CLEAN WATER WORKSHOP

Monday, August 5 & Tuesday, August 6
The LaSells Stewart Center
About the Clean and Sustainable Water Technology Initiative

Oregon State University launched the Clean and Sustainable Water Technology Initiative in 2018 with a $3.28 million gift from Jon and Stephanie DeVaan. At the core of this venture is a collaborative community of faculty and students, working together to solve one of the Grand Challenges for Engineering in the 21st century. This effort builds on the university’s strengths, to help make Oregon State a national leader in clean and sustainable water technology solutions.

Leading the initiative is Lewis Semprini, distinguished professor of environmental engineering. Several College of Engineering scholars are recognized nationally and globally for innovative research on water systems. They specialize in improving access to clean water, treating wastewater, strengthening upstream processes, and improving the infrastructure needed to manage water sustainability.
Aerobic Cometabolism of COCs in Continuous Flow Column packed with Gellan-Gum Macrobeads Encapsulated with 21198 Cells and TBOS as a SRC Source

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In situ bioremediation could potentially provide a large cost savings for treatment of contaminants of concern (CoC) mixtures, including 1,4-Dioxane, 1,1,1-TCA, 1,1-DCE, and Cis-DCE. Aerobic cometabolism is a particularly attractive option, as specific microorganisms can be stimulated in situ using specific primary substrates. Microbial growth on these substrates leads to expression of oxygenase enzymes that can then oxidize and remediate contaminants to concentrations well below drinking water. The purpose of this study is to examine how the encapsulated microbes with SRCs can treat groundwater under more realistic conditions of continuous flow in columns compared to batch reactors. The packed columns are representative of a permeable reactive barrier that could be created for in-situ treatment.

Column experiments are being conducted to examine the aerobic cometabolism cis-DCE, 1,1,1-TCA, and 1,4-dioxane, each at a concentration of 250 μg/L. The columns are packed with gellan-gum macrobeads co-encapsulated with 21198 cells and 10% TBOS, as slow release compounds (SRC). These column experiments are being conducted with synthetic groundwater containing a dilute mixture of nutrients. Bromide tracer tests were performed to determine the porosity and dispersivity of the columns. The results show greater than 99% removal of cis-DCE, 1,1,1-TCA, and 1,4-dioxane occurred during the first 25 days (flowrate of 1 mL/hr) with a hydraulic residence time of approximately 2 days. The dissolved oxygen (DO) concentration was reduced to around 5 ppm in Port 1, while only a trace amount of DO was observed in Ports 2 and 3 and at the column effluent. 1-Butanol concentrations from TBOS hydrolysis monitored in the column increased from 10 mg/L at the first port to up to 30 mg/L at the column effluent. Results show a passive reactive barrier could be constructed using the gellan-gum co-encapsulated beads with TBOS and a high permeability sand as well.
Multi-Objective Natural Treatment Systems: How Clean Water Services' Forest Grove NTS Addressed Water Quality Challenges and Created Habitat and a Community Amenity

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Clean Water Services constructed a 95-acre natural treatment system (NTS) in Forest Grove, Oregon, that is designed to provide wetland habitat for wildlife, recreational and educational opportunities for the public, and improve the overall quality of water discharged to the Tualatin River. The NTS was selected over more traditional “grey infrastructure” alternatives as it not only enhances treatment capacity and helps address population growth, but also provides ancillary benefits beyond conventional treatment for the community and the environment. The Forest Grove NTS includes surface and subsurface filtration wetlands designed to meet a variety of treatment objectives. The vertical flow wetlands are designed for nitrification and incorporate specially-selected rock media to enhance ammonia removal. A 90-acre surface treatment wetland provides cooling and enhances water quality using alternating sections of densely planted emergent vegetation and deep open water areas. The NTS complex was carefully structured to include a wide variety of native wetland plant species, trees and shrubs.

Clean Water Services worked with the City of Forest Grove and other community stakeholders and partners throughout the design and implementation of the Forest Grove NTS to ensure that the project will meet the needs of the public and wildlife and result in a positive outcome for watershed health.

2018 was the first year of full operation incorporating all elements of the NTS. This poster will highlight the technical design and operation of the NTS to meet water quality objectives and the environmental and community benefits created by the system.
Mixtures of chlorinated aliphatic hydrocarbons (CAHs) and 1,4 dioxane (1,4 D) have been observed as groundwater contaminants due to the use and disposal of commercial solvents, with 1,4 D included as a stabilizer for trichloroethane. These chemicals are classified as suspected or known carcinogens and have maximum contamination levels (MCLs) for drinking water set by the EPA. The microorganism Rhodococcus rhodochrous (ATCC 21198) cometabolically transforms these contaminants utilizing short-chain alkane monooxygenase (SCAM) enzymes. Previously, batch kinetic studies were done with co-encapsulated ATCC 21198 and alcohol producing slow release compounds transforming 1,1,1 Trichloroethane (1,1,1-TCA), cis Dichloroethene (cis-DCE) and 1,4-D. The focus of this project is to perform resting cell kinetic studies with ATCC 21198 grown on various alcohols for which we have a slow release version for the same mixture of 1,1,1-TCA, cis-DCE and 1,4-D. As gaseous substrates are not able to be co-encapsulated, this study aims to evaluate alternative non-gaseous substrates that will stimulate cometabolism of contaminant mixtures. Research will quantify and compare the transformation rates of ATCC 21198 grown on different substrates including 1-butanol, 2-butanol and 2-ethyl-1-butanol in the same mixture of contaminants.
This presentation describes a new household water treatment (HWT) product designed to replace boiling. At least 600,000,000 people rely on boiling to eliminate pathogens from their drinking water. It is not because they are under a temporary “boil water” notice, such as ones that occasionally inconvenience North Americans. These six-hundred million people depend on HWT every day. Boiling is the HWT method they have chosen or in some cases, their only option. For two-thirds of these people, the boiling is performed over an open cook-stove, powered by wood, charcoal or other bio-fuel. Although we may envision this happening in rural areas, the reality is that a large and growing percentage are urban dwellers. While HWT is making an important contribution to health by ensuring people have clean water, the lack of successful alternatives to boiling limits its value and results in negative environmental impacts. Boiling is inconvenient and fuel inefficient. It has been estimated that traditional, open-stove cooking practices comprise 2-5% of annual greenhouse gas emissions worldwide. Boiling drinking water has a similar contribution. Introducing a desirable, affordable replacement to boiling will reduce emissions of carbon dioxide, methane, and pollutants from incomplete combustion, and reduce deforestation. The new HWT product introduced in this talk uses ultraviolet light, which is 10,000 times more efficient than boiling, and does not require electricity.
Assessing the Toxicological Risk of Chemical Interactions Between Titanium Dioxide Nanoparticles and N,N-Diethyl-3-Methylbenzamide

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N,N-Diethyl-3-methylbenzamide (DEET), the most common active ingredient in bug repellents, was estimated to have been applied 8 billion times since it first became widely used in the 1950s up until 2009. DEET is used annually for bug repulsion by ~200 million people. Titanium dioxide represents one of two inorganic metal-oxide additives approved for use by the FDA. An estimated 41% of sunscreens in the U.S., as of 2018, contained either titanium or zinc oxide additives, a number that more than doubled since 2007. The results of this study may be used to inform consumers on the human health and environmental risks of applying chemical mixtures through the use of common mineral sunscreens and bug sprays concurrently. Titanium dioxide nanoparticles (nano-TiO₂) are not known to possess the ability to systematically enter human systems through transdermal absorbance. Titanium dioxide is regulated by the FDA (products can’t exceed >1% by weight), but the FDA regulation does not account for potential health risks arising from the increased surface area to mass ratio of nanoparticle varieties. The high absorbance and commercial availability of DEET pose both human and environmental health risk. To assess the toxicological risk of TiO₂ and DEET, Daphnia magna mortality rates were evaluated in response to nano-TiO₂ alone (0-2250 mg/L), DEET alone (0-168.75 mg/L), a mixture of nano-TiO₂ and DEET (0-2250 mg/L and 0-168.75 mg/L respectively, where the ratio was held constant). Data from the D.magna studies will be used to inform studies using zebrafish embryos. Because the zebrafish develop quickly, are vertebrates, and their genome has been completely sequenced, they provide a useful model for the embryonic development of humans. Malformations, developmental progress, and behavioral characteristics will be analyzed in the presence of each compound, mixture, and concentration. Preliminary data from D.magna studies suggest that the TiO₂ may reduce the potential risk associated with using DEET. It is predicted that rutile nano-TiO₂ will present little adverse effects to zebrafish embryos, which would be consistent with preliminary studies. The assessment of chemical mixtures involving nanoparticles is key to protecting public interests in the wake of emerging nanotechnology.
The Kinetics of Biological Methanol Production by Selective Inhibition of Methanol Dehydrogenase in Methylosinus Trichosporium OB3b

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Methane as a byproduct from industrial processes, is often managed as a waste gas and flared to CO2. The conversion of methane gas to a liquid product would allow for easier and more economical storage and transport. Biological conversion of methane to methanol using methanotrophs has been successful in batch processes at near ambient conditions. Without the addition of exogenous forms for energy for cell metabolism methanol production is short term and cell growth is inhibited. It is suggested that continuous biological methanol production is possible without addition of exogenous energy by balancing cell energy requirements with methanol production rate. The methanol dehydrogenase enzyme in Methylosinus trichosporium OB3b was chemically inhibited with cyclopropanol to accumulate methanol. The kinetics of methanol utilization and inhibition by cyclopropanol of methanol dehydrogenase in vivo were measured. In the presence of methanol, rapid recovery of methanol dehydrogenase activity was observed. Without methanol present, inhibition was prolonged and the duration of inhibition was dependent on the initial cyclopropanol concentration. A numerical model was used to simulate cell reducing power loss due to MDH inhibition and the effects on methanol accumulation. The model was applied to batch, chemostat, and immobilized reactor configurations and compared to experimental results. Partial methanol dehydrogenase inhibition resulted in longer term and higher overall methanol production. Cell immobilization resulted in higher methanol production per reactor volume.
Chlorinated aliphatic hydrocarbons (CAHs) and 1,4-Dioxane (1,4-D) are compounds commonly found together in contaminated aquifers. As a substitute for the expensive and inefficient decontamination method of “pump and treat,” aerobic cometabolism is being pursued as a passive in-situ bioremediation process to treat aquifers with said contaminant mixtures. Aerobic cometabolism occurs when an oxygenase-expressing microorganism is in the presence of both a growth substrate and another substrate that is able to be transformed by the non-specific enzyme. Rhodococcus rhodochrous strain ATCC® 21198 is a microorganism that is known to transform 1,4-D and other CAHs at a desirable rate when isobutane is the primary growth substrate. However, previously conducted research had suggested promising degradation rates of 1,4-D when 21198 was grown on acetate. Kinetic rate tests were conducted evaluating the ability of 21198 to transform 1,1-Dichloroethene (1,1-DCE), 1,1,1-Trichloroethane (1,1,1-TCA), and 1,4-D. Preliminary results show that the acetate-grown 21198 rates are significantly slower than isobutane-grown 21198 rates for 1,1-DCE and 1,1,1-TCA. It is anticipated that these rates will not exceed those of isobutane-grown 21198 for any of the contaminants. In aquifers with low permeability zones, a possible issue is the back-diffusion of contaminated groundwater. Back-diffusion releases low concentrations of contaminants at slow and prolonged rates. A slow release substrate, cellulose acetate, is also being pursued to achieve extended and slow transformation rates of CAHs and 1,4-D by acetate-grown 21198.
Ocean Waste Plastic to Fuel

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Plastics are long carbon chains that can be broken down into smaller carbon chains that could be waxes oils or possibly diesel fuel via pyrolysis. The UGRs are investigating this method with an overall goal to distribute these reactors into communities so that residents can convert their plastic waste into diesel fuel for localized use. The team is aiming for product quality to be like off-road or marine fuel. The product could also be blended with commercial diesel fuel. The team operated a 2-liter 4.8 kW bench-scale pyrolysis reactor for the investigation of pyrolysis kinetics and product distribution. HDPE nurdles are loaded into the reactor as reactant where it is broken down into smaller hydrocarbons through vaporization. The vaporized compounds leave out of the top of the reactor through the catalyst bed and liquefy in the condenser. Lastly, the beaker collects the pyrolysis product. Samples were collected over time in order to observe time dependency on mass flow and reactor temperatures. The tested temperatures range from 400-600°C and are measured at the top and bottom of the reactor wall, as well inside the reactant and catalyst bed.

Pyrolysis can be catalyzed to help break down polymers into an optimal chain length distribution. A good catalyst is inexpensive, robust, highly selective and active. Therefore, the team also tested iron oxide and silica alumina catalysts with the goal of decreasing reaction time to encourage the production of a diesel range hydrocarbon mixture. The products ranged from a gasoline-like liquid hydrocarbon mixture to a solid wax. The products from the pyrolysis reaction are analyzed using Gas Chromatography-Mass Spectroscopy (GC-MS) and Flame Ionization Detector (FID) to determine composition. In order to evaluate the fuel products based on carbon distribution, a python script is being developed to produce a mole fraction versus carbon number plot. This script reduces analysis time to a few minutes once the GC-MS data is collected.
Zero Liquid Discharge Water Desalination Process Using Humidification-Dehumidification in a Thermally-Actuated Transport Reactor

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The fact that 71% of the earth surface is covered in blue often leads to the misconception of water security. In reality, freshwater is often scarce. Only 3% of the water reserves in the world is freshwater. Most of that is not exploitable for drinking, irrigation, or industrial applications. It is, therefore, necessary to resort to alternative resources to cover up the rising demand of freshwater. Water desalination is the primary and foremost alternative to create a sustainable source of freshwater out of the saline water surfaces covering most of the globe. However, the sustainability of this resource is always challenged by the need of energy-intensive and economically demanding processes. A novel hybrid process is under development to treat highly-saline water with zero liquid discharge. The technology is modular, light-weight, highly portable, scalable, and operates on low-grade thermal energy. High-velocity air jets atomize and evaporate the brine, creating humid air and salt particles. In a later stage salt particles are separated from the humid air, and then air dehumidified to extract freshwater. A complete thermo-physical simulation platform is developed to simulate the entire process, optimize the operation, and help design the components. Critical parts of the platform are verified to within 10% of in-house experiments, augmented by a detailed entropy analysis. Using the thermo-physical model, the process is optimized to consume ~54 kWh/m³water, which is comparable with the most advanced RO installations.
Nitrate ions have become a leading source of groundwater contamination and can result in serious health and environmental consequences. Treatment of nitrates is typically accomplished by microbial communities due to their combination of highly selective enzymes which together convert nitrate (NO₃⁻) directly to dinitrogen gas (N₂). However, this method is expensive and could introduce pathogenic bacteria to the water. An alternative treatment method is to convert nitrate electrochemically using bimetallic catalysts. The challenge with electrochemically treating NO₃⁻ is fully converting the molecule to N₂ and not producing other nitrogen derived species that are equally or more toxic than NO₃⁻. Palladium (Pd) and Copper (Cu) have proven to be effective co-catalysts in certain stoichiometric ratios for this N₂ pathway due to their complementary characteristics. Both metals can be electrically co-deposited on a conductive substrate, such as fluorinated tin oxide (FTO) glass, by dissolving Pd and Cu salts at set molar ratios in acidic media and passing small charge densities under potentiostatic control in a typical electrochemical cell. This newly synthesized electrode can then be used in an aqueous medium that contains NO₃⁻, adsorbing the NO₃⁻ and subsequently converting it to a reduced product. Here it is believed that Cu active sites, which are excellent at keeping NO₃⁻ chemisorbed and initiating electrochemical reduction, work synergistically with Pd active sites, which are efficient sites for the critical conversion of nitrite (NO₂⁻) to N₂. Advantages to this method include the low cost of energy input, which could potentially be provided by renewable energy sources, and the lack of waste products produced in other treatment processes.
Are Rain Gardens Breeding Superbugs?

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Rain gardens, such as in the OSU-Benton County Green Stormwater Infrastructure Research (OGSIR) Facility, help control stormwater runoff volume to prevent flooding. They are of interest for their potential role in harboring antibiotic resistance, specifically of those near agricultural fields and medical facilities. Culture-based methods were used to quantify heterotrophic bacteria resistant to target antibiotics in soil along the length of OGSIR Cell 3. Tetracycline resistance was found to be 55.7-78.6% in total heterotrophs; gentamicin resistance ranged 53.0-70.2%; ciprofloxacin resistance ranged 14.2-56.1%, and ampicillin resistance was 80.2-99.3% in total heterotrophs. The clear presence of antibiotic resistance across multiple antibiotic classes begs further inquiry to assess whether rain gardens have the potential to filter multi-drug resistant bacteria and genes.
Floras Lake is a medium-sized freshwater lake (~96 hectares) located on the southern Oregon Coast in Curry County. It is an embayment separated from the Pacific Ocean by a migrating sand dune and has a fairly irregular shape due to its ‘fingers’ which extend off from its southern end. Throughout the year, four tributaries located at the southern end feed into these fingers and supply the lake with water. From here the water flows north and drains into Floras Creek followed by the ocean -- except when the lake and New River become flooded during the rainy season creating a backflow into the lake from the northern outflow point (Floras Creek). This causes an unusually large fluctuation in the water level of the lake: ~5-6 feet annual change. Land surrounding Floras Lake is a mix of state and county parks, and private land for agriculture and residential purposes. Drinking water sources in the area are well-based.

Over the past decade or so there have been several cancer cases that have been reported in the community surrounding the lake. If the lake and wells lie within an open aquifer, the wells could be more vulnerable to potential pollutants. The main objectives of this study are to: 1) Determine the groundwater interaction between the lake and nearby wells; 2) Survey surrounding land and water interactions to look for potential nearby pollutants that could be affecting the water quality; 3) Evaluate the quality of the lake and well water; 4) Determine if there is a seasonal effect on the quality of the lake and well water.
Microclimate Cooling of Green Infrastructures in Portland, Oregon

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Progressive metropolitan regions are looking to green infrastructure for innovative onsite stormwater management and for the many co-benefits it provides to the urban environment. Green infrastructure (GI) can be any high-performing green space that provides community services. One of the co-benefits of GI is the cooling of air temperatures. Previous studies show that GI cools land surface temperatures, and that the spatial scale of GI varies the extent of microclimate cooling. Quantification of air temperature (Ta) response to varying GI spatial scales is needed to understand how varying GI spatial scales interact. A network of 36 air temperature sensors were placed in six sub-regions of Portland, Oregon’s GI project area, Tabor to the River. Sub-regions were characterized by the mesoscale vegetation cover, as measured by normalized vegetation different index (NDVI). Deployment within these sub-regions was determined by the availability of microscale GI (e.g. planters) and non-GI street trees. TidbiT sensors were attached to tree branches 2.5-3 m above the ground. This study quantifies the importance and interaction of GI at different microscales (10-m) and mesoscales (50-m and greater), and how GI at these scales influences Ta. Results show the mesoscale dominates the temperature response based on the hourly means. Green mesoscale cooled microclimates 0.5-0.8 ℃, compared to Grey mesoscales. GI at the micro- and mesoscales contributed to significant and consistent nighttime microclimate cooling. These results have applications in smarter urban planning for temperature and stormwater control.
Photosynthetic Properties of Intensified Aquaculture of Clonal Red Macroalgae on Panels

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Over the last few years, the Rorrer lab has worked on a project that develops a new cultivation technology for the production of macroalgae (seaweed). The current project works with the species Palmaria, which serves as a food and value-added products. The new cultivation method will include panels to as a scalable inoculation system for the seeding of algae. A YSI Dissolved oxygen meter will be used to test for photosynthesis-irradiance (P.I.) curve to estimate photosynthetic parameters for the Palmaria plantlets. In addition, nitrogen uptake measurements will be taken for a spectrophotometric nitrate analysis will be taken for the current Palmaria panels during the light and dark cycle. The information from these tests will improve the current data and will aid in calculations using photosynthetic parameters. Additionally, the project will aid the Rorrer lab in current and future experiments with the Palmaria plantlets growth cultivation.
Investigation of Oregon Native Plants for Remediation of Trace Metals and Organic Pollutants in Stormwater

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Stormwater collects dissolved and particulate phase pollutants from improved surfaces and carries these to receiving water bodies, degrading their quality. Pollutants of concern include heavy metals, trace organics, sediments, and nutrients. Infiltration systems of various designs are increasingly being used to provide passive treatment of these waters. Inclusion of plants in these systems provides potential for phytoremediation, prevention of erosion, increased soil porosity, and an aesthetic quality against the built environment. However, plants and their associate microbes vary greatly in their abilities to provide additional degradation and removal of stormwater pollutants. In this study, 10 native Oregon plants were investigated for potential treatment of Cu²⁺, Zn²⁺, PCBs, PAHs, and PFASs in surface runoff collected from a public works utility site. Treatment was evaluated by final concentrations of constituents in plant roots and shoots compared with the accumulation in the soil phase and total removal was calculated with mass balances on the treated water. Enrichment of plant microbiomes in the rhizosphere and the bulk soil was evaluated by metagenomic profiling of 16SrRNA, mono-, and dioxygenase genes.
Effect of Extracellular Polymeric Substances on Nanoparticle Behavior

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Engineered nanoparticles (ENPs) enter natural water from manufacturing, use, and disposal of nanoparticle and nanomaterial containing products. These ENPs can be made of metals, nonmetals, carbon, or polymers; the diversity in materials parallels the diversity in behavior and uses. One route by which ENPs enter natural systems is via wastewater treatment plants. Chemical and/or physical changes to ENPs surfaces during wastewater treatment can affect their behavior once released. These processes are often controlled by interactions with natural organic matter (NOM), a complex mixture of large organic molecules present in water. Extracellular polymeric substances (EPS) are a main component in NOM and are key components in the activated sludge of wastewater treatment reactors. EPS is a mixture of complex polymers excreted from microorganisms, or released via cell lysis and hydrolysis. The fate of ENPs is in wastewater, and their behavior is greatly dependent on the composition of NOM and EPS. This study will investigate how the composition of NOM and EPS transforms nanoparticles and affects their behavior in the context of wastewater treatment.

The purpose of this investigation is to create a synthetic version of EPS based on previous studies of wastewater and EPS characterization. A synthetic analog of EPS will be used to investigate how specific components of wastewater interact with nanoparticles. From a review of the literature characterizing EPS, the main components are humic acids, proteins, and carbohydrates. The hypothesis motivating this study is that one class (i.e. proteins), or combination, of compounds dictates nanoparticle interactions. Investigating the interactions of these components will show if the organic compounds have compounding or inhibiting effects on resultant fate of nanoparticles. Comparing the interactions between ENPs and laboratory analogs with actual NOM will give insight into the behavior of nanoparticles in wastewater.
Bioremediation of a DNAPL Source and Plume Through Source Zone: Vegetable Oil Injection – 8 Years of Performance Data

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Full-scale treatment of a trichloroethene (TCE) source zone and plume began in 2005 beneath an active manufacturing building near Portland, Oregon using food-grade vegetable oil (VO). Remediation targets the shallow, unconfined aquifer beneath a former vapor degreaser/TCE supply line and a 12-acre downgradient plume. Dense non-aqueous phase liquid (DNAPL) was observed during drilling and subsequent groundwater monitoring; the maximum baseline TCE concentration in groundwater (1,170,000 µg/L) exceeded the TCE solubility limit. Baseline monitoring demonstrated TCE predominance in the source zone and cis-1,2-dichloroethene (cDCE) predominance in the downgradient plume, with low levels of vinyl chloride (VC) and end products ethene/ethane (E/E). Total organic carbon (TOC) was inadequate for reductive dechlorination under ambient conditions.

Six injections of VO emulsion have been performed in the source zone to date and have provided effective treatment at a low cost and with minimal disruption to manufacturing operations. Source zone VO injection has resulted in active bioremediation, reducing total chlorinated ethene mass in the source zone and downgradient. Source zone wells have transitioned from TCE to cDCE predominance with substantial VC and some E/E also detected. As of December 2012, biodegradation products exceeded TCE on a molar basis at 18 of 20 source wells and total chlorinated ethenes (molar sum) were less than baseline at about half of the wells. TCE concentrations were below baseline at source wells, except for two nearest the degreaser where DNAPL is still observed. VO removed from source zone wells has contained up to 8.6% wt TCE, reflecting substantial dissolution and partitioning. Abiotic degradation product acetylene is detected in source zone groundwater, indicating concurrent abiotic TCE destruction. In the downgradient active treatment zone, wells have transitioned from cDCE to E/E predominance and total chlorinated ethenes have decreased by 75 to 100 percent.
The Pure Water Wagon: A Mobile Demonstration and Research Unit for Producing High-Purity Water from Wastewater Effluent

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Water reuse is an increasingly pressing topic as water scarcity coupled with increasing demand drives consumers to new sources of water for agricultural, industrial and domestic applications. Clean Water Services, a water resources management utility in Washington County, Oregon, has performed several pilot-scale projects to demonstrate the effectiveness of advanced treatment processes for purifying wastewater to drinking-water standards and beyond. These efforts led to the development of the Pure Water Wagon, a mobile demonstration unit consisting of ultrafiltration (UF), reverse osmosis (RO) and ultraviolet disinfection with advanced oxidation (UV/AOP). The Pure Water Wagon (PWW) is capable of generating 5 gallons per minute of high-purity water using treated wastewater effluent as its source. The PWW system is operated with programmable logic-based controls for minimal operator intervention and each unit process has online monitoring sensors to verify performance. Water produced in the PWW is analyzed for constituents identified by the National Water Research Institute's Framework for Direct Potable Reuse and the Oregon Health Authority's rules for public water systems providing water for human consumption. Monitoring includes constituents such as antibiotic-resistant bacteria, perfluorinated compounds, nitrosamines and other contaminants of emerging concern. The high-purity water produced by the PWW either meets or exceeds all of these water quality standards. Additionally, cellular bioassays showed no toxicity resulting from the known or unknown chemicals present. The PWW represents a potential source of high-purity water for emergency situations and illustrates the importance of judging water by its quality, not its history. Future applications of the PWW are likely to include research on removal of microconstituents in wastewater and stormwater.
Effects of Real Stormwater on the Adsorption of Copper and Zinc on Five Different Sorbents

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Stormwater contains a wide variety of contaminants ranging from simple inorganics like heavy metals to complex organic compounds like PFAS. Historically stormwater was not much of a concern for contamination, but in recent years that mindset has changed. Typically, stormwater is hydraulically controlled through Best Management Practices (BPMs) such as bioswales, but little to no consideration was given to the treatment of the stormwater. The Department of Defense (DoD) has multiple sites with contaminated stormwater containing Heavy Metals, PCBs, PAHs, and PFAS. This research project is evaluating five different sorbents for adsorption treatment processes of stormwater for DoD sites. Our five sorbents chosen for evaluation are natural soil from a bioswale, granular activated carbon (GAC), soft wood biochar, and two commercial products; one biochar blend, and one GAC blend with high ion exchange capacity. For removal of copper and zinc bath studies have shown that biochar and the biochar blend commercial sorbent perform best in synthetic stormwater. Our experiments are conducted at low concentrations of metals, 10 to 300 ppb, where linear isotherms are typically seen. These experiments are mixed systems, containing both Zn and Cu, and deviations from the linear isotherm trend has been seen. It is hypothesized that competitive sorption is occurring between the heavy metals causing this deviation. These sorbents are being fully characterized to help in the decision making of which sorbent will best for removing a wide range of contamination. We have looked into their cation exchange capacity (CEC), anion exchange capacity (AEC), pH, background metals and surface chemistry.
Evaluating Onsite Wastewater Treatment System Nitrogen and Phosphorus Removal Efficacy in the Southern Willamette Valley Groundwater Management Area

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In the United States, 21 million septic systems are the primary method of onsite wastewater treatment for residences without sewer connections. Systems undergoing failure are easily identified, but a knowledge gap surrounds seemingly functioning systems and the ground and surface water contamination they produce. There is documented potential for septic systems to dramatically contaminate nearby waterbodies; particularly when they are not maintained, aren’t functioning properly, or are located in vulnerable areas, but the magnitude of this contamination is not well understood.

The lack of statistically significant data on residential septic performance is due to the following reasons:

• Sampling waters leaving septic drain fields is costly and timely; therefore, achieving a statistically representative sample is burdensome for researchers and oversight agencies.
• Obtaining permission from a typical homeowner, who may not be invested in the research or sampling program, is difficult.
• In existing systems, often the exact placement of the drain field is unknown.
• Surveying residents regarding their septic knowledge and maintenance practices is resource intensive.

To provide more information on septic performance we have developed a methodology for efficient sampling of soil water in a septic drainfield using suction cup lysimeters. The methodology, challenges, and ammonia, nitrate and phosphorous concentrations from the study of an existing system will be presented. This preliminary data will help secure funding for sampling a statistically significant number of septic systems in a watershed. A GIS model was developed to predict the effect of septic systems on ground and surface waters. The Southern Willamette Valley Groundwater Management Area (SWVGWMA), an area of impaired groundwater quality with an estimated 2,745 septic systems, was selected as the study site for GIS modeling. GIS modeling ultimately will include effects of soil type, precipitation, evapotranspiration, septic discharge, and land use to evaluate the contamination risk of existing systems.
Associations Between Heavy Metals and Antibiotic-Resistant Bacteria in Wastewater Treatment Systems Across Oregon

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Antibiotic resistance is currently one of the world’s most critical health concerns. In the US alone, antibiotic-resistant bacteria (ARB) are responsible for over 23,000 deaths per year. Several studies suggest that heavy metal presence provides selective pressure to promote antibiotic resistant bacterial growth in different environments. Wastewater treatment plants (WWTPs) are considered to be a reservoir for heavy metals, contribute to the growth of ARB under selective pressure, and act as a hotspot for the release of ARB to the environment. This study evaluates 17 WWTPs across Oregon to observe climate and seasonal effects on prevalence of antibiotic-resistant Escherichia coli over two years. The presence of antibiotic resistance will be determined by testing the antibiotic susceptibility of E. coli isolates in influent, secondary, and effluent wastewater, as well as biosolids against different antibiotics. Heavy metals concentrations will be measured using ICP-MS. Furthermore, physical and chemical properties of samples, such as COD, ammonia concentration, total solid content, pH and conductivity are measured to identify any potential trends and associations. Overall, some correlations between antibiotic resistance and heavy metal presence is anticipated. Also, seasonal, geographical, and demographic characteristics such as temperature, average rainfall, and area population are expected to have an impact on antibiotic resistance prevalence. Upon the completion of this study, we hope to develop a better understanding on the role of wastewater treatment processes and the effect of environmental conditions on the proliferation and release of antibiotic resistance to the environment and the associated human health risks.
Bioaugmentation of Cultures Fed Multiple Primary Substrates to Aerobically Cometabolize a Mixture of Chlorinated Solvents and 1,4-dioxane in Microcosms Containing Groundwater

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Sites contaminated with chlorinated solvents often exist as mixtures resulting from the use of multiple solvents and their transformation into chlorinated daughter products. These sites are often co-contaminated with the solvent stabilizer 1,4-dioxane which is not treated by traditional chlorinated solvent remediation techniques. Microbial aerobic cometabolism is a potential remediation technique for both chlorinated solvents and 1,4-dioxane. Aerobic cometabolism relies on contaminant transformation by oxygenase enzymes used primarily to initiate the metabolism of primary growth substrates. Cometabolic processes do not benefit the microorganism. The specific oxygenase enzyme induced and its ability to transform a compound depends on both the species of microorganism and the primary substrate it is grown on. Microcosms with contaminated groundwater and aquifer solids from a Department of Defense site were bioaugmented with four different aerobic cometabolizing cultures: isobutane grown ENV493 and Rhodococcus rhodochrous 21198, isobutene grown Mycobacterium ELW1, and a methane grown enriched culture from the site. The microcosms originally contained aqueous contaminant concentrations of 430, 380, 5.2, 850, and 470 ppb of 1,1-dichloroethylene (1,1-DCE), cis-1,2-dichloroethylene (cis-DCE), chloroform (CF), trichloroethylene (TCE), and 1,4-dioxane (1,4-D) respectively. All of the microcosms were fed isobutane and no stimulation of native isobutane utilizers was observed over 50-100 days. In all of the microcosms, Isobutane grown microorganisms were bioaugmented first, resulting in uptake of primary substrate and transformation of all contaminants except for TCE. Then, either the isobutene utilizers or methane utilizers were bioaugmented along with their primary substrate to transform the remaining TCE. The treated groundwater was removed from the microcosms, the aquifer solids were retained, and new groundwater containing the original contaminant mixture was added. After the second groundwater addition, both of the substrates originally introduced were added simultaneously to all of the microcosms. Isobutene utilizers followed by isobutane utilizers were stimulated in the isobutene and isobutane containing microcosms resulting in treatment of the contaminant mixture. Neither primary substrate uptake nor contaminant transformation was observed in the isobutane and methane containing microcosms. Inability to uptake primary substrate could prove problematic for field-scale implementation.
Layered Double Hydroxide Sorbents for Removal of Selenium from Power Plant Wastewaters

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Selenium is an essential trace element but is increasingly becoming a contaminant of concern in the electric power industry due to the challenges of removing solubilized selenate anions, particularly in the presence of sulfate. Layered double hydroxide (LDH) sorbent materials have attracted attention as promising anion-exchange materials and sorbents for a variety of anions. In this study, the effect of competing ions (the type and the concentration) on the selenium removal capacity of LDH granular media was investigated in small scale columns for the treatment of cooling tower blowdown waters and plant wastewaters. The wastewaters were obtained from a natural gas power plant in Arizona that utilized groundwater containing naturally occurring levels of selenium as make-up water for the cooling water. Due to the concentration of ions in the cooling tower blowdown during evaporation, the increased levels of sulfate and other potentially competing species may pose challenges for the treatment of the wastewater to remove selenium by adsorption or ion-exchange. Field results from a pilot-scale study evaluating the LDH media for treating wastewater on-site at the power plant will also be described. The results show that despite high levels of total dissolved solids and competing sulfate ions, selenium and other regulated metals such as chromium and arsenic are successfully removed from the wastewater using LDH media without needing any pre-treatment or pH adjustment. Sulfate and phosphate removal was also observed. Analysis of the removal mechanisms for selenium and other contaminants in the water was performed based on post-mortem characterization of the exhausted LDH media, along with assessment of the stability and re-usability of the media. We also show that LDH nanoparticles can be successfully embedded into nanocomposite polymer beads with high sorption capacities for removing both selenite and selenate anions from water.
Efficacy of Biochar Columns in the Removal of Antibiotic-Resistant Bacteria in Semi-Natural Stormwater

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Water is one of the world’s most valued commodities, and antibiotic-resistant bacteria are one of the emerging pollutants of concern. Stormwater runoff picks up pollutants such as chemicals, bacteria, and sediment as it runs over impervious surfaces and into waterbodies. The aim of this project is to test the use of biochar columns as an effective and inexpensive form of stormwater treatment. Biochar is biomass that has undergone pyrolysis. It serves as an adsorbent for contaminants in water including antibiotic-resistant bacteria. It is commonly used in land applications as a soil amendment, but there are concerns as to how long biochar is effective and what occurs when the biochar is saturated. Three infiltration columns will be tested; one containing biochar, one with soil and biochar, and one with soil. Due to the unpredictability of stormwater, semi-natural stormwater will be synthesized using stormwater sediment and raw sewage. Using culture-based methods, fecal coliforms in the semi-natural stormwater will be quantified before and after treatment through columns in triplicates. The ability of the columns to both remove and retain an adequate concentration of fecal coliforms will be analyzed to determine the best step for future use of biochar.
POSTER ABSTRACTS

Development of Integrated Watershed Model to Aid Adaptation Planning for Resilience in Food, Energy, and Water Sector

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Food, energy, and water (FEW) sectors are intimately dependent on variety of ecosystem services provided by watersheds (e.g., water for consumptive and non-consumptive uses, land for economic productivity, etc.) that helps the sectors be more resilient to environmental changes. Hence, comprehensive understanding of watershed conditions and vulnerabilities is important precursor to determining the ripple effect of environmental changes (e.g., droughts, climate change, water pollution, etc.) on sectors. This project uses the Soil and Water Assessment Tool (SWAT) to create an integrated model of the Umatilla River basin (URB) located near Hermiston, Oregon. The URB’s agriculture and energy sector are intimately tied to availability and allocation and water rights. The project’s methodology included: 1) create baseline model, 2) calibrate the SWAT model for water flow and nitrogen loadings, and 3) conduct sensitivity analysis of water-related sectoral decisions in the basin on drastic changes in water rights.
Mixed-Methods Evaluation of Clean Water Technology in Mbale Regional Referral Hospital, Uganda

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Worldwide, 88% of deaths due to diarrheal illness are attributed to unsafe water. Water, sanitation and hygiene (WASH) interventions have proven successful at minimizing water-borne disease transmission, yet up to 1.5 billion USD have been spent on WASH interventions that ultimately failed within 5 years of implementation. This failure rate is often due to the lack of project follow-up and funding, challenges of technology maintenance, or minimal perceived user benefits. Institutional Energy Solutions, a Corvallis-based company, manufactures a low-tech Water Pasteurizer designed to improve the culturally-appropriate method of water treatment by boiling, while using 97% less firewood than is required by boiling over an open fire. This three-week research project utilized a mixed-methods approach of quantitative and qualitative data collection to evaluate the practicality of long-term adoption of the Pasteurizer in Uganda at the Mbale Regional Referral Hospital. The primary objectives were to assess 1) technology factors, 2) psychosocial factors, and 3) contextual elements that influenced use of the Pasteurizer and the purified water by hospital staff and patients. Quantitative methods include monitoring fuel consumption, purified water quantity, treatment time, and assessing the microbial quality of drinking water at the source, after pasteurization, and at point of use. Qualitative methods include semi-structured interviews with multiple stakeholders to examine intended versus actual use, as analyzed by the Integrated Behavior Model for WASH. It is expected that factors impacting intended use of the Pasteurizer will include a perceived increase in hospital reputation and health benefits. Cost benefit, ease of use and access are hypothesized to impact actual use. Upon completion of the study, we hope to have an improved understanding of the facilitators and barriers to long-term adoption of the Pasteurizer in this setting, and in turn can use this to identify other successful adoption sites.
Evaluating the Antimicrobial Efficacy of Silver Nanoparticles Differentially Shielded from Dissolution

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Multi-drug resistant (MDR) microbes have emerged as a significant threat amidst the overuse of antibiotics. Yet all antibiotics brought to the market in the last 30 years are variations on existing drugs discovered decades ago, leading to no major breakthroughs in this field. With the emergence of MDR microbes, many are turning to silver nanoparticles (AgNPs) as a viable antimicrobial alternative. Since ionic Ag (Ag⁺) is the form of silver that is toxic to bacteria, we selected to study a series of 5 hybrid-lipid coated, spherical AgNPs that are differentially shielded from Ag⁺ release. Previous studies found that a thicker layer around the AgNPs resulted in lower dissolution rates of Ag⁺. The minimum inhibitory concentration range of Ag⁺ ions on Escherichia coli (E. coli) was found from a range finding study. The initial study used concentrations between 0.787mg/L – 0.0246mg/L however, the results found the range to be too low. E. coli was then exposed at concentrations ranging from 0.394mg/L to 12.59mg/L. The number of cells was counted at 0 hours and 24 hours using an Accuri C6 flow cytometer to determine growth rates. We expect that the more heavily coated AgNPs will release less Ag⁺ ions over 24 hours and thus show little to no toxicity on the E. coli. The more thinly coated AgNPs are expected to have increased dissolution of Ag⁺ ions over 24 hours and hinder growth of the bacteria. As different AgNPs are created, testing must be done to assess their toxicity. If released into the environment, AgNPs have the potential to wreak havoc on small ecosystems by indiscriminately killing microbes that are beneficial to the ecosystem. Assessing the impact of controlled dissolution rates of Ag⁺ ions from AgNP will give us a better understanding of how we can balance antimicrobial efficacy and potential off-target impacts.
Ultraviolet Photolytic Inactivation of Cryptosporidium parvum, Bacteriophage MS2 and Escherichia coli within a Microreactor: Experiment and Modeling

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Cryptosporidium is a protozoan parasite encased in a calcium shell found in surface, ground and drinking waters. This parasite and its corresponding genus species are responsible for over 500,000 cases of waterborne illnesses in the U.S. Due to its natural calcium shell, typical disinfection methods like chlorination are ineffective at removing Cryptosporidium during drinking water treatment [1]. UV treatment can be effective in inactivating Cryptosporidium, however, at UV doses much higher than typical ranges in water treatment [2].

In this project, we utilize UV microscale photoreactor to intensify Cryptosporidium, Bacteriophage MS2 and Escherichia coli inactivation efficacy. These microbes were exposed at a range of residence times and evaluated post treatment for log-removal. Escherichia coli was exposed to residence times ranging from 1.5 to 30 seconds with maximum log-removal of 7.90 CFU/mL post treatment. Cryptosporidium parvum was exposed to residence times of 1.6 to 360 seconds and saw a maximum log-removal of 1.38 oocyst/mL post treatment. Bacteriophage MS2 was tested ranging from 1.6 to 480 seconds with maximum log removal of 6.96 PFU/mL.

Additionally, a computational model was developed based on fundamental principles of fluid dynamics to mimic our micro-reactor. As a homogeneous reaction occurs, the model takes into account chemical kinetics of UV damage to the protozoan, light attenuation of the UV source, and velocity profiles of the system. The model accurately describes the first order reaction in which photons emitted from UV radiation impacts DNA replication creating pyrimidine photo-dimers by fusing adjacent thymine nucleic acids together. Using the model, optimal UV dosage, temperature ranges, residence time, and exposure length were predicted.

References:
Treatment of Fracking Wastewater Using Low-Grade Heat

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Hydraulic fracturing, or fracking, is the practice of injecting high-pressure water into rock formations to access otherwise inaccessible oil and gas. Fracking a single well requires between one and four million gallons of water. Given the water intensity of fracking, salvaging some of this water for reuse is imperative.

The wastewater that returns to the surface contains significant concentrations of toxic contaminants, which vary based on geology, additives from the fracking process, and time. The majority of wastewater is reinjected into disposal wells, leading to leaks and seepage into freshwater reservoirs. The presence of these contaminants in drinking water causes serious health problems.

Treatment of fracking wastewater poses a number of challenges, including the variation in contaminant makeup and portability. It is critical that any wastewater treatment system produces clean water regardless of the influent contaminant makeup, as it is impossible to know the exact contaminants present in any given wastewater. Fracking wastewater treatment needs to be portable because the wastewater is produced primarily within the well’s first few weeks of operation. In that timeframe building a treatment facility for each well is not economically feasible. Due to the many challenges of treating fracking wastewater almost all of the wastewater is reinjected rather than treated.

Traditional wastewater treatment methods are not suited to the variable composition of fracking wastewater. To solve this problem, we use humidification-dehumidification in a thermally-actuated swirling nozzle to extract clean irrigation water from fracking wastewater using low-grade heat. This technology drastically reduces the cost of treating wastewater, making domestic fuel production more competitive and circumventing health concerns associated with fracking wastewater disposal.
Natural Organic Matter Surface Coverage as a Predictor of Heteroaggregation Between Nanoparticles and Colloids

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Heteroaggregation of nanoparticles with naturally occurring colloids has been shown to be an important process in nanoparticle fate and transport in the aquatic environment. The advent of a functional assay to measure heteroaggregation attachment efficiencies has opened the door for further mechanistic studies. It is well known that natural organic matter (NOM) will adsorb to and coat natural colloids and nanoparticles, affecting their colloidal stability. The aim of this research is to quantitatively predict the effect of NOM on the heteroaggregation between nanoparticles and colloids. It is hypothesized that the fractional surface coverage of NOM on colloids and nanoparticles is an important variable in heteroaggregation. As surface coverage increases, the mechanism of interaction is expected to shift from nanoparticle-colloid interactions, to nanoparticle-NOM and colloid-NOM interactions, and eventually to NOM-NOM interactions at the complete coverage of both nanoparticles and colloids. The heteroaggregation attachment efficiencies are expected to reflect these changes. To test this hypothesis, 70 µm diameter glass beads equilibrated with Suwanee River NOM were mixed with 60 nm diameter gold nanoparticles coated with a branched polyethylenimine (bPEI) polymer. Samples were collected over time and the glass beads were allowed to settle. The concentration of nanoparticles remaining in suspension was measured via the absorption of light at the surface plasmon resonance peak. Preliminary results confirm that attachment efficiencies between bPEI AuNPs and glass beads are highly correlated with the surface coverage; higher surface coverage resulted in decreased attachment efficiency for this nanoparticle-NOM-colloid system. Future work will include the use of additional nanoparticle surface coatings, and other NOM and colloid types. This research will be used to inform the parameterization of fate and transport models and to determine heteroaggregation attachment efficiencies in complex and realistic media.
Development, Evaluation, and Technology Transfer of BMPs for Optimizing Removal of PAHs, PCBs, PFASs, and Metal from Stormwater at DoD Sites

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Polycyclic aromatic hydrocarbons (PAHs), polychlorinated biphenyls (PCBs), per- and polyfluoroalkyl substances (PFASs), and heavy metals are all known contaminants that have been found in stormwater at DoD sites. There have been recent efforts to remediate stormwater using green infrastructure best management practices (BMP) because they are relatively low cost and low maintenance and have been shown to be effective at preventing recontamination of receiving sediments and waters. Because of the physiochemical differences between these four classes of contaminants, this work will focus on using a combination of sorbents and plants in series as a remediation strategy. The first stage focused on the selection of the most effective sorbent out of an initial five (GAC, a biochar, local soil, EarthLite, and RemBind). Out of the four contaminant classes, PFASs are known to be the least sorptive and thus were selected as the model analytes for screening experiments. A group of 6 individual PFASs were selected with a range of properties (head group, chain length, and charge). The results indicated that GAC-based sorbents were more effective at removing PFASs than biochar-based sorbents or soil. This work also demonstrated that the sorbents have different relative removal efficiencies in real stormwater when compared to synthetic stormwater. The next steps are to evaluate a native plant/sorbent treatment train that will be transferred to a field scale experiment to demonstrate long-term performance.
Development of a Paper-Based Arsenic Sensor for Agricultural Water Sources

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Inorganic arsenic is toxic for human and animal consumption. Long-term exposure to arsenic can result in skin lesions, cancer, and in extreme cases, death. The most common source of arsenic exposure to humans is contaminated water supplies. According to the World Health Organization, arsenic concentrations in water above 10 ppb are considered toxic for human consumption. The ability to quantify the arsenic concentration of these water sources in the field would enable timely decisions that could positively impact human health. Currently available arsenic tests have critical flaws which limit their ability to accurately and safely monitor the concentration of arsenic in water in real time. The commonly used LaMotte field test allows the quick detection of arsenic at concentrations as low as 4 ppb, but has the significant downside of producing the toxic side product arsine gas. While there are laboratory tests that do not release toxic byproducts and have sensitivity below 1 ppb, these are not field ready, and the time between sample acquisition and result can be days long. We aim to create a paper-based field test which can be run quickly and safely with a limit of detection of 1 ppb. Specifically, we will translate a previously demonstrated benchtop absorbance-based method that uses polyethylene-glycol (PEG) functionalized gold nanoparticles to detect As(III) (Boruah & Biswas, 2018). Their study described the use of 200 MW PEG on gold nanoparticles to achieve a limit of detection of 5 ppb. We intend to investigate the impact of gold nanoparticle size (10 vs. 60 nm) and PEG chain length (200 vs. 350 MW) on the limit of detection of As(III). The best performing set of reagents will be implemented in the porous material glass fiber and assessed for sensitivity using colorimetric readout.
Plastic debris is a serious concern for aquatic organisms and human health due to its ubiquity in the waterways globally. Large plastic debris has the ability to degrade into smaller sized plastic pieces some of which are reduced to the nanoscale, referred to as nanoplastics (NPs). Due to its greater surface area to volume ratio, nanoplastics can become more reactive under aquatic environment, adsorb more contaminants, and potentially become toxic to the aquatic life. Therefore, understanding the transport and fate of NPs and how it behaves in the aquatic environment is extremely important. Currently, there is very limited information about where, when, and how NPs will move through streams and rivers, traverse estuaries, and enter the ocean. Many nanoparticles, metals in particular, have the propensity to agglomerate and fall out of solution when salt concentrations increase meaning that those types of particles would likely be deposited in the estuarine system when the salt concentrations increase significantly over freshwater systems. It is currently unknown if this type of behavior can be extended to plastics given their relatively low density. In this study, we will focus the size distribution and agglomeration rate of four NP types (100nm Latex, 47nm Polystyrene, 50nm PMMA-Plain, and 50nm PMMA-COOH) under various salt solutions ranging from freshwater to ocean water salinity (0 mg/L-35mg/L salinity). We are using Dynamic Light Scattering (DLS) to analyze the behavior of NPs at each salt concentration, and then will use that data to predict NPs fate and transport the aquatic environment. Our preliminary data has revealed that the size distribution of the NPs increases as the salinity concentration increases, except for the 50nm PMMA-COOH. The 47nm Polystyrene NPs had the fastest agglomeration rate, and the PMMA-Plain NPs had a slightly higher agglomeration rate compare to PMMA-COOH NPs implying that the carboxylic functional group has increased the stability of NPs. Determining where in the environment these NPs will likely be can help us to strategically select organisms that may have increased exposure and potential uptake of the NPs. This information is useful for risk assessment as well as commercial fisheries such as shellfish which may be located in areas of NP concentration.
Remote and Ground Based Methods for Monitoring Vegetation Health Parameters in a Bioretention Facility

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As urban areas expand, so does the contamination of surface water by stormwater runoff. Heavy metals, polycyclic aromatic hydrocarbons (PAHs), persistent organic pollutants (POPs), and contaminants of emerging concern (CECs) are discharged from point sources and washed from impervious surfaces into surface waters, impacting the ecology of these systems, food supplies, and the source waters for drinking water. Green stormwater infrastructure reduces peak runoff and removes contaminants, while providing the structure to support microbial communities and stabilize the soil. Vegetation health plays a large role in the effectiveness of green infrastructure installations, with unhealthy vegetation having slowed uptake and transpiration rates. When vegetation is sparse, its effectiveness as a filter is also reduced. Monitoring the health of vegetation in stormwater green infrastructure can indicate signs of water stress, disease, as well as pollutant induced toxicity. Early detection of stress in vegetation can inform management and maintenance decisions. This study examines two methods for monitoring biomass and primary production applied to a bioretention facility, one remote and one ground based. The relationship between the normalized difference vegetation index (NDVI) derived from unmanned aerial system (UAS) imagery and ground-based measurements of the fraction of intercepted photosynthetically active radiation (fIPAR) is explored to determine if NDVI can act as an estimate of fIPAR in this setting. Results show a weak relationship between NDVI and fIPAR when considering all vegetation species in the rain garden, but a stronger relationship for broad leaf vegetation and sedges when examined independently, indicating that NDVI is more closely correlated to fIPAR for broad leaf shrubs and sedges than for rushes.
Development of an Anammox Enzymatic Assay to Characterize Heavy Metal Inhibition

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Removing nitrogen from waste-water is vital to avoid eutrophication of receiving waters. Traditional nitrification-denitrification methods are expensive due to its high energy demands of aeration and the requirement of methanol as an external carbon source. Anammox can overcome these issues by oxidizing NH4+ to N2 by using NO2-. This only requires 60% of the energy demand of traditional nitrification-denitrification and no requirement for the addition of external organic carbon.

However, Anammox activity in wastewater treatment plants is difficult to maintain because of its slow growth and its sensitivity to a wide variety of inhibitors including, O2, heavy metals or even its own substrates (i.e. NO2- and NH4+).

To increase our understanding of heavy metal inhibition mechanisms in Anammox bacteria, this developed and utilized a novel hydrazine dehydrogenase (HDH) ACTIVITY ASSAY. HDH oxidizes hydrazine (N2H4), an important intermediate in the Anammox pathway, to N2 gas. The process also releases electrons to the electron transport chain, which results in the generation of energy (i.e. ATP). The HDH assay was used in conjunction with 4 different heavy metal inhibitors that were either redox active (e.g. Cu and Cr), non-redox active (e.g. Zn and Cd), biologically required (e.g. Cu and Zn) or not biologically required (e.g. Cr and Cd).

When exposed to 20ppm Cu2+, 40ppm Cd2+, 50ppm Zn2+ or 15ppm Cr6+, respectively, Anammox activity was inhibited by 70%-90%. Under these same conditions, the HDH activity was inhibited by 56%-70%. With the exception of Cd2+, HDH activity showed lower inhibition percentages when exposed to these heavy metals than the overall Anammox inhibition. This suggests that these heavy metals are inhibiting not only just HDH enzyme but other upstream processes in the Anammox cell, as well. But for Cd2+, the same level of inhibition was observed for both the HDH activity and overall Anammox activity. Thus, it is speculated that Cd2+ is only inhibiting the HDH enzymes and potentially other downstream processes.
The Effects of Biofilms in Column Testing of Sorbents for the Removal of Copper, Zinc, and PFASs from Stormwater

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This study will investigate the removal of heavy metals and persistent toxic organic compounds found in storm water runoff using bench scale flow through column studies with various sorbents in the presence and absence of biofilms. The adsorbents Earthlite, Rembind, and granular activated carbon are the adsorbents that will be used in the column study. Breakthrough and removals for copper, zinc, and PFASs will be monitored in columns containing biofilms enriched from soil collected at the OSU-Benton County Green Stormwater Infrastructure Research (OGSIR) facility, and in columns containing only biofilms from the OGSIR facility and borosilicate glass beads. The results of the breakthrough curve analysis will be used to compare the biotic and abiotic adsorption columns. Genetic diversity and microbial ecology will be monitored throughout the process to see how enrichment and interaction with the pollutants and adsorbents affects microbial ecology over time compared to the original soil sample.
Dual Microbe and Primary Substrate Approach for Aerobic Cometabolism of 1,4-Dioxane and Chlorinated Solvent Mixtures

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1,4-dioxane (1,4-D), a probable human carcinogen, has emerged as a common groundwater contaminant due to historical use as a stabilizer in industrial formulations of 1,1,1-trichloroethane (TCA). Bioremediation, specifically cometabolism, is an attractive remediation approach because environmental concentrations of 1,4-D are often low and it could be implemented in situ. Previous work has shown 1,4-D is cometabolized by isobutane-grown microorganisms, including Rhodococcus rhodochrous strain ATCC 21198. However, 1,4-D contamination often occurs in mixtures of chlorinated solvents such as TCA, trichloroethene (TCE), and their transformation products. Some co-contaminants are also transformed by isobutane-grown bacteria, however others are only slowly transformed or exert a toxic effect. As such, isobutene-grown Mycobacterium ELW1 was investigated for its complementary transformation capabilities. Transformation rates determined from batch studies were used to develop a Michaelis-Menten/Monod kinetic model to predict contaminant mixture cometabolism by the two microorganisms and their primary substrates. The model includes the influence of transformation capacities and competitive inhibition.

21198 rapidly cometabolizes 1,4-D and several chlorinated co-contaminants, including 1,1-dichloroethene (1,1-DCE). 21198 cometabolizes 1,1-DCE more rapidly than it metabolizes primary substrate (isobutane). However, this inhibits 21198 biomass growth because 1,1-DCE transformation produces a toxic epoxide. By contrast, isobutene inhibits 1,1-DCE cometabolism by ELW1, allowing for microbial growth prior to detrimental cometabolic transformation. Isobutene-grown ELW1 also cometabolizes TCE faster than 21198, however it does not transform 1,4-D or chlorinated ethanes. Therefore, both microorganisms are needed to transform complex contaminant mixtures, though cometabolism of the other microbe’s primary substrate also impacts system dynamics. Modeling analysis allows for assessment of the pulsed of delivery of primary substrates (isobutane and isobutene), and estimation of primary substrate and/or biomass required to remediate a given contaminant mixture. Model simulations are compared with the results of batch microcosm studies.
A Comparison of Ammonia Inhibition on the Anaerobic Digestion of Organic Acids Between Sludge from Anaerobic Co- and Mono-Digestion Systems

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Anaerobic digestion (AD), a technology which sits prominently in the food-water-energy nexus, is becoming increasingly popular through the co-digestion of fats, oils and greases (FOG) as well as solid food waste (FW). The productivity and stability of co-digestion is highly dependent upon the composition and loading rate of the chosen substrates. These substrates can contribute to the accumulation of inhibitory compounds. Ammonia and the ammonium ion have been shown to be the most significant inhibitors of the anaerobic digestion process.

A previous study in our lab has shown the differences in anaerobic digester performance with differing levels of ammonia present. The current study aims to compare the inhibitory effects of ammonia on anaerobic digester batch reactors digesting acetate. One set of reactors were inoculated with anaerobic digestate from the Corvallis wastewater treatment plant (WWTP), which only treats municipal sludge. The other set of reactors were inoculated with anaerobic digestate from the Gresham WWTP, which performs anaerobic co-digestion of fats, oils, and greases. Four different ammonia concentrations were tested: control (baseline ammonia at the full-scale facilities), +500 ppm NH₄⁺, +1000 ppm NH₄⁺, and + 1500 ppm NH₄⁺. Biogas production, gas composition, pH, and ammonia were monitored throughout the experiment. We hypothesize that anaerobic digestate from the Gresham wastewater treatment facility will be more resistant to ammonia inhibition than the anaerobic digestate from the Corvallis WWTP.
Trichloroethylene Cometabolic Degradation by Pseudomonas Mendocina KR1 Grown on Various Substrates: Pure Culture and Co-encapsulated with Slow Release Compounds Kinetic Studies

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Chlorinated solvents, such as trichloroethylene (TCE) are hazardous contaminants found in the subsurface. A method of treatment is bioremediation by microbes capable of aerobic cometabolism; the induction of oxygenase enzymes in microbes growing on a primary substrate that fortuitously degrades contaminants. Pseudomonas mendocina KR1 is a toluene-utilizing bacteria capable of cometabolically transforming chlorinated ethenes by the toluene-4-monooxygenase enzyme (T4MO). This study investigated both the level of induction of T4MO in KR1 grown on various growth substrates, as well as the novel development of co-encapsulating KR1 with a slow release compound (SRC) in gellan gum for in-situ bioremediation. The level of induction was evaluated through Activity Based Protein Profiling (ABPP) and resting cell kinetic tests in which a known mass of cells were exposed to contaminants of interest. Potential SRCs were co-encapsulated with KR1 in gellan gum macrobeads and evaluated through kinetic tests in batch systems.

Both the ABPP gel assay and resting cell kinetic tests found that the induction of T4MO in KR1 grown on benzyl alcohol was comparable to toluene as a non-toxic alternative. Compounds that would release benzyl alcohol upon hydrolysis, such as benzyl esters were also found to induce the T4MO. Phenol, a substrate known to support TCE cometabolism, was also tested and found to induce the T4MO in KR1, but to a lesser degree. Benzyl butyrate had the highest initial rates and TCE transformation capacity in resting cell tests, however when co-encapsulated and tested as a possible SRC, it hydrolyzed too rapidly indicated by high rates of respiration. Given the success of orthosilicate versions of SRCs seen in previous work with ATCC 21198 and for proof of concept, tetraphenyl orthosilicate—which hydrolyzes to release phenol—was co-encapsulated in gellan gum. The transformation of TCE has been observed over 100 days and is ongoing. Given these results, a benzyl alcohol orthosilicate version is being tested in a growth cometabolism test, where a low biomass of suspended KR1 is grown in the presence of both the substrate and contaminants. Based on the outcomes of this test, a co-encapsulated version may be tested.
Water Contamination Due to the 2018 California Camp Fire

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The occurrence of wildfires has increased in the western United States in the past decade with no signs of diminishing. The increasing frequency and intensity of wildfires has led to more severe impacts and damages to communities and infrastructure, especially as wildland-urban interface communities continue to expand into hazardous landscapes. Following the 2017 Tubbs Fire and 2018 Camp Fire, high levels of benzene and a variety of other volatile organic compounds were detected in the water distribution systems. The allowable level of benzene in drinking water for the state of California is 1 ppb (µg/L). However, in the town of Paradise, California, levels of benzene have been detected up to 923 ppb in the most severe case, significantly over the allowable limit. High density polyethylene and polyvinyl chloride are two materials that are frequently used for water service lines. These pipes have significant data demonstrating durability, preventing constant replacement of pipes due to corrosion, ease of installment, and ductility during a seismic event. The contamination of the water distribution system is thought to be caused by several mechanisms: 1) the heating of high density polyethylene and polyvinyl chloride service line pipes releasing benzene into the system, 2) plastic components from water meters or water meter boxes releasing contaminants into the system, or 3) toxic fumes released from burning homes being pulled into the water system when the network depressurized during and after the event.
Azo dyes are widely used in textile manufacturing, but are also toxic compounds that contaminate wastewater streams and can freely pass through certain wastewater treatment processes. Azo dyes are toxic to microorganisms, so biological treatment is ineffective against them. It is therefore important to develop a method to treat wastewater for the removal of these harmful dyes; photocatalysis may provide an efficient route to the degradation of azo dyes and other organics. Titanium oxide (TiO2) is a commercially produced and commonly used photocatalyst. The commercial substance (typically referred to as P25) can degrade azo dyes, but only in the presence of UV light. Therefore, P25 TiO2 is not an efficient photocatalyst in sunlight due to the sun emitting mostly visible light. It is therefore desirable to study other photocatalysts that have received comparatively less attention than TiO2. Pure tin oxide (SnO2) is among the photocatalysts that have not been as widely studied. In this study, we investigate the effects of the domain size of SnO2 and the effects of the doping of SnO2 photocatalysts with metallic cations such as Bi3+ or Mo4+. Our working hypothesis is that decreased size and increased doping could enable enhanced visible light activity of the photocatalyst. This hypothesis is probed by monitoring the kinetics of the decomposition of a representative azo dye, Rhodamine B (RhB), over SnO2 catalysts. Intrinsic and observed kinetic parameters are extracted based on the concentration changes of RhB in batch reactions.
Desalination is essential to fulfill the worldwide fresh water demand. With the growth of population, accelerated urbanization, developing economic, and improvement in living-standards this demand has increased dramatically. Due to the unavailability of reliable electricity in many areas facing water scarcity and dependency of conventional desalination plants on fossil fuels, such increased water demand has posed a serious concern to find alternative energy sources. In this context, abundantly available solar thermal energy is recognized as a promising candidate for desalination. However, many such conventional desalination processes show poor performance when operated using solar thermal energy. This is attributed to the reduced operating pressure and temperature while running on low-grade solar energy. Such reduced pressure and temperature of the conventional desalination processes deteriorates the cycle performance in terms of cycle efficiency and fresh water production rate. In order to enhance the cycle efficiency of a low grade heat desalination system, we are developing a facility that comprises of a thermal actuation system with film atomization methods for a solar driven humidification – dehumidification desalination with heat recuperation. Solar thermal power heats and accelerates air through a nozzle array. Hot, dry air jets break up and atomize a film of saline water. Salt is then obtained from the atomized saline water through humidification. Fresh water is subsequently extracted from the saline-free, humid air stream. The proposed cycle design operates at significantly lower pressure compared to conventional desalination methods and yields consequently to an overall higher cycle performance. The system is compact in volume and arbitrarily scalable through a modular arrangement, therefore it can be installed in rural and remote areas facing water scarcity. We present the current stage of our in-house developed prototype. First scoping tests confirm that simulated design specs are achievable.
Cartoons for Increasing Understanding of Environmental Issues as Outreach for Environmental Engineering

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Media representation and scientific literacy can influence youth knowledge of and participation in various scientific fields. Our aim is to increase overall comprehension of environmental science and promote interest and participation in the Environmental Engineering field using educational cartoons. A smaller-scale project focusing on individual strip comics that feature current principles and challenges in Environmental and Chemical Engineering is to be published in journals and magazines aimed at K-12 level students. A longer-term phase will include a multi-page comic book spotlighting famous instances of Environmental Issues, centered around specific figures and discoveries in the history of Engineering. Unrepresented and minority groups in Engineering will specifically be targeted to expand further involvement. The ultimate goal is to stoke enthusiasm for and stress the importance of an often overlooked section of Engineering.
In this work, we are presenting the conceptual design stages of the design of a small-scale, easily deployable, wave energy powered desalination system. Wave energy is a renewable energy resource which has been in development for a few decades now, but remains too costly and uncertain to receive significant support from investors and stakeholders. Seawater desalination technologies have been around since the 1960s and are gaining popularity due to current and impending water crises. Though the price and energy consumption of desalination technologies has decreased over many years of research and innovation, both remain high. A combined wave energy and desalination system gives the opportunity for application of wave energy systems at a smaller scale, opening new avenues for development. It also mitigates emissions concerns accompanying the high energy demand of desalination. With 40 of 50 U.S. states predicting water shortages between 2013 and 2024, desalination may become an essential part of providing drinking water to the population [1].

In this poster we present the design requirements of the system, 3 different concepts we have come up with to meet those requirements, the steps we have taken to arrive at those concepts, and the methods we will use to determine which concept to choose for development.

Our world is facing an ecological crisis which will require creative, combined solutions which can tackle multiple problems without detrimental impacts to the environment, animal life, and vulnerable human communities. This solution stands to address issues of water shortage and reduce carbon emissions from burning greenhouses gases while avoiding waste production and environmental degradation. Design for a small scale, easily deployable system focuses on developing solutions accessible to communities most vulnerable to the impacts of water shortages. This work is being done as part of the Department of Energy's Waves to Water Challenge.

References:
Membrane capacitive deionization (MCDI) is a developing technology employing porous electrodes and ion-selective membranes for desalination purposes. We are seeking to apply this technology in tertiary water treatment of agricultural runoff, although this technology is of growing interest for many sorts of water treatment as it is of a low energy cost and is easily scalable. For now, our primary goal is to better understand this process and prepare it in a steady state configuration. The cation and anion selective membranes used are both 30 μm in thickness and are stable for all ranges of pH. Peristaltic pumps are used to achieve very low flowrate (<100 mL/min) which allows for the optimal ion removal in a sterile manner. Variable flowrates will be tested (dependent upon the non-conductive mesh water flows through) for optimal ion removal and recovery in terms of time and energy. We will study the techniques for optimal recovery of agricultural runoff nutrients (i.e. ammonium, nitrate, and phosphate) in order to repurpose these materials. Greater specific surface area within an electrode material allows for greater adsorption potential. Ion-selective membranes increase this number even still as they reduce the negative adsorption effects of the electrical double layer. Initial experiments implement activated carbon cloth (ACC) electrodes, and experiments with powdered activated carbon (PAC) will follow. Tests will determine the optimal electrode material and thickness. A potentiostat is used to control the applied potential across the MCDI cell and will be tested at voltages up to 2 V. Effectiveness of the system will be measured by ion removal from binary electrolytes, calculated by pH and conductivity measurements of the resulting solution. Eventually, results will be found for complex solutions using spectroscopic methods. Economically optimizing cell design and flow patterns may make the difference for any community with limited economical resources.
Sustainable Approach to a High-Performance Battery Anode: Porous Hard Carbon Material from Tree Leaves Used to Adsorb Toxic Ions from Wastewater

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In this project, a sustainable use of materials is proposed that involves the use of adsorbent from Cr(VI)-polluted wastewater treatment as high capacity battery anodes for lithium-ion batteries. Non-graphitizable (hard) carbon is synthesized from pyrolysis of biomaterials (e.g., Douglas fir tree leaves) at various temperatures (900-1300°C). The porous hard carbon is used to adsorb toxic chromium ions commonly found in wastewater (in this case potassium dichromate, or K2Cr2O7, solution). Because of nitrogen-containing functional groups on the surface, Cr(VI) ions in the solution will be reduced to more stable Cr(III) ions. Then, the chromium-containing carbon material will further be used as anodes for lithium-ion batteries that will exhibit higher capacities and cycle lives than commercial graphite anodes.