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KEYNOTE LECTURE

Dr. Robert Hirsch
Research Hydrologist at USGS

Reflections on Water Resources in a Changing World

Abstract

Historically, water science and engineering has focused on describing the hydrologic environment as a set of stationary processes where the variables of interest (such as discharge or solute fluxes) are assumed to have a mean value and some variability about that mean that is unchanged over time. The existence of uncertainty was well recognized but the assumption was that the system was, and will continue to be, stationary. Today, we live in a world in which the non-stationarity of hydrologic systems is widely accepted. The drivers of the non-stationarity include: urbanization, groundwater depletion, changes in engineered land-drainage systems, changes in the application of nutrients and other chemicals at the land surface, and climate changes that result from enhanced greenhouse forcing. Understanding and quantifying non-stationarity in hydrologic variables are important for a number of reasons, including: 1) for the design and operations of water resource systems, 2) to help evaluate deterministic models of trend by comparing observed trends to model hindcasts, and 3) to identify emerging water resource issues and evaluate success at achieving environmental goals. To these ends, the water resources community needs new tools that provide a more nuanced view of hydrologic change than are commonly available, and needs to be mindful of the difficulty of distinguishing anthropogenic environmental change from long-term natural persistence. “Stationarity is Dead: Whither Water Management” has a wide range of implications for the practice of water resources science.”
Heather Doolittle

Heather Doolittle received her B.S. in geology from Bates College in 2012. Before going to graduate school, she worked for a year as a Field Geologist for an environmental consulting firm, completing a variety of air, groundwater, and soil monitoring projects throughout New England. She received her M.S. in Civil and Environmental Engineering from the University of Maine in 2015, where her research focused on lake water quality and watershed management. Heather began her role as a Staff Engineer in the Water Group at Tighe & Bond in 2015, and has since worked on a variety of projects including Lead and Copper Rule compliance, water quality, and hydraulic modeling.

Liza Faber

Ms. Faber is an assistant engineer at Hazen and Sawyer. She has experience in the civil/environmental engineering industry, with an emphasis on water resources, stormwater management, and stormwater planning. At Hazen and Sawyer, Ms. Faber works on a number of projects with a focus on stormwater BMP design and city wide green infrastructure design and implementation in both the public right-of-way, as well as on various publicly owned parcels. Ms. Faber graduated from Columbia University with a Bachelor’s degree in Earth and Environmental Engineering.

James R. Laurila

Jim Laurila is the Director of Water Operations for the Springfield Water and Sewer Commission. The Commission provides an average of 30 mgd of potable water to 250,000 customers. Prior to working in Springfield he was the Interim Director/City Engineer in Northampton, MA for about 10 years, where his responsibilities included providing 3 mgd of potable water to 30,000 customers. Jim worked as a consulting engineer for 20 years before entering the public sector. He was employed by CDM Smith and Stantec and other New England based firms. Jim earned a BSCE from UMASS-Dartmouth and a MSCE from Northeastern University. He is a registered professional engineer in Massachusetts.

Chi Ho Sham

Chi Ho Sham is a Vice President and the Chief Scientist of Eastern Research Group, Inc. (ERG). He is collaborating with the practice leaders of ERG to address drinking water protection and total water management issues. Over the past three decades, he has worked extensively in drinking water source protection, underground injection control, drinking water regulations, and water quality analysis. He is an active member of the American Water Works Association (AWWA) and the recipient of the Volunteer of the Year Award in 2016. He is currently a trustee and the vice-chair of AWWA’s Technical and Educational Council (TEC). He is also the vice-chair of the Board of Directors of the New England Water Innovation Network, a member of the Massachusetts State Board of the Conservation Law Foundation, and a member of the Board of Advisors of the Urban Watersheds Research Institute. He received his B.A. from the University of Regina in Canada and his M.A. and Ph.D. from the University at Buffalo. Prior to joining the consulting field, he was a faculty member of Boston University from 1982 to 1992. He currently is an Adjunct Professor in the International Development Community and Environment program and a research fellow of the George Perkin Marsh Institute at Clark University in Worcester, Massachusetts.
THANK YOU!
TECHNICAL SESSIONS

Water and Wastewater Treatment 1 – Resource Recovery
Technical Session I

Nutrient bioextraction and recovery from plumes of ocean outfalls of treatment works using saccharina latissima aquaculture
Nona Jesmanitafti, Shane Rogers
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This study investigates the use of macroalgae aquaculture for nutrient bioextraction / recovery and production of valuable biomass feedstock in coastal waters receiving discharges from wastewater treatment facilities as a mechanism for meeting increasingly stringent nutrient effluent performance goals. We explored bioextraction only scenarios following secondary treatment (conventional activated sludge) discharge as well as scenarios that take advantage of macroalgae farming as part of a complete nutrient management portfolio for wastewater treatment (mixed bioextraction and tertiary treatment scenarios). Wastewater treatment scenarios were designed around flow rates between 3-100 MGD and secondary effluent limitations of 30-mg/L BOD and 30-mg/L TSS; nutrient effluent limitations explored included 8 mg/L, 3 mg/L, or 1 mg/L total nitrogen, and total phosphorus of 1 mg/L, 0.1 mg/L, or 0.01 mg/L. Macroalgae farm sizes were estimated using Saccharina latissima aquaculture production characteristics and algal composition from field trials at our research sites in Maine and the Atlantic coast of Norway. Based on these data, we estimated S. latissima aquaculture production area requirements to be 16 ha / mg/L N removed / MGD plant flowrate and 165 ha / mg/L P removed / MGD plant flowrate. Considering these results, macroalgae aquaculture for nutrient recovery and biomass production may be a viable alternative, especially for smaller wastewater treatment plants and those seeking very low levels of net nutrients discharge in conjunction with tertiary treatment processes. At larger plant sizes and greater nutrient bioextraction requirements, production area requirements may quickly exceed the largest macroalgae farm sizes in the U.S. or Norway. Continuing work is exploring effects of growing macroalgae in wastewater plumes on biomass composition and growth rates and seasonality of growth periods as well as economic and life cycle assessment of the proposed processes.

Development of nutrient-rich crystals from wastewater for the fortification of compost
Campbell Weyland, Cathy Ye
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Improved management of nitrogen and phosphorus in municipal solid waste (MSW) compost could help in providing a sustainable alternative to industrially soil amendments for gardening and agricultural practices. However, limited research considers nutrient enrichment of municipal solid waste (MSW) composting. Edaphologists concern themselves with the loss of nutrients in enriched soil throughout the anaerobic and aerobic processes involved in the maturation of the compost, therefore a considerable body of knowledge is
available about the composting process. This research considers opportunities to add value to MSW compost while building on lessons of soil scientists. Our goal is to engineer a technique to maximize nutrient value of nitrogen as well as phosphorus in the compost. This study first focuses on our planned fortification process which consists of mixing enriched struvite crystals into MSW compost. The struvite crystals will be comprised of recycled nutrients (nitrogen and phosphorus) from local wastewater made available by wastewater treatment plants. In the fall of 2016, it is planned that we begin implementation of our struvite crystals in compost comparing with commercial fertilizers and a control. We hope to have substantial amount of data looking at the cycle of these fertilizers and how the nutrient value changes over a specific period of time (60 days). We also plan to present a community compost engagement plan, one which ties science, engineering and entrepreneurial thinking together.

Long term feasibility of electrodialysis technology for treatment of an anion exchange spent brine regenerant solution including by-product recovery
Katerina Messologitis, Elisabeth Vaudevire, James P. Malley Jr.  
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In the drinking water sector, anion exchange technologies are increasingly used for color and disinfection by products removal, which targets low molecular weight natural organic matter, particularly humic substances (HS). After treatment, the resin is regenerated to 99.9% recovery with NaCl resulting in a saline waste stream, generally referred to as brine. The resulting brine contains left-over NaCl, as well as desorbed inorganic and organic anions (SO\(_4^{2-}\), HCO\(_3^-\), HS, etc.) from raw water. Disposal of this brine solution is a problem, especially with regulations becoming increasingly strict. Fortunately, compounds in the brine can be reclaimed if properly separated: NaCl for direct reuse in the regeneration process; and HS as bio-stimulants for crop growth at farmland or horticultural greenhouses. Previous investigations highlighted the efficiency of using electrodialysis technology to achieve this separation of 1) NaCl specifically with mono-selective membranes and 2) divalent ions from HS with non-selective membranes. However, little was known about the effect of high organic loads from the brine solution on operations possibly causing fouling, spacer clogging or biofilm development.

The purpose of this research was to evaluate the long term feasibility of electrodialysis technology for treatment of an anion exchange brine solution including NaCl and HS recovery. Electrodialysis treatment with mono-selective membranes was evaluated on pilot scale over a six-month period while recording operational data and quality of the by-products. Additional experiments were also conducted to further understand the overall fouling phenomena, lab-scale simulation of spacer clogging, and tests for biofouling potential inherent to the brine solution.

Silver recovery from greywater: role of competing cations and regeneration
Tabish Nawaz, Dr. Sukalyan Sengupta  
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The use of silver in consumer products and its subsequent leaching in greywater show an increasing trend. Silver recovery is not only commercially lucrative but also an environmental necessity. Trace concentration of Ag\(^+\) and high concentration of other competing cations (Na\(^+\), Ca\(^{2+}\), Mg\(^{2+}\)) in a typical laundry wash water makes the separation process challenging. The use of ion-exchange resin with thiol group in its chain offers a
potential solution due to its high selectivity for silver. This work successfully recovers silver (>90%) as high purity grade Ag₂S powder (>99%) from synthetic greywater solution using a commercially available resin, Ambersep GT74, in a fixed-bed column mode. The regeneration process in the work has been optimized with respect to the solution pH and thiourea concentration (0.5 M thiourea concentration at pH 1). The resin and the regenerant have been used in multiple cycles (4 times) without compromising on their performance. The study successfully demonstrates a closed-loop sustainable scheme by reusing and recycling all the raw materials to the point of exhaustion with no chemicals/toxic released into the environment.

**Polymer production from organic waste-derived volatile fatty acids**

Ramya Ahuja, Eirene A. Pavlakis, Shashwat Vajpeyi, Wendell Khunjar, Kartik Chandran
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Nutrient recovery has emerged as a promising strategy for manufacturing valuable carbon, nitrogen and phosphorous commodities. Volatile fatty acids are a key carbon intermediate in the production of bioplastics and biodiesel. Polyhydroxyalkanoates (PHAs) are naturally accumulated from VFAs by some microorganisms for intracellular carbon and energy storage and have use as biodegradable plastics. The aim of this project was to assess the feasibility of using wastewater sludge and food waste, representing urban organic waste streams, to produce VFAs and then PHAs. The combined wastes were first converted to VFAs in an anaerobic fermentation reactor. The fermentate was fed to a mixed microbial culture in a sequencing batch reactor. After carbon source consumption, the SBR was subjected to a 6-7 hour famine phase to apply a selection pressure for PHA accumulators. The fractions of acetic acid and butyric acid in VFA feed were determined. The composition of monomers 3-hydroxyvalerate (HV) and 3-hydroxybutyrate (HB) in the accumulated PHA was determined chromatographically. During the feast phase, an increase in total PHA as a weight fraction of biomass was observed. This confirmed enrichment of PHA-accumulating organisms. A significant positive Pearson correlation (two-tailed, alpha=0.05) was found between the combined concentration of acetic and butyric acid in the total carboxylic acid feed and the ratio of hydroxybutyrate to hydroxyvalerate monomers in the accumulated polymer, in agreement with literature. This result is remarkable because proportion of HV impacts the polymer crystallinity and hence properties relevant for subsequent use, including biological degradation rate and melting temperature. Findings from this study will be useful for implementation of resource recovery in decentralized wastewater treatment systems.

**Flood Management**

**Technical Session I**

**Flexibility in flood management design: proactive planning under climate change uncertainty**

Kim Smet, Richard de Neufville and Maarten van der Vlist
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This talk presents a value-enhancing approach for proactive planning and design of long-lived flood management infrastructure given uncertain future flooding threats. Designing
infrastructure that can be adapted over time is a method to safeguard the efficacy of current design decisions given future uncertainties.

We explore the value of embedding options in a physical structure, where an option is the right but not the obligation to do something at a later date (e.g. over-dimensioning a floodwall foundation now facilitates a future height addition in response to observed increases in sea level; building extra pump bays in a drainage pumping station enables the easy addition of pumping capacity whenever increased precipitation warrants an expansion.)

The proposed approach couples a simulation model that captures future climate induced changes to the hydrologic operating environment of a structure, with an economic model that estimates the lifetime economic performance of alternative investment strategies. The economic model uses Real In. Options analysis, a type of cash flow analysis that quantifies the implicit value of options and the flexibility they provide.

We demonstrate the approach using replacement planning for the multi-functional pumping station Ijmuiden on the North Sea Canal in the Netherlands. The analysis models flexibility in design decisions, varying the size and specific options included in the new structure. Results indicate that the incorporation of options within the structural design has the potential to improve its economic performance, as compared to more traditional, build it once and build it big designs where flexibility is not an explicit design criterion.

The added value resulting from the incorporation of flexibility varies with the range of future conditions considered, and the specific options examined. This approach could be applied to explore investment strategies for the design of other flood management structures, as well as be expanded to look more at flexibility within an infrastructure network rather than a single structure.

Reconnecting Floodplains and Restoring Green Space as a Management Strategy to Minimize Risk and Increase Resilience in the Context of Climate and Landscape Change
Abigail Ericson, Dr. Richard Palmer, Dr. Christian O. Marks
University of Massachusetts, Amherst, MA

Throughout history, people have settled near rivers and in floodplains. This places communities at risk from floods, as demonstrated by the devastating impact Tropical Storm Irene had on the region. An active area of research in water resources planning and management involves understanding and quantifying the benefits and costs of high flows in rivers. This study explores the potential of increased flood attenuation by enhancing natural floodplain storage in portions of the Connecticut River. The study specifically investigates a northern section of the Connecticut River and looks at quantifying the benefits of floodplain storage through two computer models. The first analysis, performed using Hec-ResSim, makes simple assumptions of river behavior to explore the impacts of floodplain storage using stage-discharge relationships. Results of this analysis show additional floodplain capacity to the Connecticut River would further attenuate flood flows. The second, more sophisticated analysis, using Hec-RAS, incorporates detailed LiDAR and orthogonal imagery, USACE collected bathymetry, and measurements taken in the field. These results also confirm that increased floodplain capacity attenuates flows but has the added benefit of being able to incorporate projections to alternative flows based on land cover changes and floodplain loss. The Hec-RAS model allows comparison of its more detailed result to that from Res-Sim, to determine if the simpler model is sufficient to estimate changes in flows due to increased floodplain capacity. Both models are powerful tools that can quantify
floodplain benefits and provide justification for floodplain conservation and restoration for city planners and local conservation groups.

**Compared performance of ANFIS, SWMM, and SAC-SMA for real-time flood forecasting in a small urban catchment**

Babak Kasaee Roodsari  
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Rapid urban growth has increased magnitude and frequency of peak flows in many urban catchments worldwide due to increased impervious surfaces. A real-time flood forecasting system that predicts peak flows in a sufficient lead time can reduce environmental and economic damages. Several previous studies have successfully applied different data-driven and physical models for real-time flood forecasting in large river basins. But, there has been limited research on flood predictability performance of physical and data-driven models at small urban catchments. This study applies a state-of-the-art data-driven model, Adoptive Neuro Fuzzy Inference System (ANFIS), and two well-known physical hydrology models, Sacramento Soil Moisture Accounting Model (SAC-SMA) and Stormwater Management Model (SWMM), for real-time flood forecasting in a relatively small urban catchment in vicinity of Syracuse, New York. Models are calibrated for water years 2010 to 2013 and validated for water years 2014 to 2015 using hourly observed discharge at the catchment outlet. Physical models are calibrated using three independent strategies: lumped, semi-lumped, and semi-distributed. Performance of different calibrated models are compared for flood forecasting with lead times of one to six hours at low, moderate, and high flow conditions. In contrast to previous literature for large river basins, we found a poor predictability performance of ANFIS compared to the physical models for lead times of greater than two hours. Furthermore, for both SAC-SMA and SWMM, lumped model had a better performance compared to other two calibration strategies and SAC-SMA lumped had the best performance among all calibrated models. More future research on the impact of calibration strategy on the performance of ANFIS, SWMM, and SAC-SMA for flood forecasting at small to medium size catchments is suggested.

**Flood risk perceptions and management in West Africa**

Katherine Schlef, Lionnel Kaboré, Harouna Karambiri, Casey Brown  
*University of Massachusetts, Amherst, MA*

Floods are an emerging issue in West Africa and there is an urgent need for improved flood resilience. Using the 2009 flood in Ouagadougou Burkina Faso as a case study, we examine the link between flood risk perceptions and decisions for or against the implementation of flood mitigation measures. We adopt a qualitative approach, holding semi-structured interviews with flood victims and with public officials associated with flood issues. The results are analyzed using framework analysis and interpreted using protective motivation theory. Key findings are that the 2009 flood caused a dramatic shift in public awareness of flood risk, but that the motivation to implement mitigation measures was tempered by perceptions of high costs and low self-efficacy. Similar results are observed in other West African countries, highlighting the need for mitigation efforts that focus on not only funding structural solutions such as canals and levees, but also on changing perceptions regarding the nature of floods and individuals ability to mitigate against damages. The conclusions from this study, while based on Burkina Faso, can be extended to inform flood mitigation efforts in the whole region.
Models that make a difference: Participatory models and social learning among flood managers in Boston, MA
Alexander Metzger, Dr. Ellen Douglas, Dr. Steven Gray, Dr. Nardia Hague, Dr. Paul Kirshen
University of Massachusetts, Boston, MA

Extreme weather events cause damaging and costly impacts to coastal urban areas though a combination of storm characteristics, local environmental conditions and development patterns, and human flood management decisions. Climate change is expected to cause more frequent and intense weather events in the Northeastern United States and alter flood-related environmental conditions. Continued urban development places more people and infrastructure in areas that are or will be vulnerable to extreme weather events. Consequentially, urban flood managers face uncertainty in adapting to changing conditions and pressure to mitigate increasingly destructive extreme weather impacts. Interviews with flood managers and analysis of organizational flood management documents in the greater Boston, MA area have identified the many institutional challenges, including mismatch in perspectives and priorities and lack of communication and coordination in defining management strategies and organizational roles. Fuzzy cognitive mapping (FCM) is a modeling technique that is receiving increased attention for participatory applications in which stakeholder understandings can be translated into semi-quantitative, cause-and-effect models that allow empirical study and knowledge sharing. Our research proposes to evaluate the effectiveness of FCM as a social learning tool through participatory model-building and integration into a flood manager workshop. FCM will be used to elicit and compare managers perspectives and priorities regarding extreme flooding, identify important gaps in understandings and engage participants in model-based experimentation and narrative building exercises. Our talk will cover preliminary data and initial findings, participatory modeling-building and workshop design, intended outcomes, and broader scientific contributions.

Water Quality
Technical Session I

Detection of poly- and perfluoroalkyl substances (PFASs) in U.S. drinking water linked to industrial sites, military fire training areas and wastewater treatment plants
Xindi C. Hu, David Q. Andrews, Andrew B. Lindstrom, Thomas A. Bruton, Laurel A. Schaider, Philippe Grandjean, Rainer Lohmann, Courtney C. Carignan, Arlene Blum, Simona A. Balan, Christopher P. Higgins, Elsie M.
Harvard University, Cambridge, MA

Contamination of drinking water with poly- and perfluoroalkyl substances (PFASs) poses risks to the developmental, immune, metabolic, and endocrine health of consumers. We present a spatial analysis of 2013-2015 national drinking water PFAS concentrations from the U.S. Environmental Protection Agency (US EPA) third Unregulated Contaminant Monitoring Rule (UCMR3) program. The number of industrial sites that manufacture or use these compounds, military fire training areas, and wastewater treatment plants are all significant predictors of PFAS detection frequencies and concentrations in public water supplies. Among samples with detectable PFAS levels, each additional military site within a
watersheds 8-digit hydrologic unit is associated with a 20% increase in PFHxS, a 10% increase in both PFHxP and PFOA, and a 35% increase in PFOS. The number of civilian airports with personnel trained in the use of aqueous film-forming foams (AFFFs) is significantly associated with the detection of PFASs above the minimum reporting level. We find drinking water supplies for 6 million U.S. residents exceed US EPA lifetime health advisory (70 ng/L) for PFOS and PFOA. Lower analytical reporting limits and additional sampling of public water utilities serving <10,000 individuals as part of the national monitoring program would greatly assist in further identifying sources of PFAS contamination for U.S. drinking water supplies.

Fletchers Lake: A Case Study to Evaluate Discharge Impacts and Atmospheric Deposition on a Drinking Water Supply
Michael Brophy, Graham A. Gagnon
Dalhousie University, Halifax, NS

Techniques to evaluate the characteristics of natural organic matter (NOM) in drinking water sources are growing rapidly. The purpose of this research is to understand the impact of climate change and anthropogenic influences on the concentration and composition of NOM within a small lake. Fletchers Lake, the study site for this research, is the source water for the Collins Park Water Treatment Plant (WTP), and is also the receiving water for discharges from the Lockview-MacPherson Wastewater Treatment Facility (WWTF), making it an interesting site for NOM analysis. In this study, we will evaluate one calendar year of preliminary water quality data in order to quantify background concentrations, seasonal variations and anthropogenic influences on the concentration and composition of NOM within Fletchers Lake. Basic water chemistry analysis will be performed, such as pH, dissolved oxygen, turbidity, dissolved organic carbon and ultraviolet absorption at 254 nm wavelength, in addition to more advanced NOM characterization tools such as fluorescence excitation-emission matrix and size exclusion chromatography. Additionally, novel techniques such as liquid chromatography-mass spectroscopy will be used to quantify trace organic compounds within Fletchers Lake. This research is expected to help Halifax Water further understand the sources, concentration and composition of organic matter in Fletchers Lake, which will then contribute to improving NOM removal at the Collins Park WTP. It could also provide insight on the efficacy of the treatment processes at the Lockview-MacPherson WWTF. This research will aid in our research groups overall goal of understanding atmospheric affects on water quality surface water supplies.

Formation of Assimilable Organic Carbon During Vacuum UV Advanced Oxidation of Surface Water
Siddharth Bhartia, Madjid Mohseni
University of British Columbia, Vancouver

Vacuum UV (VUV) a viable Advanced Oxidation Process for the removal of micro-pollutants and various toxins in water. However, the impact of VUV process on biological stability of treated water has not received much attention. This becomes very important as partial oxidation of natural organic matter in surface water may lead to an increase in Assimilable Organic Carbon (AOC) and reduced biological stability. In this research, Flow Cytometry Analysis has been used to quantify the AOC concentration. Water from various sources undergoes VUV radiation using two different experimental
setups. First, kinetic studies are conducted using a customized completely mixed collimated beam unit allowing irradiation with 185 nm. A flow through VUV reactor, equipped with an ozone generating lamp emitting 254 nm and 185 nm UV, is used for evaluating the impact of different operating conditions. The microbial inoculum is cultivated in the raw and treated water samples in controlled environment and the cell concentration is measured using flow cytometry. The AOC concentration is then calculated using the yield coefficient determined through control studies.

The results show an increase in AOC profile thereby decrease in biological stability of the treated water, indicating the need for secondary treatment after the VUV process. Additional analyses involving Biodegradable Dissolved Organic Carbon and Disinfection By-product Formation Potential are also conducted to assess changes in treated water quality. These results are expected to be of great benefit to the scientific community and water utilities in their efforts towards obtaining the most appropriate technologies for water treatment.

Smart Sensing of Water Quality Using Micro-electrode array (MEA) Fabricated by Inkjet-printing Technology (IPT)
Zhiheng Xu, Baikun Li
*University of Connecticut, Storrs, CT*

Water and wastewater treatment processes has been monitoring using expensive yet inefficient single-point probes that can only measure single parameter at single point without obtaining a complete picture of physicochemical or biochemical status. The study targeted at this crucial challenge by developing novel micro-electrode array (MEA) sensors using ink-jet printing technology (IPT). Multiple mm-sized electrodes were printed on a flexible film for simultaneous monitoring of multiple parameters at high temporal and spatial resolution. The calibration of four types of MEA sensors (temperature, conductivity, dissolved oxygen (DO) and pH) in water solution showed high coefficient of determination (R2) between the MEA readings and the parameter targeted. The shock tests demonstrated high accuracy of MEA sensors and rapid response with a reading frequency of 0.1 second, which captured the shock impacts in more details than the commercial probes. Furthermore, patterning multiple types of MEA sensors on a single film enables the auto-correction between the parameters targeted (e.g. pH and temperature, conductivity and temperature) and reduces the measurement errors. MEA surface property observed during 4-week immersion into wastewater and waste sludge revealed the intact structure and high mechanic stability. The study clearly demonstrated the unbeatable advantages of MEAs over existing single-point probes: compact sensor configuration, multiple-parameter monitoring in a single measurement, easy fabrication and ultra-low cost ($0.2/sensor), which will decode the system black box, provide complete dataset for switch control strategy, and enhance the treatment performance at the lowest capital and operational cost.

Self-sustained high-rate Anammox: from biological to bioelectrochemical process
Yan Li, Zhiheng Xu, Brandon Holland, Baikun Li
*University of Connecticut, Storrs, CT*

Slow growth rate of anammox bacteria is the imminent problem for system efficiency and stability. An innovative solution was explored in this study by accelerating anammox in microbial electrolysis cells (MECs) and alleviating the dependence on anammox bacteria.
The batch tests showed that 85 % of total nitrogen (TN) was removed in the MEC system, while only 62 % of TN was removed in conventional anammox. Simulation of the modified Nernst-Monod model revealed that the maximum specific utilization rate (0.30-0.38 mmol g-1VSS h-1) in the anammox MEC was 60 % higher than in conventional anammox (0.18-0.20 mmol g-1VSS h-1). Harvesting the power generated in microbial fuel cells (MFCs) to support MECs substantially saved energy consumption and effectively utilized the low power output of MFCs. Simulation of power management system (PMS) interface demonstrated the charge/discharge cycles for power supply by MFCs and power consumption by MECs. The integrated MEC-MFC system accelerated anammox, avoided external carbon requirement, effectively utilized wastewater energy, and thus achieving self-sustained nitrogen removal.

**Water and Wastewater Treatment 2 – Innovative Methods**

**Technical Session II**

The development of immobilized photocatalysts to enhance the degradation of taste- and odor-causing compounds in drinking water

Sudheera Yaparatne, Aria Amirbahman, Carl Tripp

*University of Maine, Orono, ME*

Even though UV disinfection is a safe alternative for primary disinfection and is free of harmful byproducts, it doesn’t effectively degrade taste and odor compounds in water. In this study, immobilized TiO₂-based photocatalyst is synthesized and used to enhance the efficiency of UV disinfection in degrading taste and odor compound 2-methyl isoborneol (MIB) in water. Immobilization of photocatalyst onto a substrate eliminates the tedious and expensive separation of nano TiO₂ from water after UV treatment. Degussa P-25 powder modified TiO₂ (50 g/L) was immobilized on glass substrates using TiO₂-SiO₂ sol gel mixture. Coated slides were characterized using X-ray diffraction and X-ray photoelectron spectroscopy. Photocatalytic degradation of MIB was investigated by irradiating MIB under UV-A light and MIB concentration was determined using headspace solid phase microextraction/gas chromatography mass spectrometry. Around 80% of 500 ng/L MIB degraded under UV light within an hour in the presence of powder modified catalyst films. Higher SiO₂ content in catalyst films showed an increased robustness of the coating. Conversely, increased SiO₂ levels in the catalyst decreased the photocatalytic activity. Addition of P-25 to the TiO₂ sol-gel readily enhanced the photocatalytic activity due to its higher surface area, crystallinity and TiO₂ concentration. Increased SiO₂ content can suppress the crystal growth of TiO₂ and cover the TiO₂ catalyst sites on the surface, leading to a decrease in the photocatalytic activity of the catalysts. P-25 is anchored on to the glass substrate due to the SiO₂ addition, increasing the catalysts robustness.

**Organic matter capture by a high-rate inoculum-chemostat and MBBR system**

Hadi Abbasi, Charles Élyséea, Marc-André Labellea, Edith Laflammeb, Alain Gadboisib, Antoine Laportec, Yves Comeaua

*Ecole Polytechnique Montreal, Montreal, Quebec*

The goal of this study was to develop an innovative process to maximize the bio-transformation of soluble and colloidal biodegradable matter (SB+CB) into particulate
matter (XB) and to capture XB to maximize methane production. The study consisted of two configurations 1) an Inoculum-Chemostat system combining a high-rate moving bed biofilm reactor (HR-MBBR) playing the role of an inoculum and a continuous flow stirred-tank reactor operated as a chemostat, 2) typical high-rate MBBR, at pilot scale with a municipal wastewater for three months. The effect of the hydraulic retention time (HRTMBBR: 25, 36 and 54 min; HRTInoc: 15, 26 min; HRT chemo: 2.3, 3.5 and 5 h), organic loading rate per unit surface area of the media (OLRMBBR: 2-20 g COD m-2 d-1; OLR Inoc-chemo: 20-90 g COD m-2 d-1), dissolved oxygen (DO: 2-4 mg O2/L) and media filling fraction (MFFMBBR: 35% and 50%, MFF inoc: 13% and 16%) were studied. The maximum removal rate of CSB (87%) across the MBBR process configuration was obtained within the range of 1.5 to 5.5 g COD m-2 d-1 which corresponded to an HRT of 36 minutes. This value for inoculum-chemostat process configuration (72%) achieved within the range of 22 to 30 g CSB m-2 d1. Results indicated that operational efficiency and bio-transformation in the MBBR is more dependent on DO concentration than inoculum-chemostat. This comparative study in using two high-rate process configurations concluded that inoculum-chemostat is less sensitive to CSB bio-transformation than MBBR, especially based on DO level. Key words: high rate MBBR, chemostat, organic matter capture

**Coagulation of colloidal particles with Ferrate (VI)**

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Ferrate(VI), as a promising treatment agent, has obtained special attention in drinking water treatment. Although it is well recognized as an oxidant and a coagulant, the knowledge on ferrate(VI)-induced coagulation is highly limited. The objective of this study was to evaluate the performance of ferrate(VI)-driven coagulation for removal of colloidal particles in water. Laboratory-scale tests were carried out in synthetic natural water with colloidal kaolin particles under different experimental conditions (pH 6.5-8.5, turbidity = 2.5-100.0 NTU). Results show that an mean effective iron dose (MEID) was observed for the coagulation with Fe(VI) or Fe(III) to achieve a final turbidity of < 0.50 NTU after 2-hr sedimentation. Moreover, MEID for Fe(VI) coagulation was lower than that in Fe(III) coagulation. In a synthetic natural water with an initial turbidity of 25 NTU, MEID during Fe(VI) treatment was 4.0 mg/L Fe at pH 6.5-7.0, decreased to 3.0 mg/L Fe as pH increased to 7.5, and finally stabilized at 3.0 mg/L over pH 7.5-8.0. In contrast, MEID for Fe(III) coagulation decreased from 5.0 to 4.0 mg/L Fe with the increasing pH from 6.5 to 7.0, and then stabilized at 4.0 mg/L over pH 7.0-8.5. FlowCam dynamic imaging particle analysis showed that Fe(VI) resultant particles captured colloidal kaolin particles to form flocs in water.

**Flux and antifouling performance of ultrafiltration membranes enhanced with electrospun nanofibers**

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Globally, diarrhea remains the second leading cause of childhood mortality. While purification technologies featuring ultrafiltration membranes can effectively diminish this
mortality rate, the costs associated with maintaining high membrane performance hinders the production of safe drinking water. Here, we have created a new generation of ultrafiltration membranes that have higher flux, lower operating energy costs, and reduced biofouling while preserving membrane selectivity. We optimized electrospinning conditions to fabricate polysulfone and cellulose nanofibers with a statistically equivalent average fiber diameter of 1.0 m. Commercial ultrafiltration membranes were topped with a 50 m nanofiber layer, thus creating a new active top-surface. Molecular weight cut-off experiments confirmed that ultrafiltration membranes enhanced with nanofibers exhibit the same retention performance as the unmodified membranes. At a transmembrane pressure of 1 bar, the cross flow flux of the ultrafiltration membranes enhanced with polysulfone and cellulose nanofiber layer increased by 62% and 172%, respectively. The polysulfone nanofibers increased permeability from 0.5 to 4.5 bar. Independent of chemistry, the nanofiber layer increased protein antifouling properties. Biofouling as a function of nanofiber layer chemistry and time will also be presented. By testing two chemically distinct nanofiber layers, polysulfone and cellulose, we have established structure-property relationships of ultrafiltration membranes enhanced with high porosity nanofibers. In addition to improving the performance of membranes for water purification, understanding the materials-biology interface has great implications on the proper functioning of membranes for a broad range of separations, including, beverage clarification, blood filtration, and protein purification.

**Water Resources: Data and Decision Making**

**Technical Session II**

**Linking satellite remote sensing based environmental predictors to disease: an application to the spatiotemporal modelling of schistosomiasis in Ghana**

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90% of the worldwide schistosomiasis burden falls on sub-Saharan Africa. Control efforts are often based on infrequent, small-scale health surveys, which are expensive and logistically difficult to conduct. Use of satellite imagery to predictively model infectious disease transmission has great potential for public health applications. Transmission of schistosomiasis requires specific environmental conditions to sustain freshwater snails, however has unknown seasonality, and is difficult to study due to a long lag between infection and clinical symptoms. To overcome this, we employed a comprehensive 8-year time-series built from remote sensing feeds. The purely environmental predictor variables: accumulated precipitation, land surface temperature, vegetative growth indices, and climate zones created from a novel climate regionalization technique, were regressed against 8 years of national surveillance data in Ghana. All data were aggregated temporally into monthly observations, and spatially at the level of administrative districts. The result of an initial mixed effects model had 41% explained variance overall. Stratification by climate zone brought the R2 as high as 50% for major zones and as high as 59% for minor zones. This can lead to a predictive risk model used to develop a decision support framework to design treatment schemes and direct scarce resources to areas with the highest risk of infection. This framework can be applied to diseases sensitive to climate or to locations where remote sensing would be better suited than health surveys.
Assumptions in Conceptualizing Basin Groundwater Budgets: Controls on Groundwater Divides
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In order to identify the ultimate source of groundwater to a given basin, it is first necessary to place said basin in the context of the groundwater system in which it resides. Recent studies have shown that in groundwater systems with locally dynamic, topographically-controlled water tables (TC), Toth’s theory of nested groundwater flow is applicable. Conversely, the flatter, recharge-controlled water tables (RC) are characteristic of groundwater flow systems that mimic the Dupuit–Forchheimer model which ignores vertical flow. Whether a system has a TC or RC water table directly affects the given system’s groundwater budget, as TC water levels result in groundwater divides mimicking topographic divides while RC water levels allow for transboundary groundwater flow. Refinement of this basin model once contextualized should assume physical hydrologic and hydrochemical data are concomitant. Here I review several published works addressing the issues of defining water budgets with respect to regional groundwater characteristics and present examples of the systematic lack of integration between hydrophysical and hydrochemical data in hydrogeologic basin characterization. This review is meant to serve two purposes: 1) discuss regional and local-scale groundwater modeling issues as they pertain to water-resource management, water-quality, and watershed characterization; and 2) serve as an introduction to the scientific questions and data gaps I aim to address through my work in identifying water and solute sources to Clayton Valley, an endorheic basin located within the Great Basin province. Along with discussing published works I present preliminary observations and results from the field and numerical model development.

Insights into boil water advisories as gained from data mining
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Between 2004 and 2014, approximately 65% of First Nations communities in Canada experienced a drinking water advisory (DWA). Providing clean drinking water is a major challenge in these small and often remote communities, and there are a variety of factors that influence a community’s propensity to DWAs. Data from over 750 First Nations drinking water systems was collected by Neegan Burnside Ltd. from 2009 to 2010, and historical advisory data was obtained from Health Canada. By combining these two data sets, the occurrence, frequency, and duration of DWAs could be determined for each drinking water system. A data mining program called RapidMiner was then used to analyze the data and find trends in order to better understand the relationship between system attributes and DWAs. It was found that both the province and operator training had an influence on the occurrence, frequency, and duration of a DWA, and that the source water type was also a key factor in influencing whether or not a DWA would occur and how often. These insights can be used to address issues in individual systems and to redirect funding to areas of higher priority, with the ultimate goal of reducing future DWAs in First Nations systems.
Bringing insight to the decision-maker: communicating complex, multi-dimensional data using visual analytics in water resources applications
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Researchers and analysts in the field of water resources often struggle to communicate the full depth of their insight to decision-makers. The multi-dimensional complexity inherent in water resources problems and the time and resource constraints of decision-makers exacerbate this challenge. Visual analytics provides an effective method to communicate complex information through its mantra analyze first, show the important, zoom, filter and analyze further, details on demand, though its use in water resources applications has been limited. We demonstrate the application of the mantra and other core visual analytics principles in a decision-support tool designed for a climate risk assessment and adaptation setting study of a proposed dam in the Mwache river basin in Kenya. The method begins with pre-analysis, which filters out irrelevant design choices based on baseline performance metrics. Interactive filtering options allow the user to rapidly explore performance tradeoffs. Linked views between heterogeneous plots elucidate the connection between the objective and decision spaces. Selecting multiple designs allows the user to explore an in-depth, side-by-side comparison of performance and robustness metrics for only the most relevant options. The visual analytics method therefore enables the researcher or analyst to guide decision-makers in exploring and engaging with the data in a way that accelerates the learning process necessary for meaningful insight into water resources problems.

Surface Water Modeling
Technical Session II

Use of artificial neural network for fecal indicator nowcasting in a sewage impacted recreational water source
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Microbial safe water is a main concern for the development of beaches along the shore of the StLawrence river in Montreal. During and after heavy rainfall, fecal contamination is highly variable due to the cumulated impact of combined seweroverflow (CSO) discharges in recreational water sources. Therefore, a “safe” criterion level based on the value of a single sample or moving arithmetic mean of weekly fecal coliform sampling is not appropriate for daytoday management. To reduce temporal uncertainty, we developed an artificial neural network (ANN) model nowcasting concentrations of fecal coliforms. As predictors, we used the following data: cumulative rainfall, cumulative dry days, volumes of CSO discharges, river flow rate, water temperature, and weekly sampling of fecal coliforms from May to September for 2003 to 2015. We used those to train a multilayer feedforward ANN with a LevenbergMarquardt algorithm. Our preliminary work shows, using daily rainfall and river flow rates at three sites for a level of 100 CFU/100 ml, that false negative identification in the fecal coliform ANN ranged between 22 % to 33 %. Peak concentrations in fecal coliform (>200 CFU/100 ml) are underestimated with
this first model. To improve estimations during peak events, we plan to use local CSO discharges and local flows as supplemental predictors for a second model. More specific information on the microbial risk in a sewage-impacted source derived by a ANN model could provide insight, directly translatable to management actions. Our ultimate goal is to integrate our model in a mobile app to promote safe recreational water environments in the StLawrence river.

Value of hydrologic signatures for temporal transfer of model parameters
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Hydrologic signatures have been receiving increasing attention in the modeling literature as a potential tool for improving the transfer of model parameters. Most commonly such applications focus on parameter transfers under a predictions in ungauged basins scenario, where parameters are transferred spatially. In this study, the utility of hydrologic signatures as predictors of model performance in a calibration-validation testing scenario (i.e., the temporal transfer of model parameters) is the focus. The Probability Distributed Model, a simple conceptual hydrologic model, is used to test the approach across a number of catchments included in the MOPEX data set. The appropriateness of PDM model structure is assessed by considering the ability of the model to replicate several signatures. We explore the change in model performance across calibration and validation time periods and contrast it to the corresponding change in several hydrologic signatures. Results are explored in finer detail by utilizing a moving window approach to calibration and validation time periods, which allows for a more in-depth understanding of the relationship between hydrologic model predictions and hydrologic signatures. Insights into the potential added information that signatures can provide are also discussed.

Improving generalized watershed loading function (GWLF) model in the urban area by considering the urban infrastructures: a case study in Onondaga lake watershed
Javad Shafiei Shiva, David G. Chandler
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The Generalized Watershed Loading Function (GWLF) is a watershed loading model; with capability of assessing non-point source flow in the pristine and urbanized areas. This model works as a continuous simulation model with any designated time steps. According to a few required parameters in this physical base model, it has been used widely in many settings. One of the challenges in applying this model to urban area is direct and indirect anthropogenic impacts of the urbanization on the model parameters. For example, the integrity of water distribution network and water conveyance pipelines can contribute water directly to the subsurface, while sewer systems can decrease water tables through drainage. According to the literatures, in some urbanized locations, the impact of urban infrastructures, such as leaky pipes, can be more than natural water balance components. This presentation is an exploration of the improvement of the GWLF model by considering the urban infrastructures in the Onondaga lake water shed. In this simulation, it is highlighted that by recognizing and applying the effect of urban infrastructures, the Nash-Sutcliffe Efficiency as a model performance metric, has been improved.
Cyanobacteria in lake systems: Biogeographic patterns explored with a neutral agent-based model
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Cyanobacteria blooms have been a prevalent event in recent years in most freshwater resources all around the world, causing severe impacts on human health, aquatic ecosystem and the economy. Genomic observations of cyanobacteria reveal substantial biogeographic patterns within systems of connected lakes. These patterns are mostly attributed to environmental factors (e.g. nutrient loads, temperature, etc.) which promote the growth of certain types of cyanobacteria. However, another contributing factor to these biogeographic patterns is the geographic isolation (dispersal limitation) of the microorganisms which is usually neglected when exploring microbial communities. Here we quantify the role of neutral process (dispersal limitation) by simulating individual cyanobacteria cells using an agent-based modeling (ABM) approach. Cells grow (divide), die and migrate between lakes. Each cell has a 1Mbp genome that is subject to neutral mutation (i.e. the growth rate is independent of the genome). The model is verified by simulating simplified lake systems, for which theoretical solutions are available (e.g. uniform population sizes and migration rates). Then, it is used to simulate a number of real systems, including the Great Lakes, the Klamath River, the Yahara River and the Chattahoochee River. Our model predicts substantial divergence between lakes, showing that dispersal limitation can contribute to microbe biogeography. The results provide a quantitative analysis for future biogeography studies and can be an asset when predicting lake systems response to environmental changes.

Water and Wastewater Treatment 3 – Biological Treatment
Technical Session III

Functional gene expression as an indicator of nitrification inhibition by heavy metals
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Heavy metal inhibition of nitrifying bacteria can be detrimental to the performance of biological nutrient removal systems. Consequently, nitrification inhibition has been studied extensively, largely in relation to biological system process responses. On the other hand, such responses can potentially be linked to functional responses in bacterial cells using increasingly available molecular biology tools. In this work, specific functional gene expression in ammonia-oxidizing bacteria (AOB: amoA, hao, cbbL) and nitrite-oxidizing bacteria (NOB: nxrB, porA) was assessed as an indicator of inhibition through comparison to conventional indicators, such as substrate consumption rates. Inhibitory effects were studied for discrete exposure to Cu(II), Ni(II), and Cd(II) and continuous exposure to Cu(II). Discrete exposure testing indicated that for AOB, generally more susceptible to inhibition than NOB, relative expression of amoA showed a systematic response to all three metals. As NOB were more tolerant to metal doses, definitive responses to the metals were not observed in nxrB and porA expression. Continuous exposure of AOB to Cu(II) resulted in
more significant inhibition than did discrete exposure, suggesting that growth mode and exposure condition influence reactor sensitivity to heavy metals. Furthermore, the inhibition and recovery of AOB due to continuous Cu(II) exposure observed through nitrogen conversion performance was reflected by responses in amoA and cbbL expression. Practically, these results highlight the utility of specific genes as potential biomarkers for nitrification inhibition and recovery. From a fundamental perspective, gene expression markers provide insight into the underlying mechanisms by which microorganisms respond to environmentally harmful chemicals, including heavy metals.

Exploring beta blocker cometabolism by mixed culture biomass communities from water resource recovery facilities
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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 biodegradation of these PhACs. The objective of this research began as an effort to elucidate the microbial processes and biodegradation 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 had explored this in the context of AOB-enriched activated sludge; the research presented here explores this 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.

Elusive controls on greenhouse gas fluxes from biological nitrogen removal at the field’s point WWTP: testing relationships with wastewater and tank parameters
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Biological nitrogen removal (BNR) processes at wastewater treatment plants (WWTPs) have recently been identified as potentially significant sources of three potent GHGs, nitrous oxide, carbon dioxide, and methane. We previously reported that fluxes of these three GHGs (0.18 ± 0.03 µmol N2O m⁻² s⁻¹, 1.8 ± 0.20 µmol CH4 m⁻² s⁻¹, 494.4 ± 51.7 µmol CO₂ m⁻² s⁻¹) differed significantly among distinct zones of the BNR tanks and over the course of a year.
at the Field’s Point WWTP in Providence, RI. The Field’s Point WWTP utilizes an integrated fixed film activated sludge BNR method that consists of four zones: pre-anoxic, IFAS aeration, post anoxic, and re-aeration. In order to examine potential influences on GHG variability, water samples were collected in parallel with gas flux measurements and analyzed for concentrations of dissolved gases (nitrous oxide, methane, and carbon dioxide), ammonium, nitrate, and nitrite. Several additional parameters were monitored including influent water flow, dissolved oxygen levels, and water temperature. Preliminary results indicate nitrous oxide fluxes may be related to nitrate and ammonium concentrations, while carbon dioxide fluxes appear to be related to water flow rate and methane fluxes may be related to dissolved oxygen concentrations. Surprisingly, while there were relationships between concentrations of dissolved nitrous oxide and fluxes, this was not the case for methane and carbon dioxide. Further analysis including multiple regressions are planned to tackle the complex relationships between environmental factors and GHG emissions.

**Assessment on the performances of biosand filters built with untreated river sand and disinfected river sand**

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Implemented in over 55 countries worldwide, biosand filters (BSFs) have proven to be effective small-scale drinking water treatment systems. Their inexpensive material cost, low maintenance requirements, and ease of use make BSFs appealing to communities in the developing countries where they typically operate. However, the difficulty of assembling materials for the implementation process can pose an obstacle, particularly in isolated areas. Currently, the use of on-site material for building BSFs is dissuaded, upon posited risk of contamination from pathogens and organic matter. Nonetheless, many BSFs are still filled with river sand because it is more readily available. An assessment of the effectiveness of BSFs built using river sand is being conducted on two full-scale concrete BSFs, two 5-gallon bucket BSFs, and two 2-gallon bucket BSFs. Half of the BSFs are filled with untreated river sand and the other half with disinfected river sand, and two additional full-scale concrete BSFs serve as controls, packed with commercial washed sand. The performances of the BSFs are compared by regularly spiking influent water with Escherichia coli and evaluating reduction capacity, as well as measuring daily turbidity removal. Additionally, weekly flow rates and water quality measurements (i.e. conductivity, phosphates, ammonia, pH) are monitored. Results of these analyses will suggest whether it is safe to use BSFs constructed with river sand, and if river sand sanitized by chlorination improves BSF performance. If such BSFs are found to meet drinking water standards, it would lower the cost and simplify the implementation of biosand filters in emergent nations.

**Nitrogen cycling in oxygenic photogranaules during cultivation for wastewater treatment**

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The symbiotic growth of oxygenic algae and bacteria are currently utilized at some wastewater treatment plants for organic waste and nitrogen removal. The discovery of a dense biofilm aggregate of phototrophic and non-phototrophic microorganisms may significantly advance the implementation of microalgae-based wastewater treatment. These
aggregates, called oxygenic photogranules (OPGs) are a multi-layered spherical biofilm of cyanobacteria, algae and non-phototrophic bacteria. The focus of this study is to determine how the concentration of nitrogen in wastewater affects granule development and to ascertain if nitrification and denitrification play a role during granule formation. The presence of simultaneous nitrification and denitrification depend on the presence of oxic and anoxic zones within each granule. Dissolved oxygen (DO) microsensor data indicates that the outer circumference of the photogranules are supersaturated, but DO concentration declines with respect to depth, allowing for diverse microbial community functions and symbioses. Nitrogen species transformation was indicated by a decrease in ammonium and concurrent nitrate accumulation in the bulk liquid during granule formation. Subsequently, nitrate concentration was further reduced and remained below detection. Nitrogen transformation was further supported by the presence of amoA genes supporting the presence of nitrifying bacteria and of nirS genes within the biomass community, consistent with denitrification. The transformation of activated sludge into OPG appears to be correlated with its initial nitrogen content and evidence of nitrification and denitrification within granules during a cultivation may be connected to granulation success.

Water Chemistry
Technical Session III

Ozone, Ferrate, and Chlorine Dioxide - The Comparison of DBP Control in Drinking Water Treatments with Different Oxidants
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Halogenated DBPs are formed from the reaction of natural organic matter, oxidants, and halogenated species, such as chloride and bromide. With growing knowledge of disinfection by-product toxicity, it is important to study alternative treatment methods to reduce disinfection by-product (DBP) formation. The goal of this research is to compare the formation potential of halogenated DBPs with different pre-oxidants and water qualities over time. Two surface waters with different SUVA's were selected and spiked with sodium bromide concentrations covering a large range of water sources used in the United States. Three common oxidants, ozone, ferrate, and chlorine dioxide, were added to the filtered and buffered waters prior to chlorination with free chlorine. The chlorine contact times (CT) were 6 hours, 1 day, and 1 week to simulate a drinking water distribution system. HAAs and THMs were measured via gas chromatography and electron capture detector (GC-ECD) and total organic halides were measured via ion-chromatography (IC). The results show that ozone reduces the formation potential in most scenarios. Higher initial bromide concentration results in higher brominated DBPs and therefore higher bromide incorporation ratios (BIR). A longer contact reduces chlorine incorporation ratios (CIR) but reduces the BIR.
Poly- and Perfluoroalkyl Substances: Surface-Water/Groundwater Interaction and Partitioning Mechanisms
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Poly- and perfluoroalkyl substances (PFASs) are persistent contaminants introduced to the environment through a variety of sources, including industry, wastewater, atmospheric deposition, and the use of PFAS-containing aqueous film-forming foam (AFFF) for firefighting. The EPA has issued a combined drinking water health advisory of 70 ng/L for two common PFASs, perfluorooctanesulfonate (PFOS) and perfluorooctanoic acid (PFOA), to prevent adverse health outcomes that can include cancer, obesity, and immunosuppression. While PFAS presence has been well documented in the environment, further work is needed to understand PFAS transport mechanisms and precursor transformation into terminal perfluoroalkyl acids (PFAAs).

This work follows up on a previous study of PFAS transport at a site on Cape Cod with known PFAS contamination from fire training activities. Results from analysis of more than 100 groundwater samples indicate that PFAA precursors or intermediates are transporting with the PFAS plume and also suggest that a legacy wastewater plume downgradient from the fire training area affects PFAS transport. New data from ongoing column experiments that are using source water spiked with AFFF and humic acid will elucidate the mechanisms affecting transport. Additionally, PFAS results will be presented from samples collected from five ponds on Cape Cod that are impacted to varying degrees by wastewater and/or AFFF. At each pond, samples were collected of the pond water, pond water recharging the groundwater (collected below the pond bottom), and groundwater downgradient from the ponds. These results will provide insight to PFAS partitioning behavior under variable water chemistry conditions near the surface-water/groundwater interface.

A study of Matrix effects on low concentration estrogenicity analysis using YESne
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Yeast estrogen screen (YES) is a common in vitro bioassay to measure estrogenicity in liquid samples. A modification of YES has been made to further improve the efficiency by removing the solid-phase extraction of the original method (Colosi J., Kney A. 2011). In YES assays, 17β-estradiol equivalent (E2EQ) concentration is used to quantify the net estrogenic activities. For natural water samples, e.g. rivers, wastewater treatment plant (WWTP) effluents, research has shown that measured E2EQ concentrations from YES are frequently lower than the correspondent calculated values based on the concentrations of the individual xenoestrogens. Some research has suggested to attribute such phenomena to the complex chemical components of the water samples, a.k.a. the samples matrix. The purpose of our research is to describe the matrix effects in modified YES without extraction (YESne) and identify the applicability of YESne at low concentrations. Water samples have been collected weekly from variable sources, including the Delaware River section at Wy-Hit-Tuk Park, a freshwater pond in Center Valley, PA, and Easton, PA WWTP effluent. The results have been analyzed that compared to the control groups made of DI water, the samples have shown a significant enhancing matrix effect.
The Leaching Characteristics of Chromite Ore Processing Residue from China
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This study reports on the leaching characteristics of COPR from the soda ash roasting process that contained 8,500 mg/kg of Cr(VI), indicating poor recovery during the leaching process. To this end, leaching with different extraction solutions was studied as a function of time. The DI water, 0.1M NaOH and 1M NaOH leaching results were similar with around 47% of the total available Cr(VI) leaching out up to 480 hours. 1M and 0.1 M Na$_2$HPO$_4$ could leach out 58% and 51% of total Cr(VI) at 48 hours, respectively. When compared with 48.7% of Cr(VI) leached by DI water, improvement is not significant. A strongly acidic (pH 0.5) 1M HNO$_3$ results leached even less than water due to strong sorption and reduction of Cr(VI). However, the acidity of 0.1M HNO$_3$ is much weaker and the leached Cr(VI) increased significantly up to 90%. Optimum leaching was in the pH range 4-5, while pH above 6 led to decrease in recoverable Cr(VI), indicating that pH control is necessary to facilitate optimum recovery. Collectively, these results indicate that up to 50% of the residual Cr(VI) can be easily recovered with minimum costs, while the remaining is tightly held within the smallest particles, so that it may not be easily recoverable by leaching alone. Treatment of this residual fraction is a more promising avenue.

Wetland Stewardship for a Healthier Bronx: Water Quality Monitoring in Van Cortlandt Park
John D. Abbatangelo, Jessica M. Wilson, Ph.D., John Butler
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Van Cortlandt Park is a major landmark in the Bronx and features Tibbetts Brook (TB) and Van Cortlandt Lake (VCL), which flow into the municipal sewer system. One of the last above-ground natural streams left in the Bronx, TB originates outside of the Bronx in Yonkers. The Lake and Brook have both experienced a degree of multi-species contamination and eutrophication in the past and currently accept storm water runoff from several major highways and golf courses located in the park. Both water systems are listed as impaired water bodies by the New York State Department of Environmental Conservation (NYS DEC), reinforced by a past study by the organization in 1998. The purpose of this project is to perform a year-long study on the chemical profile of the Park’s fluvial and limnologic systems. Weekly monitoring was conducted from December 2015 to present for two locations along TB and four locations in VCL. Field data collected for each site includes dissolved oxygen, pH, temperature, and conductivity. Samples were collected and analyzed in the laboratory for turbidity, nitrate, and phosphorous. Findings conclude that TB and VCL are typically nitrogen-limited systems. Additionally, major contributions to sediment and contaminant influx occur in the point-load discharges, which are stormwater and drainage pipes that enter the systems. This investigation will be helpful in the Daylighting of TB, whereby VCL will be channeled directly into the Harlem River. Water from VCL will need to be checked so that its chemical and biological composition is compatible with water of the Harlem River.
Planning for Drought in Large Cities: A Case Study of the Recent São Paulo, Brazil Drought
Grace Cambareri, Dr. Richard Palmer
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This study discusses the challenges encountered by the megacity, São Paulo, Brazil, in coping with the 2013-2015 drought and the benefits of developing a drought management plan. As a result of rapid urbanization, high population growth rates, and record low streamflows during these years, the São Paulo water supply reached its lowest storage level in history, resulting in water scarcity and social unrest. The occurrence of this drought, coupled with increasing uncertainty associated with future water permit allocations and climate impacts, highlights the need for a drought management plan in São Paulo. This work presents the components of a drought plan: drought indicators, triggers, and mitigating actions; system performance metrics; and recommendations for putting drought plans into action. Actions taken during the drought are critiqued and the drought management framework is applied to develop alternative drought management plans for São Paulo. This study uses a simulation model of the Cantareira System, the largest reservoir system supplying water to the metropolitan region, to evaluate how stressed the system is at meeting current and higher future demands, to develop a drought management plan, and to assess the value of drought planning in improving performance metrics. The analysis demonstrates how a drought plan increases the resiliency of São Paulo’s water supply and its ability to weather future unknowns in demand and supply. While drought management in São Paulo has unique opportunities and challenges, this methodology for developing a drought plan can be applied in other large cities abroad and in the United States.

Water Safety Planning in Small Water Supply Systems
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Water safety plans represent a preventative risk assessment tool recommended by the World Health Organization (WHO) that critically analyzes a water treatment system from source water to consumption to prioritize possible hazards. Although the use of water safety plans (WSPs) has been advocated since 2001, implementation has progressed slowly. WSPs have been effectively applied in Iceland since 1997 and the province of Alberta recently in 2011. WSPs, however, are not ubiquitous across Canada and this study attempts to validate the application of a WSP framework to small water systems in Atlantic Canada. Small systems are a focus since they exhibit a variety of challenges associated with operation, maintenance and incidences of microbiological contamination. The framework for Atlantic Canada WSPs is derived by applying a WSP framework developed at Dalhousie University. Using risk scoring, previous annual reports and operator feedback obtained by visiting and applying WSPs to small systems in Atlantic Canada, the effectiveness of a WSP framework can be assessed. Small systems tend to have a higher degree of variability in design and challenges developing a WSP that is effective for all possible subsystems involved in water treatment. Site visits to small systems in Halifax have shown that maintenance concerns exist and
treatment systems could use revision to effectively meet the needs of the communities served. It is anticipated that the developed WSP framework developed in this research can be extended to other small systems to help understand risks and asset vulnerabilities of providing safe drinking water.

Analyzing streamflow forecasts in the context of system performance: a case study of the city of Baltimore water supply
Richard Palmer, Kathryn Booras
University of Massachusetts, Amherst, MA

This research evaluates streamflow forecast skill in the context of drought planning. The City of Baltimore’s water supply system is used a case study. Forecasts generated by the National and Atmospheric Administration (NOAA) and the National Weather Services Middle Atlantic River Forecast Center (MARFC) are integrated into a systems model to assess how using forecasts can impact operational performance during drought. This research assesses the benefits gained by using the NOAA/MARFC generated forecasts in comparison to using no forecasts, simple statistical forecasts, and using perfect forecasts. The model incorporates operating alternatives that include pumping from the Susquehanna, an alternative water supply, and calling for water restrictions. Operating policy scenarios were evaluated to find a robust operating rule that balances three key metrics: 1) Pumping Cost, 2) Economic Loss (economic impacts of droughts on the city), and 3) the Frequency of not calling for Drought Restrictions when they are, in fact, needed. In addition, the likely impacts of climate change on system performance are explored by investigating the sensitivity of indices and forecasts across a wide range of hydrologic conditions. This multi-objective study demonstrates the value of near-term forecasts, and potential future long-term forecasts, in improving system performance and minimizing operational costs.

Basin performance under climate change, internal variability and population growth: Case of the Shire River Basin, Malawi
Anthony Chiumia, Katherine Lownsbery
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The Shire River basin, located in Malawi, is part of the Great East African Rift Valley system that drains Lake Malawi and part of Mozambique. Several projects have been lined up to maximize the benefits of the water resources in the areas of Hydropower generation, Irrigation, water supply and Flood control. However, few studies on the impacts of climate change, internal climate variability and changing demand have been performed to assess future vulnerability of this basin. This study, therefore, uses a decision scaling approach to understand the impacts and spatial distribution of climate variability and change as well as changing demand (irrigation, water supply and hydro power generation) on the Shire River basin. The relative and combined effects of the stressors on the system will be assessed through a stress test and by system relevant performance metrics. The results of this study will inform decision making for future basin planning.
**Mass transport enhancement by local flow redistribution in electrodialysis**
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In an electromembrane desalination system such as electrodialysis (ED), ion transport near ion exchange membranes (IEMs) induces inevitable concentration polarization (i.e., formation of diffusion boundaries), which is often a source of additional energy loss and irreversibility of the process. Previous efforts towards mass transport enhancement were rather relying on phenomenological optimization of structures that enhances mixing (termed spacers). Detailed understanding of ion transport inside the diffusion boundary layer would be needed to optimize the spacer structures intelligently. Here, we employed ED systems to investigate the mass transport effects of embedded microstructures, which can redistribute the local flow velocity. We performed a parametric study on the location and size of the cylindrical posts, which are the structures of our choice, inside the dilute channel and studied its effect on the mass transport in microscopic detail. The study was done through microfluidic ED model experiments, and validated by direct numerical simulation. We discovered that localized flow redistribution and resulting "pinching" of boundary layers can enhance the overall ion transport significantly (~35% enhancement in limiting current density), while causing minimal additional fluid resistance. For the first time, we discovered that asymmetry in ion transport number (Na vs. Cl) is an important factor to find an optimal geometry. Detailed parametric studies as well as optimization that considers both enhanced energy efficiency and increased hydrodynamic resistance of spacers were carried out by combining experiment and numerical simulation. Combined, this study presents a systematic model-based engineering approach for ED spacers and other enhancement of electromembrane desalination techniques.

**Manganese biofouling of water transmission pipelines**
Brittany Gregory, Graham Gagnon
*Dalhousie University, Halifax, NS*

Commonly present in drinking water sources, manganese has been shown to accumulate in distribution systems at concentrations as low as 20 ug/L through sorption, precipitation, and biological oxidation. Hydraulic disturbances and changes in water quality can cause the accumulated manganese to re-enter the system, resulting in dirty water events. Within raw water transmission pipes, this release of manganese is problematic to water treatment plants as they can experience unexpected spikes in manganese requiring treatment, along with the bacteria and trace metal associated with manganese.

Recent sampling at the JD Kline Water Treatment Plant revealed a higher concentration of manganese in the source water compared to the concentration following the raw water transmission pipe. It has been suggested that manganese-oxidizing bacteria (MOB) within the pipe is the cause of the observed decrease in manganese and periodic foulant material in the plant. A bench scale study commenced in April 2016, and will continue for the next 12-16 months to confirm biofouling of the transmission pipe using annular reactors (ARs) that are set up at the plant intake.
During this study, the transmission pipe material and hydraulic conditions are simulated using ARs, with water being drawn from the raw water source. Weekly water quality testing the influent and effluent waters, as well as bi-weekly sampling of the removable coupons for adenosine triphosphate and MOB are preformed. Future testing will investigate the impact of hydraulic retention times and the addition of a disinfectant has on manganese concentrations to further comprehend its accumulation in transmission pipes. Preliminary findings and the potential significance of this work will be presented at the fall symposium.

Kinetic modeling of capacitive deionization systems for water desalination
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Pennsylvania State University, Middletown, PA

To guide practical implementations of capacitive deionization (CDI) systems for water desalination, quantitative methods to predict the CDI behavior based on the kinetic modeling of its adsorption and desorption cycles are essential but not available so far. In this research, a single-pass, continuous-flow CDI system was operated at different temperatures and salt concentrations to obtain the salt adsorption data. Potential removal, short circuit, and potential reversal were also investigated as three desorption modes. The pseudo-first-order, pseudo-second order, and Weber-Morris models were used to fit the experimental data. Results showed that the pseudo-first-order kinetics were able to give the best fit to the experimental data followed by the pseudo-second-order and Weber-Morris models. Larger adsorption capacity was found at lower temperatures and higher salt concentrations. It was discussed that convection, diffusion, and electro-migration were three major mechanisms during the CDI process. The present research emphasized a significant role of diffusion during desorption via potential removal and short circuit while the effect of diffusion was marginal during desorption via potential reversal. In addition, the observed pH fluctuations during the CDI process were attributed to chemical reactions at the surface of electrodes and competitive adsorption between metal and hydrogen ions. The research presents an important approach for gaining an in-depth understanding of the complex CDI process and the results can be beneficially used for engineering applications.

Adsorption of micropollutants and natural organic matter on magnetic activated carbon
Kim Lompe, David Menard, Benoit Barbeau
Ecole Polytechnique Montreal, Montreal, Quebec

Context
Powdered activated carbons covered with magnetic iron oxide nanoparticles (IONPs) are regularly proposed as adsorbents for dyes, pesticides and heavy metals for drinking water applications. While most authors agree on the benefits of IONPs for easy magnetic separation, the tradeoffs between high magnetic susceptibility and the reduction of surface area, porosity and adsorption capacity caused by IONPs are unclear.

Methods
We evaluated the adsorption of Suwannee River natural organic matter (NOM) and a mixture of micropollutants on magnetic carbons containing mass fractions of 0 %, 10 %, 38 % 54 % and 100 % maghemite IONPs in isotherms and kinetic tests. The adsorbents were characterized regarding the type and size of IONPs, pore size distribution, surface area and
morphology.

Results
Adsorption tests revealed low adsorption capacity of IONPs for NOM and none for the micropollutants tested. The NOM adsorption capacity of all adsorbents was similar when comparing Freundlich models normalized to accessible surface area (pores > 1nm) or by carbon content as IONPs blocked mainly the micropores that are not accessible for relatively large NOM. Adsorption of micropollutants was not hindered by IONPs as the remaining surface of adsorption was large enough to reduce the initial concentration of 10 µg/L by 80 % at doses < 5 mg/L. Reduced adsorption capacity for both NOM and micropollutants was observed at an IONP concentration >54 %.

Conclusion
IONPs neither enhance nor reduce the adsorption capacity of NOM and the tested micropollutants if compared by accessible surface area or carbon content.

A mechanistically-based model for hydraulic flocculator design
William Pennock, Monroe Weber-Shirk, Leonard Lion
Cornell University, Ithaca, NY

Hydraulic flocculators have several advantages over mechanical flocculators. Pragmatically, they have lower operation and maintenance costs as a result of using neither moving parts nor electric power. From a fundamental viewpoint, their operation as plug flow reactors gives them superior kinetics and prevents short-circuiting. In spite of their cost and treatment efficiency, hydraulic flocculators are not widely implemented because of concern about their flexibility of operation and because design guidelines currently give preference to mechanically-mixed flocculators. A mechanistically-based model to predict flocculator performance could improve design, decrease construction costs, inform flocculator operation, and lead to more widespread adoption of hydraulic flocculators. Previous work by the authors developed an agent-based model for flocculation both for collisions predominantly governed by viscous forces and for those governed by inertial forces. This presentation will demonstrate how this model can be developed into equations for flocculator design which predict flocculator performance based on the flocculator design and the influent raw water characteristics. Additionally, the applicability of the model to previously collected data will be discussed, and considerations for experiments to further test these equations will be given.

Environmental Engineering
Technical Session IV

Alternative water treatment: Designing a floating island that integrates social & technical elements at the American Farm School
Eric Fast, Mary Prescott, Talia Solomon, Meghan Trahan
Worcester Polytechnic Institute, Worcester, MA

Greece currently uses 86% of its freshwater resources for agriculture, an unsustainable practice in light of climate change projections for more frequent droughts across Southern Europe. This project provides recommendations to the American Farm School in Thessaloniki, Greece, for a multipurpose floating island that works alongside its water recycling system to conserve freshwater for irrigation. This was accomplished through
discussions, interviews, workshops, literature review, and archival research. Discussions were held with multiple stakeholders, including students, faculty, staff, and project sponsors to ensure the floating island’s benefit to all members of the community. It was found that artificial floating islands have a huge potential for improving water quality, supporting habitats, and creating beautiful community spaces. The final design is an attractive natural water treatment system that serves to educate the campus with further opportunity for research.

Simulation of Dynamics of Biomass, Hydrology and Nutrients Following Clear-Cutting of a Northern Hardwood Forest
Mahnaz Valipour, Professor Charles Driscoll
Syracuse University, Syracuse, NY

Forest biomass harvesting in the northeastern US may intensify over the coming decades in response to increased demand for renewable energy. A hydrochemical model, PnET-BGC was applied to simulate hydrology, biomass, soil solution and stream water chemistry of a whole-harvested watershed in a northern hardwood forest at the Hubbard Brook Experimental Forest (HBEF), New Hampshire, USA. Results were compared with the observed values and also reference watershed (with no disturbance) to evaluate effects of disturbance on leaching of nutrients in the ecosystem. Simulated results for biomass matched very well with observed ones, reflecting 12%, 41% and 65% of regrowth of vegetation after around 3, 16 and 26 years of cutting, respectively. It is expected to forest retain biomass prior cut after around 70 years which is very close to the value of an observed 72-year-old forest. Hydrology simulation for streamflow shows 15% increase in the second year after the cut. Also, nutrients in streamwater were modeled very well in comparison with observed values, indicating highest concentration of leaching of elements in the second year after the cut, 71 µmol/l for Ca⁺², 46 µmol/l for Na⁺¹, 31 µmol/l for Mg⁺² and 307 µmol/l for NO₃⁻³. However, streamwater SO₄²⁻ concentration showed a different trend after the cut with enhanced adsorption and reduced by 40 µmol/l compared with 55 µmol/l in reference watershed. pH also decreased by 4.8 in the second year after the cut. Harvesting results in nutrient removal from the forest ecosystem and acidification of streamwater and also may deplete plant-available pools of nutrients.

Stereo Photogrammetric Technique for Capturing the Evolution of 3D Dynamic Phenomena: Methodology Demonstration for the Case of Scour Monitoring
Nasser Heydari, Panayiotis Diplas, Polydefkis (Pol) Bouratsis
Lehigh University, Bethlehem, PA

Retaining walls are widely used to protect bridge abutments and other longitudinal structures that encroach into waterways. Local scour threatens these structure as their leading cause of failure. To date, scour development along retaining walls has not been studied extensively and little has been done toward understanding the dynamic nature of this phenomenon. Since scour develops quite rapidly, continuous monitoring of this phenomenon is essential. Also, the monitoring technique should be non-intrusive to avoid changes is flow characteristics. A stereo photogrammetry technique has been employed in this study to monitor scour development in the vicinity of a retaining wall located within a tilting flume. A pair of commercial cameras is used to record the local gravel bed topography during the experiment. The normalized cross-correlation method has been
employed to match the points and establish correspondences between stereo images. Stereo photogrammetry enables us to reconstruct the instantaneous 3D shape of the bed with high spatial resolution. Maximum temporal resolution is dictated by the capabilities of the cameras, which typically well exceed the experimental needs for scour related problems. Hence, we were able to investigate the rate of scour development and movement of maximum scour depth throughout the experiment. It is found that more than 75% of the maximum scour depth is reached during the first ten minutes of the experiments. The rate of scour hole development is significantly reduced during the remaining part of the experiment, asymptotically approaching the equilibrium condition. The proposed methodology, subject to small adaptions, should be applicable to a wide range of experiments.

The Case for Lake Recovery in Nova Scotia: A Longitudinal Review of Water Chemistry Data
David Redden, Graham A. Gagnon
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Atmospheric acid deposition in Atlantic Canada has decreased as a result of sulphur dioxide emission reduction policies in both the United States and Canada. The effects of changes in acidic loading on the region’s freshwater ecosystems is still not fully understood. Work done in other parts of the world gives some perspective as to the anticipated impacts on aquatic ecosystems. In Scandinavian countries it has been shown that the pH and alkalinity of these ecosystems return to pre-acidified ranges when acidic load is reduced. However, there can be some lag time between emission reduction and observable changes in water chemistry, particularly in regions with acid sensitive geology, such as Nova Scotia. This project aims to expand upon research done on lakes in Nova Scotia between 1990 and 2010. Several studies at that time indicated that there were no observed increases in either pH or alkalinity in lakes throughout most of the province. Using data collected from ongoing monitoring programs that began in the 1980s and 1990s, this paper will describe an ongoing assessment of evolving water chemistry in several Nova Scotian lakes. Of particular interest are the pH, alkalinity, and organic content of lakes in the region, as changes in these parameters are known to be related to reduced atmospheric sulphate deposition. In addition to this data review, on-going samples collection is underway to place historical data into context.

This research will help to better understand the effects of air emission control policies have on freshwater ecosystems. It will also offer some insight into changes in water chemistry that will have far reaching impacts for recreational water use, as well as water utility resources.
Cross-flow capacitive deionization
E. Marielle Remillard, John Rahill, Chad Vecitis
*Harvard University, Cambridge, MA*

Many communities depend on desalination for potable water, but traditional methods of desalination are energy intensive and costly. Reverse osmosis, the current state-of-the-art technology, uses 3-10 kW m\(^{-3}\) of water produced compared to >1 kW m\(^{-3}\) for freshwater sources. Capacitive deionization, an electrochemical desalination technique, could provide a low-energy alternative particularly in brackish water. Here, we propose a method for cross-flow capacitive deionization using carbon fiber electrodes.

Levels of pharmaceuticals and illicit drugs in influents: Does WWTP size matter?
Akarapan Rojjanapinun, Jiayue Luo, Sheree Pagsuyoin
*University of Massachusetts, Lowell, MA*

Pharmaceuticals and illicit drugs are a class of emerging micropolllutants that are now widespread in the environment. Most conventional wastewater treatment plants (WWTPs) were not originally designed to remove these chemicals from sewage, although advanced treatment processes have been shown to remove certain persistent compounds. In this paper, we perform a systematic review of refereed journal articles published from 2015 to 2016. A screening methodology was developed and implemented to examine the influent concentrations of 5 priority compounds in WWTPs: caffeine, erythromycin, ibuprofen, carbamazepine, and cocaine. These were grouped according to plant capacity: small (< 10 MGD), medium (10-100 MGD), and large (> 100 MGD); and geographical location (North America, Europe, and Asia). One- and two-way ANOVA tests were performed to determine if the influent concentrations of the target compounds varied by plant size and region. Results show large variabilities in the influent concentrations for each compound, ranging from 10-102, and up to 103 for caffeine. Average caffeine concentrations in Asia are much higher than in North America (p<0.10) and Europe (p<0.005) across all plant sizes. Caffeine concentrations are much higher in small plants than in medium or large plants; however, these differences were not statistically significant (p>0.50). Erythromycin levels are comparable across all regions and plant sizes while ibuprofen levels are significantly higher in North America than in Europe (p<0.001) and Asia (p<0.0001). Carbamazepine concentrations are higher in small plants and higher in Europe than in North America (p=0.33) and Asia (p=0.12). Average cocaine levels are higher in North America than in Europe and Asia although detection in influents was reported more frequently in the latter regions. Overall, we found no evidence indicating that the levels of the target analytes in influents are higher in larger WWTPs than in smaller WWTPs, suggesting that their removal from sewage should be considered regardless of plant size.
Role of oxygen functionalities in graphene oxide architectural laminate (GOAL) sub-nanometer-spacing spacing and water transport
Carlo Albero Amadei, Chad Vecitis
Harvard University, Cambridge, MA

Graphene oxide (GO) hybrid materials could represent a valid alternative to traditional polymeric membranes in environmental applications, such as water filtration. Understanding the water flow inside the GO nanochannels is paramount for designing an efficient separation membrane.

In this work, we fabricated ultrathin graphene oxide architectural laminate (GOAL) synthesized by vacuum filtration (VF) and subsequently chemically reduced by UV irradiation (in ambient or vacuum) or hydroiodic acid (HI) treatment and flake size was reduced by sonication. The extent of GO chemical and flake size reduction tuning of the nanochannels architecture, mainly GOAL interlayer spacing (2h) and tortuosity (l), was characterized by scanning electron microscopy (SEM), X-ray diffraction (XRD), and X-ray photoelectron spectroscopy (XPS). The GOAL permeability was determined in dead-end filtration mode and mesoscale LB simulations were used to elucidate hydrodynamic phenomena. The mesoscale simulations allowed us to include 105 water molecules, which represents a two order of magnitude improvement compared to traditional molecular dynamics simulations. Both experimental and simulation findings show the breakdown of fast water flow inside GO nanochannels due to the formation of hydrogen bonds between the water and the oxygen functionalities, suggesting viscous Darcy behavior. Moreover, the presence of oxygen functionalities was quantitatively correlated to the sub-nanometer-spacing (2h) of the GO nanochannels, which in turn controls the water permeability. This work paves the road for understanding how water interacts with graphene assemblies and will assist the design of engineering applications.

Treating fracturing water with acid mine drainage (AMD): experimental procedure and modeling
Jinze Li,
Lehigh University, Bethlehem, PA

Unconventional shale gas exploration has been made possible by horizontal drilling and hydraulic fracturing. For this process, large amounts of fresh water are required and about 20% of injected water will come back to the surface along with the natural gas, which is called flowback water. The total dissolved solids (TDS) of this water is usually over 150,000 mg/L, which is about 3-5 times higher than sea water. Challenges remain on treating/reusing this water as there are environmentally regulated ions, namely, Ra, Ba, and Sr. Precipitation by adding a sulfate salt (e.g., Na2SO4) will further increase the sodium concentration, thus posing potential risks to the aqueous ecologic system. Using sulfate from acid mine drainage (AMD) water would greatly reduce the cost for chemical consumption, however, a huge volume of high TDS water is produced by mixing enough AMD with flowback to remove all the divalent cations. Thus a more appropriate technique is proposed here to use AMD water as both a sulfate and fresh water source by using a self-regenerating ion exchange process. Ongoing research at Lehigh University has demonstrated: i) high removal efficiency of the divalent ions of concern without external chemical addition; ii) much lower energy consumption than reverse osmosis; iii) the treatment process can be simply and accurately modeled by PHREEQC; iv) treated flowback can be crystallized to produce insoluble and environmental friendly solids ready for landfill.
Alleviation of UV-quenching substances (UVQS) in municipal landfill leachate with chemical oxidation
Chanil Jung, Yang Deng, Renzun Zhao, Kevin Torrens
Montclair State University, Montclair, NJ

UV-quenching substance (UVQS) represents an emerging municipal solid waste (MSW)-derived contaminant. It can significantly interfere with UV disinfection when landfill leachate is disposed of at publicly owned treatment works (POTWs). In this study, Fenton process and ozonation were evaluated and compared to alleviate UV254 absorbance from a biologically treated landfill leachate under different operational conditions. Here dimensionless oxidant dose (DOD) was used to quantify an oxidant dose, which is defined as chemical equivalent ratio of the oxidant dose to initial COD (COD0). Results showed that leachate UV254 absorbance was removed accompanied with the UVQS decomposition by hydroxyl radicals (-OH) during Fenton treatment or by ozone (O3) and -OH during ozonation. Fenton process performed better than ozonation under their respective optimal conditions (90% UV254 reduction at DOD =1.0, [H2O2]:[Fe(II)] = 3:1, and initial pH = 6.0 for Fenton process; and 60% UV254 reduction at DOD = 0.14 and pH = 7.38 for ozonation). OH could effectively decompose both hydrophobic and hydrophilic dissolved organic matter (DOM), but O3 selectively oxidized hydrophobic compounds alone. Direct proportional relationship existed between the removed UV254 (ΔUV254) and the removed COD (ΔCOD) for the either treatment. A greater ΔUV254/ΔCOD observed from ozonation suggests that oxidant was more efficiently utilized during ozonation than in Fenton treatment for mitigation of UV absorbance.
POSTERS

1 Cryptosporidium characterization in the Schuylkill River watershed Leah Hall, Kristen Jellison Ph.D.
Lehigh University, Bethlehem, PA

Cryptosporidium is a sometimes deadly waterborne parasite that causes gastrointestinal illness. There are various host-specific species, including human infectious C. hominis and C. parvum, and various watershed sources, including agricultural runoff, wastewater treatment plants, and wildlife vectors. Tracking watershed contamination can provide valuable information about Cryptosporidium to utilities and healthcare/government officials.

We previously developed a cost-effective method for watershed sampling that utilizes the natural development of biofilms on submerged surfaces. The biofilm samplers provide comparable Cryptosporidium sp. detection to the costly EPA-approved filters. Our current project uses both biofilm samplers and filters to monitor Cryptosporidium sp. contamination at five locations (spanning upstream rural sites and downstream suburban/urban sites) in the Schuylkill River watershed.

In October 2015, we began sampling twice per month at each location. Samples are processed through immunomagnetic separation, DNA extraction, and nested PCR; PCR-positive samples are cloned and sent out for genetic sequencing. Genetic sequencing results, paired with water quality and ancillary data analysis, allow us to look at the patterns of Cryptosporidium sp. detection throughout the watershed.

Results to date show that agriculture is the most likely source of Cryptosporidium sp. in the upper watershed, and various other sources, including both humans and wildlife, increase the variety of detected species downstream. This research is ongoing, and more specific watershed characterization will be possible as sampling continues. Understanding the sources and species of Cryptosporidium in drinking water source watersheds will permit more strategic watershed protection efforts and reduce the exposure of the public to this waterborne pathogen.

2 Simultaneous Nutrient Removal and Recovery from Secondary Wastewater with a Hybrid Ion Exchange Bioreactor
Chelsey Shepsko, Dr. Arup K. SenGupta, Dr. Derick G. Brown
Lehigh University, Bethlehem, PA

Excessive nutrient loading to surface water bodies has become the most widespread water quality problem in the United States. A surplus of nutrients (nitrogen and phosphorus containing compounds) can cause eutrophication of a surface water body, depleting the oxygen demand for the survival of aquatic life. Current wastewater treatment technologies remove the nutrients in non-selective, segregated processes and generate a highly concentrated brine solution that must be disposed, relocating the issue instead of solving it. We propose a more sustainable nutrient-removal technology which consists of a hybrid ion exchange column that simultaneously acts as a bioreactor. A hybrid anion exchange resin with hydrated zirconium oxide nanoparticles is used to achieve high phosphate sorption recovery for future use. The column is also laden with suspended biomass which coats the
resin and performs denitrification on the sorbed nitrate, releasing converted nitrogen gas and self-regenerating the column for more nitrate uptake. During the process, phosphate levels dropped below eutrophic levels designated for surface waters for greater than 1000 bed volumes. As well, nitrate levels drop below the health hazard concentration and remain below eutrophic levels past 500 bed volumes. This ion exchange bioreactor provided a self-regenerating process for nitrate as well as a quick regeneration and a highly concentrated brine solution of phosphate for efficient recovery as struvite. Overall, the process is longer lasting than conventional nutrient removal treatment technologies, drops effluent nitrate and phosphate levels to near-zero concentrations and generates a highly-concentrated phosphate brine that can be recovered used for agricultural purposes.

3 Electro-Fenton reaction: Performance under flow conditions
Yuwei Zhao, Ljiljana Rajic, Shirin Hojabri, Roza Nazari, Akram Alshawabkeh
Northeastern University, Boston, MA

The electrochemical systems can be used to induce Fenton reaction in situ: hydrogen peroxide (H2O2) forms through the catalyzed reaction between electro-generated oxygen and hydrogen and further decomposes to hydroxyl radicals (-OH) via reaction with ferrous iron (Fe(II)). The evaluation of parameters that influence these reactions in flow-through electrochemical systems is of great importance for the application of (Electro-)Fenton reaction to treat contaminated groundwater. In this study, we evaluated the influence of the flow rate and current intensity on the rate of both H2O2 and OH formation. We tested the concentration of H2O2 and OH· at the sampling ports located between the electrodes in the flow-through electrochemical cell. The current increase from 60 mA to 120 mA, under the constant flow of 10 mL min⁻¹, doubled the production of H2O2: final concentration increased from 1.5 mg L⁻¹ to 3.0 mg L⁻¹. Consequently, this caused the increase in generation OH·. Under the constant current of 60 mA, the rate of H2O2 formation was negligibly influenced by the change of flow rate from 3 mL min⁻¹ to 20 mL min⁻¹. Since the groundwater flow rate can vary significantly, the possibility to maintain the conditions needed for (Electro-)Fenton reaction under different flows indicate that electrochemical system applied in this study has potential to be applied for groundwater treatment.

4 Source and removal of PCBs: Understanding the relative importance of ocean processes and their dynamic changes over time
Charlotte C Wagner, Helen M Amos, Elizabeth W Lundgren, Yanxu Zhang, Rainer Lohmann, Carey L Friedman, Noelle E Selin, Elsie M Sunderland
Harvard University, Cambridge, MA

30 years after the production ban of polychlorinated biphenyls (PCBs) in the US, PCBs are still prevalent throughout the global oceans. Today, the Arctic ocean is the major reservoir of legacy PCBs, however, detailed understanding of the relative importance of source and loss pathways has been precluded by difficulties in accurately measuring PCBs at great depths. The present study simulates the oceanic circulation of PCB-28, 101, 153 and 180 from 1930 to 2010 using the MIT General Circulation Model (MITgcm) forced by Goddard Earth Observing System - Chemical Transport model (GEOSChem) outputs as published by Friedman et al. in 2016. Based on the simulation of these four congeners, which cover a
range of chemical properties, we present lifetimes of particulate and dissolved PCBs for all 8 ocean basins and are able to quantify the relative importance of different removal pathways. We identify evasion and particle sinking as the most important losses for all oceans, with evasion being relatively less important in the Arctic compared to other basins. We then discuss the changes in the ocean dynamics, such as evasion trends, over time. Finally, we critically assess future implications of these dynamic changes and their applicability to other persistent, organic pollutants.

5 Nutrient Mass Balances on a Constructed Stormwater Wetland
Kelly Hogan, Emily Maj
Lafayette College, Easton, PA

A constructed wetland was built at Sullivan Park in Easton, Pennsylvania to reduce storm-related flooding and to improve water quality through the reduction of non-point source pollution. There has been excess amounts of algal production occurring within the wetland, which previous studies have linked to an overabundance of nutrients - primarily phosphorus and nitrogen (Khan 2013; Hardy 2014). We speculate that fertilizers are washed into the wetland after heavy rainfalls. Stormflow data will be compared to baseflow data to confirm this hypothesis. By sampling during storm events at the inflow and outflow channels, we can assess the import and export of nutrients. Using a v-notch weir and orifice outlet structure, the volumetric flow of water into and out of the wetland will be quantified for total mass removal. We hypothesize that this data should show a higher volume of both nutrients at the inflow due to the runoff, before absorbed throughout the wetland. By determining the source of excess nutrients, methods can be taken to reduce these amounts and limit eutrophication occurring within the constructed wetland.

6 Photochemical oxidation of selenium and formation of selenate oxyanions
Minerva Teli, Philip Larese-Casanova
Northeastern University, MA

Dissolved selenium exists in surface and ground waters as the oxyanions selenite (HSeO₄⁻) and selenate (SeO₄²⁻) and can be toxic to humans and wildlife. However, the formation of dissolved selenate from selenite and selenium-bearing minerals is not thoroughly characterized, and identifying the processes and oxidants can help explain selenate occurrence. Here we test a photochemically-produced oxidant found in natural waters hydroxyl radicals and their ability to oxidize selenite to selenate. Hydroxyl radicals were produced by irradiating nitrate and nitrite ions as well as hydrogen peroxide and titanium oxide with UV light. Production of hydroxyl radicals is confirmed with the conversion of benzoic acid to salicylic acid and hydroxybenzoic acid, and the degradation of crystal violet dye as a probe compound. Approximately 1 mM of selenate was formed from selenite after two hours of irradiation in these systems. Hydrogen peroxide was also found to oxidize selenite to selenate at millimolar concentrations after 24 hours, but only in strongly alkaline conditions. The possibility of singlet oxygen, which is produced by the interaction of light, O₂, and a photosensitizer, acting as an oxidant to selenite will also be discussed. This work will present how selenite ions react with the oxidants potentially found in surface waters, and the results will help us track the sources and fate of dissolved selenium oxyanions in natural systems.
7 
Morphology-dependent cytotoxicity of hematite (α-Fe2O3) nanomaterials
Eva Albalghiti, Amanda Lounsbury, Julie Zimmerman
Yale University, New Haven, CT

In recent years, engineered nanomaterials (ENMs) have found use in a broad range of applications due to their unique properties. Cytotoxicity, or the quality of being toxic to cells, is of particular relevance to water quality: if engineered deliberately, cytotoxic ENMs are useful in water treatment due to their antimicrobial activity. However, accidental release of cytotoxic ENMs into a watershed has the potential to devastate entire ecosystems. A deeper understanding of cytotoxicity is therefore essential to the future of ENMs. The goal of this research is to investigate the relationship between morphology and cytotoxicity in hematite (Î±-Fe2O3) nanomaterials. The cytotoxicity of several different sizes and shapes of hematite nanomaterials is established using both an acellular glutathione oxidation assay and an in vitro assay, with E. coli as the model organism. Results show that size and shape play a key role in determining the cytotoxicity of hematite nanomaterials. Additionally, size and shape are shown to be responsible for most or all of the variation in cytotoxicity between materials. This indicates that the mechanism of cytotoxicity likely requires physical perturbation of the cell wall and is less dependent on chemical processes such as ROS production. This correlation between the basic physical properties of hematite nanomaterials and their cytotoxicity, as well as the mechanistic resolution it provides, will greatly facilitate responsible engineering of hematite nanomaterials to maximize functionality and minimize hazard.

8 
Quantifying aquaculture’s effect on nutrient flux at the sediment-water interface in Maine
Elizabeth Gorse, Aria Amirbahman
University of Maine, Orono, ME

Cities in the western US are usually at the foothills of mountains and derive significant portions of their water supply from snow-fed rivers. Due to increasing urbanization, demand for water is rising, though recent studies indicate that cities supply from snow accumulation and melt is changing variably across the west. Adapting to these changes in snow is a challenge for cities; to address it, we first need to quantify the extent of their reliance on snow-fed rivers. We identify 13 western US cities (with a total population of over 12 million people) and the headwater basins associated with their water supply to quantify: 1) How much annual precipitation falls as snow?; 2) How much annual surface water runoff comes from snowmelt?; and 3) To what extent does reservoir storage act as a buffer to changes in snow? Using climatological data from North American Land Data Assimilation Systems (NLDAS) and PRISM high-resolution spatial climate data, we establish that San Francisco derives the most (74%) of their water supply from snow among the selected cities, whereas, Portland derives the least (~0%). Analysis from the two datasets yield similar results, suggesting a defensible and accurate methodology for determining snowfall reliance. Although inter-annual snow variability is common, some cities with expansive reservoir storage infrastructure and capacity, such as San Francisco and Denver, are able to buffer their water supply for over three years. The findings demonstrate that western US cities are variably reliant on snow for water supply and that adaptation to changes in snow will be challenging.
9

**Improvement of the numerical prediction of extreme weather events using Analog ensemble and Bayesian regression techniques in NE U.S**

Jaemo Yang, Marina Astitha, Luca Delle Monache

*University of Connecticut, Storrs, CT*

This study examines the effectiveness of Bayesian regression and analog ensemble techniques to improve the prediction of extreme weather events for NE U.S., which are defined by the occurrence of high wind speeds and/or intense precipitation. The predicted wind speed, wind direction and temperature by two state-of-the-science atmospheric models (WRF and RAMS/ICLAMS) are combined using the mentioned techniques under various combinations of the predictors (atmospheric variables). The basic concept behind the Analog ensemble and Bayesian regression approach is to take advantage of the strengths of two atmospheric modeling systems and, similar to the multi-model ensemble approach, limit their weaknesses which are related to systematic and random errors in the numerical prediction of physical processes. The first part of this study is focused on retrospective simulations of 146 storms that affected the NE U.S. in the period 2005-2016. In order to evaluate the two techniques, leave-one-out cross validation procedure was implemented regarding 145 storms as the training dataset. The analog ensemble method selects a set of past observations that corresponded to the best analogs of a numerical weather prediction and calculates an ensemble mean of the selected observation dataset. In the Bayesian regression framework, optimal variances are estimated for the training partition by minimizing the root mean square error and are applied to the out-of-sample storm. The preliminary results indicate a significant improvement in the statistical metrics of 10-m wind speed for 146 storms. This presentation will illustrate the implemented methodology and the obtained results for wind speed as well as set the research steps that will be followed in the future.

10

**Developing Iridium and Platinum Alloys as Effective Catalysts for Direct Ethanol Fuel Cells**

Lida Mehdizadegan Namin, Nathaniel Aaron Deskins

*Worcester Polytechnic Institute, Worcester, MA*

**Context/Purpose:**

Our goal for this project is to develop realistic atomic models of alloys as effective catalysts for use in the ethanol oxidation reaction (EOR) in direct ethanol fuel cells (DEFCs). The application of different Pt-based alloys in DEFCs has been studied extensively by different research groups. We modeled novel platinum alloys and we also proposed to use iridium and iridium alloys as alternative catalysts for DEFCs.

**Methods:**

Our research focuses on modeling different alloys by means of density functional theory (DFT). Different platinum and iridium alloys including PtRh-SnO2, Pt-SnO2, Ir-Rh, and Ir-Rh-Sn have been modeled and the C-C bond splitting in CHCO, CH2CO, and CH3CO were considered as these are crucial reactions in the EOR.

**Results:**

We found that all the Rh-containing models in Pt-based alloys had lower reaction energies than Pt-SnO2. Comparing iridium with Ir-based alloys, we realized that iridium had the most negative reaction energy.
Interpretation:
Lower reaction energy in the Rh-containing species in Pt-based alloys demonstrate the fact that Rh facilitates C-C bond splitting. The lower reaction energy in the C-C bond splitting in iridium surface implies that Ir is the best option to be used among these Ir-based alloys. Comparing iridium and platinum based alloys, it can be observed that all these alloys have almost similar reaction energies indicating they are effective catalysts to be used in the EOR.

Conclusion:
PtRh-SnO2 alloy and Ir (111) surface are the most efficient catalysts among the ones studied in this research.

11
Isolation of phototrophs from Oxygenic Photogranules used for Wastewater Treatment
Joann Rodriguez and Caitlyn Butler
University of Massachusetts, Amherst, MA

Wastewater treatment using activated sludge is an effective method for treating organics and inorganic pollutants. However, this conventional treatment could be considered energy-intensive due to the aeration process. For this reason, we are exploring the use of oxygenic photogranules (OPGs) as a single sludge process to eliminate the aeration requirements of conventional treatment. For full-scale application, a better understanding of the granulation mechanisms is needed to optimize the OPG growth. Our hypothesis is that the granule morphology and performance is correlated to the proportion of cyanobacteria, microalgae and aerobic heterotrophs present in the initial sludge inoculum. The objective of this study is to establish granulation in a constructed community of microorganisms. Isolation of phototrophic communities from mature seed granules was performed using serial dilution and plating techniques. The mature granules were from different initial sludge inocula exhibited different morphologies. According to microscopic observations, the microalgae Chlorella and Scenedesmus dimorphus and the cyanobacteria Oscillatoria were present in each granule. The dominance of the phototrophic species varied with morphology. A partially-settled sphere granule contained less filamentous cyanobacteria compared to the floating sphere granule. The high abundance of filamentous cyanobacteria in the floating sphere granule may have led to high compaction and more defined shape. On-going work will establish granulation in isolates, co-cultures and tri-cultures of a pure culture of Oscillatoria and the Chlorella and Scenedesmus dimorphus isolated from the mature granules.

12
Combination AOPs and GAC treatment of high concentration COD from industrial wash process
Kun Yang
Lehigh University, Bethlehem, PA

Industrial wastewater generated from diesel particulate filters regeneration process contain highly concentrated COD and heavy metals, which makes the pretreatment process difficult. In the current study, COD removal efficiency will be evaluated by applying AOPs combined with GAC adsorption. The hydrogen peroxide dosage, catalyst dosage, pH and GAC dosage are selected as key parameters. After the treatment, the reaction will be ended
simply by adding lime to increase the solution pH. The metal removal efficiency are determined at the same time. After the treatment, pH will be brought back between 6 to 9.

13
Upgrading an Existing Wastewater Treatment Plant to Perform Co-Digestion of Different Food Wastes
T.J. Bolen, Timothy Conway and Hossain Azam
Manhattan College, New York City, NY

To investigate the expected performance of the co-digestion system with recuperative thickening for an upgrade plan of a NY wastewater treatment plant (WWTP), two lab scale digesters are being run to simulate and benchmark the treatment plant's existing conditions. Currently the digesters are operating with a working volume of 6L, headspace of 4L, long solid retention time of 30 days and low average solid concentration of 20,000 mg/L. The reactors are able to provide a volatile solids reduction as high as 41%, while producing approximately two liters of biogas per day; this translates to a biogas yield between 1.1 and 1.3 m3*kg-1 of volatile solids destructed. Furthermore, several trials of biochemical methane production (BMP) tests are underway to determine the optimal ratios of the various sludge and food wastes to maximize methane production. The treatment plant being modeled plans on upgrading its facilities to co-digest several different types of wastes including, grease interceptor waste, cheese whey, food processing byproducts, and pulped food waste. Primary sludge seeded with the WWTP anaerobic digestate clearly shows higher methane production when compared with cheese whey and primary sludge mixed with waste activated sludge (WAS) in the BMP assays. Microbial communities and communities shift due to the food waste addition are being analyzed at different time periods and at different conditions of the digesters and BMP bottles. Furthermore, the effects of recuperative thickening on dewatering properties of different types of sludge/food waste will be performed to determine its additional benefit in the upgraded co-digestion system.

14
Degradation of estrogens by carbon nanotube electrochemical filtration
Gustavo Cunha, Marcia Dezotti, Chad Vecitis
Harvard University/UFRJ, Cambridge MA

Natural and synthetic estrogens are excreted daily by humans and animals. Due to their low concentration, conventional wastewater treatments are not always able to remove them below acceptable levels. Researchers have reported that wildlife in areas close to sewage treatment plants have been affected by exposure to estrogens, identified by feminization of local fish and extinction of some aquatic animal species. Moreover, these compounds can increase the incidence of cancer in humans. Recent studies have shown that a porous carbon nanotube (CNT) electrochemical filter can effectively remove organic dyes, phenol and ions via adsorption and electrooxidation.

In this study, a CNT electrochemical filter was utilized for the electrooxidation and adsorption of estrogens. Experiments were carried out at an initial concentration of estradiol and ethinylestradiol of 37 μmol.L-1, applied voltage in the range of 1.0 - 2.5 V and flow rate of 1.5 mL.min-1 and 10mmol.L-1 of Na2SO4 as supporting medium. Each reaction took 5 hours to be completed. Initial pH of the electrolyte (pH 2-10) was also examined. The CNT anodes were characterized by Scanning electron microscopy (SEM), X-ray
photoelectron spectroscopy (XPS) and Cyclic voltammetry (CV). From the results it can be founded that when the pH was 6 and the applied voltage was 2.5 V, the estrogens removal could reach up to 98% after 1 hour. In addition, with the increase of the pH, the oxidation peak potential shifted to a less positive potential. In conclusion, this novel electrochemical technology could be an alternative for estrogen removal.

15
**pH modeling in electroremediation process in a batch reactor**
Andre Gonzaga, Shirin Hojabri, Ljiljana Rajic, Akram Alshawabkeh *Northeastern University, Framingham, MA*

Electrochemical remediation is an innovative in-situ remediation method that uses direct electric current to decontaminate groundwater. This method has been getting increasing attention due to its relatively low energy consumption. When current is applied to the system, several transport mechanisms take place simultaneously, including advection, diffusion, and migration. Depending on the physical properties of the reactor, a number of the aforementioned mechanisms can become significantly more prominent than others. Mathematical models are invaluable when simulating the remediation process as they provide a thorough understanding of the phenomena. In this study, the electrochemistry module in the COMSOL Multiphysics software was used to describe pH changes with the use of inert (mixed metal oxide, MMO) and active (iron) anodes during electrochemical processes in a batch reactor. This study focuses on concentration changes for each species within the electrochemical process. The model features water association and dissociation as well as water electrolysis, explicit chemical and electrochemical reactions that aid in further describing the system. The final results of the simulation have been compared to the available experimental data.

16
**Characterization of corncob-based activated carbons prepared with various activators and their adsorption for aqueous lead and phenol**
Qing-Song Liu, Yang Deng *Montclair State University, Montclair, NJ*

Activated carbons (ACs) were prepared from corncob using various activators under conditions of: temperature 500°C, holding time 2 h, activator to precursor weight ratio 1:2.5. The H₃PO₄ activated AC (AC-PA) exhibited a higher carbon yield (45.7 ± 3.4 %) than KOH activated (AC-PH, 14.7 ± 1.9 %) and K₂CO₃ activated ACs (AC-PC, 19.7 ± 3.1 %). Their surface physical and chemical characteristics were analyzed using SEM, FTIR, XPS, XRD and BET. Compared to other ACs, AC-PA had more oxygen-related groups and a hydrophilic surface. Its surface area (680.7 m²/g) was larger than those of AC-PH and AC-PC. The pore size distribution of AC-PA was more heterogeneous. Studies on the adsorption of lead showed that, resulted from its abundant acidic groups, AC-PA gave more favorable adsorption with a capacity of 298.5 mg/g. As for phenol adsorption, due to the combined effects of several interactions, the performance of various ACs related to the equilibrium concentration. A post-heat treatment of AC-PA strongly improved phenol adsorption, with a capacity of 132.1 mg/g.
Using a Chemically Hydrolyzed Biosolids as a Carbon Source for BNR
Joshua Registe, Jeanette Brown, Robert Sharp
Manhattan College, NY

Manhattan College is performing an independent study on the use of a chemically hydrolyzed biosolids product as an external carbon source (electron donor) for biological nitrogen removal. The biosolids product is produced by Lystek, Cambridge, Ontario Canada. Lystek biosolids treatment process is an innovative, energy efficient and cost effective low temperature-thermal-chemical technology which utilizes a proprietary combination of heat to 70-75°C (160-165°F), pH 9.5-10.0 using alkali / KOH, and high shear mixing treatment to convert biosolids into high solids (15-17%), homogeneous, pathogen-free, and nutrient rich liquid product. The objective of this independent study was to determine if the hydrolyzed Lystek product could be used as carbon source for BNR systems. The study was divided into two phases; Phase 1, an initial study to determine specific denitrification rate (SNDR) compared to methanol and glycerol and Phase 2, a more in-depth study of the Lystek product using sequencing batch reactors. Following an initial acclimatization phase of about 2 weeks, both reactors achieved full nitrification with average effluent ammonia concentrations of 1.3 and 1.6 mg/L, respectively, from the glycerol and Lystek reactors. For the first three weeks, both reactors exhibited high effluent concentrations of nitrites and nitrates, before decreasing over time. Ammonia concentrations in the glycerol reactor at the end of the anoxic phase were between 0.4 and 1.4 mg/L, with the corresponding values in the Lystek reactor ranging from 2.9 to 3.9 mg/L. The results of this research indicate that the carbon in the chemically hydrolyzed biosolids product, Lystek, can serve as an inexpensive electron donor for a biological nitrogen removal. Because of Lystek’s ammonia attributes, adding that may attribute to increased effluent ammonia concentrations, to prevent this, mixed carbon source substrate utilization can be further studied to understand optimal carbon source ratios for efficient denitrification while still meeting permit regulations. The presentation will describe in detail the experimental procedures and discuss the results obtained during the three month testing period.

Persulfate Oxidation for In Situ Degradation and Regeneration of Granular Activated Carbon Sorbed Perfluoroalkyl Compounds
Blossom Nzeribe, Nageshrao Kunte, Dinusha Siriwardena, Michelle Crimi, Thomas Holsen, Christopher Bellona
Clarkson University, Potsdam, NY

Perfluoroalkyl substances (PFASs) are characterized as contaminants of concern. They are used extensively in industrial applications as a result of their unique properties such as high surface activity, thermal acid resistance and hydro-lipophobic properties. They are mostly used as formulation for Aqueous Film Forming Foams (AFFF), surfactants and lubricants. They are ubiquitous in environmental media including groundwater, environmentally persistent, bioaccumulative and pose potential risk to humans. They have proved inherently recalcitrant to most conventional water treatment techniques. For these reasons, there is a need to develop a promising remediation technique to remove them from aqueous solutions or mineralize them to less/non-toxic species.
In situ chemical oxidation of sorbed contaminants (ISCO-SC) is a treatment approach designed to remediate contaminated groundwater which involves the use of granular
activated carbon (GAC) to sorb and concentrate contaminants followed by contaminant destruction and carbon. This study was conducted to investigate the effectiveness of heat-activated persulfate in in situ degradation of GAC sorbed PFASs. Perfluorooctanoic acids (PFOA) and perfluorooctanesulfonic acid (PFOS) were chosen as the representative compounds as they are the most commonly detected at contaminated sites. Adsorption isotherms and kinetic data from previous experiments showed that FILTRASORB 400 GAC by Calgon Corporation had highest PFASs sorption capacity.

Batch and column experiments were conducted to determine optimal operating conditions and analyze for pH, sulfate, persulfate, PFASs removed, byproducts and intermediates at different times and pore volumes. PFOA was completely oxidized in aqueous phase and sorbed GAC showed 50% degradation while PFOS exhibited a poor desorption rate.

19 Disinfection of Secondary Effluent and CSO
Xiao Lin, Kathy Ammari, Robert Sharp, Jessica Wilson
Manhattan College, Riverdale, NY

The New York City Department of Environmental Protection (DEP) owns and operates 14 Wastewater Treatment Plants (WWTPs) located throughout New York City. Each plant is designed to treat some portion of wet weather flow with any excess flow being diverted to combined sewer overflow (CSO) detention facilities or CSO outfalls. The objective of this work is to address a number of issues related to the disinfection of both wastewater effluent and CSO discharges.

It is expected that New York State will adopt a new indicator organism criteria for all New York State WWTPs. This new criteria will replace fecal coliforms as the biological water quality indicator with Enterococcus. The switch will propose a number of potential challenges for WWTPs in that Enterococcus is considered more difficult to inactivate using traditional disinfection methods compared to fecal coliforms. Currently all NYC plants use chlorine to disinfect their wastewater prior to discharge in order to meet to biological water quality criteria. This study also investigates the effectiveness and applicability of an alternate disinfectant, peracetic acid (PAA) for meeting the new Enterococcus standard. Along with the pending change in indicator organism, the new permits also include standards for cyanide as well as total residual chlorine (TRC). This work is aimed to better understand the disinfectant dose and contact times required to meet the new enterococcus criteria. It will also help to understand what impact an increased dose might have on cyanide production, the formation of disinfection by-products (DBPs), effluent TRC concentrations and/or the possible need for dechlorination.

Secondary effluents before chlorination were collected from 4 NYC wastewater treatment plants. 2 batch reactors were set up in 4 L beakers, apply specific dose of Chlorine and PAA to the beakers. The Chlorine and PAA decay is measured at 2, 4, 10, 15, 30, and 60 minutes. The Fecal Coliform and Enterococcus is measured at 15, 30, and 60 minutes. The results were then compared with NYC discharge standards.

Based on the results, WWTPs will require 0.5 - 1.0 mg/L more Chlorine dose to met Enterococcus standard than Fecal Coliform standard. WWTPs will require 0.5 - 1.0 mg/L more PAA to met Fecal Coliform and Enterococcus standard than Chlorine. Also, PAA decay relatively slow after initial PAA uptake. In general, high dose of disinfectant are needed to met Enterococcus standard, therefore it has impact on formation of DBPs and possible need
for dechlorination. Process of chlorination and dechlorination might also impact on the formation of cyanide.

20
Preliminary Assessment of Greenhouse Gas Emissions from Advanced Nitrogen Removing Onsite Wastewater Treatment Systems
Gina Celeste, Elizabeth Brannon, Brittany Lancellotti, George Loomis, Jose Amador
University of Rhode Island, South Kingston, RI

Coastal ecosystems have been severely impacted by nitrogen pollution. One source of nitrogen overloading in RI is onsite wastewater treatment systems (OWTS), which serve 1/3 of all households in the state. To lower N-loading to Narragansett Bay, state regulations require the installation of upgraded technologies that include advance biological N-removal processes throughout N-sensitive areas within the Narragansett Bay watershed. However, N-removing OWTS have the potential to produce potent greenhouse gases (GHG) as by-products, including carbon dioxide (CO2), methane (CH4), and nitrous oxide (N2O). We carried preliminary measurements of GHG emissions in the summer of 2016 from three of the most commonly installed advanced N-removal OWTS technologies within the watershed: Orenco Advantex AX20, Bio-Microbics MicroFAST, and SeptiTech D Series. A cavity ring-down spectroscopy analyzer connected to a closed chamber was used to measure CO2, CH4, and N2O emissions in real time from the systems. To evaluate differences within and between N-removal technologies, two initial measurements (one each in denitrification and aerobic compartments) were made at 9 sites (3 per technology). Preliminary data indicate differences between technologies, with higher emissions of all three GHGs from Orenco Advantex AX20 systems. Our results suggest that GHG fluxes differ among N-removal technologies. This information can be used to improve system designs to reduce GHG emissions while maximizing N-removal.

21
Struvite precipitation, inhibition and dissolution in wastewater systems: modeling and experimental analysis
Arvind Damodara Kannan, Sebastian Gerlak, Richard Carbonaro, Hossain Azam
Manhattan College, Riverdale, NY

Struvite (NH4MgPO4·6H2O) is an important phosphate mineral found in natural and engineered systems. This study will provide detailed characteristics of struvite formation/inhibition/dissolution and will assist in designing future phosphorus removal, recovery and/or scale removal systems. Laboratory experiments and chemical equilibrium modeling (MINEQL+ and PHREEQC) were undertaken to investigate three aspects of struvite: (a) formation potential and precipitation, (b) inhibition characteristics and (c) dissolution potential in presence of chelating agents. The precipitation experiments at equimolar (5 mM) concentrations (at 25, 50 and 100 mM CHES buffer) of magnesium, ammonium and phosphate at pH 9.5 showed maximum precipitation of 92.7% magnesium within 24 hours with the greatest drop in ammonia, magnesium and phosphate concentrations within 2 hours. The precipitate characterization of struvite was confirmed using XRD (X-ray diffraction) and optical microscope (Olympus BX-40). Inhibition experiments showed no formation of struvite with an EDTA to struvite ratio of 5:1. Dissolution experiment with EDTA showed complete dissolution of struvite (expected
dissolved concentration of 5 mM) at 25 mM EDTA within 24 hrs. Precipitation experiments at different interfering ions (iron, calcium etc) and inhibition/dissolution experiments in the presence of different chelating agents (NTA, NTMP, IDA, HEDTA, DTPMP etc) are being conducted. MINEQL+ modeling results indicate that saturation indices of struvite decrease with increase in chelating agents concentrations and potential of struvite precipitation as well as optimal pH range are influenced by the presence and types of other competing ions and chelating agents. Further microcosm studies on struvite will be conducted using anaerobically digested centrate samples.

22
Characterizing vernal pool biogeochemistry across a land use gradient in Maine
Lydia Kifner, Aria Amirbahman, Aram Calhoun, and Stephen Norton
University of Maine, Orono, ME

Vernal pools are small seasonal wetlands that are crucial for maintaining amphibian and reptile biodiversity in northeastern USA forests. The pools’ sizes make them especially vulnerable to human disturbance, which can have detrimental effects on water quality and other ecosystem functions. This study explores pool water chemistry, carbon turnover, and cycling of phosphorous, nitrogen, and carbon in the water column and at the sediment water interface at four Maine vernal pools (two with low modification and two with higher modification). We examine if these systems are closed with respect to nutrients, and investigate the drivers behind the chemical reactions in the pools. We monitor pH, dissolved oxygen, strong acid anions, strong base cations, gasses (CO2, CH4, and N2O), P, N, Fe, Mn, Al, Si, DOC, and chlorophyll a between April and August 2016 on a weekly basis in order to characterize their chemical trends. We hypothesize that (a) vernal pools release and potentially export P and possibly particulate Fe to surrounding waters, but reduce dissolved N concentrations, and (b) pools vary in their biogeochemical activity, water chemistry, soil respiration rates, and nutrient cycling. This research will allow us to identify key biogeochemical processes that influence nutrient cycling and water quality in four northern New England vernal pools.

23
Radical Detection During Chemical Oxidation of 1,4-Dioxane
Michaela Cashman, Dr. Thomas Boving
University of Rhode Island, RI

1,4-Dioxane (C4H8O2) is a heterocyclic organic contaminant found in groundwater plumes at industrial sites across the globe. Dioxane’s high aqueous solubility and low retardation makes conventional remediation technologies insufficient for its removal from groundwater. Hence, alternative remediation strategies, such as advanced oxidation processes (AOPs), are being pursued for difficult to treat compounds. Peroxone activated persulfate oxidation of 1,4- Dioxane is an AOP that is believed to facilitate radical production. Currently, there is a limited understanding of the underlying chemistry of these radical reactions, including which radicals are produced and their duration of activity. My research investigates how OxyZone, a peroxone activated persulfate oxidant patented by EnChem Engineering (Newton, Massachusetts) can be used to oxidize 1,4-Dioxane from contaminated groundwater sources. In our study, Electron Paramagnetic Resonance (EPR) spectrometry is used to characterize the radicals involved in the destruction of 1,4-Dioxane.
While this project is ongoing, we have successfully confirmed the presence of sulfate radical (-SO\(^{4-}\)) and hydroxyl radical (-OH) production through Dioxane oxidation with OxyZone. This research further advances the understanding of how AOPs can be used as an in-situ chemical oxidation (ISCO) technique for organic contaminant groundwater plumes.

### 24

**Efficiency of Outer Membrane Vesicles as a Defense Mechanism**

Mahdisoltani, Masoud, Hellweger, Ferdi L.

*Northeastern University, Boston, MA*

Bacteria employ different defense mechanisms to alleviate effects of imposed stresses on their population. Producing and releasing Outer Membrane Vesicles (OMVs), which costs energy and resource, is recognized to aid bacterium population against viruses. The question is whether producing OMVs by consuming resource will efficiently reduce viral infection rate or not. In our study, we modified existing models for system of bacteria-virus to include OMVs and analyzed concentration of nutrients to investigate the efficiency of vesicle production. To quantify this, we compared the average limiting resource concentration (R*) of the bacteria with OMVs to the one of the bacteria without OMVs. We found out that bacteria benefit from producing OMVs when viral infection is responsible for the majority of bacterium population loss (i.e. higher density of bacteria and viruses); otherwise, it is efficient for the bacteria to devote the biomass to growth. However, it has been observed that bacteria always divert fraction of the biomass to OMVs for other purposes (e.g. intercellular transport and signaling). In terms of an innate defense mechanism, we concluded that OMVs can efficiently mitigate the effects of viral infection on the bacterium population under both resource limiting and high infectious conditions.

### 25

**Does water stress increase the incidence of antibiotic resistance genes in drinking water supplies?**

Maria Sevillano, Charles Knapp, Szymon Calus, Zihan Dai, Ameet Pinto

*Northeastern University, Boston, MA*

Increasing water stress due to population growth, industrial/agricultural productivity, and drought suggest the consideration of direct or indirect use of reclaimed water (i.e. treated wastewater) to boost existing drinking water supplies (DWS). This raises concerns about the potential for introduction of anthropogenic contaminants into DWS. Extensive work has been carried out to characterize and quantify chemical contaminants in DWS, however little has been done to evaluate emerging biological contaminants like antibiotic resistance genes (ARGs) for potable use of reclaimed water.

We conducted a sampling campaign to characterize ARGs across a gradient of water stress within the United Kingdom in the summer of 2015. 28 samples were collected at drinking water taps from 11 densely populated cities in mainland UK, with variable water stress classification ranging from low, medium, and high. Water quality data was gathered, and samples were filtered to harvest bacterial cells, followed by DNA extraction. Samples were characterized for a range of clinically relevant ARGs using qPCR. Additionally, the samples were submitted for shotgun DNA sequencing for non-targeted detection of ARGs.

qPCR indicate that ARGs are present at low concentrations in treated DWS and their incidence does not follow the geospatial trend expected from available data on water stress in the UK. Nevertheless, there is increased abundance of certain ARGs at sampling sites.
located in water scarcity hotspots. Metagenomic sequencing indicates that top antibiotic resistance ontologies (AROs) found are typically efflux pumps. As expected, Proteobacteria dominates the community composition with top AROs most frequently associated with them.

26
Study of the Dynamics of Class 1 Integrons Gene Cassette Arrays in Wastewater Treatment Systems
Yu Yang, Bing Guo, Shameem Jauffur, Dominic Frigon
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Wastewater treatment plants (WWTPs) are important hotspots of the release of antimicrobial resistance genes (ARGs) from human microbiome to the natural environment. Class 1 integrons are ubiquitous in the environment, and they often harbor ARGs in the form of gene cassettes (GCs) that can be readily added and removed to a gene array under the gene-expression control of a unique integron promoter. As such, class 1 integrons are one of the most important genetic elements facilitating the transfer of ARGs between species and the assembly of genes to resist several antimicrobials. While the architecture of class 1 integrons and their abundances have been studied in both environmental and clinical contexts, the dynamics of gene assembly and removal from the gene cassette arrays are much less understood. In the current work, the diversity of gene cassette arrays in class 1 integrons was determined in the influent, mixed liquor, and effluent samples from three different WWTPs in Quebec, Canada. It was found that the size of the arrays varied between these samples due to differences in the number and types of resistance gene cassettes being harbored in the integron. Furthermore, it seems that the proportion of GC-harbor class 1 integrons with the genetic architecture associated with environmental origin is higher than that associated with clinical origin. This suggests that active gene rearrangement and possibly exchange occur during biological wastewater treatment. It also suggests that genetic and environmental factors may influence the dynamics of rearrangement, providing potential targets for process improvements.

27
Toxicogenomic-based Risk Assessment by Consensus Clustering
April Gu, Xin Wen, Sheikh Rahman, Matthew Greenlaw
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There is a great need for enhanced methods of water risk assessment, as demonstrated by initiatives including Tox21 of the EPA and the REACH campaign of the EU. Our research involves designing a time-effective, inexpensive, informative, and reliable tool to identify ecological contaminants and their toxicity levels to infer their ecological effects. The investigation focused on the 2014 coal ash spill in the Dan River, in which we searched for similarity groups between the toxicity and the location or time that assays were recorded. The toxicity assays of the environmental sample matrix (i.e. water and sediment mixtures) were collected randomly about the site on different dates. With risk assessment performed in vitro, a library of 146 stress-related genes of yeast received a GFP biomarker to measure gene alteration by the ratio between fluorescence and OD600. Control groups had yeast genes observed without exposure to river samples. By taking our proposed Protein Effect Level Index (PELI), we quantified the net transcriptional effect a certain river sample induced upon yeast genes. Data were visualized via consensus clustering, which has both
HTS and stability to generate similarity groups. Results indicated associations between gene expression and both assay location (i.e. distinguishing water and sedimentary samples) and time. Future studies would use consensus clustering to find how toxicity potential could vary throughout the Dan River. Due to the synergistic effects of mixtures in river samples, more information on samples chemical composition is necessary to determine the toxicity level in genes of microbes such as yeast.

28

Testing and Application of a Modified Normalized Sediment Load Function for the Tidal, Freshwater Hudson River
Nelson da Luz, Kevin J. Farley Ph.D.
Manhattan College, Bronx NY

The Lower Hudson River receives sediment loads from the Upper Hudson and Mohawk Rivers at Federal Dam (Troy NY), and several other tributaries along the tidal, freshwater and estuarine sections of the river. The New York U.S. Geologic Survey (NY-USGS) has conducted extensive monitoring of these sediment loads from the Upper Hudson, the Mohawk River, Catskill Creek, Rondout Creek and several smaller tributaries. The objectives of this study were threefold: (i) use NY-USGS monitoring data to develop and test a modified version of the Normalized Sediment Load (NSL) function for relating sediment loads to daily flows, (ii) construct a 15-year continuous record of sediment loads from Lower Hudson tributaries, and (iii) compare the sediment load record to observed sediment loads 83 miles downriver at Poughkeepsie NY to evaluate trapping of sediment in the tidal, freshwater section of the river.

Results showed that approximately 17 million tons of sediment entered the tidal, freshwater Hudson from March 2002 to September 2014. A large portion of this load was discharged during Tropical Storms Irene and Lee in August-September 2011. In comparison, approximately 10 million tons of sediment was transported past Poughkeepsie. This suggests that up to 7 million tons of sediment may have been retained in the tidal, freshwater section of the river. These results will be used in sediment transport and contaminant fate models to determine how sediment trapping in the tidal, freshwater portion of the river is affecting response times for reduction of PCB concentrations in the Lower Hudson.

29

Applying MP UV Disinfection with Low Wavelength Monitoring to Achieve Sustainable Public Health Protection
Alexandria Hidrovo
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Drinking water treatment is essential in obtaining a healthy community. There are various methods to disinfect water; some have more negative affects toward public health than others. For example, disinfection with chlorine causes disinfection byproducts (DBPs) within treated drinking water. DBPs are regulated by the Environmental Protection Agency because they have the potential to cause cancer and other negative health effects if levels of exposure exceed legal limits. Ultraviolet (UV) light disinfection does not produce these DBPs which is why it is becoming a preferred method for water disinfection. The issue that medium-pressure UV disinfection technology faces currently is the lack of a proven,
regulatory accepted method to monitor low wavelengths. These low wavelengths (200-240nm) have been demonstrated in the literature to effectively inactivate regulated viruses, such as adenovirus, that are found in drinking water. EPA, 2006 Groundwater Rule requires demonstration of 4-log removal/inactivation of human enteric viruses. The purpose of this research is to evaluate the ability of low wavelength monitoring in UV treatment units that have the potential to reduce their energy use and total UV system costs while improving public health protection in small drinking water systems. This research will study the effectiveness of new sensors that can effectively monitor low wavelengths and determine the energy and cost savings that will result in more sustainable UV disinfection systems. Data is recorded and analyzed at two different water treatment plants; a small ground water system and a larger surface water system. Preliminary results indicate positive savings in energy and cost.

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A study of nutrients concentration changes in Newark Bay, New Jersey
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Over decades, high nutrients concentrations become a major issue in Newark Bay due to the expensive treating process. Human activities is the dominant impacts on water quality in aquatic ecosystems. A historical study of the changes in nutrients concentration of the Newark Bay were conducted based on the water quality data collected from New Jersey Harbor. According to the different nutrient sources, the paper discusses the causes of the concentration change. The results showed that (1) the major resource of total Kjeldahl nitrogen is from the Hackensack River and the Passaic River; (2) nitrate and nitrite concentrations are controlled in a proper range that has no harm to the human health; (3) The high phosphate-phosphorus and orthophosphate mainly come from the Passaic River and the Hackensack River; and (4) Most of these nutrients are a result of run off from agricultural use and wastewater treatment plant. With the awareness of the impacts from human activities, nutrient pollution in Newark bay has decreased by proper management methods. However, the water quality in Newark Bay still needs to be improved in the future.

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Use of Zooplankton for Removal of E. coli in Freshwater Systems
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High levels of fecal indicator bacteria, such as Escherichia coli (E. coli), can have negative implications for ecosystem and human health. Innovative approaches are needed to manage levels of microbial pollutants in freshwater systems. The use of zooplankton can be an attractive approach to improve water quality through the removal of E. coli in impaired natural systems. Zooplankton are ecosystem engineers that play a vital role within aquatic ecosystems as filter feeding organisms. Research is needed to better understand the filter feeding capabilities of different assemblages of zooplankton under varying environmental conditions. Results from field surveys as well as laboratory experiments will be presented. Field surveys were conducted at Smith College's MacLeish field station in a stream impacted by grazing cows. E. coli levels in the water within the stream were quantified and paired with zooplankton population data. Laboratory batch experiments of varying duration were
conducted to quantify the uptake rates of E. coli by zooplankton. Initial results show filter feeding activity by zooplankton can have a quantifiable impact on E. coli levels in the water column. The data collected from laboratory experiments and field surveys will be used for model development and provide guidance for future aquatic system restoration efforts.

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**Adsorption Properties of Plastic Microbeads and Other Soap Additives**
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Pollution from plastic microbeads added to cosmetics and soaps is a concern in aquatic environments. In addition to problems regarding the persistence of plastics, these beads adsorb organic contaminants such as DDT and PCBs, concentrating pollutants and introducing them into the food chain. State and federal regulations have subsequently banned the use of microbeads, and they are being replaced with natural exfoliants and adsorbents that include apricot kernels, charcoal, jojoba oil, sugars, and salts. Given the importance of organic contaminant adsorption associated with the microbeads, it is necessary to quantify the aqueous phase adsorption performance of these new additives and compare to that of the plastic microbeads. Particles, including microbeads, activated charcoal, jojoba beads, and apricot kernels, were extracted from 6 body washes and face scrubs using filtration and centrifugation. Isolated solids were characterized to identify their physical (surface area) and chemical (elemental composition and hydrophilicity) properties. Specific surface areas ranged from $< 1 \text{ m}^2/\text{g}$ to $> 100 \text{ m}^2/\text{g}$, with plastic microbeads having the lowest area. Adsorption tests with 75 mg/L methylene blue show that the higher surface area additives adsorb at least 66% more contaminant than the plastic microbeads. While adsorption remains a concern for plastic microbeads, these results indicate that many natural replacements have even greater capacity for aqueous phase contaminants. This suggests that these alternatives may not address all of the issues associated with pollution from cosmetics, face scrubs, body washes, and other products designed to be washed down the drain after use.

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**Evaluating potential for water quality decline in Maine lakes**
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Understanding lake vulnerability with respect to eutrophication and loss of water quality is important in a changing chemical and physical environment. This project aims to identify and measure physiochemical characteristics that make lakes vulnerable to external stresses, such as regional warming and land use changes. We hypothesize that physiochemical factors such as sediment chemistry, lake morphology, water temperature, and percent agriculture control phosphorus (P) concentration, and hence, lake water quality. Twenty-four lakes in Maine were chosen covering a wide range of trophic states. Water samples were collected twice in June and August 2015, and analyzed for a variety of elements, with a primary focus on P. Sediment samples were collected in June 2015, and were sequentially extracted and analyzed for P, aluminum (Al) and iron (Fe) in different fractions. The results show that lakes whose sediment has a NaOH-extractable Al to dithionite-reducible Fe ratio ($\text{Al(NaOH):Fe(BD)}$ ratio) $> 3$ are less susceptible to internal P
release. Likewise, lakes that stratify strongly during the summer have lower epilimnetic P concentrations. Among other factors, lakes that are susceptible to internal P release are those with sediment Al(NaOH):Fe(BD) ratio < 3, and those that stratify weakly during the summer. Identifying and quantifying factors that lead to lake eutrophication allow us to classify susceptible lakes and inform the stakeholders, such as lake residents and policy makers, with respect to best practices for lake stewardship.

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Saw Mill River Study: An Assessment of Water Quality in an Urbanized Stream
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The Saw Mill River is a 23.8 mile stream that is located in Westchester County, just north of New York City. The upper portion of the watershed is largely residential, while the lower portion flows through the City of Yonkers and is highly urbanized with many channelized sections of the river. A 2008-2011 water quality study showed contaminant levels exceeded state standards. Since 2011, several corrective actions have been taken to improve access to the lower portion of the river (through daylighting a portion of the stream) and to improve water quality (through identification and removal of leaky and illegal sewer connections). The objective of this project was to determine whether any of the corrective actions has resulted in improvements in the water quality of the lower portion of the river. During the summer of 2016, three water quality surveys were conducted along the lower portion of the river. Parameter measurements included conductivity, pH, fecal coliform, enterococcus, total phosphorus and nitrate. Comparisons of 2016 data to the 2008-2011 results do not show any clear improvements in water quality over the past five years. However, results for the three 2016 surveys showed large variations that were largely associated with dry and wet weather conditions. Further evaluation of contaminant concentrations as a function of rainfall are currently being conducted and will be used to provide a more meaningful comparison of the 2016 and 2008-11 datasets.

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Assurance of Drinking Water Quality on Tugboats
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Panama Canal tugboats assist ships in their transit through narrow channels of the Canal. Currently locomotives help guide ships through locks, however, with the expansion of the Panama Canal, and the increased capacity of ships, locomotives are no longer the most efficient method for assistance. Therefore, Panama Canal tugboats will serve a more crucial role in the transportation of ships by assisting them through the new locks. Although the ships have the mechanical ability for this increased responsibility, there was speculation as to whether the water stored on the vessels, for the consumption by crewmen, met drinking water standards. Therefore, this project assessed the current water quality provided to and stored in the potable water storage tanks on board Panama Canal tugboats. Water was tested against microbial contamination and disinfection parameters. Additionally, the potable water tanks were inspected. Results found that water provided to the vessels met the health targets, however water stored in the tanks had high turbidity and low residual chlorine levels. Further investigation led to the discovery of rust inside the tanks. The presence of rust was believed to be the source of the water turbidity and the reason for
decay of the residual chlorine. A drinking water management plan was developed to mitigate potential hazards from the current drinking water quality. The drinking water management plan recommended cleaning of the potable water storage tanks, epoxy coating the interior walls, and continued surveillance of the drinking water quality.

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**Conceptual Model of Groundwater Emerging at Springs on Eastern Slope of Salar de Atacama, Chile: Provenance and Flowpaths in large Arid Basins**

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The Salar de Atacama hosts a brine and freshwater aquifer that is subject to substantial and increasing resource demand; its brines have some of the highest know concentrations of lithium in the world. Despite this demand, fundamental questions still exist regarding the nature of groundwater flowpaths responsible for transporting this water and its provenance. In order to answer these questions, I characterize in detail the physical, geochemical and isotopic characteristics of spring waters emerging on the southeastern slope and their hydrogeologic context.

I develop a conceptual model building off previous work done in the region along with hydrogeologic and water data from around the region. My results suggests that these waters are anomalous with respect to both the potential source waters in higher elevations of the topographic watershed and springs emerging to the north at similar elevation. Since this region is extremely arid, receiving very little rainfall except at very high elevation, these perennial springs are a primary expression of the groundwater system. The distinctive and anomalous nature of groundwater emerging at these springs precludes employment of a relatively simple or classic fluid transport model to fully explain this system and suggests a groundwater system of regional extent or one which includes water drawn from transient storage recharged thousands of years ago during pluvial periods would be required to explain my results. This hydrologic model is not the expected one for arid basins such as this and would constitute a substantial change in our understanding of how these systems behave.

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**Isotopic and Hydrogeochemical Assessment of Groundwater quality of Punjab and Haryana, India**

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Punjab and Haryana lie in the semi-arid region of northwestern India and are characterized by a limited access to freshwater resources and an increasing dependence on groundwater resources to meet human demand, resulting in overexploitation. The objectives of the present study was to characterize groundwater recharge sources using stable isotopes of ($\delta^{2}H$) and ($\delta^{18}O$) and to trace geochemical evolution of groundwater using rare earth elements (REEs). Samples were collected from 30 different locations including shallow domestic handpumps, deep irrigation wells, surface water and rainwater. Samples were analyzed for stable isotopes of ($\delta^{2}H$) and ($\delta^{18}O$) using Isotope Ratio Mass Spectrometry (IRMS) and trace elements using Inductively Coupled Plasma Mass Spectrometry (ICPMS) at University of Massachusetts Boston. Precipitation, surface water and irrigation return flow
were identified as the primary sources of recharge to groundwater. Sustainability of recharge sources is highly dependent on the glacier-fed rivers from the Himalayas that are already experiencing impacts from climate change. Geochemistry of REEs revealed geochemically evolved groundwater system with carbonate subsurface weathering as major hydrological processes. Enhanced dissolution of carbonates in the future can be a serious issue with extremely hard groundwater leaving scaly deposits inside pipes and wells. This would not only worsen the groundwater quality but would impose financial implications on the groundwater users in the community. If irrigated culture is to survive as an economically viable and environmentally sustainable activity in the region, groundwater management activities have to be planned at the regional scale.

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Assessing the Risk of Hazardous Waste Facilities surrounding Boston Harbor to Sea Level Rise and Coastal Inundation
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Massachusetts Department of Transportation recently developed a new high resolution sea level rise and coastal inundation model for Boston Harbor. The model incorporates all of the physical processes that occur during a storm, as well as the bathymetry of the harbor that could influence coastal inundation and sea level rise in the future. My research goal is to develop and apply a risk assessment framework in order to assess the risks that hazardous waste facilities and the surrounding areas in Boston will experience due to projected sea level rise and coastal inundation in the year 2013, 2030 and 2070. The model outputs identify 107 hazardous waste facilities exposed to sea level rise and coastal inundation in Boston by 2070. To assess the risk associated with these hazardous waste facilities, I have combined the risk assessment frameworks typical of climate change and ecological risk assessments into a new framework that allows for a full system future risk analysis. In the new risk assessment framework, the exposure associated with sea level rise and coastal inundation is considered when assessing the exposure due to the release of hazardous waste to the surrounding area. These two exposure components are then combined with sensitivity and adaptive capacity of the systems in order to categorize the total risk for each facility. The new proposed framework will be applied as a case study to one of the hazardous waste generating facilities in Boston that is at risk of sea level rise and coastal inundation in the future.

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Temporal Fish Mercury Trends in Relation to Food Web Dynamics in Little Moose Lake, Adirondacks, NY
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Mercury contamination within aquatic ecosystems is of particular concern in the Adirondack Park of New York State due to elevated levels of mercury deposition from global and regional atmospheric sources and watershed characteristics that drive biophysical interactions that mobilize and transform mercury altering its bioavailability. Short-term internal biological forces impact mercury bioaccumulation as fish communities and populations change due to species introductions and lake management practices causing
alterations in food web structure and energy transfer. Utilizing archived samples and historical data, total mercury concentrations, stable carbon and nitrogen isotope ratios, diet and age data were evaluated for lake trout, the native top-predator, and smallmouth bass, an introduced top-predator removed annually for over 15 years from Little Moose Lake in the Adirondacks. Mercury concentrations in lake trout have increased over time while no significant trend was observed for smallmouth bass over the same interval and so changes in mercury deposition are likely not the main driver for these observations. Diets for both species also changed over time with lake trout consuming higher trophic level prey containing higher levels of mercury. The annual bass removal could result in shifts in many different trophic transfer mechanisms that may have influenced the observations in temporal mercury trends in the two top-predator species. The knowledge gained from this in-depth study will allow better evaluation and monitoring of spatial patterns and temporal trends in sportfish mercury concentrations in the context of food web changes to protect human health and the environment.

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Water quality assessment and determination of pollution sources in Souss-Massa Basin in Agadir, Morocco
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Preliminary hydrogeochemical studies have been conducted on groundwater in the Souss-Massa Basin in Agadir, a modern resort city in southern Morocco whose main economic activities are agriculture, fishing, and tourism. Moreover, the city has expanded rapidly over the past decade, mainly due to the migration of people from the surrounding countryside, an increase in the number of large farms, as well as touristic development. In this study, the water samples (n=39) were taken from selected farms, industrial facilities, and private residences located on the periphery of the city. Measurements of conductivity, dissolved oxygen, pH, and temperature were taken in situ while further chemical analyses, including nitrate and sulfate, were taken at the local laboratory. Our preliminary results indicate relatively high conductivity and sulfate concentrations, with values ranging from 4000 to 8000 mS/cm, and 200 to 800 mg/L for conductivity and SO4-2, respectively, especially near agricultural and developed areas. The initial results suggest saltwater contamination from marine intrusion, most likely caused by the over pumping of the unconfined Sous-Mass Basin aquifer. Moreover, the average concentration of nitrate was above 200 mg/L significantly higher than the WHO recommended maximum limit 50 mg/L for the nitrate concentration in drinking waters. This is most likely caused by heavy fertilizer from agriculture activities as well as sewage contamination. In this ongoing project, future studies may include the measurement of the related heavy metal contaminants and isotopic fractionation analysis of N-15 and O-18 of the samples together with the multivariate statistical analysis to reveal the possible anthropogenic sources.
Streamflow and Nitrate Load Predictions in the Drinking Water Reservoir of New York
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Neversink Reservoir is one of six in the Catskill Mountains that supply water to New York City and other communities along its water supply network. The Neversink River is the most acid-sensitive watershed in the Catskill Mountain region, and among the most acid-sensitive watersheds with elevated nitrate (NO3-) in the state. Atmospheric deposition is the major source for this nitrate loading in such a forested watershed like Neversink River Watershed (NRW). Model predictions, calibration and simulations of hydrologic processes and water quality parameters at NRW would provide decision support tools for water resource management and planning. The main objective of this study was to calibrate and simulate the streamflow for the watershed and then use that streamflow to simulate nitrate loads. This research utilizes the USDA hydrologic and water quality model SWAT (Soil and Water Assessment Tool) to simulate streamflow and nitrate loads in Neversink River. Model calibration and uncertainty analysis was performed using the Sequential Uncertainty Fitting (SUFI-2) algorithm under SWAT-CUP calibration tool. The model simulated the daily USGS measured flow data with Nash-Sutcliffe Efficiency (NSE) as 0.58 and coefficient of determination (R2) as 0.58 for calibration period (2001-2005). While for validation period (2009-2013), values were 0.47 for R2 and 0.44 for NSE. SWAT model was used to predict the monthly nitrate loading for 2001-2005. The nitrate model performed good with R2 of 0.54. The preliminary results show good model performance; however it does require improvement in calibration of streamflow and nitrate loads to get better results.

Quantifying contributions of snow-fed rivers to water resources of large cities in the Western U.S
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Cities in the western US are usually at the foothills of mountains and derive significant portions of their water supply from snow-fed rivers. Due to increasing urbanization, demand for water is rising, though recent studies indicate that cities supply from snow accumulation and melt is changing variably across the west. Adapting to these changes in snow is a challenge for cities; to address it, we first need to quantify the extent of their reliance on snow-fed rivers. We identify 13 western US cities (with a total population of over 12 million people) and the headwater basins associated with their water supply to quantify: 1) How much annual precipitation falls as snow?; 2) How much annual surface water runoff comes from snowmelt?; and 3) To what extent does reservoir storage act as a buffer to changes in snow? Using climatological data from North American Land Data Assimilation Systems (NLDAS) and PRISM high-resolution spatial climate data, we establish that San Francisco derives the most (74%) of their water supply from snow among the
selected cities, whereas, Portland derives the least (~0%). Analysis from the two datasets yield similar results, suggesting a defensible and accurate methodology for determining snowfall reliance. Although inter-annual snow variability is common, some cities with expansive reservoir storage infrastructure and capacity, such as San Francisco and Denver, are able to buffer their water supply for over three years. The findings demonstrate that western US cities are variably reliant on snow for water supply and that adaptation to changes in snow will be challenging.

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Accounting for Soil Moisture Variability in a New Jersey Catchment Using STI, Temperature, and Precipitation
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Growing concern regarding non-point source (NPS) pollution caused by storm runoff in humid areas has presented the need to accurately predict soil moisture distribution. Due to the complexity of the physical mechanism that controls soil moisture distribution, a parsimonious model is required for practical estimation of soil moisture. Numerous efforts have been made to predict soil moisture patterns using topographic indices (TIs), but with limited success in accounting for the spatial variability of soil moisture. Therefore, this study attempts to explain soil moisture variability using precipitation, temperature, and soil topographic index (STI) as inputs. Twelve days of soil moisture data were collected at two fields in northwestern New Jersey from the months of April 2013 to July 2015. Additionally, precipitation and temperature data were obtained from nearby weather stations for the same time period. All data were analyzed using linear mixed effect models, created with the “lme4” R statistical software package, where soil moisture was the response variable and the explanatory variables were precipitation, temperature, and STI. In the best case, these explanatory variables accounted for 41% of soil moisture variation. This analysis showed significant correlations between soil moisture and the explanatory variables. As expected, STI and precipitation were positively correlated with soil moisture, while temperature and soil moisture had a negative correlation. These observed trends in soil moisture distribution have practical implications for identifying denitrification hotspots and hydrologically sensitive areas (HSAs) in order to guide watershed managers and policy makers in decisions that will protect water quality.

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GRACE-derived TWS variations over the Saq aquifer in KSA and Jordan
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Monthly (April 2002-April 2015) gravity field solutions from the Gravity Recovery and Climate Experiment (GRACE), acquired over the Kingdom of Saudi Arabia/Jordan transboundary aquifer system, the Saq aquifer, were analyzed and spatiotemporally correlated with other relevant land surface models (e.g., GLDAS), remote sensing (e.g., CMAP and NDVI), and field (e.g., water levels) datasets to quantify the temporal variations in the Saq’a water resources and to identify the factors that control these variations. Examination of the GRACE-derived Terrestrial Water Storage (TWS) and Groundwater Storage (GWS) data indicates the following: (1) the Saq aquifer system is witnessing TWS and GWS depletion rates of -9.05 ± 0.25 mm/yr (-4.84 ± 0.13 km³/yr) and -6.52 ± 0.29
mm/yr (-3.49 ± 0.15 km³/yr), respectively, related to both climatic and anthropogenic factors; (2) the observed TWS depletion rate is partially related to a decline in rainfall as is evident from comparison of average annual precipitation (AAP) for the investigated period to the previous 23 years (AAP for 1979-2001: 104 mm; AAP for 2002-2014: 60 mm); (3) the observed GWS depletion in the Saq aquifer is attributed to groundwater extraction for irrigation; and (4) the observed GRACE-derived GWS depletion is highly correlated with the observed water level depletion rates within the investigated wells. Our analysis indicate that the availability of the global monthly GRACE solutions currently provides, and will continue to provide, the most practical, informative, and cost-effective tool for monitoring aquifer systems across the world.

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Estimation of flow regime for a spatially varied Himalayan watershed using improved multi-site calibration method of SWAT model
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The monsoon and snow driven regime in the Himalayan region has received increasing attention in the recent decade regarding the effects of climate change on hydrologic regimes. Modeling streamflow in such spatially varied catchment requires proper calibration and validation in hydrologic modeling. While calibration and validation are time consuming and computationally intensive, an effective regionalized approach with multi-site information is crucial for flow estimation, especially in daily scale. In this study, we adopted a multi-site approach to calibration and validation of the Soil Water Assessment Tool (SWAT) model for the Karnali river catchment, which is characterized as being the most vulnerable catchment to climate change in the Himalayan region. APHRODITE’s (Asian Precipitation - Highly-Resolved Observational Data Integration Towards Evaluation) daily gridded precipitation data, one of the accurate and reliable weather date over this region were utilized in this study. The model evaluation of the entire catchment divided into four sub-catchments, utilizing discharge records from 1963 to 2010. In previous studies, multi-site calibration used a single set of calibration parameters for all sub-catchment of a large watershed. In this study, we introduced a technique that can incorporate different sets of calibration parameters for each sub-basin, which eventually ameliorate the flow of the whole watershed. Results show that the calibrated model with new method can capture almost identical pattern of flow over the region. The predicted daily streamflow matched the observed values, with a Nash–Sutcliffe coefficient of 0.73 during calibration and 0.71 during validation period. The method perfumed better than existing multisite calibration methods.