**Research Projects: Environmental Sustainability Research Experiences for Undergraduates (REU) Site**

**University of Colorado Boulder**

**Summer 2013**

**Climate Change Impact on Land Use Patterns** [Chinowsky]

Climate Change is an international issue with far reaching effects on many sectors of a country’s social, economic and environmental systems. Changes in temperature and precipitation can have the greatest impacts on developing communities throughout the world, at times hindering a region’s capacity to develop due to the already existing vulnerability of populations living in poverty. What’s more, climate change research most often explores global warming effects qualitatively, but leaves much to be desired with regards to quantitative evaluation of actual consequences. To address these concerns, this research effort will build on the existing work by Prof. Chinowsky under the direction of graduate students to explore quantitative impacts of climate change (specifically environmental impacts) on land development. The undergraduate will work with the research team to develop ways to examine climate effects on market access, education and health access as well as direct effects such as water availability and water access.

**Characterization of the Water-Soluble Organic Matter in Atmospheric Aerosols** [Hannigan]

Particles in the atmosphere, or aerosols, are a public health threat and environmental concern. Composition varies most obviously with aerosol diameter, with particles less than 2.5 µm (PM2.5) emitted from biomass burning (including fossil fuels) and secondary atmospheric formation processes. Particles greater than 2.5 µm and less than 10 µm (PM10-2.5) are typically emitted from abrasive processes (i.e. vehicle- and road-wear) and dust resuspension. Due to PM10-2.5 organic matter resembling that found in soils and aquatic systems, and due to the presence of significant amounts of humic-like substances in PM2.5, analysis techniques were borrowed from other fields of terrestrial organic matter characterization and applied to samples of aerosols. Filter samples of both size fractions were collected throughout the Colorado Front Range region during 2010 and 2011. Additional samples are currently being collected at the Boulder Atmospheric Observatory (BAO), a 300 meter research tower in Erie, CO. During the last six months an analysis protocol was developed to characterize the organic fraction of the collected aerosols. The REU student’s research effort will apply the developed analysis protocol to the two previously described sets of sample filters and will involve some field work, including visits to the BAO tower to collect samples. In the laboratory, the student will perform aqueous extractions of collected filters for later analysis (performed by collaborators) and run filter samples on a bulk elemental/organic carbon analyzer. Results will highlight differences in aerosol organic matter between size fractions, as well as differences between urban and rural aerosols. Data from the BAO tower will provide insights into the vertical distribution of particulate matter composition in the atmosphere.

**Title: Sol-Char Toilet Development [Linden]**

The Sol-Char Toilet research project is seeking a student assistant for Summer 2013. This project is within the Bill & Melinda Gates Foundations [Reinventing the Toilet Challenge](http://www.gatesfoundation.org/watersanitationhygiene/Pages/reinventing-the-toilet.aspx). The student will have a chance to be a part of an international initiative to move sanitation technology forward and will work on a toilet prototype that uses solar energy to turn human fecal waste into valuable products. The student will work closely with the project staff researchers and Professors Linden and Summers. Analysis may include (1) evaluation of off gasses from the solar-thermal waste processing; (2) testing of the individual components of the toilet; (3) work on integrating the components of the toilet into an operational prototype; (4) studying biochar product properties; (5) investigating urine disinfection and resource recovery. For more information check out the project on FaceBook at : <http://www.facebook.com/SolarBiochar>

**Protecting Public Health: Innovative Water Treatment with UV Light** [Linden].

Chemicals of emerging concern are present in natural water supplies because the drugs we take are not fully metabolized in our bodies or fully degraded in traditional wastewater treatment systems. Toxic pathogens from human and animal sources and chemicals that run off from agriculture also threaten our water. We need better ways to treat our water to neutralize chemical and microbial contaminants from causing harm to aquatic life, and affecting human health and development. The REU student(s) will participate in current research activities, developing their own line of research under the mentorship of professor Linden and his graduate students including: (1) oxidation processes for degradation of emerging chemical contaminants, (2) analytical chemistry and toxicological analyses of contaminants in wastewater, (3) investigating the use of innovative UV technologies for the disinfection of pathogens and degradation of pesticides, herbicides, volatile organics, and taste and odor compounds found in water supplies, and (4) treatment of wastewater effluent to enable proper re-use for the benefit of society.

**Climate and water quality controls on the growth of algae in lakes in the Colorado Front Range** [McKnight]

Aquatic ecosystems in the alpine areas in Colorado are responding to increases in the duration of ice-free conditions, which allows for more growth of algae for longer periods in the summer. The extent of this response is dependent upon the nutrients in the lake to support growth of algae. In turn, the growth of algae contributes to the formation of dissolved organic material in the lake, which can form disinfection by-products when used as a water supply source. There is an opportunity to conduct field and laboratory research on water quality and algal growth in an alpine lake studied as part of the Niwot Ridge Long-term Ecological research project.

**Climate change effects on hydrology and stream ecosystems in the McMurdo Dry Valleys, Antarctica** [McKnight]

Although the Antarctic continent is predicted to experience a warming climate due to the accumulation of greenhouse gases in the atmosphere, over the past two decades the summer temperatures have been colder because of the ozone hole. We have found that the endemic species of diatoms are more abundant in cold summers when the streamflow is low and there are intermittent periods of no flow during the summer. We are investigating the adaptation of the diatoms that result in this change in species distribution. The diatoms exist in a mat that is composed of cyanobacteria and mucilaginous material. There are opportunities to study the response of diatoms in culture to changing temperatures, intermittent drying and changing nutrient concentrations.

**Emissions Consequences of Shale Gas Production in the Rocky Mountain Region** [Milford]

Increasing production and use of shale gas has mixed consequences for emissions of conventional air pollutants and greenhouse gases. Combustion of natural gas for electricity generation has lower emissions than use of coal, per kWh of electricity produced; however, production of natural gas using either conventional or unconventional techniques results in local emissions of volatile organic compounds and nitrogen oxides, which are conventional air pollutants contributing to ozone formation, as well as emissions of methane, a greenhouse gas.

This project will help compile information on emissions from natural gas production in the

Rocky Mountain Region for use in modeling the air quality impacts of expanded production activities. This REU experience will develop familiarity with emissions sources and mitigation measures in the oil and gas production sector.

**Exposure to flame-retardants indoors** [Miller].

Recent studies show that exposure to phthalates and flame-retardants on the indoor air environment can cause adverse health effects. Phthalates are commonly used as plasticizers in poly vinyl chloride (PVC) plastics (phthalates give plastics their flexibility), and are used in various consumer products such as: building materials, household furnishings, clothing, cosmetics, pharmaceuticals, nutritional supplements, medical devices, dentures, children’s toys, glow sticks, modeling clay, and food packaging. Flame retardants are additives that can be applied as a treatment to organic materials such as plastics and textiles. Some of these additives are used as chemical modifiers for some plastic materials. The main function of a flame retardant is to reduce the chances of a fire starting increasing the resistance to ignition. The objective of this research is to better understand exposure to phthalates and flame-retardants and any health effects as a result of these exposures in the homes of more than 100 families in Colorado. A web-based questionnaire will be distributed that was developed during the summer of 2012. Data will be analyzed using statistical techniques for associations. Dust will be sampled in the homes of a subset of the families participating in the study using a vacuum. Phthalate and flame retardant levels will be analyzed in the dust using gas chromatography mass spectrometry.

**Combustion and Biological Components of Indoor Air PM in Poor Communities [**Montoya]

Air pollution has been associated with global increases in respiratory, cardiovascular and allergic diseases. In the US, proximity to roads has been determined as a risk factor in the development of asthma and cardiovascular disease. Studies have demonstrated that there is a synergistic heightened effect when combustion pollution (i.e., diesel exhaust) precedes exposure to biological aerosols. While the outdoor environment has historically received a lot of attention from air quality scientists and engineers, the indoor environment has come under greater scrutiny given that people spend most of their time indoors. Americans, for example, spend an average of 90 percent of their time indoors, where the highest exposures to airborne pollutants often occur. This situation is especially acute in developing countries, where an estimated 1.6 million people (mostly women and children) die each year from exposure to smoke emitted from traditional biomass stoves. In the US, some Native American communities, for example, use coal for heating, generating indoor pollution that directly affects the health of the residents. This study seeks to determine exposure and health effects due to combustion and biological components of indoor particulate matter in communities in the US, Peru and Chile.

**Engineering Injection and Extraction to Enhance In Situ Remediation of Groundwater**

[Neupauer].

In situ remediation of contaminated groundwater often involves the injection of a treatment solution into a contaminated aquifer to promote reactions to degrade the contaminant. Reactions occur where the contaminant and treatment solution are in contact with each other, or where they are sufficiently close that molecular diffusion will bring them together. In the laminar flows that are characteristic in porous media, the treatment solution and contaminated groundwater do not readily mix. In this work, we are investigating methods for enhancing mixing in groundwater through the operation of a system of wells. Water will be injected into or extracted from the wells in a prescribed pattern to create a transient flow field in the vicinity of the treatment solution and contaminated groundwater to enhance mixing of the two fluids, thereby increasing the overall reaction rate. The student will work on groundwater modeling analyses of the injection/extraction system to investigate the optimal system design or to quantify the increase in the overall reaction rate for various scenarios. The work could involve genetic algorithm optimization, reactive transport modeling, analysis of chaotic flow, or related work that is of interest to the student.

**Acid Mine Drainage Suppression by Carbon Addition** [Rajaram]

Acid mine drainage is an important environmental problem, impacting thousands of miles of streams. Acid mine drainage results from the oxidation of sulfidic materials such as pyrite in waste rock (typically resulting from mining operations) exposed to water and air. Bacterial iron oxidation is the critical process catalyzing the acid generation cycle once pH is less than 4-4.5. The factors that allow iron-oxidizing bacteria to dominate the biogeochemistry of waste rock piles are (1) availability of water and oxygen and (2) absence of organic substrates that would allow the growth of competitive, non-iron-oxidizing bacterial populations. Not surprisingly, inundation, capping or other approaches to limiting oxygen availability in waste rock piles is one commonly used acid control strategy. Another potentially inexpensive and effective strategy is to add organic substrates to promote the growth of heterotrophic bacteria that compete with iron-oxidizing bacteria for oxygen, thus suppressing acid generation. Previous studies in our laboratory also suggest that soluble microbial products from heterotrophic bacteria can form complexes with ferric iron, disrupting another important step in the pyrite oxidation cycle - the chemical oxidation of pyrite. The undergraduate researcher will work with a graduate student to conduct column experiments in large waste rock columns to evaluate the effectiveness of organic carbon addition as a strategy for suppressing acid generation. The columns are already operating under acid generating conditions. Experiments will involve addition of glucose or other recycled waste (e.g. bagasse) sources of organic carbon. Chemical and microbial analysis of the column effluent and rock samples will lead to an improved understanding of the fundamental processes that control suppression of acid generation. This understanding will be abstracted into reactive transport models in the graduate student's research, to develop organic carbon addition strategies for field-scale waste rock piles.

**Impact of forest fires on water quality** [Rosario-Ortiz]

One of the impacts of climate change is the increased frequency of forest fires. When these fires occur in a watershed that also serves as source for drinking water, the overall impact on both water quality and treat ability needs to be assessed. The impact of forest fires on water quality includes increased particles, higher concentrations of inorganics and potentially changes in the disinfection byproduct formation potential of the dissolved organic matter. We are currently evaluating the effect of a recent forest fires on water quality, focusing on DBP formation and treatability.

**Fate of Mercury in Reservoirs** [Ryan]

Fish consumption advisories have currently been posted for all of the reservoirs in southwestern Colorado because of high mercury concentrations in fish. These reservoirs are downwind of numerous coal-fired power plants, which release mercury to the atmosphere. We are investigating the processes that affect mercury speciation and bioavailability in these reservoirs, including the nature and composition of the organic matter, the geochemical gradients in reservoir sediments, and forest fires.

**Sorption of Organic Contaminants by Low-Cost Chars** [Summers]

Organic contaminants (OCs) in drinking water, wastewater, and nonpoint sources are often difficult problems as their treatment is expensive, e.g. granular activated carbon (GAC). Biochar is a recalcitrant, carbonaceous material generated from the pyrolysis of biomass. When applied in agricultural soils to enhance fertility and/or sequester carbon, biochar has demonstrated the ability to strongly ad/absorb OCs. The sorbent is an alternative to GAC that is gaining attention because it is less expensive (estimated to be <1/6 the cost of GAC) and more environmentally sustainable to produce. For example, GAC is often derived from coal whereas biochar can be generated at lower energy costs from agricultural and forestry residues. Although biochar has the potential to be widely used to remove OCs, a better understanding of the relationship between its structure and sorption behavior is necessary. We have been generating biochar from a wide range of feed stocks, including beetle-kill pine, bamboo, sugarcane bagasse, jatropha seedcake waste pellets, switchgrass and rice husks, and more recently looking at the use of human fecal matter as part of a Bill & Melinda Gates Reinvent the Toilet project. Biochar application has a role in developed and developing communities.