H04: Recent advances in peatland hydrology, Part 2: Flow and transport of water, solute, and energy in organic soils

Conveners: Colin McCarter[1], Tobias Weber[2], and Jonathan Price[3]

Co-chairs: Colin McCarter[1], Tobias Weber[2], and Jonathan Price[3]

[1] Dept., of Earth and Environmental Sciences, University of Waterloo, Waterloo, ON, N2L 3G1
Phone: 519-569-9190, E-mail: cmccarte@uwaterloo.ca
[2] Soil Science and Soil Physics Division, Institute of Geoecology, Technische Universität Braunschweig, Langer Kamp 19c, 38106 Braunschweig, Germany,
Phone: +49 (0) 531 391-5633, E-mail: to.weber@tu-bs.de
[3] Dept., of Geography and Environmental Management, University of Waterloo, Waterloo, ON, N2L 3G1, Phone: 519-888-4567 ext. 35711, E-mail: jsprice@uwaterloo.ca

Session Description

With increasing northern developmental pressure, the need to understand the processes governing the flow of water, solutes, and energy in organic soils, which are prevalent in northern Canada, is increasing. Unlocking the underlying processes is a major scientific challenge to improve our understanding and our ability to predict water fluxes, nutrient and contaminant transport, peatland development, and ecosystem services under a changing climate and developmental pressures. The physical structure of organic soils controls the movement of water, solutes and energy and results in non-linear unsaturated hydrology, an abundance of macropores and inactive porosity, and are subject to shrinkage and swelling. Thus, describing water, solute, and energy transport in organic soils is complicated due to these complex physical soil properties, in addition to the relatively unknown transport processes (i.e., dispersion, diffusion, sorption, and local non-equilibrium), high moisture and organic content, and abrupt temporal/spatial changes in geochemical conditions (e.g., anoxia). Recently, there has been a push to understand how advection, dispersion, diffusion, sorption, and biogeochemical processes govern the flow and transport of water, solutes, and energy in organic soils from the pore to regional scale. Thus, the goal of this session aims at providing a platform for hydrologists, hydrochemists, wetland scientists, and soil physicists to discuss the recent advances in our understanding of the processes governing the transport of water, nutrients, contaminants, and energy in organic soils. Our scale of interest ranges from the laboratory to the regional scale. In particular, contributions will be welcome that cover hydrological fluxes, soil physics, sorption and desorption processes, contaminant and nutrient fluxes, thermal transport and hydrological models that illuminate these processes in organic soils and organic horticultural substrates. Additionally, we welcome the presentation of new, developing, or novel methodologies and experiments that highlight these complex processes.

Primary Affiliation: Hydrology & Biogeosciences

NOTE: THIS DOCUMENT CONTAINS INFORMATION FOR ALL SESSION SUB-SECTIONS. PRESENTER ABSTRACTS ARE FOUND AT THE END OF THE DOCUMENT.

SCHEDULE MAY BE SUBJECT TO CHANGE.

ORAL SESSION H04a

Chairs: C. McCarter, T. Weber & J. Price **Room: ESB 1012**

Wednesday, May 31st

TIME	AUTHORS	TITLE
16:00	T. Weber*, S. Iden & W. Durner	Peatland bog pedogenesis is reflected in effective unsaturated hydraulic properties
16:15	M.F. Nehemy* & C.P. Laroque	Tree-rings: a proxy for peatland water-table variability
16:30	B. Gharedaghloo* & J. Price	Investigating the influence of pore surface heterogeneity on adsorption and retardation of dissolved-hydrocarbon solutes in peat soils
16:45	R.B. Simhayov, T. Weber & J.S. Price	Reactive and non-reactive solute transport in peat from a constructed fen
17:00	N. Balliston & J. Price	Saturated and vadose zone solute dynamics of a sodium chloride tracer in sub-arctic bog peat
17:15	C. McCarter, B. Branfireun & J. Price	Effect of decomposition due to the treatment of domestic wastewater on the hydrochemical transport properties of peat

POSTER SESSION H04

Chairs: C. McCarter, T. Weber & J. Price **Room: ESB Atrium**

Tuesday, May 30th

Poster No.	AUTHORS	TITLE
P01-H04	C. Ackley*, S. Tank, F. Rezanezhad, W. Quinton & C. McCarter	Hydro-ecological impacts of wildfire on a permafrost plateau, Scotty Creek, NWT
P02- H04	B. Gharedaghloo*, F. Rezanezhad, & J. Price	Using pore scale simulations to characterize transport properties of peat in variably saturated condition: a micro- to meso-scale approach
P03- H04	O. Sutton* & J. Price	Numerical modelling of sodium transport and fate at a constructed fen watershed, Athabasca Oil Sands Region, Alberta
P04- H04	E.D. Kessel & J.S. Price	The field scale transport of Na+ and Cl- through a peat deposit of a constructed fen peatland in a post-mined landscape of the Athabasca Oil Sands Region

SUBMITTED ABSTRACTS

H04-01: Peatland bog pedogenesis is reflected in effective unsaturated hydraulic properties

Tobias KD Weber[1], Sascha Iden[1], Wolfgang Durner[1]

[1] Institute of Geoecology, Soil Science and Soil Physics, Technische Universität Braunschweig, Langer Kamp 19c, 38106,
Phone: +49 531 391-5633, Email: to.weber@tu-bs.de

Abstract
As the time variable moisture content in Sphagnum peatlands is the primary control on organic matter turnover, its precise quantification is required to for estimating gas exchange. A partitioning can be based on the water retention curve, and together with the hydraulic conductivity are the required input parameters for the Richards equation (RE), a frequently used process model to simulate variably-saturated water flow in the acrotelm of Sphagnum peatlands. In mineral soil profiles, individual soil horizons are in most cases easily delimited and horizon-specific soil physical and chemical properties can be specified. This is often different for undisturbed Sphagnum bog peatlands, because Sphagnum mosses grow continually upward in the acrotelm and leave behind dead plant remnants, which are increasingly decomposed with increasing depth. Thus, in these profiles, a continuous change of soil properties is characteristic. To be able to quantify the gradual change of soil hydraulic properties (SHP) with depth in Sphagnum bog profiles, we conducted laboratory evaporation experiments with a series of 5 cm tall samples throughout the entire profile of the acrotelm. The successful parameterisation of the SHPs was based on pore size density distributions for Sphagnum including trimodal pore spaces. We present size classes defining a unifying nomenclature to be used when describing the pore size classes in Sphagnum moss and peat. These refer to the inter plant pore space which is constituted of the voids between individual mosses, the intra plant pore space representing the voids between branches and leaves, and the inner plant pore space which is mainly contained in the water bearing hyaline cells. We extended the traditional van Genuchten-Mualem model to account for non-capillary water storage and flow, and only then consistent descriptions of the observations were possible. With increasing depth and advanced state of decomposition, this reduced to a bimodal pore structure.

Presentation type: Presentation

H04-02: Tree-rings: a proxy for peatland water-table variability.

Nehemy, Magali F.[1*], Colin P. Laroque[2]

[1] School of Environment and Sustainability, University of Saskatchewan, Saskatoon, SK, S7N 5C8
Phone: 639-317-6821, E-mail: magali.nehemy@usask.ca
[2] Dept. of Soil Science, University of Saskatchewan, Saskatoon, SK, S7N 5A8

Abstract

Northern peatlands are undergoing rapid warming and are expected to experience more severe changes than most other ecosystems. Climate change is expected to alter precipitation patterns and increase temperature, which will alter hydrological process in these peatlands. Water-table level controls important ecological processes in peatlands such as plant community composition and carbon cycles. Understanding their hydrological processes and how this affects a peatland's ability to provide ecological services is limited due to a lack of hydrological records that capture sufficient long-term water-table variability. Tree-ring chronologies were developed to assess whether trees growing on peatlands are useful as an annually resolved proxy to water-table level. Correlation analyses were conducted to explore the relationship between water table and trees from different species and locations in a fen in northern Saskatchewan. Moving correlation analyses were developed to understand whether this relationship has been stable or changing through time, and to provide understanding on how this relationship may be affected by future climatic alterations. A climate -tree growth relationship was also developed within the fen. While temperature and precipitation illustrated little influence on tree growth, water table level was revealed as the main factor controlling radial-tree growth. *Larix laricina* growing at the edge and in the center of the fen presented a negative correlation to water-table level, while *Picea mariana* growing at the outer edge of the fen presented a positive correlation to water-table level. These correlations allowed for a water-table level to be reconstructed by using a model developed with the use of the *Larix laricina* chronologies. Considering these findings and the scarcity of long-term hydrological data, the use of tree rings as a proxy for past hydrological fen condition can be applied to achieve quantitative assessments of past variability. This information will help guide management and restoration process of peatlands.

Presentation type: Oral Presentation

H04-03: Investigating the influence of pore surface heterogeneity on adsorption and retardation of dissolved-hydrocarbon solutes in peat soils

Behrad Gharedaghloo[1*], Jonathan Price[1]

[1]Department of Geography and Environmental Management, University of Waterloo, Waterloo, ON, N2L 3G1
Phone: 519-888-4567 ext. 35397, E-mail: bghareda@uwaterloo.ca

Abstract
Organic carbon present in the structure of soils is well known as an adsorbent of organic pollutants such as BTEX compounds. However, the majority of these studies have been done in mineral media, in which the mass content of organic carbon is only a few percent. The adsorption of hydrocarbon solutes onto organic soils like peat, which contains a high mass fraction of organic carbon, has received little attention. The organic carbon within soils is not chemically homogenous; the term actually refers to a group of organic molecules including lignins, waxes, lipids, cellulose, etc., which have different affinities for adsorbing hydrocarbons. The relative fraction of these compounds in peat pore surfaces can vary considerably with degree of peat decomposition, which typically increases down the peat profile. This leads to systematic variation of organic carbon partitioning coefficients in and between peatlands for a given organic solute. Better knowledge is needed on the adsorption of hydrocarbon solutes onto peat, and on the influence of peat pore surface heterogeneity on the removal of organic solutes from aqueous phase. Thus, a series of adsorption batch experiments were conducted on benzene and toluene solutions using different peats with varying degrees of decomposition. In addition, since hydrocarbon contamination commonly releases a wide range of organic solutes into the pore water, a series of competitive sorption experiments were done using solutions containing both benzene and toluene to address the effect of cosolvency on their adsorption coefficient. Experiment results showed that peat surface heterogeneity leads to the variation of the adsorption partitioning coefficient, thus increasing the variation of solute retardation as it passes from relatively undecomposed near-surface matter, to deeper horizons with more decomposed peat.

Presentation type: Oral Presentation

H04-04: Reactive and non-reactive solute transport in peat from a constructed fen

Reuven B. Simhayov[1] Tobias K. D. Weber[1,2] and Jonathan S. Price[1*]

[1]Department of Geography, University of Waterloo, Waterloo, Ontario, Canada N2L 3G1
Phone 519 888-4576, E-mail jsprice@uwaterloo.ca
[2]Soil Science and Soil Physics Division, Institute for Geoecology, TU Braunschweig, Langer Kamp 19c, 38106 Braunschweig, Germany

Abstract
To determine the underlying transport processes in peat from a fen constructed as part of the landscape reclamation in the Athabasca Oil Sands region, soil hydraulic properties were measured and saturated and unsaturated solute breakthrough experiments were performed using Na^+ and Cl^- as reactive and non-reactive solutes, respectively. Inverse modeling and robust statistical evaluation indicated that the soil hydraulic properties and saturated solute breakthrough show that the unimodal van Genuchten-Mualem model (unimodal) described the results well using the Convection Dispersion Equation alone. Parameterization using the more complex mobile-immobile physical non-equilibrium model (MIM) resulted in saturated hydraulic conductivity (454 cm/d) much higher than the measured value (100 cm/d); the unimodal approach produced a value of 106 cm/d. Furthermore, the MIM inverse fit required two additional parameters, one with high uncertainty. Post-hoc analysis indicated that there was instantaneous equilibration between mobile and immobile phases, which underscored the redundancy of the MIM approach for this particular peat, which is degraded sufficiently that cell-walls have disintegrated. Thus, while physical non-equilibrium of the MIM approach was unnecessary, chemical non-equilibrium for Na^+ breakthrough occurred, and could be modeled with the one site adsorption model. The parameters were used to predict the Cl^- and Na^+ rise in a lab based unsaturated steady state evaporation experiment using HYDRUS-1D. The simulation showed a good fit to observations, confirming the suitability of the parameters for use in a slightly unsaturated transport simulation.

Presentation type: Oral Presentation

H04-05: Saturated and vadose zone solute dynamics of a sodium chloride tracer in sub-arctic bog peat

Nicole Balliston[1*], and Jonathan Price[1]

[1] Geography and Environmental Management Dept., University of Waterloo, ON, N2L 3G1
Phone: 226-203-1778, E-mail: nballiston@gmail.com

Abstract
Resource extraction and transportation activities in the Canadian sub-arctic Boreal zone can result in unintentional release of contaminants in subarctic peatlands. In the event of a release, a thorough understanding of flow within the saturated and vadose zones of the unconfined aquifer is necessary to predict solute fate and transport. To better understand contaminant transport in these systems, approximately 14 000 L/day of sodium chloride (300 mg/L) was released into a bog in the James Bay Lowlands over a 45 day period into a fully penetrating well. EC measurements were collected in the saturated zone via a well and piezometer network, and in the vadose zone using Time Domain Reflectrometry (TDR) sensors installed at 5, 10 and 15 cm depths. Following the spill, four 30 cm long cores were extracted from the site. An unsaturated breakthrough experiment was conducted for 60 days in-lab using a 300 mg/L sodium chloride solution. Depth dependent parameters were analyzed for each core (porosity, bulk density, hydraulic conductivity, etc.) to verify processes observed in the field. Field scale characterization of the vadose zone showed a strong dependence of saturated zone movement and unsaturated solute accumulation on hydrological conditions. In particular, elevated water table conditions increased connectivity within and between unsaturated hummocks and the saturated zone, greatly accelerating the rate of solute movement. Heterogeneity in soil structure increased the complexity of this relation. In the saturated zone, flow occurred preferentially along higher conductivity hollows. In the vadose zone, denser soil experienced solute accumulation at a slower place but had a greater water and solute retention capacity, better facilitating capillary rise and long term accumulation. The results of this study highlight the complexity of saturated/ vadose zone interactions and the importance of extracting samples representative of site conditions due to a large amount of inter-core heterogeneity.

Presentation type: Oral Presentation

H04-06: Effect of decomposition due to the treatment of domestic wastewater on the hydrochemical transport properties of peat

Colin McCarter[1*], Brian Branfireun[2], and Jonathan Price[3]

[1] Department of Earth and Environmental Sciences, University of Waterloo, Waterloo, ON, N2L 3G1
Phone: 519-888-4567 ext. 31326 , E-mail: cmccarte@uwaterloo.ca
[2] Department of Biology and Centre for Environment and Sustainability, University of Western Ontario, London, Ontario, Canada N6A 3K7
[3] Department of Geography and Environmental Management, University of Waterloo, 200 University Avenue West, Waterloo, Ontario, Canada N2L 3G1

Abstract

Many northern countries have used peat and peatlands to treat domestic wastewater, which can contain nutrient concentrations above background levels. Peatlands are anoxic and the addition of additional nutrients, such as nitrate and sulphate, has shown to increase the decomposition of peat by accelerating microbial activity. It has been suggested that greater peat decomposition results in changes in physical properties that can result in higher dispersion and less diffusion into the inactive porosity; thus, increasing the concentration of redox sensitive nutrients (nitrate and sulphate) could alter the hydrochemical transport properties of the peat. The primary objective is to understand the effect of accelerated decomposition due to domestic wastewater on the hydrochemical transport properties of peat. To achieve this, 28 surficial peat cores were exposed (3 pore volumes changed monthly) to 7 treatments (n=4 per treatment) consisting of: control, low (nitrate = 9 mg/L, sulphate = 35 mg/L), high (nitrate = 90 mg/L, sulphate = 350 mg/L), low + glucose (added to evaluate the potential for carbon limitation), high + glucose, only glucose low, and only glucose high. Chloride breakthrough curves (BTC) were measured at 0, 1, 3, and 7 months and the curves were fit to a mobile-immobile convection dispersion equation. On average, retardation (sorption) decreased in all samples over the 7-month experiment, likely due to incomplete desorption during flushing after each BTC. Similarly, the average diffusion rate into the inactive porosity increased in all samples, except for the control treatment. Dispersion only increased in the low and low + glucose treatments (~7-times increase), while the other samples remained constant. The increase in dispersion suggests changes in pore structure due to decomposition (i.e., enhanced decomposition). The addition of domestic wastewater at low concentration (similar to wastewater polishing) may accelerate the decomposition of peat; thus, altering the long-term utility of peat and peatlands to treat domestic wastewater.

Presentation type: Oral Presentation

P01-H04: Hydro-ecological impacts of wildfire on a permafrost plateau, Scotty Creek, NWT

C. Ackley [1*], S.Tank[2], F. Rezanezhad[3], W. Quinton[1], C. McCarter[3]

[1] Cold Regions Research Centre, Wilfrid Laurier University, Waterloo, ON, N2L 3C5
Phone: 519-729-5764, E-mail: ackl2230@mylaurier.ca
[2] Biological Sciences, University of Alberta, Edmonton, AB
[3] Earth and Environmental Sciences, University of Waterloo, Waterloo, ON, N2L 3G1
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Abstract

The trend in wildfire throughout arctic and subarctic regions shows decreasing fire return interval and increasing fire size and severity. Occurrence of wildfire in the zone of discontinuous permafrost can impact the health and stability of boreal peatland ecosystems. As snowmelt provides a significant source of freshwater in northern regions, changing fire regimes coupled with climate warming urgently calls for an improved understanding of the impacts of wildfires on water resources. Disturbance of the vegetative groundcover and tree canopy influence critical hydrological processes in this region that can lead to ecological changes. Here we examine a tree-covered permafrost plateau at Scotty Creek in the Northwest Territories, Canada, where roughly half of the plateau was affected by a localized burn in July, 2014. This study provides key insights into both the hydrological and geochemical impacts of wildfires. Field measurements were made between April and August 2016 at study plots located in adjacent burned and non-burned areas. These measurements were complimented by laboratory reactor experiments to examine the impacts of fire on physical and hydraulic properties of soils in the plots. Preliminary results show increased SWE and melt rate in the burn leading to a greater volume of runoff and earlier time to snow-free. Greater depth of seasonal thaw under the burn indicates permafrost degradation and favorable conditions for talik development. This, coupled with assessment of changes in peat physical and hydraulic properties offer new insight into the mechanisms governing partitioning of water between runoff and storage, and water quality changes that result from wildfire.

Presentation type: Poster

P02-H04: Using pore scale simulations to characterize transport properties of peat in variably saturated condition: a micro- to meso-scale approach

Behrad Gharedaghloo[1*], Fereidoun Rezanezhad[2], and Jonathan Price[1]

[1]Department of Geography and Environmental Management, University of Waterloo, Waterloo, ON, N2L 3G1
Phone: 519-888-4567 ext. 35397, E-mail: bghareda@uwaterloo.ca
[2]Department of Earth and Environmental Sciences, University of Waterloo, Waterloo, ON, N2L 3G1

Abstract
In recent years, researchers have investigated a variety of approaches to characterize the hydraulic and transport properties of peat soils. However, up to now, the majority of these have focused on macro-scale and saturated conditions, rather than on micro-scale and partially saturated states. Thus, the influence of micro-scale properties of peat pore space on its hydraulic and transport properties, and the variation of its transport properties in partially saturated conditions have been poorly understood. Characterizing this relation can improve our knowledge of the processes controlling contaminant transport through saturated and unsaturated zones in peatlands. Pore network modeling (PNM) using pore networks extracted from X-ray micro-computed tomography images, was used to characterize the influence of peat micro-scale properties on its meso-scale hydraulic and transport characteristics in variably saturated condition. Simulation results showed that peat pore tortuosity increases with depth, which is a cause for reduction of peat hydraulic conductivity with depth. The results also revealed that the increase in the tortuosity leads to the reduction of effective diffusion coefficient with depth. Dispersivity of peat, obtained in saturated and unsaturated conditions, showed that unsaturated dispersivity can be either higher or lower than saturated dispersivity depending on the volumetric water content of peat soil.

Presentation type: Poster

P03-H04: Numerical modelling of sodium transport and fate at a constructed fen watershed, Athabasca Oil Sands Region, Alberta

Owen Sutton[1*] and Jonathan Price[1]

[1] Dept. of Geography and Environmental Management, University of Waterloo, Waterloo, ON, N2L 3G1 Phone: 519-888-4567, E-mail: ofsutton@uwaterloo.ca

Abstract
Reclaiming the post-mined landscape in the Athabasca Oil Sands Region (AOSR) to ecosystems of equivalent land capability has become both a matter of public interest and a statutory obligation for the major oil sands companies. In response to the legal obligation to investigate peatland reclamation, a pioneering constructed fen-upland watershed was designed and built on a post-mined oil sands landscape. This system was constructed using locally available materials that are anticipated to be used in large-scale landscape reclamation in the AOSR. These materials included in-situ oil sands process-affected materials (tailings sand and petroleum coke), which contain residual contamination of sodium (Na^+). Of particular concern is whether these contaminants will be flushed from the system, or will accumulate in the rooting zone, potentially influencing the health of vascular plants and mosses in the constructed fen. To address this concern, a numerical reactive solute transport model is under development in MODFLOW and coupled with the multispecies transport model MT3DMS to simulate the movement of Na^+ from the tailings sand aquifer to the fen peat. The model will be parameterized using field data collected between 2013-2016 and laboratory experiments. Dispersivity of the tailings sand will be characterized through inverse simulation of a LiBr tracer test conducted at the site in 2017. Sorption will only be considered in the peat, due to limited adsorptive capacity of other construction materials. Anticipated results include peak and average Na^+ concentration at the fen surface, solute concentrations received by downgradient receptors, average solute residence time in the fen, and total solute mass over time. This will allow inferences to about the potential trajectory and composition of the vegetation community in the fen to be made, and more broadly, the suitability of incorporating process-affected materials in landscape-scale peatland reclamation.

Presentation type: Poster

P04-H04: The field scale transport of Na^+ and Cl^- through a peat deposit of a constructed fen peatland in a post-mined landscape of the Athabasca Oil Sands Region

E.D. Kessel[1] & J.S.Price[1]

[1]Geography and Environmental Management, University of Waterloo, Waterloo, ON, N2L 3G1
Email. e2kessel@uwaterloo.ca

Abstract
Extraction of near-surface bitumen through surface strip mining in the Athabasca Oil Sands Region (AOSR) has disturbed large areas of boreal forest and fen peatlands. Processing of oil sands requires the addition of sodium hydroxide to optimize the solubility and separation of bitumen from the sand. This process results in sodium contaminated waste materials known as tailing sands. In an attempt to reclaim the post-mined landscapes of the AOSR, tailing sands are being used to construct landscape features such as uplands, which can supply groundwater to low-lying areas. The Nikanotee Fen Watershed is a pioneering constructed fen peatland that uses a tailing sands upland aquifer to supply adequate water quantity to maintain saturated conditions within a lower-lying fen. By design, it is expected that within the first several years' post-construction the residual sodium within the tailings sand will migrate upwards through the peat deposit. This study aims to better understand the vertical transport processes controlling the migration of sodium from the tailings sand to the rooting zone from 2013 - 2016. Given the potential for both high and low vertical fluxes, both the advection-dispersion equation and diffusional (Fick's 2nd Law) transport will be evaluated. Low average linear groundwater velocities (~10^{-8} m/s) and low Peclet numbers (<0.1) in the peat have indicated that the vertical transport of solutes within the fen is dominated by molecular diffusion. Diffusion coefficients will be estimated for both Cl^- and Na^+, which will allow for the calculation of solute breakthrough and arrival times of contaminants throughout the fen peat. The concentration and timing of contaminant arrival at the fen surface could influence and potentially harm the recently planted vegetation, resulting in loss of important moss species and instigate a transition to a more saline-tolerant fen peatland.

Type: Poster