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Abstracts

Host:
Southern Illinois University Edwardsville

Participating Universities:
- Washington University in St. Louis
- Missouri University of Science and Technology
- University of Missouri Columbia
- Southern Illinois University Carbondale
- Saint Louis University

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In 2007, the State of Missouri and the United States Environmental Protection Agency, along with the Missouri Coalition for the Environment, filed a lawsuit against the Metropolitan St. Louis Sewer District (MSD) regarding overflows. In August 2011, the Department of Justice filed a consent decree requiring MSD to spend a minimum $4.7 billion over the next 23 years to address the issue of overflows and other sewer system improvements. This presentation focuses on how MSD is reducing sewer overflows, including the use of green infrastructure.

Jeffrey Theerman, P.E. has more than 25 years of experience with MSD, where his prior positions include director/assistant director of operations, director/assistant director/manager of wastewater. In his current position, Jeff is responsible for overseeing all district operations and managing all financial, leadership and regulatory responsibilities of the District. Prior to joining MSD, he was an Environmental Protection Engineer with the Illinois EPA. Jeff holds a Bachelor of Science Degree in Civil Engineering from the University of Missouri-Rolla (now MS&T), a Master of Science Degree in Civil Engineering from Southern Illinois University Edwardsville, and is a licensed professional engineer in Missouri. He serves on the Board of the National Association of Clean Water Agencies and is its immediate past president. In 2008, Jeff was named Engineer of the Year by the St. Louis Chapter of the Missouri Society of Professional Engineers. In 2011, Jeff was named to MS&T’s Academy of Civil Engineers.

Metropolitan St. Louis Sewer District is responsible for the interception, collection and treatment of wastewater, as well as stormwater management. MSD serves all of St. Louis City and approximately 80 percent of St. Louis County. MSD currently operates seven wastewater treatment facilities, treating a combined average of 370 million gallons of sewage per day.
Tracking Sources and Fate of E. Coli Contamination at a Lake of the Ozarks State Park Public Beach

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\textbf{Abstract:} Grand Glaize Beach, at the Lake of the Ozarks State Park (LOSP), is a popular vacationing spot for many Missourians. On several occasions E. Coli concentrations have exceeded standards set by Missouri Department of Natural Resources (MDNR). Exceedances lead to beach closures which not only represent a public health threat but are also detrimental to the local economy and the public’s perception of the lake’s general water quality. In a collaborative effort between Missouri S&T, USGS and MDNR, an in-depth, 2-summer study was conducted which included collection of over 1,000 water samples in less than 8 weeks, runoff analysis, sediment suspension studies and two intensive dye traces. Preliminary results indicate correlation between beach use and E. Coli concentrations attributed to contamination by resident geese and suspension of E. Coli-laden sediments by beach users. Runoff analysis shows significant E. Coli loading into surface waters, constituting another input under rainfall events. Future work includes utilizing current data from two dye tracer tests to calibrate a vertically-averaged, finite element model of E. Coli flow and transport and performing host-specific PCR source tracking of \textit{Bacteroides}, to be conducted by the USGS Ohio Water Science Center (OWSC). Resulting findings will impact Missouri’s water quality, recreational value of the Lake of the Ozarks and tourist economics of Missouri.

Quantification of Change in Disinfection By-Product (DBP) Formation Kinetics under a Set of Operational Conditions Typical to Small-Scale Water Utilities

Sandhya Rao Poleneni and Enos C. Inniss, University of Missouri Columbia

\textbf{Abstract:} The Stage-2 Disinfectant/Disinfection By-Product (D/DBP) regulations force water utilities of all sizes to be more concerned with their finished and distributed water quality. Complying with stringent regulations with limited resources has always been a challenging issue for small scale utilities and requires changes to their operational strategy, which can affect DBPs formation over time. This study attempts to quantify the changes in DBP formation kinetics under different operational conditions typical for many small-scale water utilities. A physical model (Pipe Loop) of a distribution system was used to evaluate the change in water quality as a function of time under different operational conditions such as high chlorine dosage, a chlorine booster system, and variable usage of clearwells/storage tanks. The effect of surface conditions on formation kinetics was also determined. Reaction coefficients were calculated for both bulk and wall reactions for all the scenarios to understand the effect of surface conditions and DBP formation is modeled as a function of chlorine decay over time. The relationship between DBP formation and chlorine consumption under different operational conditions is only fairly linear at pH >8 when compared to a more strongly linear relationship reported in the literature for the 6-8 pH range.
Using Municipal Waste Incinerator Bottom Ash to Replace Sand in Bioretention Media

Akosua Ofori-Tettey, Jessica Eichhorst, and Susan Morgan
Southern Illinois University Edwardsville

Abstract: Bioretention is a green infrastructure as well as a best management practice (BMP) through which storm water runoff quantity is reduced and the quality is improved. The use of bottom ash in place of sand in bioretention media would provide a use for a waste product and extend the life of landfills while reducing ash disposal fees and eliminating the cost of sand. The overall goal of this research is to evaluate the suitability of bottom ash as a replacement for sand in bioretention media by studying the effect of the bottom ash on hydraulic conductivity and water quality.

In the first phase of the project from fall of 2011 through summer of 2012, a hydraulic conductivity study was conducted. The hydraulic conductivity of the experimental media ranged from approximately 1.5 to 29 inches per hour. Our findings verified that the use of a 50:50 mixture of incinerator bottom ash and mulch satisfies the drainage requirement of at least 2 feet per day. The second phase of the project from fall of 2012 to fall of 2013 is to analyze the water quality impacts and suitability for plant growth. To do this a 50:50 ash and mulch mix will be compared to a control of 50:50 sand and mulch for pollutant removal effectiveness. The study will be conducted using 8-inch diameter columns with 18 inches of media. Twelve of the 18 columns will be planted with switch grass; the remaining columns will remain unplanted to study the impacts of the plants on the water quality. Water quality parameters being studied include pH, total suspended solids, turbidity, nutrients, and metals. Synthetic rainwater will be used as the influent. Its composition will be based on samples of local rainwater and the literature.

Impact of Long Term Exposure of Cerium Oxide Nanoparticles on Tomato

Qiang (Dennis) Wang and Xingmao (Samuel) Ma
Southern Illinois University Carbondale

Abstract: Cerium Oxide Nanoparticles (CeO2-NPs) are commonly used in polishing, engine enhancement agents and many other products. Even though the acute toxicity of CeO2-NPs to plants has been widely scrutinized, information is severely lacking on the chronic toxicity, especially the long-term effects over several generations. Current study monitored and evaluated the physical and physiological responses of wild-type tomato plants to CeO2-NPs over two generations (0-10 mg/L) in soil. After the maturity of first generation plants, seeds were collected from control parent plants (control F1 seeds) and plants previously exposed to 10 mg/L of CeO2-NPs (treated F1 seeds) and were grown hydroponically in solutions containing 0 and 10 mg/L of CeO2-NPs. The results suggested that CeO2-NPs at 10 mg/L enhanced plant growth and fruit production in the first generation. However, elevated CeO2-NPs were detected in all plant tissues including fruit tissues. Even though the germination rate was similar regardless of the seed source and treatment, CeO2-NPs accelerated seed germination in the control F1 seeds, as observed previously. Such effect was not observed for treated F1 seeds. CeO2-NPs also enhanced root elongation of the second generation seedlings compared with their relative
controls, but the development of lateral roots in the second generation seedlings (treated F1 seedling) was strongly inhibited. Interestingly, the treated second generation seedlings developed extensive root hairs compared with the second control seedlings, irrespective of the treatment. Treated F1 seedling root contained higher amount of Reactive Oxygen Species (ROS) than their respective controls. Second generation treated seedlings tended to take up and accumulate higher amount of ceria even though such differences are not statistically significant. Root leakage test suggested that root membrane integrity was not damaged by the treatment for both generations.

**Engineered Magnetite Nanocrystals: Synthesis, Water Stabilization, and Interfacial Analysis with Model Environmental Surfaces**

Wenlu Li, Jiewei Wu, Di Liu, and John D. Fortner, Washington University in St. Louis

**Abstract:** Engineered magnetite nanocrystals have high potential as platform materials for environmental sensing and remediation due to their tunable surface areas and magnetic properties. Size control and surface chemistry of magnetite nanocrystals are crucial for application, especially in saturated, and often complicated, porous (media) matrixes. Monodisperse magnetite nanocrystals with sizes ranging from 8 to 30 nm (discreet) were prepared using thermal decomposition method for greater control over size, structure and dispersivity. These nanoparticles can be transferred into water through a variety of surface modification, as we demonstrate with a tailored series of surfactants, varying in charge and hydrophobicity, and/or simple organic acids. Once stabilized, interfacial surface interactions were quantitatively investigated with a quartz crystal microbalance with dissipation monitoring (QCM-D) using both hydrophilic (SiO$_2$) and hydrophobic (polystyrene) sensor surfaces. Changing particle size and the water chemistry directly influences both the surface density and viscoelastic properties of (surface) sorbed particles.

**Development of Multi-Walled Carbon Nanotubes (MWNTs)/Polysulfone (PSU) Mixed Matrix Hollow Fiber Membranes for Enhanced Water Treatment**

Jun Yin and Baolin Deng, University of Missouri Columbia

**Abstract:** Due to carbon nanotubes’ unique one-dimensional tubular structure and superior mechanical and chemical properties, we explored if the incorporation of oxidized multi-walled carbon nanotubes (MWNTs) into polysulfone (PSU) hollow fiber membranes could affect the membrane performance. Polyvinylpyrrolidone (PVP) and 1-Methyl-2-pyrrolidinone (NMP) were used as porogen and solvent, respectively, in the phase inversion spinning process, and deionized water was used as bore fluid and coagulant. MWNTs was first purified and oxidized in the mixed acid solution (H$_2$SO$_4$/HNO$_3$ = 3/1 in volume) and then used as the filler at concentrations ranging from 0 to 1 wt.% based on the amount of PSU. Results indicated that at three different PSU concentrations (15, 18, 20 wt.%), pure water flux of all membranes showed similar characteristics, with increasing MWNTs concentration, the flux first increased and then gradually decreased. The optimized blend membranes showed a significant increase of pure water flux (60% to 100%) while maintaining the same ability for solute rejection. The water contact angle of the mixed matrix membrane slightly decreased with increasing filler
concentration, which indicated the improved membrane surface hydrophilicity, and the fouling resistance of the membrane to protein was also enhanced.

An Evaluation of NAPL Wettability in 2-D Visualization Experiments

Ricot Sainte-Aimé, Lizette R. Chevalier, Krishna Dhakal
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Abstract: A study was conducted in 2-D tanks to examine the influence of NAPL wettability on flow visualization. Two tanks, one lined with glass and one made from plexiglas, were used. The overall dimensions of tanks were approximately 90x90x4cm³. In the experiments, LNAPL (dodecane) was released in the vadose zone in Ottawa sand where two external constant head reservoirs were used to maintain a constant water table in the tank. Digital pictures were taken at various intervals to measure the geometry of the plume and locate its position relative to the water table. In the glass tank, water is the wetting fluid and the LNAPL (dodecane) is the non-wetting fluid for both sand and glass. However, on the plexiglas tank, the LNAPL is the wetting fluid. As a result, 15%, 45% and 50% difference were observed respectively in the thickness, the length, and the area of the plume in glass and plexiglas tanks. This experiment demonstrates that plexiglas causes the volume of NAPL pooled through the capillary zone to appear larger due to “pulling” of the free phase NAPL from the pore space to the plexiglas surface of the tank. Therefore, the nature of material used for the tank design is an important factor in the visualization of LNAPL plume in 2-D tanks.

Integrated Investigation of Phosphate-Based Uranium Immobilization Strategies for Contaminated Subsurface Environments

Vrajesh Mehta and Daniel Giammar, Washington University in St. Louis

Abstract: Phosphate addition to uranium-contaminated subsurface environments is a promising approach for in situ remediation that promotes the formation of sparingly soluble uranyl-phosphate solids. Depending on the groundwater composition, different types of solids are formed, which then govern the solubility of uranium and its fate and transport. In the presence of cations like sodium and calcium, the uranium containing solids sodium autunite [Na₂(UO₂)₂(PO₄)₂] or calcium autunite [Na₂(UO₂)₂(PO₄)₂] form instead of chernikovite [H₃O(UO₂)₂PO₄·3H₂O] or uranyl orthophosphate [(UO₂)₃(PO₄)₂·4H₂O], and these cation-containing solids generally have lower solubility. Additionally, solids like hydroxylapatite [(Ca)₅(PO₄)₃OH] or calcium phosphate [Ca₃(PO₄)₂] can precipitate under specific conditions, and dissolved uranium concentrations may then be controlled by adsorption to these solids. Experiments on the identity and solubility of the solids formed integrated aqueous phase analysis, solids characterization, and equilibrium modeling. When sodium was present at environmentally relevant concentrations, the solid that formed was sodium autunite for all the pH values (4, 6 and 7.5) studied. However in the presence of calcium, some form of amorphous calcium phosphate precipitated at pH 7.5 while calcium autunite-like solids precipitated at pH 4 and 6. Further analysis using X-ray absorption spectroscopy (XAS) and laser induced fluorescence spectroscopy (LIFS) can distinguish the exact contribution of dominant modes of
uranium immobilization (adsorption versus precipitation), which in turn can play an important role in the successful design of remediation projects.

**Trace element Accumulation in Rice: Effects of Soil Arsenic, Irrigation Management and Cultivar**

**Eric Farrow and Jianmin Wang, Missouri University of Science & Technology**

**Abstract:** Accumulation of trace elements in rice, including arsenic (As), selenium (Se), molybdenum (Mo) and cadmium (Cd) has been reported in many regions of the world, including the United States. This research investigated the accumulation of trace elements of concern in native and MSMA-amended soil for six rice cultivars commonly grown in the south central U.S. The effect of irrigation management on total grain accumulation was also evaluated. Results indicated MSMA amendments increased the accumulation of As and Se, but decreased Mo and Cd under all irrigation treatments. In MSMA-amended soil, irrigation using intermittent flooding significantly decreased total grain-As, but significantly increased Se and Cd, with insignificant impact on Mo. In non-MSMA soil, intermittent flooding significantly decreases total grain Mo with insignificant impact on As, Se and Cd. Evaluating grain correlations between elements, a negative As-Se correlation was identified as total grain-As increased and Se decreased; whereas a positive As-Mo correlation was identified as total grain-As and Mo increased. The As-Cd correlation was negligible. Statistical analysis using SAS 9.2 evaluated the split-split plot experimental data and revealed interactions between experiment factors significant for As, Se and Mo, indicating the impact of changing levels of one factor is influenced by the level of the other factor(s). Interaction terms for Cd were not significant. This research concludes As, Se, Mo and Cd uptake to be a complex function rather than a function of a single element in soil or rice grain.

**Fast Growth and Mobilization of Fibrous Illite during Biotite Dissolution Under Geologic CO\textsubscript{2} Sequestration Conditions**

**Yandi Hu and Young-Shin Jun, Washington University in St. Louis**

**Abstract:** To ensure safe and efficient geologic CO\textsubscript{2} sequestration (GCS), it is crucial to have a better understanding of CO\textsubscript{2}–brine–caprock interactions under GCS conditions. In this work, CO\textsubscript{2}–brine–biotite interactions were studied under conditions relevant to GCS sites (at 95ºC, under 102 atm CO\textsubscript{2}, in 1 M NaCl, 0.4 M MgCl\textsubscript{2}, or 0.4 M CaCl\textsubscript{2} solution). In these salt solutions, after reaction for 3 hrs, fast growth of micron-sized fibrous illite on flat basal planes of biotite was observed. After 22 hrs reaction, microscale cracks formed on the biotite basal surface, resulting in fibrous illite detaching from the surface. The cracking of the biotite surface can increase the surface area in contact with solution and accelerate biotite dissolution. In control experiments with water under the same temperature and pressure, neither micron-sized fibrous illite nor cracks were observed, while oriented aggregation of hexagonal nanoparticles starting to form the fibrous-shaped illite was observed. The fibrous illite formation and its later mobilization in the salt solutions after its detachment could decrease the permeability of the aquifers greatly. This information can help design safer and more efficient operations at not only GCS sites, but also other important energy-related subsurface project sites.
Start-up Performance Evaluation of an Algae-based Membrane Bioreactor for Improved Phosphorus Removal

Meng Xu and Zhiqiang Hu, University of Missouri Columbia

Abstract: An algae-based membrane bioreactor (A-MBR) was developed and operated to determine its potential for nutrient removal as a post wastewater treatment measure. The A-MBR (effective volume = 7.2 L) was operated under continuous flow conditions at a hydraulic retention time of 1 day and a prolonged solids retention time (with minimal wastage). It took about 150 days for the algae biomass concentrations to increase from initially 385 mg /L (on a dry weight basis or 315 mg biomass COD/L) to a final concentration of 4840 mg/L (or 1664 mg COD/L) with an average algae production rate of 33.0 g dry weight/ m³·day. Results of the start-up performance suggest A-MBR significantly improved biomass settling and removed an average of 65% (± 9%) of phosphorus at the influent ortho-P concentration of 5.0 mg/L. Extracellular and intracellular P results indicate the phosphate removal through a combination of biosorption and algae-facilitated coprecipitation rather than luxury uptake. Compare to activated sludge based MBRs, the A-MBR had a much less biofouling problem due to its lower production of loosely bound extracellular polymeric substance (EPS).

Metabolic Engineering of a Cyanobacterium for the Direct Conversion of CO₂ into biofuels

Arul M. Varman and Yinjie J. Tang, Washington University in St. Louis

Abstract: Global warming and decreasing fossil fuel reserves have prompted great interests in the synthesis of advanced biofuels from renewable resources. In an effort to address these concerns, we have performed metabolic engineering of the cyanobacterium Synechocystis sp. PCC 6803 to develop a strain that can synthesize isobutanol under both autotrophic and mixotrophic conditions. With the expression of two heterologous genes from the Ehrlich Pathway, the engineered strain can accumulate 90 mg/L of isobutanol from 50 mM bicarbonate in a gas-tight shaking flask. This strain does not require any inducer (i.e., IPTG: Isopropyl β-D-1-thiogalactopyranoside) or antibiotics to maintain its isobutanol production. In the presence of 0.5% glucose, isobutanol synthesis is moderately promoted (titer = 114 mg/L). Since isobutanol is toxic to the cells and may also be degraded photochemically by hydroxyl radicals during cultivation process, we employed in situ removal of the isobutanol using oleyl alcohol as a solvent trap. This resulted in a final net concentration of 298 mg/L of isobutanol under mixotrophic culture conditions.

Battlefield Phytoforensics: Analysis and Modeling of Explosives in Plants

Yuan Yuan, Joel G. Burken, Riupu Mu, A. Karnjanapiboonwong, Honglan Shi, and Yinfa Ma, Missouri University of Science & Technology

Abstract: Military munitions and propellants are common contaminants from years of production, distribution and use. Fugitive contaminants are difficult to detect in groundwater and the potential remediation efficacy relies on accurate delineation of the contaminated areas.
Vascular plants accumulate trace contaminants from their surroundings while extracting water and nutrients from the subsurface, they also. Novel sampling and analytical approaches can access this data which exists in planta, and modeling efforts can relate exposure to these in-planta contaminant levels.

To analyze plant samples, LC-MS-MS analytic methods for Perchlorate, PETN, HMX, RDX, TNT, 2A-DNT, nitroguanadine, and DNAN were developed with a total run time of < 6 minutes and method detection limits (MDLs) are the lowest yet reported for many compounds, down to 20 ng/l. Novel centrifugation techniques extract the transpiration tissues stream fluids mechanically without any solvents and extracts are filtered injected directly, compared to traditional solvent extractions and condensing. The advantages and disadvantages of the rapid plant sampling methods will be discussed. Plant tissue - subsurface concentration relationships of HMX, RDX, and Perchlorate have been shown to be essentially linear for the rapid centrifugation methods, revealing potential for using a variety of plant species for phytoforensic analysis. Different plant species had widely varying subsurface: plant relationships. By developing novel plant sampling/analytical methods and advancing current modeling on plant uptake, subsurface contaminant delineations may be conducted without ever touching soil or groundwater, thereby minimizing concerns of UXOs in preliminary site investigations. These methods are also very rapid, inexpensive and minimally invasive to property or to the ecosystems we are working to protect.

**Modeling Total Suspended Solids in Combined Sewer Systems**

**Zhang, W., Lizette R. Chevalier, and Bruce A. DeVantier**

**Southern Illinois University Carbondale**

**Abstract:** The untreated overflow of combined sewer system contains a variety of pollutants that can contaminate the receiving water body. Total suspended solids (TSS) transported in the sewer networks can adsorb and transport these pollutants. Existing models contain numerous formulas that make the calculation process complex and time consuming. A simplified model developed simulate the process of TSS transport in combined sewer pipes.

The combined sewer system evaluated was developed from data of an existing sewer system in Le Marais and an example system provided with the Storm Water Management Model (SWMM). SWMM was used to simulate the rainfall event, pollutant build-up and wash-off process, and to provide hydraulic calculations for the combined sewer system. A spreadsheet model was created to calculate the TSS concentration profile and flow velocity profile. The total TSS transport rate was computed using a numerical estimation of the integral of the concentration in the cross-section area multiplied by the velocity. The study of TSS profile showed that the concentration distribution was controlled by the solid density. The TSS particle size also affected the transport rate (maximum rate at 35 μm). A sensitivity analysis of particle size was conducted in this thesis. A second order polynomial was used to describe the relationship between median particle size d50 and TSS transport rate.
Posters

Use of Drinking Water Treatment Plant Solids to Further Reduce Harmful Pollution by Storm water Runoff
Jacob Novak and Enoc C. Inniss, University of Missouri Columbia

Fabric Settling Plates for Enhanced Sedimentation at Drinking Water Treatment Facilities
Liu Cao and Enos C. Inniss, University of Missouri Columbia

Determining the Effectiveness of Biological Filtration on the Reduction of Disinfectant By-Products
Tyler Shoemaker and Enos C. Inniss, University of Missouri Columbia

Organics Removal through Enhanced Floc Formation, Adsorption, and Sedimentation in Small Water Utility Lime Softening Processes
Lin Liu and Enoc C. Inniss, University of Missouri Columbia

Developing a Suitability Analysis to Determine Locations for Wetland Water Quality Sampling
John Brito and Enos C. Inniss, University of Missouri Columbia

Assessment of the Technological, Economic, and Regulatory Environments Required for the Viability of Emerging Technologies, Using the Hydrogen Economy as a Test Case
M. Erik Traudes and Kathleen M. Trauth, University of Missouri Columbia

Inventory of Green Infrastructure in Metropolitan St. Louis for Stormwater Management to Protect Water Quality of the Great Rivers
Azadeh Akhavan Bloorchian, Jianpeng Zhou, and Susan Morgan
Southern Illinois University Edwardsville