Abstracts for Brace Research Day March 29 2012

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Nick Carriere, Role of Growth Temperature on the Transport Potential and Viability of the Pathogenic Campylobacter jejuni under Model Groundwater Conditions, Chemical Engineering

Daniel Gillis, Simulated versus measured transport of diazepam and iopromide by artificial rainfall in a re-packed soil column, Bioresource Engineering

Sanaz Alizadeh, New Approach for reducing Hormone pollution in soil, Bioresource Engineering

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Examining the Fate of Metal Oxide Nanoparticles in Water Saturated Soil Environments

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The increased production, consumption and disposal of metal oxide nanoparticles (NPs) will result in their heightened discharge to soils and aquatic environments. To better understand the transport potential and fate of various metal oxide NPs, deposition studies were performed with bare and polymer (polyacrylic acid)-coated cerium dioxide (*n*CeO_2), titanium dioxide (*n*TiO_2) and zinc oxide (*n*ZnO) NPs in natural water saturated granular systems. Laboratory-scale column experiments were conducted with packed beds consisting of pure quartz sand or loamy sand, and particles suspended in artificial or natural groundwaters. Prior to the transport studies, the NPs were characterized using dynamic light scattering and nanoparticle tracking analysis to establish aggregate size, and laser Doppler velocimetry to establish particle surface potential. Uncoated (bare) metal oxide NPs exhibited high retention and dynamic (time-dependent) deposition patterns within the saturated porous media. In contrast, polymer-coated NPs suspended in monovalent salt were highly stable and demonstrated substantial transport potential. Still, these same polymer-coated NPs exhibited limited mobility in the presence of divalent salts at high IS and in natural groundwater. Finally, for a given IS, enhanced particle retention was observed in loamy sand-packed columns when compared to pure quartz sand-packed columns. These observations emphasize the need to consider NP surface modification, aquatic matrix composition and soil type when evaluating metal oxide contamination potential.

Keywords: cerium dioxide, titanium dioxide, zinc oxide, nanoparticle, transport

Stable isotopes of nitrogen and oxygen to pinpoint the source of soluble and particulate nitrogen losses from agricultural fields

Sogol Rasouli

The Missisquoi Bay of Lake Champlain, located in southern Quebec, has become progressively eutrophic since 1999, as evidenced by frequent cyanobacteria blooms during summer months. Eutrophication in Missisquoi Bay is attributed partially to elevated concentrations of nitrogen (N) from agricultural activities in Pike River watershed, which drains into Missisquoi Bay. Isotopic analysis of total N forms, nitrate (NO_3) and particulate organic nitrogen (PON), provides valuable information on N sources contributing to eutrophication of the Bay. The objective of this study was to detect the source of N lost by subsurface tile drainage using the stable isotopes of $\delta^{15}N$ and $\delta^{18}O$ for NO_3 and $\delta^{15}N$ for PON. Water samples were taken from subsurface tile drainage of two agricultural fields with contrasting soil texture at discrete events during fall 2010, spring and fall 2011. Subsamples were selected and analyzed for natural isotopes of $\delta^{15}N$ and $\delta^{18}O$ of NO_3. Sediment as well as soil samples were analyzed for $\delta^{15}N$ of PON. Results showed that $\delta^{15}N$ and $\delta^{18}O$ values of NO_3 were closer to the values of soil NO_3 than the values of mineral N fertilizer and manure. The $\delta^{15}N$ values of PON were close to the $\delta^{15}N$ values of stable soil N from the top soil layer. In conclusion, the source of NO_3 in tile drainage was microbially-derived NO_3 produced from the nitrification of mineral fertilizers and manure, and the source of PON was soil organic N, a byproduct of microbial decomposition.

Super-critical exchanges in shallow flows

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High speed super-critical shear flows in open channels are observed in steep mountain streams, in flow down the fish ladders and in the advancing front of flood and tsunami over dry land. The mixing of mass and momentum across these flows at high Froude number are governed by processes not solely describable by the conventional theory of turbulence. Waves have dominant influence on the exchange process across the turbulent shear layer. There are no experimental and numerical data available to explain the role of wave on turbulence exchange despite the significance of the wave-and-turbulence interaction in engineering application. Numerical simulations and laboratory experiments of supercritical shear flow have been carried out. Some of the results obtained in the study of the exchanges between the river flow and side basins will be presented. The focus will be on the role of wave radiation in the development of shear flow at high Froude number. The gas-dynamic analogy with shear flow in compressible gas is explored. Past model simulations of turbulent flow in shallow waters have been developed based on the rigid-lid assumption, neglecting the interaction of the gravity waves. Most existing numerical methods use the Riemann solver that capture shock wave well but has difficulty with turbulence simulation. A much more efficient solver has been developed at McGill. The application of this efficient solver to include friction and turbulent sub-grid scale modelling in the study of wave radiation from turbulence flow is verified by comparing the simulation results with experimental data obtained recently in the hydraulic laboratory.

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Uncertainty in Soil Test Phosphorus (STP) Simulation Using Gaussian Sequential Simulation

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Abstract

This paper applies geostatistics procedures to model soil test phosphorus (STP) in 11km^2 Castor Watershed in Southern Quebec, Canada. Phosphorus in the soil is impacted by processes such as landuse pattern, management practices, soil properties, geomorphology etc. This is a challenge when developing or determining the covariance functions for the experimental variogram in geostatistical modeling. Ordinary kriging (OK) method was used to estimate the STP at un-sampled points, but this has a smoothing effect. This smoothing underestimate high values and overestimate low values. Therefore, there is need for an efficient technique such as the sequential Gaussian simulation (SGS) which was utilized to draw from the conditional probability distribution at the simulation grid nodes. SGS produced several equal-probable realizations. SGS reproduced the original data better compared to OK where several of the high values were masked during estimation. This result is very relevant especially in the reduction of phosphorus (P) load into Missisquoi Bay, southern Quebec, Canada where there is reported cases of eutrophication due to excess P from non-point sources. In addition, the results could be very relevant in nutrient use efficiency, classification of management zones in form of polygons, adaptive agricultural management practices and optimization of Phosphorus-Index for land-use and ecosystem management.

Keywords: Ordinary Kriging, Sequential Gaussian Simulation, Soil Test Phosphorus, P-Index, Uncertainty

Statistical Modelling of Extreme Rainfall Process in the Context of Climate Change for South Korea

Min Young Lee

Abstract

The presentation is about statistical modeling of extreme rainfall process in the context of climate change for South Korea. Traditional method of statistical modeling, referred as 'At-site frequency analysis', has some limitations, but its result which is presented as an Intensity-Frequency-Duration (IDF) curve is commonly used in hydrology. In this study, the scaling property is applied to the statistical modeling in order to derive IDF more effectively. Furthermore, GCMs estimates are incorporated with the scaling-applied statistical modeling to reliably project future extreme rainfall process. The IDF curves for current period drawn by the scaling-applied statistical modeling using GCMs estimates are reliably comparable to the observed extreme rainfall data. The IDF curves for future, however, provide different results according to the CO_2 emission scenarios.

Positive Correlation between Cellular Levels of Storage Compounds and RNA in Activated Sludge Bacteria

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Abstract

Activated sludge microbial communities have shown wide diversity, while the link between heterotrophic populations and specific functional niches is still tenuous. A flow cytometry method was developed to determine the cellular levels of functional biomarkers using fluorescent dyes: RNASelect for RNA, Nile Red for polyhydroxyalkanoates (PHA) and 7-AAD for DNA. 4% PFA followed by 75% methanol was selected as the best fixation procedure. The method was validated against five strains representing a wide range of bacterial diversity: *Escherichia-coli* K-12*, Rhodococcus jostii* RHA1*, Bacillus subtilis, Cupriavidus necator* DSM428 and DSM 541 (a non-PHB producing mutant of DSM428). For all tested cultures, the RNA/DNA ratios determined by flow cytometry and by nucleic acid extraction were generally correlated. The method was used to study samples from three independent activated sludge reactors: a full-scale reactor, a pilot-scale reactor using ozone for sludge reduction, and a pilot-scale control reactor. In all cases, it was found that high RNA/DNA fluorescence signals ratios correlated with high fluorescence signals for PHA. Furthermore, it was found that the PHA signal was higher in the ozone-treated reactor samples than the control. The increased PHA probably resulted from the production of extra readily degradable substrates by the ozone treatment of sludge. We suggest that this correlation between RNA/DNA ratios and PHA abundance represents a functional characterization of heterotrophs. Populations consuming readily degradable substrates would have a high RNA/DNA ratio and accumulate storage compounds, while it would be the opposite for populations consuming slowly degradable substrates.

Examining environment and poverty trade-offs in payments for environmental services (PES) from a watershed-scale perspective

Vijay Kolinjivadi

Payments for watershed services have been identified as a conceptually attractive policy tool for both conservation and livelihood objectives through their use of negotiated incentives to engage in more sustainably-oriented land management activities and improve consensus for watershed management between upstream and downstream communities. This research plan focuses on upstream communities residing in Shivapuri-Nagarjun National Park in the foothills of the Himalayas in Nepal where downstream beneficiaries of high quality fresh water in Kathmandu Valley are encouraged to maintain and enhance their stock of watershed goods and service flows by compensating impoverished communities upstream who are suffering from significant opportunity costs of restricted resource extraction and land use. The primary focus of this research is to understand the trade-offs that exist in designing a compensation scheme which not only targets the most environmentally vulnerable locations, but also the poorest individuals and communities in the catchment area. A number of communities of differing biophysical and socio-economic or cultural makeup will be investigated using the same procedure in an effort to examine a how socially constructed design of pro-poor PES varies across the basin.

Effect of High Temperature due to Joule Heating on Biosolids Electro-dewatering Kinetics and Microbial Inactivation

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Cost increases for biosolids disposal from secondary wastewater treatment demand more efficient dewatering technologies. Electro-dewatering uses an electric field to increase the sludge dryness from 10-15% to 30-50%. Furthermore, according to the US-EPA, biosolids can be applied to agricultural lands if they meet Class A microbiological requirements. In this study, a laboratory scale electro-dewatering unit was used for tests on sludges from five different treatment plants. Sludge temperature increased from room temperature to about 100°C, where Joule heating appears to be the key parameter controlling dewatering kinetics and microbial inactivation. To minimize the effects of this parameter, electrodes were cooled such that the maximum temperature did not exceed 50°C. Although there was no significant difference in the removed filtrate volume using both electrodes, final cake dryness was 40.9% using standard electrodes compared to 26.0% using cooled electrodes. This indicates that there was a higher evaporation rate at the higher temperature. In addition, total coliforms and MS coliphage were reduced to their detection limits with standard electrodes, but when cooled electrodes were used, no significant inactivation of bacterial pathogen indicators was observed. In contrast, aerobic endospores were not inactivated under any conditions. Thus Joule heating during electro-dewatering was responsible for achieving the high dewatering levels, resulting in the production of Class A biosolids.

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Effect of radiation coefficients on reference evapotranspiration estimation in eastern Canada

Olanike ALADENOLA and Chandra MADRAMOOTOO

Abstract

Solar radiation is a key meteorological component for estimating reference evapotranspiration and crop water requirement. This data is often not available in many parts of the world including Canada. Solar radiation (Rs) and reference evapotranspiration (ETo) have been estimated using readily available meteorological parameters. The accuracy and suitability of the recommended coefficients used in radiation-based methods were assessed and compared with locally calibrated values for Ontario and Quebec provinces. The effects of the methods and coefficients on reference evapotranspiration were evaluated using error analysis. An analysis of the available meteorological data on Environment Canada website shows that sunshine hour (n) which is important for estimating solar radiation is missing in many stations. The performance of an alternative radiation estimation method in the absence of sunshine hours (n) will be discussed.

Keywords: Error analysis, reference evapotranspiration, solar radiation

Multi-site statistical downscaling of daily temperature extremes for climate-related impact assessment

Ju Eun Kim

Civil Engineering and Applied Mechanics

For last few decades, global surface temperature has significantly increased and it related to the drastic climate change. The Intergovernmental Panel on Climate Change (IPCC) provided the impacts of climate change on not only the environment and the health of citizens, but also civil engineering practices such as water resources management, energy production and use, agriculture, forestry, coastal development, flood control and public infrastructures. Thus, the accurate estimation of future temperature change is required for reducing the risk of those impacts.

Global Climate models (GCMs) are commonly used to predict future climate change. However, the coarse temporal and spatial resolution of GCMs is inappropriate to many hydrological impact studies. The downscaling techniques allow obtaining the local climate information from linkage of GCMs outputs and historical observations at a local scale.

In current, Statistical DownScaling Model (SDSM) is the most popular statistical downscaling technique and the model is recommended by IPCC. However, SDSM is the single-site downscaling technique and the model assumes that the result at point station represent the surrounding areas. Therefore, the generated resulting series from uni-site generators (SDSM) for the different locations cannot account the spatial dependence between different sites.

Due to the limitation of the single-site downscaling technique, the development of multisite-downscaling technique is needed. In this study, the combination of Singular Value decomposition (SVD) technique and multivariate-multiple regression model is suggested as the multisite-downscaling technique and the proposed approach can effectively reproduce temporal and spatial dependence, and the statistical characteristics of Tmax and Tmin.

By
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Bioresourse Engineering Department

Advisor
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Title:

Assessment of Irrigation and Soil Water Content Capacity on A Vegetable Farm Using an Electromagnetic Inductance Technique

Abstract

Soil water content capacity (SWCC) is critical information for managing crop growth. Crop stress, mainly due to limited available of water in the soil, can cause low yields and crop damage. One way of measuring the SWCC employs a manual gravimetric technique. However, this technique is time consuming, destructive, and not applicable to automatic control of moisture levels in a vegetable farm. Measurement of apparent soil electrical conductivity (EC_a) using vertical sounding of electromagnetic inductance (EMI) technique provides a rapid check of SWCC variability across the field. Measurements of soil EC_a in vertical mode are highly correlated to the SWCC. Ground truthing data for the SWCC will be provided by a stationary matrix potential moisture sensor and conventional gravimetric technique. This wireless sensor measures the soil water potential in real time and the moisture variation over time and soil depth. All these proximal soil sensing technologies are important tools for water management in precision agriculture. Measurement of SWCC using EMI is significant in delineating the irrigation requirements into different management zones. The combination of EMI measurements and matrix potential moisture sensors offer the capacity for quick decisions regarding irrigation management. Therefore, determining the appropriate amount of water at any given time during irrigation operations and the depth of application needed for next scheduled irrigation would be their main applications.

Keywords: soil water content capacity, apparent soil electrical conductivity, vertical sounding, matrix potential sensor

Inter-Basin Water Transfer and its Role In Water Supply for Modern Society

Simon Dagher

Inter-basin water transfer (IBTW) is the practice of moving or exporting bulk water volumes between adjacent or distant water-basins. It is currently being applied to hydro-projects, irrigation and for local municipal water supply. There is concern that IBTW projects may go up a level of magnitude in terms of scale and importance, to the point where entire States or regions may depend on it. The issue from a philosophical perspective addresses the commoditization of water in the context of IBWT. A historical, legal, macro-economical, institutional and political perspective discussion address the difficulties that the Canadian governments face to effectively protect its fresh water resources from exportation. Following this is a feasibility study from an engineering perspective. Canadian water resources are scrutinized to identify potential water extraction locations. Three proposals are described: exporting water using pressurized pipelines into the water-stressed Ogallala aquifer of the Southern-States; reversing river flows to supplement the Great Lakes Basin; and using trans-oceanic water tankers for exploration. Each proposal is rated depending on their potential environmental impacts, namely hydrologic disruptions, green house emissions and social impacts, and by their potential costs and benefits. It was found that the pipeline proposal was the most beneficial of the three options, yet all three would not be economically or environmentally feasible.

Role of Growth Temperature on the Transport Potential and Viability of the Pathogen *Campylobacter jejuni* under Model Groundwater Conditions

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According to the World Health Organization, waterborne disease remains the leading cause of death worldwide, with millions of deaths attributed annually to a lack of access to clean sources of potable water.[1] *Campylobacter jejuni* is one of the most commonly reported yet least understood of these pathogens. Previous research has shown that both heat and cold shocks of this microorganism can lead to a significant change in virulence and protein expression.[2] In fact, even more outbreaks of waterborne illness have occurred at sites which were considered safe until they were later contaminated with microbial pathogens after specific climatic events, such as rainfall during heavy storms and snowmelt.[3] To better understand the influence of temperature on the transport, migration, and viability of this pathogen in soil and subsurface environments, they must be studied under environmentally relevant conditions. Laboratory-scale column experiments were conducted at 10^{o}C with packed beds consisting of quartz sand and varying model groundwater chemistries following bacterial growth at both 37^{o}C (human body) and 42^{o}C (native avian body) as well as after being subjected to multiple freeze-thaw cycles. In accordance with colloidal theory, increases in the salt concentration of the model groundwater resulted in an increase in bacterial retention and surface (zeta) potential, with bacterial attachment efficiencies varying from ~0.005 to ~1 when the solution ionic strength was increased from 1 to100 mM KCl. Growth temperature did not appear to have any effect on the viability, zeta potential, or transport behaviour of the pathogen in the quartz sand.

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Simulated versus measured transport of diazepam and iopromide by artificial rainfall in a re-packed soil column

Daniel Gillis, Shiv Prasher

Abstract:

Pharmaceuticals are an emerging class of environmental contaminants that are receiving increased attention, although their environmental fate is for the most part unknown, especially in the vadose zone. HYDRUS-1D, a model of water and solute transport in the vadose zone, was used to describe the leaching of diazepam and iopromide, two pharmaceuticals. Data from a soil column study was extracted from the literature that reported concentration of these two compounds at increments of 5 cm depth, along with artificial rainfall rate and total leachate collected. Values for the organic carbon-water distribution coefficient were obtained from external sources. The inverse solution was used to obtain optimized parameter estimates for α, DL, and DW. Predicted diazepam concentration was most sensitive to DL, a non-measurable parameter, while the least sensitive parameter was DW. There was good agreement between observed and predicted diazepam concentration and a low mass balance error. The pattern of iopromide distribution was not described well by HYDRUS-1D, and there was a large error in the final mass of solute (157% recovery). It was assumed that the poor fit was from the difference between the pKa of iopromide (9.9) and the pH of the soil (5.8), since iopromide contains many ionisable groups. This may have led to reduced sorption and higher water solubility. Decreasing the KD led to a pattern of iopromide transport that more closely resembled the observed values, but increased the solute mass balance error. The reason for the mass error for iopromide is not known.

New Approach for Reducing Hormones Pollution in Soil

Sanaz Alizadeh, Shiv-O Prasher

In the last decade, several cases of reproductive abnormalities and sexual dysfunction (e.g. feminization of male fish) have incited the concerns regarding the poorly documented but significant category of toxic contaminants known as Endocrine Disrupting Compounds. EDC's toxicity at extremely low concentrations (ppt) has the potential to disrupt endocrine system function in a number of aquatic organisms and humans. Spreading of cattle and poultry manure on agricultural lands could lead to the disturbing appearance and presence of the sex hormones, natural steroids and estrogens in environment. One of the most used organic fertilizers in the North America, poultry manure contains a considerable concentrations of 17-β estradiol, estrone, testosterone and progesterone, all compounds with remarkable physiological effects. Lipophilic and thus poorly soluble in water, these hormones exhibit a high affinity of sorption to soil .However the presence of these compounds in surface- ground-water resources has recently been approved. The primary objective of this study is to evaluate the fate and transport of three steroid hormones (17-β estradiol, estrone , and progesterone) in soil, in the context of field study, where poultry manure application serves as fertilizer. The major objective of our study is to examine the remediation potency of three different types of biochar on the sorption and desorption pattern of these hormones. The sorption and desorption process of these hormones will be examined by batch equilibrium studies. We expect an indication of non-linearity in the sorption isotherm data, fitting Freundlich and Langmuir models. Based on recent documented effective attributes of biochar as soils amendment on the adsorption-desorption and transport of pesticides and antibiotics, the results of our study could lead to novel remediation technique for agricultural-hormone pollutions.

Key words: 17-β estradiol, estrone, testosterone, progesterone, biochar, sorption