Research Projects: Environmental Engineering Research Experiences for Undergraduates (REU) Site

University of Colorado Boulder

Summer 2012

Photochemistry of organic matter in surface waters (Prof. Fernando Rosario-Ortiz)

The presence of organic matter (OM) in the environment has a major influence on many processes, from contaminant transport to the regulation of environmental processes. In addition, OM affects treatment systems—both water and wastewater—by interfering with the processes designed to eliminate pathogens or organic contaminants. Of specific interest is the photochemistry of OM, specifically related to the decay of organic contaminants in wastewater-impacted streams. This project will evaluate the formation of reactive oxygen species (ROS) through the photochemical processes with OM. It will focus on the formation of hydroxyl radical (HO) and singlet oxygen to evaluate how they impact the oxidation of organic contaminants.

Effects of Natural Gas Extraction on Water Quality in the Raton Basin of Colorado (Prof. Joe Ryan)

We are investigating the effects of natural gas extraction on water quality in the Raton Basin of southern Colorado as part of research being done by our Colorado Water and Energy Research Center. The REU student will assist in identifying and gaining access to sampling locations, developing sampling protocols and collecting samples for analysis of carbon-13 and organic compounds, conducting analyses of the samples, and interpreting and using the sampling results to assess the risk of exposure of drinking water wells to contaminants associated with hydraulic fracturing and natural gas drilling.

Effects of nutrient enrichment and earlier loss of ice-cover on algal growth and water quality in alpine lakes (Prof. Diane McKnight)

The Colorado alpine areas are experiencing rapid changes due to changes in climate and increasing nutrient loading from atmospheric deposition. For the alpine and sub-alpine lakes, the combined effect of these changes is to cause increases in the amount of algae in the lakes and and warmer temperatures in the surface layer of the lakes. This project involves sampling an alpine lake, Green Lake 4, as part of the Niwot Ridge Long Term Ecological Research project. The Green lakes Valley provides a significant portion of Boulder's water supply. The student will analyze past and current monitoring data to evaluate the extent to which the excess nutrients are taken up by the algae in the lake. The student will also learn to identify algae in the lake using an imaging flow through microscope.

Engineering Injection and Extraction to Enhance Mixing to Promote In Situ Remediation of Groundwater (Prof. Roseanna 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. The pattern will be designed in such a way that the transient flow field enhances 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.

Asthma Incidence and the Role of Exposure to Contaminants in the Indoor Environment (Prof. Shelly Miller)

Asthma incidence has been increasing in the U.S. over that past thirty years. The US Centers for Disease Control and Prevention report that the prevalence of asthma in children was 3.6% in 1980, 5.8% in 2003, and is currently at 14% in 2009. A recent study conducted in TX showed a dose-response relationship between time spent at a daycare center and prevalence of asthma. Another recent report showed an association between flooring material and incidence of asthma. The risk of developing asthma was highest for children living in homes in which vinyl flooring was used in the parents bedroom. The objective of this research is to better understand what characteristics of the indoor environment contribute to asthma disease in children who live in Colorado. Tasks will include a detailed literature review, development of a questionnaire, and identification of a cohort of families with young children who would be willing to participate in a questionnaire-based assessment of asthma and the indoor environment.

Air Pollutant Deposition on Solar Panels and Resulting Impacts on Energy Yield (Prof. Hannigan, working with grad student Liza Boyle)

From the year 2004 to 2008 spending on renewable energy quadrupled and the capacity of installed photovoltaic systems increased six fold. Once solar panel systems are deployed there is a limited understanding of the many factors that affect their performance. A study in Saudi Arabia found that after just six months a solar panel's power output dropped to 40% of its initial output. A study in Egypt found that solar transmittance through a horizontal glass plate decreased by 75% in just one month due

to particle deposition. The original transmission was restored when the plates were cleaned. These large drops in performance are primarily caused by particle deposition on the surfaces.

As solar power becomes a more prominent part of our energy infrastructure understanding reductions in power will be an important part of grid integration and plant sizing. This will involve understanding both methods of particle deposition on the surfaces, and the effect on solar radiation transmission. Our research aims to develop two models: deposition process model that relates ambient concentration of particulate matter with deposition on solar panel surfaces, and a transmission process model that relates the mass and chemical composition of particles deposited with the change in solar radiation transmission. To develop these models, we have developed a measurement field campaign on an elementary school roof in northern Denver. We have deployed airborne particle measurement tools as well as glass deposition surfaces that mimic particle deposition on the glassing of a solar energy harvesting system. Weekly, the deposition surfaces are collected from the site and taken to the Solar Radiation Research Lab (SRRL) at the National Renewable Energy Lab (NREL) in Golden where we measure the transmission through the surface over the complete solar spectrum. This activity at SRRL is in need of refinement as we currently just hold the surface in a perpendicular angle between the solar energy measurement device and the sun. It would be very interesting to rotate the surface and explore how the surface angle impacts transmission. We would be excited to have a student join this project during the summer of 2012 and take on the refinement of this measurement protocol.

Protecting Public Health: Innovative Water Treatment with UV Radiation (Prof. Karl G. Linden)

Have you ever wondered what happens to all the medications that are consumed and discarded? How about all of our perfumes, lotions and shampoos we apply? The fact is that pharmaceuticals and personal care products are making their way into our natural water supplies because they are not fully metabolized in our bodies and then rinsed away down the drain. How about all the toxic pathogens that run off from contaminated animal Agriculture operations or from our wastewater treatment processes. Our modern day industrial way of life is threatening the health of our water environment. We see this in hormonally active chemicals altering the sex of fish and reproductive health of many species and the incidence of emerging pathogens causing diseases. There is a growing need for better ways to treat our water to neutralize chemical and microbial contaminants form causing harm to aquatic life, and possibly affecting human health and development. Opportunities exist to participate in current related research activities 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 microbes 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. These research projects are excellent opportunities to learn about an emerging technology and fundamental principles behind water treatment processes. Requirements are: undergraduate laboratory courses in chemistry, microbiology, and/or physics, interest in environmental engineering.

Life Cycle Assessment of Transportation Fuels Used in Colorado (Prof. Jana Milford)

To help in understanding the environmental costs and benefits of transitioning to electric vehicles, this project will investigate the life cycle environmental impacts of current transportation fuels used in Colorado -- gasoline, diesel, and ethanol. These impacts will then be compared to those associated with powering vehicles with electricity from coal, natural gas, or renewables. The project involves tailoring an existing life cycle assessment model to represent the fuel supply chain in Colorado. Results from the project will support efforts of a multi-institutional team investigating prospects for EV use in our state.

Bioaerosol Characterization: Biopolymers, Toxicity, and Phylogeny (Prof. Mark Hernandez)

The organic fraction of airborne particulate matter is heterogenous in chemistry and origin. We estimate that up to 25% of this fraction originates from biological sources. In order to assess the biological contribution, we measure biopolymers (carbohydrates, phospholipids, proteins, and DNA), and construct 16S clone libraries to understand the source of biological matter. As biological particles have a pronounced health effect, we also assess the genotoxicity of particulate matter to bacterial and eukaryal cells.

Microbially-Induced Concrete Corrosion: Characterization & solutions (Prof. M. Hernandez)

The microbially-induced corrosion of concrete in wastewater infrastructure costs wastewater utilities millions of dollars in replacement and rehabilitation costs and negatively impacts public relations. We aim to better understand the microbial players in this community and to design a biological-based approach to inhibiting their growth. We will are using genetic community analysis, available substrate, and pH to assess how the corrosion community differs across environmental gradients. A metal-based antimicrobial coating will be designed and tested in lab and in field manholes

Bioremediation of Acid Mine Drainage (Prof. Mark Hernandez)

Runoff from mining operations is a world wide environmental problem. We are investigating the potential of sugarcane bagasse to act as a host media to facilitate the passive treatment of acid mine drainage (AMD) where AMD refers to the microbially-mediated oxidation of pyrite which produces an acidic, oxidized, metals laden solution. Sugarcane bagasse is an agricultural residue, i.e., the fibrous, shredded cane material that is the byproduct of the sugar extraction process (Paturau 1982). Grubb et al (1999) described several of the physical, compositional and engineering parameters of sugarcane bagasse that are relevant to its potential incorporation into passive water treatment systems. Grubb et al (2000) presented microcosm experiments involving sugarcane bagasse seeded with sulfate reducing bacteria which illustrated that the oxidized, acidic and elevated heavy metals concentrations associated with AMD leachates could be reversed and sustained between timeframes between 90 and 270 days. The focus of the work presented here was to both confirm and further optimize the work of Grubb et al (2000), i.e, to demonstrate reversal of AMC conditions in timeframes less than 90 days, and to moreover identify the bacteria consortia associated with the changes in water quality using gene probing techniques.

Ceramic Water Purifier for Household Potable Water Treatment [Bielefeldt; Summers]

The colloidal silver lined CWP is a filter that can be produced inexpensively in communities around the world using locally available clay and a fine organic material (such as sawdust or rice hulls). Small pores filter out larger pathogens while the silver is intended to inactivate pathogens that pass through the filter. Although the filter is already being used in at least 14 different countries worldwide, the effectiveness and limitations have not been fully characterized. To date, 12 undergraduates and 4 graduate students at CU have studied the CWP to evaluate its performance under a range of water quality conditions. Further work is needed to quantify the effectiveness of colloidal silver for inactivation of viruses and bacteria. It is important to know the time needed to achieve a given level of disinfection under conditions typically encountered by users such as varying water pH, turbidity, etc. The ability of the filter to retain its treatment properties over years of field use as the silver leaches out over time will also be evaluated.

In-situ chemical oxidation of DNAPLS: studies of diffusion and reaction between permanganate and TCE (Prof. Rajaram)

A recently popular approach for remediation of fractured rock sites contaminated by TCE is to inject oxidants such as permanganate, which diffuse into the rock matrix and react with TCE that had dissolved into water in the rock matrix over several decades (and hence requires long clean-up times with conventional pump and treat approaches). We have developed a theoretical formulation for the diffusion-reaction problem, which predicts the rate of propagation of a reaction front from the fractures into the matrix. In this project, the REU student will carry out diffusion-reaction experiments in rock or fine-grained coil cores to validate the theoretical results and also develop new insights into behavior during cyclic oxidation treatments.

Water Balance Methods for Estimation of Riparian Evapotranspiration (RET): A field study in the Whitewater basin, Central Kansas (Prof. Rajaram)

In narrow riparian zones, conventional methods for measuring evapotranspiration such as flux towers are inapplicable due to inadequate fetch. Water balance techniques are the only cost-effective methods - in this approach, RET is estimated as a closure term in the water balance, with detailed monitoring of water storage in groundwater, vadose zone and the stream. At our field site in the Whitewater basin, the unique feature is a very thick vadose zone (~10-12'), which leads to significant challenges in estimating vadose zone storage. We have established a high-resolution instrumentation network involving groundwater wells, stream gages and soil moisture profilers. All sensors are connected to dataloggers and data is transmitted via cable modem. The REU student will participate in the 2012 summer field campaign, which is anticipated to involve a combination of manual soil moisture profiling with capacitance sensors, and measuring sap flow rates in tree trunks. Some of the student's effort will also go towards laboratory characterization of soils from the site, and analysis of soil moisture data.

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. This study seeks to determine exposure and health effects due to combustion and biological components of indoor particulate matter in three communities: Denver (US), Langui, (Andean Peru) and Santiago (Chile). Contact: Lupita.Montoya@colorado.edu