF model is currently the most accurate representation of the shallow geometry of SdA's interface. The HSF's interface exhibits a higher migration rate and a response rate that is three to four times longer than its homogenous counterpart. Results from the geostatistical realizations suggest that continuity impacts time-sensitivity of the saline intrusion. Increased continuity of high-permeability pathways increases interface sensitivity regarding its travel distance. Increased continuity decreases an interface's stability with response rates that increase by between a factor of two to an order of magnitude. Results suggest that subsurface heterogeneity is an important aquifer characteristic for predicting time scales of saline intrusion.

### Preserving Long-Term Variability in Multisite Simulation of Streamflow Extremes

Yash Amonkar*, Upmanu Lall
*Columbia University, New York, NY*

The prediction and simulation of streamflow extremes across a river basin has significant implications for water management strategies. In particular, the clustering and correlation of wet and dry extremes in space and their persistence in time poses portfolio risks to agriculture, insurance, disaster response, and utility sectors. The proposed method uses dimensionally reduced components of the multi-site streamflow field and wavelet analysis to identify key modes of variability. Using linear and nonlinear autoregressive models, the underlying structure is evaluated. A case study in the Ohio River (United States) Basin shows significant predictive skill at intermediate time scales.

### Warm, Calm, and Green: The Future of Water Quality in Drinking Water Reservoirs Amidst a Changing Climate

Cristina Mullin*, Christine Kirchhoff, Guiling Wang, Penny Vlahos
*University of Connecticut, Storrs, CT*

Thousands of drinking water systems in temperate regions rely on surface water reservoirs vulnerable to increases in temperature, thermal stability, and harmful algal blooms associated with climate change, yet few studies have investigated water quality changes in these reservoirs. Here, lake-specific statistical predictive models are developed using fourteen years of observed data to predict epilimnion temperature, total Relative Thermal Resistance to Mixing/RTRM, and max RTRM in six Connecticut reservoirs. The models are then used to assess future changes driven with statistically downscaled historic (1971-2000) and midcentury (2041-2070) climate from the MACAv2-METDATA database based on projections by General Circulation Models under Representative Concentration Pathway/RCP 8.5. Model results suggest that higher future air temperatures will lead to significant increases in both

epilimnion temperature and the length and strength of thermal stability by midcentury, with the most significant increases from July to September. Reservoir epilimnion temperature is projected to exceed 25 °C for an additional 48 ± 14 days annually by midcentury. At the lake-specific level, observed relationships from 2003 to 2018 indicate high reservoir epilimnion temperature, high total RTRM, and high max RTRM is associated with high-risk cyanobacteria blooms (depth integrated total cyanobacteria biomass > 100,000 cells mL-1) in two out of the six study reservoirs. We anticipate warmer, more stable future lake conditions will continue to increase biological growth and shift phytoplankton community composition to favor cyanobacteria species over time, especially in reservoirs where harmful algal blooms are already a concern.

## *Posters:*

### Optimization of Riparian Zone Nitrogen and Phosphorus Management Through the Development of Riparian Model in the State of Rhode Island

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Riparian zones are widely used as best management practices to mitigate the impact of agriculture on the quality of our waters. However, the buffering capacity of riparian zones regarding Nitrogen varies largely as a function of both upland land use/land cover and riparian hydrogeomorphic setting such as topography, soil type, and surficial geology of the riparian zone. So, the location is critical in determining the potential impact of a riparian zone on water. In spite of the acknowledged value of riparian zones in mitigating Nitrogen pollution, only a limited number of numerical models or landscape-based approaches have been developed in glaciated settings. We used REMM (Riparian Ecosystem Management Model) to simulate the water quality functions of managed riparian ecosystems. In order to successfully predict riparian function(s), REMM requires daily surface flow data from the upland area. In general, this information is missing from most field studies, which can hinder the ability of REMM to properly predict riparian functions. To address this issue, the Annualized AGricultural Non-Point Source model (AnnAGNPS) is being used to predict the surface runoff loading and sediment loading to the riparian buffer simulated by REMM. The simulated surface runoff and sediment loading from AnnAGNPS is calibrated by means of comparing with observed data (USGS gauge). The calibrated daily runoff and sediment loading are being used as input data in REMM. This study presents REMM model input development, model calibration and validation to predict water table depth, groundwater nitrates, groundwater phosphate concentration from riparian sites in Rhode Island.

### Copper Uptake and Assimilation in Periphyton – Simulating Storm Events

Nafis Faud*, Timothy Vadas
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The exposure of algae to Cu is very different depending on the water sources given the strong metal binding by various sources of organic matter (OM). Storm events expose periphyton to these various exposure conditions. The objective of this study was to examine uptake and assimilation of copper in periphyton from different exposure scenarios. Periphyton were colonized in freshwater collected from the Fenton River in Connecticut in aquariums under controlled temperature, nutrient, and light conditions. Uptake from collected Stream water effluent and stormwater was investigated. Intracellular and extracellular copper concentrations were determined throughout the exposure period. Copper speciation was calculated with respect to conditional OM stability constants or using a competing ligand exchange to determine readily exchangeable Cu. Conditional uptake rate constants with respect to total dissolved, free, or exchangeable copper fraction shows similar order of magnitude differences and it is difficult to pinpoint one Cu fraction that correlates more strongly to uptake. Efflux rates from periphyton were estimated to model exposure scenarios. Exposure conditions before, during and after storm events will be simulated by adjusting desired Cu concentration in collected stream water, effluent, and stormwater with stable Cu isotopes. Periphyton will be brought to equilibrium, in approximately 2 days, on exposure water made of stream water: effluent of 70:30 %. Stormwater exposure condition will then be applied for 24 hours. Chemical characteristics of the water will be kept comparable by adjusting major cations as well as OM extracted from collected effluent and stormwater.

### Modeling the Effects of Reduced Road Salting Practices on Reservoir Intake Chloride Concentrations

Joshua Soper*, John Tobiason Colin J. Gleason, Emily Kumpel

*University of Massachusetts Amherst, Amherst, MA*

Chloride exports from road salting practices serve as a primary contributor to water body salinity in cold climate regions. The road salts are transported either through overland flow or subsurface infiltration to receiving waters and pose a number of risks to the environment and human health. With increased urbanization that is categorized by dense networks of paved surfaces, the long-term salinity trends observed in water bodies are expected to continue. This study explores the variability in chloride loading and transport at a sub-basin scale with respect to the Wachusett Reservoir watershed from 2013 through 2018. Annual tributary chloride loads, and runoff factors are calculated for a range of scenarios using tributary streamflow and specific conductivity measurements coupled with approximations of paved surface coverage. Results reveal chloride runoff rates ranging from 22% to 145% across all scenarios with an average runoff rate of 63.5%. Runoff rates are positively correlated with percent impervious surface with high values potentially indicating an alternate source of chloride loading within the sub-basin. Paved surface coverage at a moderately-rural sub-basin scale is heavily influenced by non-roadway paved surface area. An accurate approximation of surface areas that receive road salt application incorporates the removal of rooftop surface area and impervious area within bare or disturbed land uses. Water management authorities concerned with increasing salinity can use sub-basin level chloride loading and transport characteristics to better inform decision making with respect to surface water quality control.

### Influence of Octahedral Cation Distribution in Montmorillonite on Interlayer Hydrogen Counter-Ion Retention Strength by DFT Simulation

Yayu Li*, Kevin Co, Cristian P. Schulthess, Sanjubala Sahoo and S. Pamir Alpay
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Although multiple types of adsorption sites have long been observed in montmorillonite, there is still no consistent explanation about the nature of these adsorption sites. A Density Functional Theory (DFT) simulation was conducted to investigate the properties of these types of adsorption sites. A clay structural model (H[Al6MgFe]Si16O40(OH)8) with similar composition to Wyoming montmorillonite was built, where two octahedral Al were respectively substituted by Fe and Mg, and H+ was the charge compensating cation. This model had twenty-one different possible configurations as a function of the distribution of octahedral cations. The DFT simulations of 15 of these different configurations showed that there is no preference for the formation of any specific configuration. However, differences with the H+ adsorption energy were observed, which were separated into three distinct groups based on the number of octahedral jumps from Fe to Mg atoms. The H+ adsorption energy is significantly different in these three groups. Assuming an even probability of occurrence of 21 octahedral structures in montmorillonite, the percentages of these three groups are 43%, 43% and 14%, respectively, which are similar to published cation adsorption data. These DFT simulations offer an entirely new explanation on the location of the three adsorption sites on montmorillonite, namely, all three sites are in the interlayer, and their adsorption strengths are a function of the number of octahedral jumps from Fe to Mg atoms.

### Exploring Lateral Inflow Impact on Surface Water and Ocean Topography (SWOT) Mission River Discharge Algorithm Performance

Cassandra Nickles*, Edward Beighley, Michael Durand, Renato Prata de Moraes Frasson
*Northeastern University, Boston, MA*

Central to the Surface Water and Ocean Topography (SWOT) satellite mission is deriving river reach discharge from measured surface water extents and elevations. SWOT, though near-global in its coverage, will not observe tributaries smaller than 50-100 meters in width draining laterally into a given river reach. Discharge algorithms use the Mass conserved Flow Law Inversion (McFLI) approach in addition to prior information to derive discharge, yet assuming mass is conserved ignores the smaller streams and the overland flow SWOT will not capture. In this study, we aim to quantify the effect of lateral inflows on the discharge algorithm solution to the McFLI problem. Using a combination of in-situ gauges and the Community Ohio River HEC-RAS Model, a truth series of lateral inflows, river discharges, and water surface elevations are generated. These model-based lateral inflows are ingested into existing SWOT discharge algorithm, MetroMan. MetroMan is then adapted to deal with lateral inflows and the truth lateral inflows

are integrated into MetroMan as well as lateral inflows based on simulated runoff from NASA's North American Land Data Assimilation System (NLDAS) and the Hillslope River Routing (HRR) model. Results indicate that adapting MetroMan to include lateral inflows, even if they are an order of magnitude smaller than the truth, drastically improves MetroMan's performance.

# B. Drinking Water Treatment

***Summary:***

All organisms, from small bacteria to big elephants, need water to survive. We humans need to drink water to sustain our bodies because just going a few days or even a week without drinking water can kill us. With the Earth covered by about 70% of water one would think we would not have an issue with drinking water, but the reality is that roughly 1% of this water is accessible and fresh. We could obtain water from streams and lakes, but the challenges are that they could be contaminated with toxic chemicals, pathogenic organisms and other constituents which degrade the water quality (taste, color, and odor). People in the drinking water field then focus on developing strategies to improve the treatment of the source water to remove such contaminants and pathogens. Researchers highlighted in this section have worked on methods such as the use of ferrate, membrane-based electro-redox processes, complete ammonia oxidizer (comammox) bacteria, hydrodynamic cavitation, carbon nanomaterials, peracetic acid (PAA), ceramic membranes, activated carbon and hydrogen peroxide to treat contaminants such as natural organic matter (NOM), bromide, nitrogen, phosphorous, and perfluorooctanoic acid as well as to remove, kill or deactivate biofilms, Legionella pneumophila, and other microorganisms. Not only different methods were designed, but also existing practices were studied to find optimal conditions for the addition of coagulants, disinfectants, and corrosion inhibitors as well as the replacement of lead pipes, considered old infrastructure and the placement of equipment such as ceramic filters.

Intermittent water supply (IWS) is another big concern within the drinking water field. With IWS, water is only supplied to households at certain time intervals during the day, sometimes not even daily. One study looks to understand the dynamics of biofilm formation and change in water quality within IWS. While one other study looked to assess drinking water source options such as rainwater collection systems and trucked water as alternatives to the IWS system. Another concern in the field relates to alternative sources of drinking water such as saline or brackish water. Because of their high salt content, we would need to desalinate the water to be able to treat and use it. Studies highlighted here have explored improved desalination membrane performance by targeted heating, changing the membrane structure and decreasing silica scaling with nanoparticles, as well as improving electrodialysis desalination with responsive sensing. Other interesting research also included are a study looking to implement inexpensive real-time, image-based identification of bacteria in water sources, as well as research that focuses on utilizing risk-based water quality management tools, such as a water safety plan (WSP) to proactively deal with water issues.

“I wish you water”-Georgi

## *Presentations:*

### Inductive Heating Based Membrane Distillation: Role of CNT-Fe Membranes

Arezou Anvari*, Avner Ronen
*Temple University, Philadelphia, PA*

Membrane Distillation (MD) has been gaining growing interest in the recent decade as a method for providing desalinated water. MD is a thermally driven process in which the vapor pressure gradient over the hydrophobic membrane leads to the transport of water vapor through the membrane. The energy consumption required for feed heating, as a driving force, and temperature polarization are the main limitations of MD systems in addition to heaters corrosion. As most of the heat is not directly used due to a limited surface area and mass transport limitations, we suggest a novel approach which heats only the membrane-water interface through induction heating (IH). Thus, significantly decreasing the required energy and increasing the permeate flux. We use a CNT-Fe membrane with high thermal conductivity sprayed on a PTFE base support (Fig.1 A) to provide the hydrophilic layer with the heating process directly applied to the membrane surface. Heating is done by exposing the magnetic CNT-Fe particles with a high iron loading of about 45 Wt. % (Fig.1 B) to a high-frequency magnetic field.

Preliminary results show the ability of heating water directly on the surface of the membrane leading to water evaporation (Fig.1 C) by exposing the CNT-Fe membrane to an electromagnetic field at a fixed frequency (283 kHz). Permeate flux from the IH-MD system is significantly higher than from a conventional MD system. Therefore, the high flux and low power consumption indicate the promising potential of IH membrane systems to improve MD processes and overcome their main limitations.

### Low-Cost Imaging Platform for Microbial Monitoring

Benjamin Gincley*, Ameet Pinto
*Northeastern University, Boston, MA*

Accurate, real-time quantitative monitoring of microbial communities is essential across a range of application settings including, but not limited to, drinking water distribution systems, algal photobioreactors, and surface waters. Traditional methods involve sample collection and in-lab culturing, which is labor intensive (and precludes real-time data collection) and limited to species amenable to growth in lab conditions. Sophisticated real-time cell quantitation methods have been developed, but these techniques are often unable to discern microbes on the species level, and/or prohibitively expensive for widespread use (e.g. flow cytometry-based methods). We have developed an approach that leverages recent advances in inexpensive optics and computing, microfluidics, and machine learning to provide real-time image-based data via an automated platform. The modular design features (1) a multi-channel microfluidic chip for responsive sample flow and rapid image volume refreshing, (2) a high resolution, high contrast multimodal microscopy configuration, and (3) machine learning-based image processing software to autonomously discriminate between morphologies and quantify species. A Raspberry Pi computer centrally controls sample intake, image capture, and image processing. Preliminary benchmark testing against the gold standard for microbial cell counting (i.e. flow cytometry) has demonstrated the device returns dilution-consistent cell counts, and that the device can operate at higher cell densities than flow cytometry. With a component cost of <$500 USD and operated using open-source software, the Autonomous Real-Time Image-based Microbial 'Scope (ARTIMiS) is designed to make accurate and timely water quality monitoring accessible to researchers, water utilities, and general consumers/citizen-scientists.

### Asymmetric Membranes for Membrane Distillation and Thermo-Osmotic Energy Conversion

Evyatar Shaulsky*, Akshay Deshmukh, Vasiliki Karanikola, Anthony P. Straub, Ines Zucker, Menachem Elimelech
*Yale University, New Haven, CT*

Asymmetric membranes with a thin, small pore size upper layer have the potential to facilitate a high vapor flux while maintaining high liquid entry pressure, which is critical for membrane distillation (MD) and thermo-osmotic energy conversion (TOEC) processes. Here, asymmetric mixed cellulose ultrafiltration membranes were modified with perfluorodecyltrichlorosilane to produce 50 nm and 25 nm pore size membranes with highly hydrophobic surfaces (contact angle greater than 115°) and unprecedented liquid entry pressures greater than 24 bar. The 50 nm membrane performance was evaluated in a series of MD and TOEC mode experiments, where the membrane dense layer faces the hot feed stream or the cold permeate stream, respectively. Our results demonstrate that the membrane water vapor permeability coefficient is significantly higher when operating in MD mode (1.7 × 10-7 kg m-2 s-1 Pa-1) compared to TOEC mode (0.9 × 10-7 kg m-2 s-1 Pa-1) at a similar temperature difference of 39 °C, suggesting an additional resistance to vapor flux in TOEC mode. We developed a model for mass and heat transfer through the membrane to explain the change in performance due to reversing the asymmetric membrane orientation. As expected, the model and the experimental results show a linear increase in the water vapor permeability coefficient with respect to temperature difference across the membrane for the MD orientation. However, for the TOEC orientation, the water vapor permeability coefficient was relatively constant across all the temperature difference range investigated. Our results predict that the additional mass transport resistances in TOEC mode decrease as the transmembrane temperature gradient decreases. We conclude with a discussion on the implications of using asymmetric membranes for MD and TOEC processes.

## Optimizing Drinking Water Treatment Processes Amid Lake Recovery & Changing Source Water Quality

Isobel DeMont*, Jessica Campbell, Wendy Krkosek, Amina Stoddart, Graham Gagnon
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Pockwock Lake, the source water for the J.D. Kline Water Supply Plant (JDKSWP), is undergoing lake recovery as observed through increased concentrations of natural organic matter (NOM). JDKSWP is a direct filtration treatment plant and thus, has a limited capacity to increase their coagulant dose. To ensure high quality drinking water is maintained, optimization of treatment processes is required. The presented study investigates the use of a cationic polymer as a supplement for aluminum sulphate (alum) in coagulation. Pilot-scale studies are ongoing at varying the polymer type and dose across different alum concentrations. Optimal conditions will be selected based on conventional water quality parameters, such as turbidity and NOM removal, but also on filter hydraulic performance and disinfection by-product formation potential. Initial results indicate that the addition of polymer can supplement turbidity removal at decreased alum doses to increase the filter run time, however, sufficient NOM removal was not obtained at the lowered alum concentration. The polymer study will be repeated at the bench scale with source water modified with elevated NOM to evaluate the plant's current ability to manage the significant changes to source water quality that can occur as a result of lake recovery. It is anticipated that the use of cationic polymer could provide a short-term treatment solution to address water quality events and that retrofit with dissolved air flotation could be implemented to support long-term water quality goals.

## Interactions of Natural Organic Matter (NOM) and Chemical Oxidants: Ferrate(VI) Versus Ozone

Junkui Cui*, Yang Deng
*Montclair State University, Montclair, NJ*

Ferrate(VI) is recognized as an alternative agent for drinking water treatment due to its multiple reaction mechanisms and effective treatment performance. Once dosed to water, besides its self-decay, ferrate(VI) is consumed by the reactions with target pollutants as well as various water matrix constituents, such as natural organic matter (NOM). NOM plays a crucial role in chemical oxidation treatment because it can alter the degradation rate of a chemical oxidant, thus affecting its oxidant exposure, as well as can be subject to chemical transformation to influence water quality (e.g., alternation of water color or disinfection byproducts formation potential). The objective of this study was to evaluate and compare the interactions of ferrate(VI) and ozone with NOM in raw water. Mechanisms and performance in ozone for water treatment practices have been well understood. Therefore, the difference of ferrate(VI) and ozone in chemical degradation kinetics and NOM transformation would provide valuable information regarding ferrate(VI) performance. Laboratory scale studies showed that ferrate(VI) and O3 decomposition both exhibited a pseudo-second-order kinetic reaction pattern in the presence of humic acid (HA) or fulvic acid (FA) and FA was more readily degraded than HA in the treatment with ferrate(VI) or O3. Ferrate(VI) generally had a greater oxidant exposure than ozone at a neutral condition. For either NOM fraction, ferrate (VI) provided a better treatment than ozone in terms of the reduction of dissolved organic carbon (DOC) or UV254 absorbance. The results suggest that ferrate (VI) is capable of performing better than ozone in terms of NOM transformation.

### Role of Electro-Active Membranes in Water Treatment

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Population increases in recent years have escalated agricultural, and energy demands and have led to an increase in nitrogen, phosphorus, and bromide concentration in water sources. The suggested work uses a novel membrane process to remove nitrogen, phosphorus, and bromide from water. Electroactive membranes are fabricated by depositing a layer of conductive nanomaterials (such as carbon nanotubes, CNT) on a polymeric base support membrane. EAMs have been shown to electro-oxidize and electro-reduce compounds. The EAMs can control surface properties by application of an external field or potential. We developed and evaluated a membrane-based electrooxidation process to remove bromide and an electro-reduction method to recover nitrogen and Phosphorus. The electrooxidation takes place through an external potential applied on the membrane surface to oxidize bromide during filtration. We initially tested the oxidation using cyclic and linear voltammetry, which allowed us to detect bromide oxidation. Applying a whole cell potential of 2.5V allowed continuous removal of about 60% of the bromide from the permeate stream in a single pass. Our research shows the ability of P and N recovery from a concentrated solution (10-100 mg/L) of synthetic agricultural wastewater. The recovered P and N are in the form of Struvite, which is considered an “eco-friendly” fertilizer. The electrochemical reduction of dissolved oxygen and water molecules generate a local pH gradient in the close vicinity of the electrode. The pH near the cathode increases, leading to nucleation and growth of Struvite and, importantly, high yield with no chemical additives.

### Investigating Population Dynamics of Nitrifying Bacteria Subject to Variable Electron Donor Availability

Katherine Vilardi*, Ameet Pinto
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Since their recent discovery, complete ammonia-oxidizing bacteria (CMX – comammox) have challenged the traditional understanding of two-organism nitrification involving ammonia-oxidizing microorganisms and nitrite-oxidizing bacteria. Comammox are widely distributed in both drinking water and wastewater systems but there is insufficient knowledge regarding their cooperation and competition with other nitrifying metabolisms under environmentally relevant conditions. Prompted by the National Academy of Engineers challenge to manage the nitrogen cycle, an updated understanding of dynamics between nitrifiers is necessary to re-evaluate biological nitrogen removal to inform optimal engineering strategies for nutrient management. We used batch reactors to investigate dynamics among nitrifying bacteria on granulated activated carbon (GAC) from a rapid filter taken from a drinking water treatment plant. The reactors were subjected to three concentrations of either ammonium (direct electron donor) or urea (indirect electron donor) which can be converted to ammonia via urease activity over a period of two months. Concentrations of ammonia, nitrite, and nitrate were measured in the influent and effluent of the batch reactors, and GAC samples were collected for DNA extraction. DNA was extracted from biomass samples and qPCR targeting the 16S rRNA genes of ammonia oxidizing bacteria (AOB) and Nitrospira-bacteria and the amoB gene of comammox bacteria. Select samples were also subject to metagenomic sequencing. qPCR analysis revealed that comammox bacteria were dominant ammonia oxidizers in all conditions but were not enriched over time. Metagenomic data is currently being analyzed to determine the species level dynamics within the three nitrifying guilds, i.e. AOB, NOB, and comammox bacteria.

### Applying and Optimizing a Water Safety Plan Approach in Atlantic Canadian Water Systems

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Currently, in many small communities, water quality management and safety follow the approach of measuring water quality parameters at the tap and comparing to a known regulatory standard to determine compliance. However, in the past ten years, there has neither been an improvement in the water quality small community members are receiving, nor a reduction in the prevalence of drinking water advisories being issued in these communities. A more proactive, risk-based water quality management tool, such as a water safety plan (WSP), is needed to improve both the safety and security of drinking water in small communities. This study explores the potential added benefits of using a WSP in fourteen small water supply systems to increase community knowledge of the hazards present in their water supply systems.

A survey-based hazard identification tool was developed and tested in fourteen water supply systems with varying source waters, treatment processes (chlorination, membrane filtration, etc.) and community type (indigenous communities and municipal communities). This study demonstrated the prevalence of specific hazards across all communities but also revealed the diversity of hazards and issues present in individual communities. As opposed to water quality testing, the WSP shows how operational and maintenance concerns also play a role in the management of these water supply systems. Visualization and presentation of risk obtained from a WSP was also examined to determine the best ways to communicate risk to all of the stakeholders within a water supply system. This allows regulators and water operators to better prioritize and management needed improvements in their water supply systems.

### Evaluation of Hydrodynamic Cavitation on Oxidation Technology Performance for Drinking Water Treatment

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As the utilization of hydrodynamic cavitation is substantially increased in various applications of the water treatment. The hydrodynamic cavitation could be considered an advanced oxidation process (AOP) device. The hydrodynamic cavitation with constant pressure gradient, flow velocity, and constant cavitation number might have a significant impact to treat emerging contaminants, such as perfluorooctanesulfonate (PFOS) and perfluorooctanoic acid (PFOA), to decay bacterial contaminants such as total coliform, E. coli, and L. pneumophila. The hydrodynamic cavitation's ability to generate locally high temperature (higher than 5000 K) and produce hydroxyl radicals by homolytic cleavage of water might allow for the treatment of cyanobacterial blooms, algal blooms, and/or organic pollutants. This might be worthy of future investigation.

### Computational Investigations of the Adsorption of Humic Acid on Functionalized Carbon Nanotube

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This study examines the adsorption of humic acid (HA) on carbon nanotube (CNT) using molecular dynamics simulations. CNT surface is functionalized with -OH, -NH2, -COOH, or -COO groups to investigate the effect of functionalities on HA adsorption. Moreover, the influences of solution pH, ionic strength, as well as the presence of calcium ion are also studied. The simulation results show that at acidic condition HA molecules are rapidly absorbed on pristine as well as functionalized CNT separately. HA molecules have a high mobility on pristine CNT and finally aggregate together on CNT surface, while they are almost fixed on functionalized CNT. VDW interaction is the main driving force for HA adsorption at acidic condition, and the interaction energy for HA and CNT is in the sequence: CNT-COOH > CNT-OH ≈ CNT-NH2 > pristine CNT. At neutral condition, there are no HA molecules absorbed on CNT-COO- surface, but electrostatic interaction between HA and other functionalized CNTs becomes more important. The HA-CNT interaction energy is in the sequence of CNT-OH > CNT-NH2 > pristine CNT. Interestingly, our modeling results show that changing the ion strength have limited effect on HA adsorption. The presence of Ca ions can improve HA adsorption on CNT-COO- surface by forming association with -COO- groups, as well as increase HA aggregation by acting a bridge to bind -COO- groups of HA molecules, and the latter effect is more significant. These results are important for estimating and optimizing the removal of organic substances by the use of carbon nanomaterials.

### Pilot-Scale Lab-Based Investigation of Water Quality in Intermittent Water Supply

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One billion people globally receive piped water for less than 24 hours a day in what is referred to as intermittent water supply (IWS). IWS poses a risk to public health because the nature of intermittency allows for increased microbial regrowth and contamination from the surrounding environment. There are still many gaps in our understanding of IWS and a question we would like to answer is if the present literature on stagnation in continuous household water supply can be linked to phenomena in IWS. Increased knowledge on IWS will allow us to better understand the methods of contamination in these systems and allow us to begin to develop solutions to minimize contamination and improve public health.

For this study of IWS, we designed and constructed two identical pipeloops, 22-foot closed loops of 2-inch diameter PVC, for the simulation of full-scale distribution systems. One pipe loop serves as a continuous control while the other operates intermittently. Both circulate municipal tap water. Each pipeloop has a set of biofilm sampling coupons installed, as distribution system biofilms can be a source of contamination in drinking water systems. The analysis being presented as part of this research are effects of intermittency on chlorine residual, turbidity, HPC, and ATP as compared to a continuously operated system. Biofilms from the pipeloops with undergo microscopy analysis which will include coverage, thickness, density, and tomography of the biofilms. The results of this study will guide the direction of future research that aims to understand the mechanisms influencing IWS water quality

### Epoxide Chemistry: Pushing Aside Polyamide?

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TFC-membranes dominate the current nanofiltration (NF) and reverse osmosis market for water treatment and desalination. However, their applicability in more aggressive feeds (extreme pH, hypochlorite, solvents) is limited due to their limited chemical robustness. Provided the enormous growth potential of membrane technology in these industries, there is an ongoing quest to obtain solvent-, pH- and chlorine-stable (TFC) membranes, which are additionally performing well in terms of rejection and permeance.

To comply with this demand, we successfully converted the well-known monophasic bulk epoxide polymerization (commonly used in e.g. the automotive and coating industry), into the synthesis of thin, yet cross-linked top-layers via interfacial polymerization. Nanofiltration membranes with >90% Rose Bengal and 70% Methyl Orange rejection with water permeances above 2 L/m²hbar were achieved in the proof-of-concept study. Optimization studies already resulted in permeances of 25 L/m²hbar without compromising RB rejection. Additionally, the homopolymerization of the epoxy monomer results in a network of chemically stable polyether chains. As a consequence, unchanged membrane performance after immersion in oxidizing and acidic environments was achieved.

The correlations between IR, PALS, SEM and performance results further demonstrate the feasibility of this innovative membrane synthesis technique.

The plethora of available epoxy monomers, reaction initiators and catalysts ensure high tunability in terms of final membrane performance, morphology and synthesis time. We therefore believe that this novel interfacial polymerisation chemistry may lay the foundation for a new generation of exceptionally stable (solvent resistant) NF TFC-membranes, opening immense possibilities with respect to chemical cleaning and novel membrane applications.

### Measuring the Inactivation and Removal Effectiveness of Oxidants on Biofilms in Premise Plumbing

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The inactivation and removal effectiveness of biofilms has been an issue in premise plumbing for many years. While these biofilms are not always harmful, they can harbor opportunistic pathogens that pose a public health risk such as *Mycobacterium avium*, *Legionella pneumophila*, and *Pseudomonas aeruginosa*. These biofilms can be unique to the premise plumbing system and have been shown to grow under oligotrophic conditions and many demonstrate resistance to standard chlorine disinfection. As biofilms develop within certain areas of premise plumbing, mass transfer resistance and disinfection ineffectiveness increase the difficulty in controlling these biofilms. This project aims to measure the effectiveness of various oxidants and treatment scenarios on the inactivation and removal of biofilms.

*P. Aeruginosa* (ATCC 15442), a biofilm forming bacteria commonly used in the water treatment/distribution industry to study biofilms in premise plumbing, was used to develop steady-state biofilms in a low alkalinity, low carbon drinking water. The steady-state biofilms were established in two parallel annular reactor systems (Test and Control). The test and control biofilms were treated with different disinfection scenarios, including changes in pre/post low dose oxidation, high dose oxidation, sequential oxidation with multiple oxidants, and exposure to oxidants for different contact times. Result from a set of studies will be presented that demonstrate the effectiveness of specific disinfection variables (ie. pre/post treatment, oxidant dose, contact time, type(s) of disinfectant, etc.) on biofilm inactivation, removal, and regrowth.

### Control Effect of Peracetic Acid on Disinfection By-product Formation from Chlorination and the Application of PAA as Pre-oxidant in Drinking Water Treatment

Sophie Sun*, David Reckhow, John Tobiason
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Chlorine is a widely used disinfectant for drinking water treatment in the US. Chlorination is efficient and economic friendly yet there are problems including bad taste of treated drinking water and formation of disinfection byproducts which may cause cancer. Alternative disinfection methods including ozone, chlorine dioxide and UV light have been studied. They are not applied in treatment because of costly generation process or no residual problem.

Peracetic acid (PAA), an easy-to-operate and economic friendly oxidant, has been applied as an alternative disinfectant of chlorine in wastewater treatment. However, the study and application of PAA in drinking water treatment is limited. In this study, PAA disinfection ability and control effect of DBP formation from chlorination in drinking water treatment was proved. Different PAA operation scenarios were tested: disinfection in dark under 20 C with contact times up to 72 hours, decay under direct sunlight up to 18 hours and decay in dark under 20C with short contact times. Best DBP control effect was observed in the 72-hour PAA pre-disinfection test. However, it was not an ideal operation condition in real water treatment procedures for water treatment plants. Direct sunlight accelerated the process but it ended up with poor DBP control efficiency. Among the scenarios tested in this study, the optimum disinfection condition for PAA was 2 hours PAA pre-disinfection in dark under 20C.

### Removal of Silica Using Magnetic $Al(OH)_3@Fe_3O_4$ Nanomaterials: Measurements, Adsorption Mechanisms, and Implications for Silica Scaling in Reverse Osmosis

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Composite magnetic aluminum hydroxide at iron oxide nanomaterials, $Al(OH)_3@Fe_3O_4$, with a well-defined core-shell structure, were used as pretreatment adsorbents for the removal of silica in brackish water. The $Al(OH)_3$ outer shell confers silica adsorption capacity and the superparamagnetic $Fe_3O_4$ core allows material separation and magnetic recovery. The as-prepared nanomaterials (2 g L–1) remove ~95% and ~80% silica from Si-rich solutions with 0.5 and 2 mM initial silica concentrations, respectively. Regeneration under basic conditions was evaluated, and post-adsorption treatment with 0.05 M NaOH yielded optimal material reusability. After four regeneration cycles, the $Al(OH)_3@Fe_3O_4$ nanomaterials retain their magnetic property while still being able to remove ~40% silica from solutions at an adsorbent concentration of 2 g L–1. The mechanism of silica adsorption onto the surface of the nanomaterials was probed using several spectroscopic techniques. ATR-FTIR integrated with two-dimensional correlation analysis shows that silica species vary from Q2 to Q4 with adsorption time corresponding to silica polymerization. 29Si solid-state NMR spectra show an upfield chemical shift displacement of the Q2 signal, which indicates the formation of Q4 units, suggesting silica polymerization onto the $Al(OH)_3$ shell. In addition, a lab-scale reverse osmosis (RO) setup was used to evaluate $Al(OH)_3@Fe_3O_4$ as pre-treatment materials for silica removal. Results show that silica scaling was significantly alleviated and water recovery was enhanced when feedwaters were pre-treated with the magnetic nanomaterials. Taken together, our study highlights the promise of magnetic $Al(OH)_3@Fe_3O_4$ nanomaterials in treating brackish water and achieving higher water recovery for inland desalination.

### Interaction Analysis Between Gravity-Driven Ceramic Membrane and Smaller Organic Matter: Implications for Retention and Fouling Mechanism in Ultra-Low Pressure-Driven Filtration System

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Gravity-driven membranes (GDM) generally achieve high retention performance in filtration of organic matter with smaller size than membrane pore, yet the in-depth mechanism remains unclear. Thorough analysis of the retention mechanism is crucial for optimizing GDM property and improving GDM filtration performance. Performance and interaction mechanism of gravity-driven ceramic membrane (GDCM) filtrating smaller organic matter (SOM) were systematically studied. Rejection rate grew noticeably for like-charged foulant, while slightly for opposite-charged foulant as operation height decreased. Flux declined more seriously at lower operation height probably due to heavier cake fouling caused by the more rejected foulant. Interactions of ceramic membrane-SOM were analyzed through Extended Derjaguin-Landau-Verwey-Overbeek theory (XDLVO) and hydrodynamic permeation drag (PD). Among van der Waals (LW), acid-base (AB) and electrostatic (EL) forces in XDLVO, EL played a significant role on GDCM filtrating SOM and altering membrane electrostatic property could greatly influence SOM filtration. Furthermore, the rising PD force largely weakened EL dominant zone with operation height increasing, while barely influenced LW and AB dominant zones. Therefore, the weakened EL-dominant repulsive zone caused less rejection of like-charged foulant with operation height increasing. Fe2O3 and MnO2 modified membranes further validated comprehensive influence of LW, AB, EL and PD interactions on GDCM filtration. The possible "trade-off" of pore blocking-cake fouling with operation height decreasing demonstrated potential enhancement for both rejection and antifouling performance by electrically modified membrane under ultra-low pressure. This study would provide insight on membrane selection/preparation/modification and performance control of ultra-low pressure-driven filtration.

### Using Standardized Protocol for Evaluating Ceramic Water Filters Impregnated with Silver Nanoparticles

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The World Health Organization recognized point-of-use (POU) water treatment as an appropriate alternative for those lacking access to safe drinking water in developing communities. Ceramic water filters (CWFs) have been used as POU water treatment systems in developing countries around the world. Quality control techniques are severely lacking at the factory level for CWFs, which can vary widely in quality. The objective of this study was to evaluate the use of a standard EPA protocol in the quality control testing of CWFs produced by Potters without Borders, a Canadian nonprofit. Influent water chemistry and quality play an important role in this study as filter performance is evaluated based on flow rate, effluent turbidity, bacteria (E. coli K12) reduction, and silver release (in nanoparticulate or ionic form). The CWFs were characterized using X ray photoelectron spectroscopy, mercury intrusion porosimetry, and X ray diffraction in order to study the mechanisms involved in ceramic water filtration. The protocol employed in this experiment was an improvement over those used in past studies because it is relatively short and provides results useful at the factory level. The standardization of quality control techniques at CWF factories would allow comparisons between filters manufactured at different locations to highlight variables that affect filter performance. In this study, we remove water chemistry as a potential variable in the quality control of CWFs. The EPA protocol demonstrated its utility as a potential quality control technique at the factory level and a method of promoting consistency in the study of CWFs.

## *Posters:*

### Modified Carbon Cathodes for H2O2 Production Via Two Electron Reduction Reaction Under Plug Flow Reactor

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Highly efficient hydrogen peroxide ($H_2O_2$) electrogeneration is required in electro-Fenton process for treatment of refractory pollutants. A cost-effective strategy was developed by combining column reactor with polytetrafluoroethylene (PTFE) modified graphite felt cathode. In this design, anodic oxygen can be directly used for efficient H2O2 generation at the modified cathode. Experiment result showed that modified cathode can produce about 29.6 mg/L, at the optimum PTFE volume of 0.5 mL, which is 16 times higher than the unmodified graphite felt under flow condition (3 mL/min). The maximum H2O2 production, up to 30.7 mg/L, was obtained at 120 mA 3 mL/ min at initial pH 13 without external aeration.

### Novel System Designs for the Application of Electrodialysis to Desalination of Brackish Groundwater in India

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The goal of this research is to design a high recovery Electrodialysis (ED) desalination system that is competitive with existing reverse osmosis (RO) products on cost, power consumption and production performance for domestic use in urban India. The primary source of drinking water in India is groundwater however this water supply is scarce and a majority of it is brackish (with a salinity between 500 and 2000 mg/L TDS). The desalination system

we are developing aims to significantly reduce water wastage by using ED instead of RO (down to 25% from 75% of the feed water rejected as brine). This work discusses the methods by which we have been able to maintain the system as cost competitive to RO and presents the results of recent field trials in Bangalore, India. Emerging markets such as India provide additional design parameters when implementing water purification due to resource constraints such as high perceptibility to capital cost and unstable water sources. Novel continuous water flow path profiles and responsive sensing have been implemented in the system that have enabled cost and size reduction in the system by leveraging the ability to tune desalination rates and times via the electrical parameters the drive ED desalination.

### Enhanced Adsorptive and Oxidative Removal of Perfluorooctanoic Acid (PFOA) Over Activated Carbon

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Perfluorooctanoic acid (PFOA) is an important member of per/polyfluoroalkyl substance (PFAS) family, which has been recently detected in river waters worldwide and is difficult to be treated by most conventional methods. Recently, it has attracted significant attention due to the worldwide distribution, environmental persistence and bioaccumulation potential. In this study, the synergistic effect of enhanced adsorption of PFOA over activated carbon and subsequent hydrothermal- activated persulfate oxidation are systematically investigated. The results indicate that fresh activated carbon shows excellent adsorption capacity for PFOA (about 99%), but saturated activated carbon has a lower PFOA removal efficiency at 25°C since the active sites of the material surface are almost occupied. Then the spent activated carbon is effectively regenerated by persulfate oxidation at 60°C. More specifically, through the regeneration method, the adsorbed PFOA on activated carbon surface is degraded by sulfate free radicals ($SO4\bullet^{-}$), making the sorption sites available. As a result, the removal and defluorination rates of PFOA are high with the combined activated carbon and persulfate in this system. The activated carbon can be used with efficient adsorption performance of PFOA in even six cycles. This work provides a new insight into PFOA removal over activated carbon and favors its application in actual water treatment.

### Bench-scale Approach to Investigate the Accumulation and Growth of Legionella pneumophila in Corrosive Environments

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Legionella pneumophila (L. pneumophila) is a waterborne opportunistic pathogen that causes Legionnaires' disease (LD), which is an acute pneumonia[1]. A serious LD outbreak occurred in Flint, Michigan, during 2014 and 2015, which resulted in 87 reported illnesses and 11 deaths[2]. Biofilms in drinking water distribution systems (DWDS) can harbor L. pneumophila, which are resistant to common disinfectant residuals. Most DWDS use cast iron piping, which consume chlorine (a frequently used disinfectant) and create a rough corrosion scale on the inner walls, allowing thick biofilm to develop, potentially increasing the chances of L. pneumophila growth. Many previous studies that have investigated the relationship between biofilm growth and disinfectant residuals used non-corrosive, smooth surfaces such as PVC to simulate DWDS. The goal of this study is to investigate the accumulation of L. pneumophila in biofilms that have developed on corroded cast iron surfaces that were exposed to a variety of combinations of disinfectant residuals and corrosion inhibitors. The proposed study will examine L. pneumophila accumulation and growth in flow-through reactors containing a mixed microbial biofilm on corroded cast iron coupons. Biofilms will be investigated using DNA extraction, x-ray powder diffraction (XRD) analysis and quantitative polymerase-chain-reaction (qPCR) techniques. The results of this study will help to build a knowledge base of recommended disinfectant residuals and corrosion inhibitors for DWDS based on their particular piping materials.

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[2]Shen, Y., Huang, C., Lin, J., Wu, W., Ashbolt, N. J., Liu, W. T., Nguyen, T. H. (2017). Effect of disinfectant exposure on Legionella pneumophila associated with simulated drinking water biofilms: release, inactivation, and infectivity. Environmental Science & Technology, 51, 2087-2095.

### Determining Optimal Sources of Water for a Household in Mexico City

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Intermittent water supply (IWS) prompts many residents in Mexico City to turn to water sources other than the city-supplied pipe network to meet their needs, such as water trucks and rainwater. I modeled household water decisions using Radial Basis Function (RBFs). Household water purchases for 12 years were simulated at a daily time-step with RBF-based decisions made each day. The model was optimized by altering decision variables of RBF parameters and storage tank volume in order to minimize cost and maximize reliability of water deliveries. The model was run for varying IWS schedules and rainwater harvesting investments. Results show that the optimal household water portfolio is to purchase a large enough storage tank so that all water needs can be met from rainwater harvesting and the city-supplied water system. Water costs between continuous-supplied water systems and these intermittent-supplied systems are similar, since the only additional cost is the investment in a larger storage tank. Water truck purchases are only recommended if the total volume of water supplied by the city is insufficient to meet a household's weekly needs regardless of their storage capacity. Under these extremely low-supply scenarios, water costs are significantly higher since trucked water has a much higher per-liter cost than city water. Rainwater harvesting systems are shown to be a good investment, even when city water is available continuously. The model is currently designed for one delegation of the city but can be easily modified to model other areas.

### Private Lead Service Line Replacement Effects on Water Quality: A Case Study

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Dissolved lead in drinking water is toxic to human health and a contaminant of concern for older distribution systems and indoor plumbing containing lead pipes. Many utilities are replacing water mains throughout their systems; however, service lines connecting public mains to private houses are the financial responsibility of the homeowner. This study is a case-study of a 1920's home in Edgewood, RI serviced by Providence Water and examines the tap water quality before and after a private lead service line replacement with a copper pipe. The utility owned street water main was previously replaced. Providence Water provides treated drinking water to Providence Rhode Island and surrounding communities and the utility manages approximately 1,040 miles of water mains. Providence Water also uses lead control strategies to limit the amount of lead in drinking water. Consecutive samples from a kitchen tap were tested after 8 hours of stagnation for lead, copper, and iron by ICPMS methods and temperature, pH, conductivity, and free chlorine were tested using Hach colorimetric methods. Data before replacement show that copper and iron concentrations were very low, and lead concentrations were elevated in the water volumes originating from the lead service pipe. Lead levels ranged from 4.9 – 29.8 ppb and the maximum contaminant level is 15 ppb. Results after replacement show that lead, copper, and iron levels remained low after pipe replacement. The study illustrates the importance of private lead service line replacement for reducing the risk of drinking water lead exposure.

### Finding Optimal Conditions for Filtration in Use of Water Treatment

Victoria Adams-Forne*, Isaac Reyes, Anna Pauls
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Jar testing is used to test experimental conditions on a small scale. Conditional variables are adjusted and tested in a small time period to later be applied to a larger scale experiment. For this specific project, the coagulants aluminum sulfate hydrate (ASH) and aluminum chlorohydrate (ACH) were used to test several scenarios; to observe if the coagulants ASH and ACH are comparable, and how they react with electrochemically produced peroxide versus commercially produced peroxide. The objective was to test ASH and ACH under different conditions involving control of pH using caustic and citric acid and the addition of two types of peroxide. ACH is produced with caustic and ASH is produced without caustic. By adding caustic to ASH, the two coagulant's performance was assessed. The results indicated they are similar, so when applied to commercial use, we could recommend the most energy and cost-effective option. Further testing includes assessing which coagulant reacted best with peroxide and later, which reacted best with the electrochemically produced peroxide.

### Impacts of Climate Change on Drinking Water Treatment Process: Story of Unusual High Haloacetic Acid Concentrations in Massachusetts Drinking Waters

Xian Ma*, David Reckhow
*University of Massachusetts Amherst, Amherst, MA*

This research collected about 60,000 HAA datasets from public drinking water facilities in Massachusetts that use surface water as the water source (1999 - ). The relationship between HAA concentrations and time, rainfalls, or locations were studied. As an example, Figure 1, showed data from one community in MA where the HAA concentration showed an increasing trend since 2014. Similar trends were found in most communities across the state and studies reveal a positive relationship between rainfalls and HAA concentrations. The second part of the research included bench-scale experiments on freshly collected surface water samples during rain events. Each was treated in the laboratory to test the level of HAA precursors. Results indicated that rainfall events increase the level of HAA precursors as compared to other organic parameters. On average the HAA precursor concentrations returned to baseline levels in about 96 hours after the end of the rainfall event.
Based on this work, we conclude that climate changes are likely to contribute to increases in HAA formation in drinking water systems in Massachusetts

### Assessing the Seasonal Variation in Disinfection Byproduct Formation for Algal Impacted Surface Waters

Zachary Kralles*, Kaoru Ikuma, Ning Dai
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Algal organic matter (AOM) has been shown to contribute to the formation of disinfection byproducts (DBPs). However, most studies focused exclusively on AOM derived from laboratory cultures. This study used field samples from algal-impacted surface waters to assess the relationship between DBP formation potential and algal activities. The samples were collected over a thirteen-week period and subject to uniform formation condition test in the laboratory. The formation of 4 trihalomethanes (THMs), 4 haloacetonitriles (HANs), trichloronitromethane (TCNM), and 2 haloketones (HKs) were monitored. THMs formed at higher concentrations than all other classes of DBPS, 1.3 - 15 times greater than HANs and 11 - 486 times greater than TCNM. When taking into consideration the relative toxicity of DBPs, HANs contributed 14 - 174 times more to the overall cytotoxicity of the water, than did THMs. Total chlorophyll, the most common indicator of algal blooms, did not correlate with the formation of any of the four classes of DBPs suggesting that both AOM and background organic matter can play a role in DBP formation. Among the other water quality parameters monitored, SUVA correlated well with THMs, TCNM, and HKs, but not HAN; nitrite concentration correlated with the formation of TCNM.

## *C. Wastewater Treatment*


### *Summary:*

At NEGSWS 2019, there was a variety of research on macroscale and microscale wastewater treatment. More and more, we are seeing research not only on improving conventional wastewater treatment and enhanced nutrient removal but also treatments of industrial and septic waste streams, with emerging contaminants such as perfluorinated compounds, and pharmaceutical and personal care products. There is increased interest in characterization of organic and inorganic fractions of these concerning chemicals. These efforts aim to better preserve our water resources through improving discharged wastewater (grey water, runoff, domestic and industrial wastes, etc.) quality and enhanced resource recovery of wastewater.

Research on wastewater presented at the conference highlights the need for more cost-effective and eco-friendly methods of treating contaminants and recovering resources. Researchers were able to present methods to improve conventional wastewater treatment with processes that decrease environmental footprints such as higher flow rate reactors, lower chemical demanding activated sludge processes, renewable resources (such as sunlight) utilizing processes, and more resilient liquid-solid separation techniques.

Researchers also placed an emphasis on better identification and monitoring of concerning micro and nano-contaminants for more effective removal. This emphasis played out in the form of clever modeling and measuring techniques. Novel sensors and probes were developed along with clever use of existing technology to identify and quantify the compounds of concern. Development and incorporation of molecular biology techniques in wastewater treatment also enhanced efforts to identify and quantify said compounds. These findings contribute to our continuous efforts to decrease environmental footprints, and improve the overall sustainability of treatment processes.


*“There is no away”* – John E. Tobiason

## *Presentations:*

### Piloting the Anaerobic Side-Stream Reactor Treatment Process to Reduce Waste Activated Sludge Production

Andrew Keyser*, Chul Park
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The activated sludge process is used throughout the United States to treat municipal wastewater. A major cost of operation is associated with the handling and disposal of waste activated sludge (WAS). The means of disposal in New England are becoming more expensive and less abundant as landfills reach capacity and incinerators face stricter emissions standards, leading to waste sludge being transported further, increasing the environmental impact of wastewater treatment. The anaerobic side-stream reactor (ASSR) process was developed at the University of Massachusetts at Amherst to minimize the quantity of WAS produced by common wastewater treatment processes. The process utilizes a relatively small, high-rate anaerobic reactor (1.5-2 Day HRT) for WAS to undergo hydrolysis reactions that do not occur in aerobic digestion, then return the WAS to aeration for further degradation. A pilot of the ASSR process was constructed at a local wastewater treatment plant to better understand how the process could be employed and operated at the full-scale through simple retrofits of existing infrastructure. The pilot was built and operated to scale of full-scale system to compare the two systems treating the same primary effluent. The pilot showed a sludge yield of 0.15 grams Volatile Suspended Solids per gram Chemical Oxygen Demand, a 50% decrease in sludge production compared to the full-scale. Sludge settleability was similar between systems, with the pilot consistently meeting permit requirements, with an average Chemical Oxygen Demand of 29.9 mg/l, 10.9 mg/l Total Suspended Solids, and pH between 6.5 and 7.5.

### Real-Time In-Situ Monitoring of Ultra-Low Pb(II) Pollutant in Wastewater Treatment Process Using Wireless, Solid-State, pH Auto-Compensation, and Ion-Selective Membrane Sensors

Yingzheng Fan, Baikun Li
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Pb(II) is easily and promptly bound with complex microorganic molecules, and reduces the microbial bioactivity and deteriorates wastewater treatment efficiency. In this study, innovative mm-sized sensors with Pb(II) solid-state ion-selective membrane (S-ISM) using screen-printed electrodes (SPEs) were developed to tackle the critical challenge of Pb(II) monitoring in water and wastewater. The developed Pb(II) S-ISM sensors capable of real-time in situ monitoring ultra-low Pb(II) concentration (15 ppb - 960 ppb) at low-cost, simple instruments, high accuracy and selectivity. The breakthrough of this study was to explore the principle of pH influence on Pb(II) S-ISM sensors and develop a novel compounds, beta blocker pharmaceuticals are frequently detected at the ng/L to low mg/L level downstream of WRRFs.

Existing research has explored the biological treatment component of WRRFs and the biotransformation of these PhACs. The objective of this research began as an effort to elucidate the microbial processes and biotransformation mechanisms that contribute to the removal of beta blockers. The focus of this research aims to explore the cometabolism of these PhACs by ammonia oxidizing bacteria (AOB) that is attributed to the broad substrate range of the enzyme ammonia monooxygenase. Previous related research has explored this in the context of AOB-enriched activated sludge; this research explores cometabolism in the context of mixed-culture communities from WRRFs operated under variable operating conditions. Batch experiments were performed on three individual beta blockers with activated sludge from two WRRFs. The results of the experiments were interpreted within the context of the cometabolic process-based model which was used to develop coefficients specific to the context of mixed culture communities where AOB typically comprise a small fraction of the community.

## A Sustainable and Cost-Effective Method of Nutrient Recycling from Wastewaters Using a Pressurized System

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Current commercial fertilizers are both reliant on nonrenewable resources to be manufactured, and responsible for high amounts of nutrient pollution in waterways since the bulk of the nutrient is often carried into nearby rivers during precipitation events. At the same time, nowadays post-treatment wastewater that is sent back into water bodies still contains a concerning level of nutrients.
This research proposes a process that creates a fertilizer out of wastewater, which is high in nitrogen and phosphorous and otherwise contributes to nutrient pollution in waterways. By adding a Mg source to wastewater, Magnesium-Ammonium-Phosphate (MAP) mineral precipitates out of the water that has a high nutrient content and releases nutrients slowly, making it a more environmentally friendly replacement for commercial fertilizers. The most common magnesium source used to create MAP has been MgCl2, which is highly soluble in water but very expensive. This research thus focuses on decreasing the price of MAP production by directly using naturally occurring magnesium sources such as $MgCO_3$ and MgO, with a focus on finding ways to make these compounds soluble in water. Our research proposed a pressurized system to achieve the goal in a cost-effective fashion, where insoluble Magnesium source is dissolved into water under high-pressure environment created by excess Carbon Dioxide. In this process, insoluble Magnesium sources are mixed with wastewater and pressurized to high pressure with $CO_2$. The pressure is then released while ions still remain in a metastable stage for a short period of time and combine to be MAP crystals.

## Locating Denitrifying Bacteria in Soil Profiles of Soil Treatment Areas

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Onsite wastewater treatment systems (OWTS) are used to treat domestic wastewater production in nearly 25% of homes in the United States. However, OWTS can also be a significant contributor to nitrogen (N) pollution to ground and coastal waters. Too much N in the water can lead to eutrophication of habitats, as well as methemoglobinemia (blue baby syndrome). To combat this, microbial soil communities are utilized to reduce the amount of nitrate entering the water, and increasing the amount of nitrogen gas released back into the atmosphere. In this experiment we aimed to identify where these processes were taking place in the wastewater collection tank and the pump basin. To do so we painted PVC rods with birnessite (manganese oxide) paint and inserted them vertically into the collection chamber and the pump basin. After seven days we removed the PVC rods from the system. Then, we determined amount of manganese oxide that was removed from the rods. Due to the fact that manganese oxide is reduced under similar conditions as nitrate, the birnessite paint is a good indicator of the location of denitrification in the soil. If the process is successful in determining denitrification in the system, then it will be an inexpensive and easily accessible tool for professionals to analyze nitrogen removal.

## Identification and Quantification of Inorganic Nanoparticles in Wastewater

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Engineered nanoparticles have become increasingly more common in consumer products and industrial processes. This increasing use has resulted in an inevitable increase in the presence and concentrations of inorganic nanoparticles in wastewater streams. Due to the potential environmental impacts of these nanoparticles, it is important to understand the occurrence, fate and transport of inorganic nanoparticles in wastewater sources, and in wastewater treatment plants (WWTP).

The objectives of this research are:
1) To develop techniques to identify, quantify, and characterize inorganic nanoparticles in wastewater; and
2) To investigate the presence of inorganic nanoparticles in a local WWTP in influent and effluent streams.

Wastewater samples were collected over monthly, weekly and hourly time-scales within a local wastewater treatment facility. Experimental protocols were developed for nanoparticule extraction and concentration from the wastewater samples, and procedures established for particle analysis using single particle inductively coupled plasma – mass spectrometry (ICP-MS), Transmission Electron Microscopy (TEM), Dynamic Light Scattering (DLS), and other instruments. Results indicate the presence of significant quantities of inorganic particulate material in wastewater sources, with differing levels of removal in WWTPs. Further research is ongoing.

### Pharmaceutical Biotransformation by Nitrifying Activated Sludge

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There is an increasing concern of pharmaceutically active compounds (PhACs) in the natural environment as studies have detected the presence of an array of PhACs downstream of water resource recovery facilities (WRRFs) and have attributed these facilities as a point source for injection into the environment. Much of the research has emphasized PhACs that act as endocrine disruptors that impact development, reproduction, metabolism, growth, and cardiovascular functions of aquatic species. Of these compounds, beta blocker pharmaceuticals are frequently detected at the ng/L to low mg/L level downstream of WRRFs

Existing research has explored the biological treatment component of WRRFs and the biotransformation of these PhACs. The objective of this research began as an effort to elucidate the microbial processes and biotransformation mechanisms that contribute to the removal of beta blockers. The focus of this research aims to explore the cometabolism of these PhACs by ammonia oxidizing bacteria (AOB) that is attributed to the broad substrate range of the enzyme ammonia monooxygenase. Previous related research has explored this in the context of AOB-enriched activated sludge; this research explores cometabolism in the context of mixed-culture communities from WRRFs operated under variable operating conditions. Batch experiments were performed on three individual beta blockers with activated sludge from two WRRFs. The results of the experiments were interpreted within the context of the cometabolic process-based model which was used to develop coefficients specific to the context of mixed culture communities where AOB typically comprise a small fraction of the community.

### Thin Film Composite Membrane Compaction in High-Pressure Reverse Osmosis

Douglas Davenport*, Cody Ritt, Rhea Verbeke, Menachem Elimelech
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Water scarcity, expected to become more widespread in the coming years, demands renewed attention to freshwater protection and management. Critical to this effort are the minimization of freshwater withdrawals and elimination of wastewater discharge, both of which can be achieved via zero liquid discharge (ZLD), an aggressive wastewater management approach. High-pressure reverse osmosis (HPRO) (i.e., reverse osmosis operated at a hydraulic pressure greater than ~100 bar) offers great promise to efficiently desalinate hypersaline brines. However, currently available membrane materials are limited to applied hydraulic pressure of 70 bar and are thus unsuitable for HPRO. The primary limitation of membrane materials is the severe decrease in water permeability as a result of membrane deformation, often termed compaction. This performance-limiting phenomenon is widely observed but remains poorly understood.

In this work, we elucidate the fundamental mechanisms of thin film composite (TFC) membrane compaction. We first describe the compaction behavior of commercially available membrane materials at conventional RO and HPRO pressures up to 150 bar. We then highlight the impact of compaction on both the support layer and selective layer of TFC membrane. Importantly, we explain the unique impact of compaction in each layer to influence overall membrane transport. TFC membranes were also synthesized in order to observe morphological changes to each membrane layer before and after compaction. We evaluate these results to identify the specific characteristics which lead to a severe decline in water permeability. In doing so, we also provide a roadmap to design novel compaction-resistant membranes suitable for HPRO applications.

**Peering Below the Ground Surface: Ground-Penetrating Radar and Long-Term Monitoring Wells Suggest Coastal Septic Systems Are Threatened by Elevated Groundwater Tables**

Alissa Cox*, Deborah Surabian, Jim Turenne, George Loomis, Jose Amador
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Many coastal communities along the eastern seaboard rely on individual septic systems to treat and disperse household wastewater. Proper wastewater treatment in these systems depends on an adequate volume of unsaturated soil below the drainfield's infiltrative surface. Separation distance, defined as the distance between the groundwater table and the infiltrative surface, is specified in onsite wastewater system regulations for systems in Rhode Island's coastal areas to ensure that there is sufficient unsaturated soil to treat wastewater. Groundwater tables along the southern New England coast are rising, raising questions about whether current in-place systems are becoming compromised. By combining long-term shallow groundwater monitoring wells and ground-penetrating radar (GPR) surveys of 10 coastal drainfields in southern Rhode Island, we investigated whether systems currently have adequate separation distance below the drainfield. We hypothesized that older systems would be compromised to greater extents than more recently installed systems. Our results indicate that only 20% of the systems are not impaired by elevated groundwater tables, while 40% of the systems are experiencing compromised separation distance at least 50% of the time. Additionally, 30% of the systems in this study do not meet separation distance requirements at any time of the year. Age of system does not appear to be correlated with compromised separation distance. More research is required to understand whether these findings are representative for systems along the southern New England coast, but the results suggest that changes in the permitting process for coastal systems might be in order to protect coastal drinking and surface water resources.

**Assessing Nitrogen Inputs to the Charlestown Coastal Watershed from Advanced Onsite Wastewater Treatment Systems**

Bianca Ross*, Jose Amador, George Loomis
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Wastewater from onsite wastewater treatment systems (OWTS) can serve as a source of nitrogen (N) to coastal watersheds. Because excessive N loads can cause eutrophication in coastal ecosystems, advanced OWTS technologies have been used to mitigate their impact on these ecosystems by reducing N inputs. Advanced N-removal OWTS can facilitate the processes of nitrification and denitrification before the effluent is applied to the soil treatment area and percolates to the groundwater. In this study, we selected 50 advanced N-removal OWTS in Charlestown, Rhode Island to determine the capacity of six different N-removal OWTS technologies (Orenco Advantex AX20, Orenco Advantex RX30, BioMicrobics MicroFAST, and Norweco Singulair Models TNT, 960, and DN) to meet the Rhode Island Dept. of Environmental Management's standard for final effluent total N concentration of 19 mg/L or less. Twenty-four of the systems are for houses occupied year-round, while 26 are for seasonally-occupied houses. The year-round systems are sampled quarterly and the seasonal systems are sampled four times over the summer occupancy period. For all systems, field measurements are made of effluent pH, temperature, and concentration of dissolved oxygen (DO), ammonium (NH4+), and nitrate (NO3-) in the final effluent. Final effluent is also analyzed in the laboratory for pH, alkalinity, biochemical oxygen demand, NH4+, NO3-, and total N. These data will allow us to quantify the rate of compliance with state effluent standards as a function of technology, seasonality/temperature, and home occupancy pattern, and help identify conditions that may be adjusted within each technology to optimize N-removal treatment performance.

**Formation of Low-Molecular-Weight Dissolved Organic Nitrogen in Full-Scale Wastewater Treatment Plants**

Andrew Keyser*, Chul Park
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Coastal waterways and estuaries are being negatively affected by algal blooms and eutrophication. Coastal ecosystems are primarily limited by nitrogen, a common contaminant found in wastewater treatment plant (WWTP) effluents and agricultural runoff. WWTP's have successfully reduced nitrogen loads to receiving waters through a variety of biological nutrient removal (BNR) processes. The most common processes employ "pre-denitrification",

utilizing organic substrate in an anoxic environment to support heterotrophic denitrification. The Ludzack-Ettinger (LE) and Modified Ludzack-Ettinger (MLE) processes are common applications of the pre-denitrification nitrogen removal strategy. However, the LE and MLE processes have been found to produce and accumulate dissolved organic nitrogen (DON), specifically in the low-molecular-weight (LMW-DON) fraction (<1kDa). This LMW-DON has shown a strong stimulatory effect on algal growth in laboratory bioassays and may have the potential to alter the algae community composition. A survey of 11 full-scale WWTP effluents found facilities employing BNR strategies for nitrogen removal produce higher concentrations of LMW-DON than conventional activated sludge and nitrification processes. Pre-denitrification BNR processes consistently produced effluent containing 1.20 mg/l LMW-DON and higher, constituting greater than 50% of total DON in the effluent. Non-BNR effluents contained less than 0.55 mg/l LMW-DON. A WWTP that temporarily change from a LE process to nitrification showed a >75% decrease in LMW-DON in its effluent during this period. Bioassays are performed to understand the impact of LMW-DON on algal growth, both overall algae yield and the potential to support and stimulate harmful algal species growth.

### Sunlight Inactivation of CrAssphage Assay Markers in Wastewater

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Fecal indicator bacteria are used to evaluate water quality against risks of contracting gastrointestinal illnesses. However, these indicators cannot distinguish human fecal contamination from wildlife sources and they do not correlate with human enteric viruses which are also abundant in water bodies. Enteric viruses react to environmental conditions in different ways compared to currently used bacterial fecal indicators. Hence, there is a need to identify a fecal indicator that is suitable for enteric viruses and predict its persistence in water.
CrAssphage virus is a newly discovered bacteriophage that is present in the human gut and specific to humans. The most common cell host are the bacteroides species, which are strict anaerobes and are a major component of the human gut and feces. Recent studies suggest that gene marker for crAssphage could be used as an indicator for viral pollution in water bodies because its structure, morphology and size resemble those of human enteric viruses. However, the virus' fate in the environment is still undetermined. In this study we will investigate the decay rate of crAssphage assays markers due to sunlight using solar simulator. We will develop new qPCR prime sets for CrAssphage to better detect longer amplicon gene sequence. The investigated decay of the new crAssphage qPCR assay will be compared to the traditional fecal indicators such as E. coli, Enterococcus spp., Bacteroides HF183 and bacteriophage MS2, as well as the current crAssphage qPCR assays (i.e., CPQ_056 and CPQ_064). The experimentation work is still ongoing so we will present the scientific method and preliminary results.

## *Posters:*

### Sustainable and Affordable Wastewater Treatment: Gravity-Powered UASB Reactors

Cara Smith*, Nina Balhut, Shania Fang, Emily Liu, Kanha Matai
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An Upflow Anaerobic Sludge Blanket (UASB) Reactor is a primary wastewater treatment system, designed to minimize the challenges of setting up wastewater treatment in developing countries. The cost of setting up and running an UASB reactor is significantly less than the traditional methods of wastewater treatment in the United States, as well as requiring less land and having lower retention times. In a UASB reactor, wastewater is pumped to the bottom of a large tank, filled with colonies of anaerobic bacteria (the "sludge blanket"). The wastewater slowly rises up through the sludge blanket, where the bacteria break down the fecal and other organic matter in the water. This process of anaerobic digestion produces methane as a by-product, which can be easily captured and used as an energy source. The water then exits out an effluent pipe for secondary treatment.

Our design is unique in that it requires zero electrical input: when the UASB reactor is placed downhill of the community it serves, the elevation difference can be used to drive the flow of wastewater into the tank. The undergraduate team at Cornell University has been researching and working on this model since 2017, but this summer, we will be building small-scale, functional UASB reactors at the local wastewater treatment plant. There, the team will be testing the efficiency and the long-term stability of the design, as well as working on evenly distributing the wastewater throughout the reactor.

**Investigating denitrification in soil wastewater treatment areas by monitoring for the reduction of manganese oxide**

Owen Placido*, Jose Amador, Alissa Cox, Bianca Ross, Sarah Wigginton
*University of Rhode Island, Kingston, RI*

Septic systems, or onsite wastewater treatment systems, are used by nearly a quarter of US households to treat domestic wastewater. Nitrogen pollution from theses systems is a significant threat to the health of coastal ecosystems. In conventional septic systems, the soil treatment area consists only of sand. These conditions contribute to nitrogen pollution because the conditions are not proper for denitrification, the process by which nitrate is reduced to $N_2$ gas. By adding a layer of sand enriched with sawdust, advanced soil wastewater treatment areas hope to promote the anaerobic conditions required for denitrification. Manganese oxide paint has a very similar reducing potential to nitrate, and so will be reduced under the same conditions. This study will attempt to quantify where denitrification is occuring in the soil profile by coating plastic sheets with manganese oxide paint and inserting them into the soil treatment area of both traditional and advanced systems. The sheets can then be analyzed using imaging software to indicate where in the soil profile the conditions for denitrification are optimal. In order to determine if this method can accurately indicate the presence of denitrification, this study will also test the soil and water collected from traditional and advanced septic systems for nitrate content. If this study finds that the reduction of manganese on the painted sheets correlates with the removal of nitrate from the system, this method will prove to be a valuable tool for professionals in the field to assess the functionality of a septic system.

**Decay of the Antibiotic Resistance Genes tetA and sul2 in the Water Environment: Opportunities for Sunlight Inactivation and Environmental Transmission**

Fiona Dunn*
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Antibiotic resistant bacteria (ARB) are a serious global health threat. Since ARB are excreted in the feces of infected individuals, their presence in human and animal waste presents a challenge in the design of water and wastewater treatment processes. While ARB can be inactivated by engineered disinfectants used at wastewater treatment plants, antibiotic resistance genes (ARG), the genes that code for resistance, often persist through the treatment process and end up in the environment. ARG can continue to pose a serious danger to public health given that bacteria containing ARG can convey resistance to surrounding bacteria through horizontal gene transfer mechanisms, such as transformation. Therefore, understanding the fate of ARB and ARG in the environment is essential in order to design control measures, predict health risks, inform ARG surveillance activities, and prioritize policy interventions. The objective of this study was to quantify and model the sunlight decay of ARG in order to better inform the development of proper environmental monitoring and control systems. Data from sunlight photolysis experiments conducted on the resistance genes *tet*A and *sul*2 from tetracycline and sulfonamide resistant *E. coli* will be presented in the context of environmental decay of other microbial contaminants of concern. ARG were quantified using (1) qPCR protocols used in environmental surveillance and (2) long amplicon (LA)-qPCR methods previously described in the literature. Preliminary results from experiments conducted in photosensitizer free water indicate that while sunlight inactivation occurs, LA-qPCR is more sensitive at detecting DNA damage than assays more commonly used in environmental surveillance.

**Characterization of Hydraulic Fracturing Wastewater Toxicity Using Aliivibrio fischeri and Thiol Reactivity Analysis**

Mina Aghababaei*, Jenna L. Luek, Paula J Moser
*University of New Hampshire, Durham, NH*

The process of extracting hydrocarbon resources from low permeability formations such as black shales using horizontal drilling and hydraulic fracturing techniques is increasingly utilized around the globe. The hydraulic fracturing process generates large volumes of wastewater fluids known as flowback and produced waters (FPW). FPW contain a wide range of organic and inorganic constituents derived from both xenobiotic and geogenic origin,

including known toxicants. Additionally, recent studies have suggested FPW contain previously uncharacterized organic compounds generated within the shale formation, including iodinated and brominated organic substances with unknown toxicity to human and ecological health. Here, we assess the toxicity of injected, flowback, and produced fluids from samples collected from the Utica Formation and Marcellus Shale in the Appalachian Basin using two distinct toxicity endpoints. General toxicity was assessed using a BioLuminescence Inhibition Assay (BLIA) employing the halotolerant bacterium Aliivibrio fischeri while human cytotoxicity was evaluated using a N-acetylcysteine (NAC) thiol reactivity assay. The toxicity of early stage flowback was higher than later time points for both filtered and unfiltered fractions, suggesting a decrease with toxicity as the natural-gas well matures. This research provides new insight into the environmental and human health hazards of wastewaters generated from hydraulically fractured black shale, with implications for toxicity sources and wastewater management of shale-produced waters.

### Identification and Fate of Per- and Polyfluorinated Alkyl Substances (PFAS) in Wastewater Treatment Plants

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Per-and polyfluoroalkyl substances (PFAS) represent a major class of emerging contaminants composed of more than 3000 human-made chemicals. PFAS make up a large group of persistent chemicals used in industrial processes and commercial products. Drinking water contaminated by PFAS poses risks to the developmental, immune metabolic, and endocrine health of consumers which have recently drawn great attention due to their wide distribution in aquatic environments, widespread use, and extreme resistance to degradation. Wastewater treatment plants (WWTPs) are a source of PFAS which are not originally designed for the removal of these low level and diverse contaminants. The identity, fate, and possible degradation of twenty-four PFAS were investigated within a six WWTPs. Of the 24 PFAS compounds analyzed, 2 to 11 PFAS metabolites were detected in all six WWTPs influent and effluents. The average PFAS concentrations were 35-105 ng/l in influent, and 30-130 ng/l in effluent. The major detected PFAS compounds were short and long-chain constituents of Perfluoroalkyl Carboxylic Asides (PFCA), e.g., Perfluorohexanoic acid (PFHxA) and, Perfluorooctanoic acid (PFOA) with a concentration increase in effluent of all WWTPs. A greater number of PFAS metabolites were detected in activated sludge and UV treatments, indicating their potential efficiency at breaking down PFAS precursors. Findings from this study showed the importance of further study on PFAS fate and sinks in WWTPs treatments.

### Investigating the Effects of Operational Parameters, Solution and Solid Characteristics on PFAS Leaching from Sewage Solids

Farshad Ebrahimi*, Erica McKenzie, Rominder Suri, Andrea Silverman
*Temple University, Philadelphia, PA*

Antibiotic resistant bacteria (ARB) are a serious global health threat. Since ARB are excreted in the feces of infected individuals, their presence in human and animal waste presents a challenge in the design of water and wastewater treatment processes. While ARB can be inactivated by engineered disinfectants used at wastewater treatment plants, antibiotic resistance genes (ARG), the genes that code for resistance, often persist through the treatment process and end up in the environment. ARG can continue to pose a serious danger to public health given that bacteria containing ARG can convey resistance to surrounding bacteria through horizontal gene transfer mechanisms, such as transformation. Therefore, understanding the fate of ARB and ARG in the environment is essential in order to design control measures, predict health risks, inform ARG surveillance activities, and prioritize policy interventions. The objective of this study was to quantify and model the sunlight decay of ARG in order to better inform the development of proper environmental monitoring and control systems. Data from sunlight photolysis experiments conducted on the resistance genes *tet*A and *sul*2 from tetracycline and sulfonamide resistant *E. coli* will be presented in the context of environmental decay of other microbial contaminants of concern. ARG were quantified using (1) qPCR protocols used in environmental surveillance and (2) long amplicon (LA)-qPCR methods previously described in the literature. Preliminary results from experiments conducted in photosensitizer free water indicate that while sunlight inactivation occurs, LA-qPCR is more sensitive at detecting DNA damage than assays more commonly used in environmental surveillance.

### The Fate and Removal of Pharmaceuticals and Personal Care Products within Wastewater Treatment Facilities Discharging Upstream from the Great Bay Estuary

Alexandria Hidrovo*, Jenna Luek, James P. Malley, Paula J Mouser
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Pharmaceuticals and personal care products (PPCPs) are contaminants of emerging concern that derive primarily from combined sewer overflows and discharges from industrial and municipal wastewater treatment plants (WWTPs). Some PPCPs may exhibit a wide range of health or behavioral effects in aquatic life (e.g., neural, instinct response, reproductive) at part per billion levels while others may bioaccumulate, amplifying effects up the food chain. In collaboration with six local WWTPs, we have: (1) investigated concentrations for 21 PPCPs occurring in WWTFs discharging into the Great Bay National Estuarine Research Reserve and (2) examined differences in WWTF design influencing removal of select PPCPs. The six WWTPs highlight different secondary treatment designs and disinfection methods to better understand the treatment mechanisms associated with PPCP removal. All 21 PPCPs analyzed were detected in the influent and/or effluent samples for each WWTP. Sampling at the influent and effluent locations from the different WWTPs provides a preliminary estimate of removal rates per compound to elucidate the most effective treatment method for reducing PPCPs in effluent. Due to the widespread use of PPCPs and their incomplete removal from WWTPs, the literature suggests 13 out of the 21 PPCPs are frequently detected within the aquatic environment. A surface water sample collected at the mouth of the Great Bay estuary confirms this previously reported observation, resulting in 9 of the 13 frequently detected PPCPs being present. Understanding the fate of PPCPs in conventional WWTPs is important to protecting coastal ecosystems and supporting long-term stewardship of our marine resources.

### Phosphorus Removal Using Ferrate (VI) in Wastewater Treatment

Lei Zheng*
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Eutrophication gets plenty of surface water bodies impaired in the past decades. Various researchers have pointed out that phosphorus is the critical element for such water quality deterioration. As a steady and continuous source, wastewater treatment plants are considered as a significant contribution to phosphorus in surface water. Therefore, increasingly strict phosphorus discharge standards or permits have been brought out around the world. Meanwhile, along with civilization development, more and more people are connecting into sewage systems, leading to more pressure on wastewater treatment plants. Thus, there is an urgent need for an environmental friend, cost-effective, and high-efficiency technology to relieve such pressure. In this study, we proposed ferrate (VI) treatment as an advanced process to remove phosphorus from secondary effluent, evaluating its general performance, and exploring relative removal mechanisms. Biologically treated secondary effluent was collected from a local wastewater treatment plant. After ferrate (VI) treatment under both acid and basic conditions, phosphorus removal efficiency will be evaluated from inorganic and organic phosphorus perspectives, respectively. The results showed that ferrate (VI) could effectively remove phosphorus from secondary effluent, more than 90%. The removed phosphorus included inorganic and organic forms, and the mechanisms are mainly adsorption. Meanwhile, ferrate (VI) had the capability to transform organic phosphorus through oxidation, indicating a possible mechanism to remove organic form. This study broadens the understand of phosphorus removal and ferrate (VI) treatment.

### Consideration of 3D Printed Biofilm Carriers for Wastewater Treatment

Bryan Ovelheiro*
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Wastewater infrastructure is aging in the United States, and low-cost retrofits to existing infrastructure are needed for treatment plants to maintain or improve their treatment efficacy. Optimization of biofilm carriers is one way of improving infrastructure, but limits in manufacturability have limited growth of the field. Therefore, the effects of geometry, unit cell density, and strut thicknesses of 3D-printed biofilm carriers were explored. The treatment efficacy of these biofilm carriers was explored and compared to conventional carriers of an equal volume. We used microscopy to observe changes in biofilm thickness over time in 50 3D-printed plates of varying architectures to detect trends in biofilm growth. We found that geometries with more void space had higher peak biofilm growth patterns (the simple cube geometry (0.2 mm radius) grew to 0.59 +/- 0.13 mm), while more dense geometries had lower peak biofilm growth patterns (the octet + simple cube geometry (0.2 mm radius) grew to a peak of 0.29 +/- 0.06 mm). The removal efficiency of both the 3D-printed geometries and the conventional carriers were found to be over 90% for both chemical oxygen demand (COD) and ammonia. We found that architecture may influence the overall biofilm growth. Unit cell density and strut configuration (geometry) seem to play a role in biofilm formation, but more research is needed to identify the specifics of this role. Generally, we were successful in using additive manufacturing to improve biofilm carriers.

### Effect of Light Intensity on the Formation of Oxygenic Photogranules (OPG) Under Hydrostatic Conditions

Abeera Ansari*
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Latest advancement in bio-granule technologies for wastewater treatment has brought attention to oxygenic photogranules (OPGs). OPGs are compact, spherical bio-granules with good settling ability that are formed in the presence of an illumination source. These OPGs are comprised of high levels of phototrophic communities, along with heterotrophic bacteria in a granular biomass. The OPG-based process has the potential to treat wastewater with biomass-based oxygenation (i.e., photosynthesis) instead of external aeration, which currently causes the highest energy demand in the activated sludge process. By far multiple studies have been conducted to understand the OPG formation phenomenon and means to enhance the process effectiveness. In this study, we investigated the effect of light intensity as a potential driving factor for OPG formation in a hydrostatic environment. Activated sludge was collected from the aeration basin of Amherst wastewater treatment plant (Amherst, MA, USA) and pipetted into transparent 12 well-cell sterile culture plates. These well-plates were then incubated hydrostatically under continuous illumination of (a) low (2±0.5 Klux), (b) medium (12±2 Klux) and (c) high (30±6 Klux) light intensities. In results, light intensity was observed to impact the rate of photogranulation by influencing cyanobacterial physiology in terms of pigment production, vertical migration and abundance. It was also found to significantly affect extracellular polymeric substances (EPS) production which is known to play pivotal role in bio-granulation process. This study is expected to enhance fundamental understanding of OPG formation as well as aid in designing a successful engineered OPG system.

### The Effect of Shear Force on the Formation of Oxygenic Photogranules (OPGs) in Stirred Tank Reactors Treating Wastewater Without Aeration

Ahmed Abouhend*, Caitlyn Butler, Chul Park
*University of Massachusetts Amherst, Amherst, MA*

Shear force is a key operational parameter that influences biogranule formation. In biogranular systems, hydrodynamic shear is commonly created by upflow aeration. Unlike other biogranules, oxygenic photogranules (OPGs) can be produced in stirred tank reactors in which the hydrodynamic turbulence caused by overhead stirring serves as the main shear force. Shear force may not necessarily be the driver for photogranulation but likely influence the formation of photogranules. Currently, no information is available on the essential role of shear force in the OPG formation. In this study, we investigated the effect of shear force on photogranulation in three sequencing batch reactors (SBRs) that were operated at three different mixing speeds (50, 100 and 250 rpm) for 250 days to treat wastewater without aeration. Results showed that the size and structure of photogranules were substantially influenced by the shear force. It seemed that a low hydrodynamic shear stress favors the growth of granules size. In contrary, high hydrodynamic shear forces seemed to increase the disintegration of granules and thus suppress the development of large photogranules. The photogranules produced at a low shear force had more compact structures and smooth surfaces compared to photogranules produced at high shear forces. It was also found that the shear force has a positive impact on the production of extracellular polymeric substances (EPS) particularly, the polysaccharides. The shear-stimulated production of polysaccharides favors the formation of a stable granular structure even at 250 rpm. This study show that shear force plays a crucial role in photogranulation and further influences the size and characteristics of granules.

### Characterization of Fats, Oils, and Grease from NYC Water Resource Recovery Facilities

Logan Graney*
*Manhattan College, The Bronx, NY*

This study involved the analysis of fats, oils, and greases (FOG) from wastewater treatment plants. Wastewater FOG, also called scum or skimmings, can be found floating on the surface of various treatment tanks. This material contains high amounts of fats and grease as well as several physical inerts and other materials. FOG can cause several operational problems for wastewater treatment facilities including blockage of flow due to buildup on the walls of collection systems. The purpose of this study was to characterize the FOG from several WWTPs to evaluate potential disposal options, the primary option of these being a possible co-digestion process in the anaerobic digesters of these plants. For this study, twelve samples were taken at two locations for each of three treatment facilities. These include the Newtown Creek, North River, and Red Hook NYC WWTPs. These samples were analyzed for VFA, COD, sCOD, and pH. In addition, a mass analysis was conducted to determine the percent concentration of volatile and inert solids in the FOG. COD an VFA values were consistent among all the treatment facilities with little variation. Percent total solids concentration was found to have the largest variation among samples and facilities. This was as to be expected due to the complex nature of FOG and the many particulates associated with it. However, upon analysis of the BTU values at all three plants, the material was found to be a viable option for energy production via pyrolysis technology.

### Understanding the Fate of Escherichia Coli Exposed to Daphnia Magna

Emma Underdah*, Vivian Nelson
*Smith College, Northampton, MA*

The concentration of Escherichia coli (E. coli) is an important indicator of water quality which is monitored by the US EPA to protect human health. The filter feeding zooplankton, Daphnia magna, can remove E. coli from water, and has the potential to improve water quality in natural systems. In addition to monitoring E. coli level reduction in water by D. magna, it is important to understand the fate of E. coli after exposure to daphnids. The aim of our research was to determine the viability of E. coli present in D. magna after feeding experiments. E. coli stained with the BacLight LIVE/DEAD assay were fed to D. magna and organisms were analyzed with fluorescence microscopy. Evidence was found that the E. coli within the gut of the daphnids was no longer viable which indicates that D. magna inactivate E. coli via ingestion rather than accumulate E. coli in the gut. Implications regarding application of D. magna in natural systems will also be discussed.

### The Effect of Nanoparticle Presence in EPS Production in a Pseudomonas aeruginosa Biofilm.

Joann Rodriguez*, Caitlyn Butler, Boris Lau
*University of Massachusetts Amherst, Amherst, MA*

Researchers have identified NPs in the municipal wastewater system likely released during the manufacturing, use or disposal of nanomaterials. Municipal wastewater is treated in a wastewater treatment plant (WWTP) through a combination of physicochemical and biological processes before it is released into rivers, lakes, and oceans. In a wastewater treatment biological process, biofilms are attached to a carrier and its bioactivity is used for nutrients removal. Biofilms are complex structures of microorganisms embedded in matrix well known as the extracellular polymeric substances (EPS). EPS has been identified as essential for the biofilm establishment and contains the structural elements of the biofilm. The structure and composition of the biofilm is key to promote a diversity of metabolic activities to achieve treatment objectives. My hypothesis is that the introduction of nanoparticles to a bioreactor could lead to a stress environment for bacteria and affect the cell production of EPS components as an active response to the stress. In this study, Pseudomonas aeruginosa will be cultivated and after biofilm development, the formed biofilms will be exposed to 10mg/L of plastic and metal nanoparticles in a batch mode. After 48 hours of NPs exposure, polysaccharides, extracellular DNA and proteins will be extracted and quantified to measure the response of the Pseudomonas aeruginosa cells to the NPs exposure in terms of EPS key structural components concentration. The results from this study could lead to a better understanding of the response of biological wastewater treatment process to nanomaterials that could be introduced to the WWTP through the sewage system.

**Application of Mycoremediation to Reduce Escherichia coli in Runoff**

Ojaswi Aryal*
*Smith College, Northampton, MA*

The degradation of freshwater sources due to microbial pollution has adverse impacts on human health and the environment. A novel approach to water-pollution management is the implementation of Best Management Practices (BMPs). A BMP is an engineered pollution-control system that supplements traditional water treatment methods with alternate filtrative, vegetative and structural practices. Bioretention basins are a type of BMP that can be used to treat runoff, but additional research is needed to improve treatment efficacy. One potential addition to traditional bioretention basin designs is applying mycofiltration, which is a type of biofiltration that uses the enzyme-expressing ability of mycelium to remove contaminants. Studies have indicated that the fungi species *Pleurotus ostreatus,* has the potential to facilitate bacteria inactivation, but experimental data is lacking. In addition, mycofiltration systems optimized for *Escherichia coli* (*E. coli*) inactivation have yet to be developed. The aim of this study was to obtain proof of principle data to show that *E. coli* inactivation occurs through mycofiltration and to examine designs for lab-scale flow-through filtration systems. Experiments were conducted using synthetic freshwater, *E.coli* -12 and *Pleurotus ostreatus* fungal mycelium inoculated on sawdust. EPA method 1602 was used to quantify *E. coli* colonies in the samples taken at set time-points throughout the experiment. It was concluded that the pre-soak element of mycelium preparation is an important criteria for mycelium health. A 1-log inactivation of *E. coli* was observed to date. Results from the various experimental iterations completed to determine optimal conditions for inactivation will be presented. The long term goal of application of mycelium in bioretention basins to treat agricultural runoff will also be discussed.

# D. Hydrology and Water Resources

## Summary:

Research related to hydrology and water resources presented at the conference this year spanned many focuses, regions, and scales. Large scale approaches which focused on watersheds, aquifers, reservoirs, and dams addressed algal blooms, heavy metal pollution, fish passage design, development, and groundwater extraction, fully integrating so called “human” and “natural” systems by exposing the ways in which both “natural” and man-made water bodies can be affected by human systems. Not only did these studies address their linkages, but also looked at potential solutions and adaptations whether be it improved ways of tracking algal blooms, better filtering systems for stormwater, quantifying how why certain fish passages are ineffective, and how and why storm surge is related to groundwater and the water table in Rhode Island. Many of these studies, at all scales, focused on the North East, allowing us to better understand changes, often driven by anthropogenic influences, within our own communities.

Studies focusing on smaller scale processes had just as large implications, focusing on bioretention basins and bioswales in stormwater to prevent excess nitrogen, phosphorus, and potentially toxic elements, and using additive-augmented microwave irradiation for soil remediation contaminated with hydrocarbons from petroleum.Several studies also presented new technologies and techniques, such as the advent of mm-Sized soil moisture probes that can capture a more holistic picture of soil moisture in a cost-feasible way.  Many of these studies focused on the assessment of known problems, finding solutions, and bettering existing solutions, cleverly drawing off of existing research while paving the way for the future.

From interviewing students at the universities, the range of topics presented below is also characteristic of the research occuring at these institutions, indicating a wide array of diverse research across the North East, committed to better understanding, treating, and researching our water supply systems for drinking, energy, living, and sustainability.

*“The real wealth of the Nation lies in the resources of the earth soil, water, forests, minerals, and wildlife. To utilize them for present needs while insuring their preservation for future generations requires a delicately balanced and continuing program, based on the most extensive research. Their administration is not properly, and cannot be, a matter of politics.”* -- Rachel Carson

## *Presentations:*

### Tracking Algal Blooms: Which Parameters Tell Us the Whole Story?

Max Rome*, Varshini Reddy, Ed Beighley
*Northeastern University, Boston, MA*

Throughout the United States many eutrophic freshwater bodies experience seasonal blooms of toxic cyanobacteria. These blooms limit opportunities for recreation and pose a threat to both human and ecological health. Changes in water temperature and precipitation associated with global warming are anticipated to increase both the duration and intensity of these events. Accurate monitoring of blooms is critical for the issuance of timely public health advisories as well as long-term trend monitoring. Manual cell counts are considered the most reliable way of estimating algal density however these counts are time intensive and costly. For this reason Chlorophyll a, a common photosynthetic pigment, is widely used as a proxy for algal biomass. Many regulatory limits use chlorophyll a as an indicator of ecosystem health and rely on either lab-based chlorophyll extractions or field monitoring using in-vivo fluorescence. Recent analysis of aphanizomenon-dominate blooms in the Charles River lower basin highlight the limitation of relying solely on chlorophyll a. During peak bloom periods, Chlorophyll a was seen to have a poor relationship to cell counts. A strong linear relationship was observed between both turbidity and in-vivo phycocyanin fluorescence.

### Possible Accumulation of Heavy Metals in Water and Aquatic Organisms in the Goreangab Dam

Princewill Udochukwu Uzoma
*Namibia University of Science and Technology, Windhoek, Namibia*

Contamination of water bodies with heavy metals is a global crisis especially in developing countries like Namibia. In aquatic environment, heavy metals are produced from natural and anthropogenic sources and the levels of contamination depend on the activities predominant around the aquatic environment. Namibia is among the driest countries in the sub-Sahara with low and irregular rainfall, with extended periods of droughts and mainly dependent on underground resources and surface dams. Goreangab dam which is located at the central part of Windhoek and also a re-creation center, receives waste effluents from rapidly expanding informal settlements. The industrial effluent contributes a significant amount. In this study, the levels of heavy metals in water samples will be measured with Inductive Coupled Plasma-Optical Emission Spectroscopy (ICP-OES).

Also concentration of heavy metals in some parts of the body of some selected aquatic organisms will be determined with ICP-OES to verify the parts of the body with bioaccumulation of heavy metals after digestion of the samples with heating digester. Through this study, the possible presence of heavy metals, evaluation of their levels and concentrations as well as their impacts on aquatic organisms can be determined.

### Complexities in Attraction Flow: Effects of Wall Diffuser Auxiliary Water Systems on Fish Behavior

Marcia Rojas*, Kevin Mulligan, Richard Palmer, Alex Haro, Brett Towler, Bjorn Lake
*University of Massachusetts Amherst, Amherst, MA*

Fishways at hydropower dams are an essential mitigation strategy for the dramatically low migratory fish populations in rivers around the world. Adequate attraction flow is key in guiding fish to the entrance of successful fishways. To meet this need, flow is often added into the fishway entrance channel via an Auxiliary Water System (AWS) with either a floor or wall diffuser. However, the hydraulic complexities associated with AWS inside the entrance channel are suspected to cause behavioral responses that negatively affect safe and timely fish passage. The research presented in this paper provides primary insight on the behavioral response of American shad to wall diffusers in the fishway entrance. During the spring of 2019, research was conducted on a full-scale wall diffuser using actively migrating American shad to assess the behavioral responses in a controlled environment. The experiment held constant 2.0 fps flow conditions in the entrance channel immediately upstream of the diffuser, while varying wall diffuser velocity from 0.5 to 1.0 fps. Hydraulic data on the diffuser was gathered from a 1:8 scale physical model. This study was conducted at the United States Geological Survey Leetown Science Center Conte Anadromous Fish Research Laboratory in collaboration with the University of Massachusetts Amherst, the United States Fish and Wildlife Service, the National Marine Fisheries Service, and the Department of Energy.

### Simulation of Potentially Toxic Elements (PTEs) Transport in Green Stormwater Infrastructures (GSIs)

Ali Behbahani*, Erica McKenzie
*Temple University, Philadelphia, PA*

Bioswales are a common stormwater management practice (SMP) which uses the infiltration and adsorption capabilities of the soil, along with the vegetative cover, to mitigate the harmful impacts of contaminants in stormwater runoff, including potentially toxic elements (PTEs). Under chemical equilibrium conditions, the soil-water adsorption coefficients (Kd) quantifies the relationship between the soil-associated and aqueous PTE concentrations, and thus the PTE removal efficiency and mobility through the SMP soil layer during the infiltration process. However, loading ratio (LR), the ratio of drainage (impervious) area to bioswale infiltration basin area, combined with runoff concentration determined the mass load to the SMP and is also expected to impact PTE breakthrough. A simulation model was developed to investigate PTE breakthrough and their build-up pattern in the media. The impacts of Kd and LR on the basin functionality as an inseparable part of the design procedure and a requirement for proper maintenance, were assessed. Also, contamination indices of porewater and soil, as an indicator of SMP efficient lifespan, were estimated. Eight PTEs were simulated (Cl-, Cr, Fe, Zn, Cu, As, Cd, and Pb), and Cl- was the only PTE that showed high mobility and quickly reached the groundwater table, while the other PTEs were effectively immobilized in the top ~60 cm of soil considering 20 years of simulated use. Porewater concentration breakthrough was observed to be a slow process for the other PTEs and more than 5 years were required for Cr, Cd, Zn, and As to breakthrough a 5 cm media depth; Fe and Pb did not completely breakthrough the 5 cm depth during the 20 year simulated period. Higher LR and Kd were generally associated with higher accumulation of PTEs in top layers, however, the simulation showed that combination of high LR and low Kd may result in faster breakthrough of PTEs through the media. Prioritization of the PTEs based on comparing published standards with their aqueous and solid phase concentrations after 20 years, suggested the following order of environmentally importance: Cl- > Cr > As > Pb > Fe > Cu > Cd > Zn.

### Raised Versus Inverted: The Significance of Bioretention Underdrain Configuration on Denitrification in Stormwater

Adrienne Donaghue*, Sarah Beganskas, Erica McKenzie
*Temple University, Philadelphia, PA*

Bioretention basins are widely used to retain and treat stormwater runoff; however, field sites demonstrate variable performance with regards to total nitrogen (TN) removal and can behave as a net TN exporter. Data from our field site, without an internal water storage (IWS) layer, demonstrates that TN in filter media increases with depth compared to influent stormwater runoff (in some cases by a factor of 10) and nitrate on average comprises 35% of the total mass fraction. Basin design can include an IWS zone to promote denitrification in an anoxic water layer prior to discharge via an underdrain. This talk discusses how underdrain configuration can impact mixing within the IWS layer and nitrate removal. U.S.G.S VS2D is utilized to evaluate hydraulic retention times (HRT) and mixing as a function of drain elevation. Laboratory-scale column experiments will be performed to evaluate underdrain elevation on nitrate removal rates. It is hypothesized that raised underdrains will prove to be more effective in denitrification by enhancing mixing between “old” and “fresh” runoff prior to discharge.

Finally, laboratory column tests are compared to two bioretention field sites with and without an IWS zone. Preliminary data from bioretention site with IWS layer and a raised underdrain show TN outflow concentrations equal to or less than influent stormwater runoff with dissolved organic nitrogen (DON) constituting more than 80% of the total mass fraction. Improving understanding of how flow design choices impact TN removal performance is critical to achieving stormwater treatment objectives.

### Comparison of Different Filter Media Materials for PAHs Removal from Urban Stormwater Runoff Using Green Stormwater Infrastructure

Narges Esfandiar*, Erica McKenzie, Rominder Suri
*Temple University, Philadelphia, PA*

Urban storm water runoff can contain potentially harmful contaminants such as polycyclic aromatic hydrocarbons (PAHs). PAHs are persistent hydrocarbon micropollutants that are mostly released from incomplete combustion of fuels and are considered carcinogens. Green stormwater infrastructure (GSI) is increasingly being employed as a stormwater management tool in urban areas, with the intent of using infiltration to address both water quantity and quality concerns. However, GSI media have limited sorption capacity, so amendments may be required to enhance pollutant removal. In this study, batch kinetic and equilibrium experiments were conducted to investigate the ability of green adsorbent materials including: biochar (BC), iron amended biochar (FeBC), scrap tire (ST) and iron chips (FeC); four PAHs were evaluated: naphthalene(NAP), phenanthrene(PHE), pyrene(PYR) and acenaphthylene(ACY). The results showed that kinetic data of PAHs adsorption on FeC, FeBC, BC and ST could be best fitted by pseudo-second order model. Moreover, the adsorption isotherms of PAHs were well-fit by both Langmuir and Freundlich models, and that BC, FeBC, ST had good removal efficiencies of all selected PAHs (greater than 90%), but FeC performance was mixed and achieved removal efficiencies of 11-45% for ACY and NAP, 18-84% for PHE and 64-99% for PYR . However, compared with BC and FeC, FeBC and ST had higher adsorption capacities for all selected PAHs, which is likely due to a comparatively larger surface area and greater diversity of functional groups. The adsorption mechanism of these adsorbents was mainly attributed to the action of surface functional groups and π–π-conjugated reactions. Based on previously published studies, it is believed that the adsorption of PAHs on FeBC and FeC mainly occurred in the functional groups of C–O and $Fe_3O_4$, but that on BC and ST occurred mainly in the functional groups of –OH, C=C and C–O.

Overall, this study demonstrates that the selected filter media have great potential to remove PAHs from urban stormwater runoff. This is in line with literature review showing that biochar has good removal capacity and extends the results of previous studies to include more sorbents and more PAH analytes.

## *Posters:*

### Water Table Response to Coastal Storms

Jeeban Panthi*, Mamoon Ismail, Thomas Boving, Soni M. Pradhanang
*University of Rhode Island, Kingston, RI*

Coastal aquifers are vulnerable to seawater intrusion for many reasons, including over-extraction of groundwater to supply the growing population moving into coastal areas or increasing climatic extremes, such as strong storms. For instance, all drinking water systems in RI's South Coast area pump groundwater from either public or private wells. When more freshwater is pumped than is replenished by natural processes, saltwater might intrude into coastal aquifers. The natural interaction of fresh groundwater and saline ocean water is also affected by storms and heavy rains that can push saltwater landwards or can change aquifer hydraulics, respectively. The focus of the study is to analyze the interaction of storm surge and heavy precipitation with coastal aquifer during winter storm and hurricane events. In particular, the project aims at analyzing the temporal variations of groundwater level and precipitation, possibly amplified by sea-level change and anthropogenic factors. Results show that storm events have an effect on groundwater. However, the degree of interaction between storms and groundwater is highly variable.

### Control of Harmful Algal Blooms by Pre-oxidation with Ferrate

Kyle Gerlach*, Erika Addison, Jeanine Dudle, Joseph Goodwill
*Worcester Polytechnic Institute, Worcester, MA*

Harmful algal blooms (HABs) in water supply systems pose a threat to public health and are a growing concern for many utilities. Microcystis aeruginosa is of interest because it can impart toxins and disinfection byproduct (DBP) precursors into waters. Options to treat HABs include carbon filtration, dissolved air flotation, and chemical oxidation. Ferrate (Fe(VI)) may be an effective oxidant; however, little research exists on its use to treat HABs. Fe(VI) has several potential advantages, including a high oxidation potential, a low potential for DBPs, and the in-situ formation of Fe(III) which can benefit coagulation. The objective of this research is to evaluate the use of ferrate oxidation for mitigation of HABs. Potassium ferrate is being tested in a laboratory setting as a pre-oxidant for treatment of water containing Microcystis aeruginosa. Testing conditions include doses of 20-100Î¼M Fe(VI), algae concentrations from 20,000-100,000 cells/mL, and various pH conditions. The algae are characterized before and after treatment through particle counts, turbidity, total and dissolved organic carbon (TOC and DOC), and surface charge, among other parameters. For waters with low algae concentration dosed with 20uM Fe(VI), a 70% particle count reduction and a shift in particle size distribution to larger particles was observed. The coagulation benefits of Fe(III) likely caused this occurrence. The UV254 absorbance in some samples slightly increased while DOC decreased by an average of 18.5%. The oxidation of algal cells and microcystin-LR could account for these organic matter changes. An increased negative surface charge of algae particles was also observed.

### Field Tests of High-Resolution Real-Time In Situ Profiling of Soil Moisture Using mm-Sized Soil Moisture Sensors (MSMS)

Wangchi Zhou*, Baikun Li
*University of Connecticut, Storrs, CT*

Over-irrigation and over-fertilization are the crucial problems in modern agriculture and lead to high energy and water consumption and water resource contamination. Real-time in situ monitoring of soil moisture could be a solution. However, existing “single-point” sensors suffer from bulky size, disturbance of soil texture, and incapability of obtaining soil moisture at high spatial-temporal resolution. This study aims to develop flat thin mm-sized soil moisture sensor (MSMS) (< 1mm thickness and <$1/sensor) that can be easily inserted into soil at multiple depths to obtain a complete picture of soil moisture. Briefly, MSMS sensors were fabricated by compact disc (CD) etching and coated with “inter-fingered” shaped carbon lines. Field tests at UConn Farm were conducted by deploying a rod (length 1.0 meter with 3 MSMS sensors) into soil, and side-by-side comparison with commercial “single-point” sensors. Soil moisture was measured through the “resistance” and “capacitance” readings of each MSMS sensor along soil depth. Nine-week field tests demonstrated a good correlation of MSMS readings with soil moisture. The variation of the groundwater table before and after rain precipitation was clearly visualized through MSMS high-resolution profiles. By installing at multiple depths with a 2-minute interval frequency of data collection, MSMS sensors provide a whole profile of soil moisture at any time. The field test reveals the great potential of MSMS to achieve high resolution real-time profiling and reduce over-irrigation and over-fertilization.

### Characterizing the Variability of Phosphorus Export from Urban Storm Water for Potential Treatment Strategies

Sadia Khan*, Edward Beighley, David VanHoven, Kathy Watkins
*Northeastern University, Boston, MA*

The escalating awareness of improving the eutrophication situation of Charles River by has led to regulations aimed at reducing phosphorus loading to the river. The stormwater runoff from industrial, commercial, and residential lands which account for most of the phosphorus loading might not be controlled by traditional mitigation measures. To address these loadings, as per regulations, the City of Cambridge, MA, must reduce its annual phosphorus export over a period of years based on incremental reductions. One potential treatment approach for areas with separated sewers is to divert stormwater to some type of treatment. However, it is not possible to treat all stormwater. To develop an optimized diversion and treatment strategy, a collaborative study between the City of Cambridge, Stantec, and Northeastern University is conducting stormwater sampling to understand the variability in phosphorus export from different urban landscapes. The focus on particle size provides a connection to flow velocity required for transport (i.e., shear stress), which can be modeled to trigger flow diversions. To characterize the potential export reductions based on flow velocity thresholds, 1-hour composite samples for six storm events were collected from four locations within the City of Cambridge. The samples were divided into six subsamples: unfiltered, filtered through 250, 100, 50, 25, and 10 μm filters. They were then analyzed for total phosphorus and total solids. The analysis of these high-resolution stormwater samples shows that the phosphorus is not uniformly distributed between particle size fractions. However, the loading distribution is highly dependent on rainfall and landcover characteristics.

### Using Flow Cytometry to Connect Optical Density Measurements with Microbial Cell Counts in Hydraulically Fractured Systems

Catherine L. Murphy*, Jenna L. Luek, Paula J. Mouser
*University of New Hampshire, Durham, NH*

Engineering processes such as hydraulic fracturing play an important role in supplying the demand for energy resources (e.g., natural gas). Hydraulic fracturing introduces pressurized fluid (e.g., water) into the subsurface, causing hydrocarbon-bearing shale to break apart and allow gases and other petroleum products to be released. These technologies change the subsurface environment, creating a microbial ecosystem where unique taxa thrive under harsh environmental conditions. These microorganisms can potentially create problems within the well, including gas flow reduction and corrosive agent production. A dominant anaerobe found in shale wells, *Halanaerobium* (*H. congolense* WG10 strain*)*, has been isolated and cultured under laboratory conditions. *Halanaerobium* was grown on differing substrates (glucose, guar gum) as a model organism for optimizing cell count protocols in combination with optical density measurements for ongoing experiments. The objectives of this project were to (1) characterize the relationship between cell numbers (flow cytometry) and cell density (absorbance measured using optical density) for *Halanaerobium*; (2) quantify microbial growth rates and cell yields under laboratory systems; and (3) apply these methods to field samples containing shale particles and other colloids. Experiments involved developing a standard curve relating optical density to cell counts and tracking cell concentrations during batch growth of *Halanaerobium.* Methods will be further optimized for shale well samples, and cell numbers will be determined on field samples from hydraulically fractured wells at the Marcellus Shale Energy and Environment Laboratory in West Virginia. These data will provide insight into how dense microbial communities grow under engineered subsurface conditions.

### Additive-Augmented Microwave Irradiation for Remediation of Soils Containing Heavy Hydrocarbons

Ritchie LaFaille*, Paul Dahlen, Onur G. Apul
*University of Massachusetts Lowell, Lowell, MA*

Remediating soils contaminated with heavy hydrocarbons from petroleum is a major environmental challenge across the globe. Incidents such as leaks, spills, and exploration activities do not only contaminate our lands but eventually the groundwater and the ecosystem. Thermal desorption using microwave irradiation is a novel method used to remediate contaminated soils. Our research is focused on augmenting microwave irradiation using various additives such as magnetite, silicon carbide, carbon nanofibers, and activated carbon. The goal is to design a permanent microwave-powered platform, ex situ, upon which soils will be decontaminated with better efficiency than common remediation techniques. Our laboratory-scale experiments have shown promising results for this technology. Using magnetite as a base layer, microwaving a sample of contaminated soil of 25 g for 26 seconds reached a final temperature of 240°C. Methanol was mixed with the sample, before and after microwave irradiation in order to extract the petroleum. The UV absorption of the solution was then measured using a spectrophotometer. With this method the percent removal of total hydrocarbons can be estimated. Some of our results are seen in Figure 1.

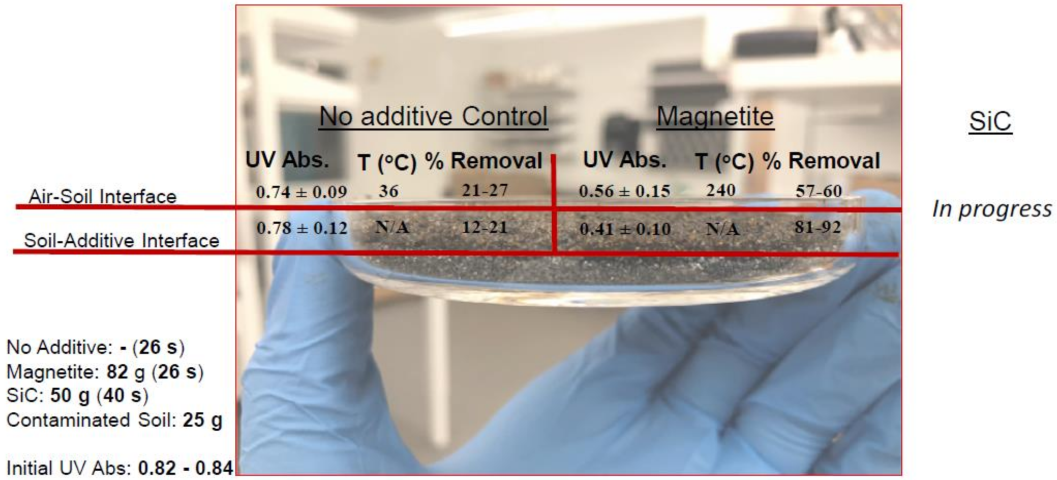


**Figure 1. Total petroleum hydrocarbon removal from soil using additive augmented microwave treatment**

### Growing Green by Building Blue: Guidelines for Sustainable Development

Rose Determan*, Pallavi Kalia Mande
*Framingham State University, Framingham, MA*

The Charles River is a critical recreational and natural resource to the Boston area, and given the rate of development in the watershed, it is important that development is planned and executed in a sustainable manner. Planning with the principles of low impact development (LID) benefits residents and municipalities. The principles center around avoiding, minimizing, and mitigating the impacts by restoring and maintaining the natural hydrology of the land. Retaining and filtering stormwater through bioretention cells, constructed wetlands, or roof gardens are several examples of green infrastructure. By combining science, policy, and engineering, the guidelines and case studies demonstrate the successful use of green infrastructure that benefits residents, municipalities, as well as the Charles River and will help to maintain its health in the future.

# III. NEGSWS Over the Years

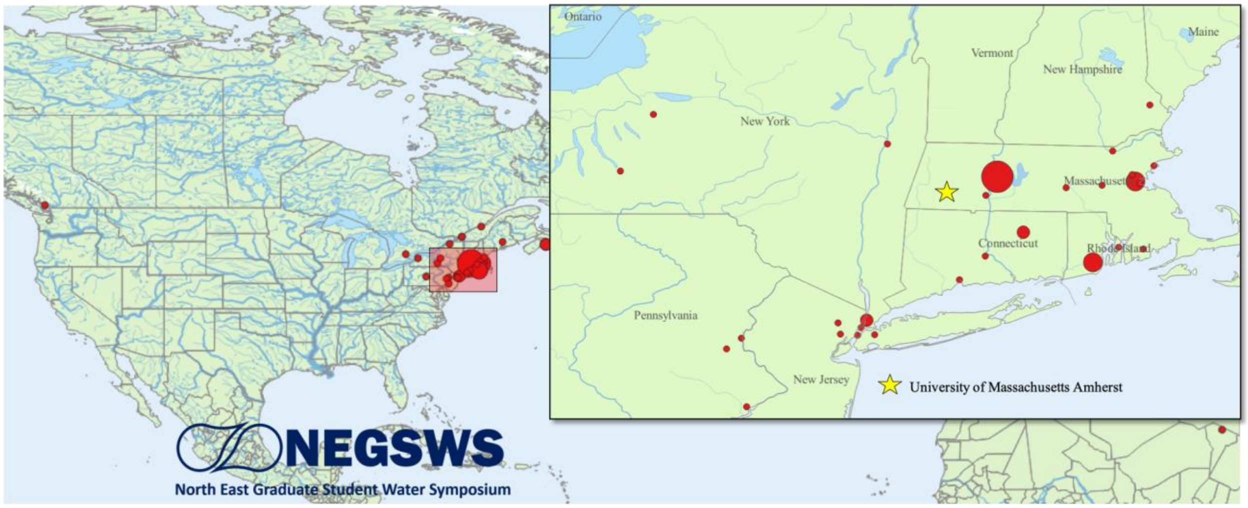


***Figure 1.*** Locations of universities from varying NEGSWS attendees from 2015-2019, weighted by number of students, ranging from 1-75 students. Universities with the highest number of attendees from the past four years include University of Massachusetts Amherst (75), University of Rhode Island (32), Northeastern University (32), and Manhattan College (29). Over the past four years, 44 universities have taken part in NEGSWS, with an average of 29 different universities attending per year.

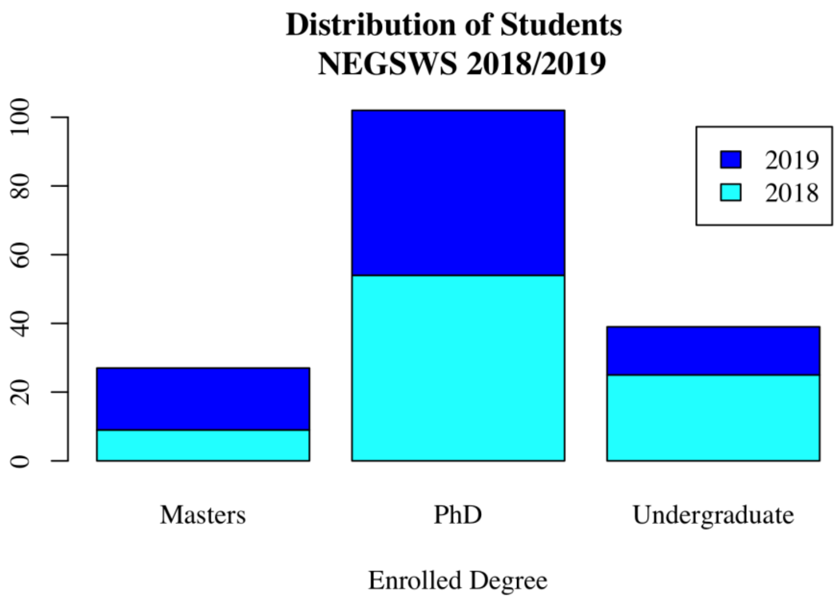


***Figure 2.*** Distribution of NEGSWS attendees from 2018 and 2019 conferences based on if they are enrolled in a masters, PhD, or undergraduate degree program. By and large, there is the highest number of PhD students, but 2019 attracted more masters students, while fewer overall undergraduate students.

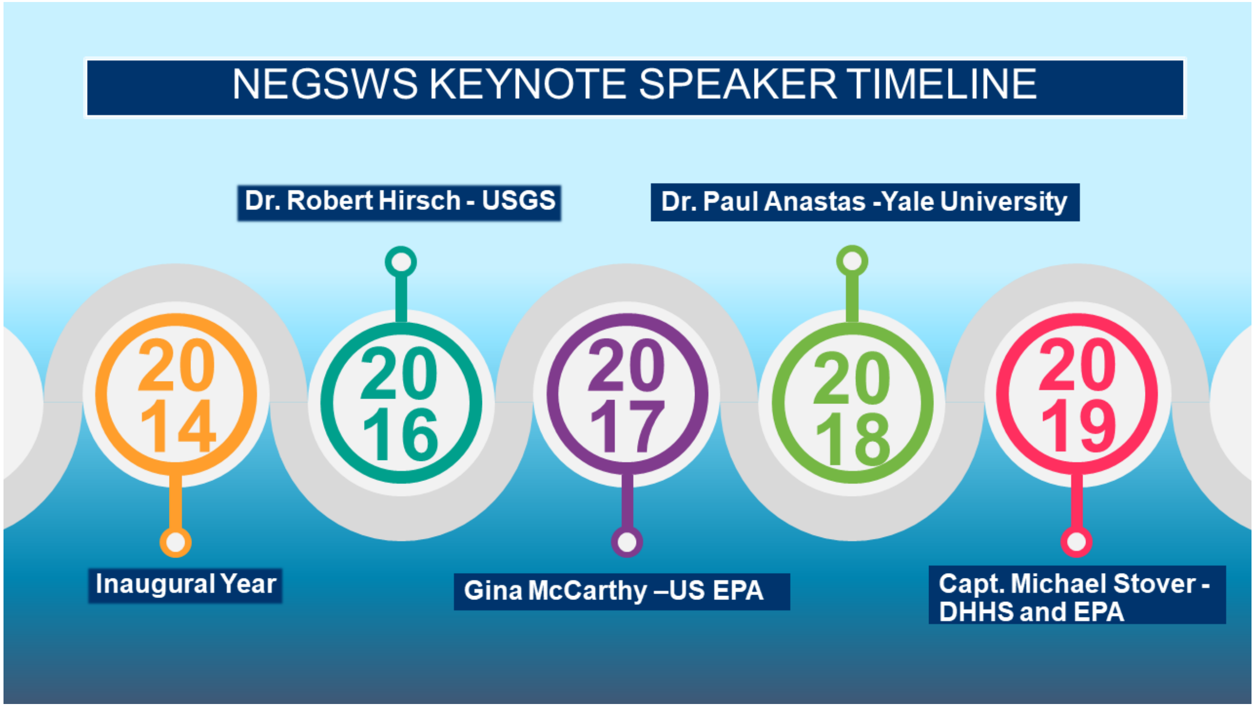


Figure 3. Keynote speakers at NEGSWS from 2014-2019. We have had the privilege to host speakers renowned in their areas of expertise. Dr. Hirsch, who was a chief hydrologist at USGS from 1994 to 2008, gave a talk titled “*Reflections on Water Resources in a Changing World*.” Gina McCarthy, who was the USEPA 13th administrator appointed by President Obama, gave a talk titled “*Water, Water Everywhere but Not a Drop to Drink: Protecting Public Health and the Environment in Uncertain Times*.” Dr. Anastas, who is the director of Yale University Center for Green Chemistry and Green Engineering, gave a talk titled “*Designing a Sustainable World: From Molecules to MegaTrends*.” Captain Michael Stover, who is the manager for Native American Programs at EPA, gave a talk titled “*Sacred Water: Perspectives from Working with Native American Communities.*”

# IV. Research Highlights

## University of Rhode Island

Researchers from four URI colleges (College of the Environment and Life Sciences, College of Engineering, College of Art and Sciences, and the Graduate School of Oceanography) collaborate in a strongly interdisciplinary research program known as “Water: Engineering, Economics, Science, and Society” or simply Water:E2S2. By bridging natural and social sciences, engineering, economic development and outreach activities, they have effectively integrated the theme of “water” into the URI curriculum and can offer attractive global collaboration and education opportunities for URI students and faculty.

https://web.uri.edu/cve/vcraver/

https://web.uri.edu/cve/joseph-goodwill/

https://web.uri.edu/cve/tboving/

https://web.uri.edu/geo/simon-engelhart/

https://web.uri.edu/geo/soni-pradhanang/

https://web.uri.edu/watere2s2/ali-akanda/

*Highlight: “**Engineering Professor Vinka Oyanedel-Craver** dreams of a world where everyone can enjoy a glass of safe, clean water. Turning that dream into a reality will take pioneering research like that happening right now in her engineering lab at the University of Rhode Island.”*

https://www.uri.edu/features/vinka-oyanedel-craver/

## Northeastern University

Researchers at Northeastern University focus on systems engineering approaches to understand the impact of engineered and environmental stresses on bacteria life cycles with applications in health, ecology, water, and wastewater treatment. Specifically, their interests spread across (not exhaustive) 1. microbial ecology and physiology, drinking water treatment and distribution, wastewater treatment, public health microbiology, molecular microbiology, and ‘omics analyses; 2. geo-environmental engineering, soil and groundwater remediation, electrokinetic and electrochemical processes, and contaminant fate and transport environmental restoration; 3. sustainable resilient water resources and wet infrastructure, spatial/temporal data analyses, climate and land cover change forecasts, and hydrologic/hydraulic modeling with in-situ and remotely sensed measurements at local, regional and global scales; 4. hydrological extremes and connections to the natural and built environment and the influence of climate variability, greenhouse warming, urbanization, and land use on flood risk.

https://www.pintolab.com

https://web.northeastern.edu/alshawabkeh/

https://web.northeastern.edu/beighley/home/

https://web.northeastern.edu/munoz

https://www.northeastern.edu/envsensorslab

http://www.northeastern.edu/helmuthlab/

https://jb2032.wixsite.com/bowenlab

*Highlight: The Puerto Rico Test-site for Exploring Contamination Threats (PROTECT) and Center for Research on Early Childhood Exposure and Development in Puerto Rico (CRECE) are led by faculty in the Department of Civil and Environmental Engineering at Northeastern. Research on phenomena affecting fate and transport of hazardous substances in karstic aquifers is central to both research centers in their aim to monitor water quality (among other exposures) and develop green remediation strategies that attenuate and mitigate exposure to protect human health and ecosystems.*

***https://web.northeastern.edu/protect/protect-study-evaluates-how-cvoc-chemicals-are-distributed-and-travel-through-the-karst-system-of-northern-puerto-rico/***

## Yale University

There are at least 5 groups working on water research at Yale University, including Drs. Elimelech, Jaehong Kim, Anisfeld, Peccia and Zimmerman research groups. These research groups are involved in membrane-based processes for energy-efficient desalination and wastewater reuse; sustainable production of water and energy generation with engineered osmosis. They have been pioneering several breakthrough, sustainable environmental technologies and advanced materials to provide clean, safe water in the developed and the developing world. These include: Fullerene-based sun-light sensitized disinfection and pollutant destruction, food-dye sensitized solar water disinfection, adsorption-photocatalysis hybrid materials and processes, self-healing membrane fabrication and in-site healing process development, photoelectrochemical hydrogen peroxide synthesis for energy and water treatment applications. These also implement biotechnology engineering to address important environmental problems such as human exposure to microbes in buildings and genetic studies to enhance biofuel development. In addition, the researchers also expand to studying the various aspects of salt marsh ecology. In specific, submergence in the Quinnipiac river marshes.

https://www.yaleseas.com/jaehongkim/?c=research

https://environment.yale.edu/profile/anisfeld/research

https://zimmermanlab.yale.edu/

https://elimelechlab.yale.edu/research-nexus https://www.eng.yale.edu/peccialab/

*Highlight: "In a new study, Yale researchers describe a novel methodology that tracks the inland movement of marshland by analyzing for microscopic fossils in the layers of sediment, a process that enabled them to identify marsh migration that might not be evident through other methods."*

https://environment.yale.edu/news/article/will-marshland-keep-up-with-rising-seas-yale-study-looks-at-sediment/

## University of Massachusetts Amherst

***Environmental and Water Resources Engineering (Civil and Environmental Engineering)***

Research at the Environmental and Water Resources Engineering (EWRE) program at UMass Amherst work on many projects dealing with water quality and water modeling. Areas of research include water resources and climate change (Dr. Richard Palmer), environmental microbiology and biotechnology (Dr. Caitlyn Butler), hydrosystems research (Dr. Casey Brown), drinking water and particle transport (Dr. John Tobiason), water and analytical chemistry (Dr. David Reckhow), computational hydrology (Dr. Kostas Andreadis), rivers, remote sensing and the Arctic (Dr. Colin Gleason), water, sanitation and development (Dr. Emily Kumpel), environmental bioprocesses (Dr. Chul Park), groundwater/road salt ISA (Dr. Erich Hinlein), water resource recovery systems (Nick Tooker, P.E.), and nutrients modeling in water systems and sediment (Dr. Christian D. Guzman). Other programs include the Water Innovation Network for Sustainable Small Systems (WINSSS) which includes research across many institutions, including UMass Amherst, where they look to develop novel technology for the treatment of contaminants in small water systems (SWS). This includes developing new concepts/technology, implementing them at a pilot scale, testing for regulation compliance and overcoming barriers, and then assessment and planning for implementation.

EWRE Research: https://cee.umass.edu/environmental-water-resources-engineering/research

WINSS: https://www.umass.edu/winsss/

Resources and Instrumentation: https://cee.umass.edu/ewre-equipment-instrumentation

*Highlight: "The name of the revolutionary trailer lab is the "University of Massachusetts Amherst Mobile Water Innovation Laboratory," which was funded with a $100,000 grant by the Massachusetts Clean Energy Center, the U.S. Environmental Protection Agency, and the New England Water Innovation Network. The trailer allows scientists to move around the state and conduct reliable water tests that can transform the way local communities treat their water."*

News: https://cee.umass.edu/news/transformative-umass-mobile-water-lab-unveiled-state-house

Trailer Page: http://www.ecs.umass.edu/eve/facilities/Trailer.html

***Hydrogeology (Geosciences)***

"The Water and Environment group focuses on water resources, hydrogeology, and ground water modeling with strong connections with UMass Extension and the Massachusetts Geological Survey. Critical issues of sustainability and environmental quality lie at the interface of basic and applied research.

A principal goal of this research group is to provide basic and applied research on water that allows citizens and decision makers to make choices that ensure sustainable economic development, enduring environmental quality, and cultural resource preservation for the people, businesses and governments of Massachusetts and the world beyond. Issues of sustainability and human impact on the environment highlight natural connections within the Department of Geosciences and across the campus."

Water and Energy Page: https://www.geo.umass.edu/research/water
Hydrogeology Research Page: http://blogs.umass.edu/hydrogeology/datareports/ongoing-research/

***Department of Environmental Conservation (ECO)***

The Department of Environmental Conservation's focus extends from the ecology and management of fish and wildlife populations, trees, forests, watersheds and landscapes to the physical, social, and policy aspects of conservation involving urban forests, human habitat, and sustainable building and construction. Areas of study and research include: building and construction technology, natural resources conservation, environmental science, environmental conservation, and sustainability science. They also offer the Doris Duke Conservation Scholars Program (DDCSP) Collaborative which provides an exciting opportunity for undergraduates at the UMass who have a passion for biodiversity conservation and for increasing diversity in the field of conservation. This scholars program is a two-year experiential training program that empowers the next generation of conservation leaders to make a difference.

ECO Webpage: https://eco.umass.edu/
DDCSP Webpage: https://eco.umass.edu/about-us/doris-duke-conservation-scholars-program-collaborative-at-the-university-of-massachusetts-amherst/
ECO Facilities: https://eco.umass.edu/facilities/

*Highlight: "A team led by director of the Gloucester Marine Station, Adrian Jordaan, and including ecologists Michelle Staudinger and Allison Roy of the U.S. Geological Survey recently received support for their study of migrating alewife and blueback herring in freshwater, river and estuary environments.The project is one of seven sponsored by Woods Hole Sea Grant that will focus on priority issues in the Massachusetts coastal environment, including not only river herring population studies but shark-seal-human interactions, coastal resiliency and the sources and fate of microplastics in marine ecosystems"*

News: https://eco.umass.edu/news/caring-for-the-coast/
For more news: https://eco.umass.edu/news/

***Department of Environmental Health Sciences (EHS)***

The Department of Environmental Health Sciences at the University of Massachusetts Amherst School of Public Health and Health Sciences combines the public health sciences of biostatistics, environmental health and epidemiology with natural sciences, mathematics and engineering to provide a quantitative basis to measure and mitigate the effects of environmental stressors on human health. As the Department Chair, Tim Ford, says: "The environmental health challenges we face - with global environmental changes occurring at unprecedented rates - make this one of the most exciting, fast moving and relevant areas of study today. Housed in newly renovated laboratories, our cutting-edge research programs broadly explore the environmental determinants of human health. Areas of focus include exposure and risk assessment to chemicals and pathogens, environmental toxicology, and molecular epidemiology. Students in our research labs gain hands on experience in environmental monitoring, toxicology and health risk assessment, with access to state-of-the-art analytics in chemistry and molecular biology."

EHS Webpage: https://www.umass.edu/sphhs/environmental-health-sciences
EHS Research Areas Webpage: https://www.umass.edu/sphhs/environmental-health-sciences/research/research-expertise

*Highlight: "Studies have shown that perinatal exposure of rats and mice to common flame retardants found in household items permanently reprograms liver metabolism, often leading later in life to insulin resistance and non-alcoholic fatty liver disease. Now, research led by Associate Professor of Environmental Health Sciences Alexander Suvorov, with co-authors in Moscow, Russia, has identified the likely mechanism responsible for the pollutant's effect: an altered liver epigenome."*

News: https://www.umass.edu/sphhs/news-events/suvorov-study-shows-flame-retardant-chemicals-predisposes-rats-metabolic-disease
For more news: https://www.umass.edu/sphhs/environmental-health-sciences/news-events/news