CAWQ
ACQE

Canadian Association on Water Quality
Association canadienne sur la qualité de l'eau

47TH CENTRAL CANADIAN SYMPOSIUM ON WATER QUALITY RESEARCH

Book of Abstracts

Advances and Emerging Issues in Water Quality Management

Canada Centre for Inland Waters
Burlington, Ontario

FEBRUARY 21 & 22, 2012

Book of Abstracts

47th Central Canadian Symposium on Water Quality Research

February 21 & 22, 2012
Canada Centre for Inland Waters, Burlington, Ontario

Program 5

Plenary Presentation 14

Climate Change and its Implications for the Water Industry 15

Contaminants of Emerging Concern 21

Contaminants of Emerging Concern - Advances in Wastewater Treatment (Joint Session) 29

Great Lakes Nearshore Water Quality Issues 43

Harmful Algal Blooms and Source Water Impacts: Causes, Consequences and Controls 50

Nanotechnology in Water Treatment and Sampling Applications 69

Research and Advances in Drinking Water Treatment 77

Research and Advances in Stormwater Management 86

Research and Advances in Wastewater Treatment 90

Risk Management in Drinking Water Quality and Environmental Pollution Control 106

Surface and Groundwater Quality 112

Rural and Agricultural Water Stewardship 126

Poster Presentations 130

47th Central Canadian Symposium Committee 154

Program

47th Central Canadian Symposium on Water Quality Research

Tuesday, February 21, 2012

Main Mall				
7:45	Registration and Poster Installation			
Auditorium				
8:30	Opening Remarks: Clayton Tiedemann (President, CAWQ)			
8:35	Welcome to the Canada Centre for Inland Waters and Introduction of Plenary Speaker: Dr. John Lawrence (Director, Aquatic Ecosystem Management Research Division, Environment Canada)			
8:40	CAWQ Plenary Lecture: Emerging Contaminants: Why are we always playing catch up? Dr. Chris Metcalfe Environmental and Resource Studies, Trent University, Peterborough, ON			
	AUDITORIUM	SOUTH SEMINAR	NORTH SEMINAR	GUEST LOUNGE
	Contaminants of Emerging Concern - Wastewater Treatment (Joint session) Shirley Anne Smyth & Paula Guerra	Climate Change Mike Lywood	Surface and Groundwater Quality Veronique Hiriart-Baer & John Spoelstra	Risk Management in Drinking Water Quality and Pollution Control Roland Bradshaw
9:30	Comparison of "in silico" and Environmental Measurements for Identifying New, Emerging, and Re-emerging Chemicals of Concern D.C.G. MUIR, A. DESILVA, B-H. LEE, P HOWARD	Causes and Solutions of the Urban Heat Island M. HULLEY, G. ZUKOVS		
9:50	Wastewater Treatment Plant Inputs of Emerging Pollutants to the Atmosphere L. AHRENS, M. SHOEIB, L. JANTUNEN, T. HARNER, C. CHENG, E. REINER	Climate Change and Water Utilities: The Role of Economics in Encouraging a More Sustainable Use of Water D. DUPONT	Environmental Selection of Phenotypic Diversity in *E. coli* S.M. CHIANG, T.A. EDGE, and H.E. SCHELLHORN	Making the Source Water Events-based Approach Operational: A Screening Method T. ARNOLD
10:10	BREAK & POSTER / EXHIBITOR SESSION – Main Mall			

Tuesday, February 21, 2012

	AUDITORIUM	SOUTH SEMINAR	NORTH SEMINAR	GUEST LOUNGE
	Contaminants of Emerging Concern - Wastewater Treatment (Joint session) Shirley Anne Smyth & Scott Dunlop	**Climate Change** Mike Lywood	**Surface and Groundwater Quality** Veronique Hiriart-Baer & John Spoelstra	**Risk Management in Drinking Water Quality and Pollution Control** Roland Bradshaw
10:40	Wastewater Treatment Plants as Sources of Perfluoroalkyl Substances to the Aquatic Environment P. GUERRA, M. KIM, L. KINSMAN, T. NG, M. ALAEE, S.A. SMYTH	Managing the Impact of Climate Change on Municipal Source Water Supply L. GYUREK, S. CRAIK, & S. NEUFELD	Spatial Variation of Groundwater Contaminants Discharging to an Urban Stream, Barrie, Ontario A. FITZGERALD, J. ROY	Computational Modelling in Site-specific Risk-assessment for Trace Metals: Forging the Path Forward P.M.C. ANTUNES, M.L. SCORNAIENCHI
11:00	Drugs of Abuse in Canadian Municipal Wastewater and Estimates of Community Drug Use V. YARGEAU, K. TINDALE, H. LI, A. RODAYAN, C. METCALFE	Greenhouse Gases from and Impact of Climate Change on Wastewater Treatment Plants L. GUO, Y. AMERLINCK, I. NOPENS, J. PORRO, P. VANROLLEGHEM	Risk to Benthic Organisms (Juvenile Mussels) from Road Salt in Groundwater Discharging to an Urban Stream J.W. ROY, P.L. GILLIS, R. McINNIS, G. BICKERTON	Introducing Layer of Protection Analysis for Water Safety Risk Assessments R. BRADSHAW
11:20	Impact of Tetracycline on Bacterial Wastewater Treatment Communities G. ISLAM, K. GILBRIDE	Climate Change Vulnerability Assessment for Municipal Stormwater and Wastewater Infrastructure for the City of Welland, Ontario, Canada R. SCHECKENBERGER, L. WIDDIFIELD, P. NIMMRICHTER	Assessment of Contaminated Groundwater Effects on Benthic Invertebrates in Streams L. GRAPENTINE, J. ROY, G. BICKERTON	Effectiveness of *E. coli* Biofilm for Prevention of Concrete Deterioration in Wastewater Treatment and Collection Structures S. SOLEIMANI, B.ORMECI, B. ISGOR
11:40	Comparison of Four Extraction Methods for Determination of Bisphenol-A in Sewage Sludge B. BANIHASHEMI, R. DROSTE	Implementing a Project Sustainability Management Framework P. BEUKEMA	Fluorescence Analysis of Natural Organic Matter (NOM) in Shallow and Deep Groundwaters on a Canadian Shield Sampling Site: Influence of pH and Salinity. F. CARON, V. BORRARO, R. RIOPEL, S. SIEMANN	Cyanobacteria Transport: Cyanobacteria Movement and Hydrodynamic Effects on the Vulnerability of a Drinking Water Intake M. NDONG
12:00	L U N C H - M a i n M a l l			
12:30	A N N U A L G E N E R A L M E E T I N G - A u d i t o r i u m			

Tuesday, February 21, 2012

	AUDITORIUM	SOUTH SEMINAR	NORTH SEMINAR	GUEST LOUNGE
	Contaminants of Emerging Concern - Wastewater Treatment (Joint session) Mehran Alaee and David Kim	**Research and Advances in Drinking Water Treatment** Ron Hofmann & Souleymane Ndiongue	**Surface and Groundwater Quality** Veronique Hiriart-Baer & John Spoelstra	**Harmful Algal Blooms and Source Water Impacts** Sue Watson, Jennifer Winter and Lewis Molot
13:00	Comparison of Membrane Assisted Solvent Extraction to Static Headspace GC/MS Analysis for the Determination of Volatile Methyl Siloxanes in Wastewater T. BISBICOS, M.ALAEE, D.WANG	Comparison of 4 Media Types for Traditional and Biofiltration Treatment Goals: Assessment of Rough Engineered Media and Implications for Filter Media Choice M. SPANJERS, M.B. EMELKO	The Impact of Eutrophication on Mercury Cycling in Lake 227 at the Experimental Lakes Area in Northwestern Ontario A. GLEASON, J. KIRK, I. LEHNHERR, D. MUIR, V. ST. LOUIS	Evidence on Human Health Risk Resulting from Exposure to Harmful Algal Blooms; Specifically Cyanobacteria and Cyanotoxins A. SAMUEL
13:20	Kinetic Model Development for Enzymatic Oxidation of Aqueous Aromatic Trace Contaminants S. RANGELOV, J. NICELL	Optimization of Dissolved Air Flotation for Drinking Water Treatment through CFD Modeling B. LAKGHOMI, R. HOFMANN, Y. LAWRYSHYN	Tracking the Source of Contamination of Wheatley Harbour: An Exercise in Multivariate Statistical Analysis È. GILROY, D. MUIR, C. DARLING, L. CAMPBELL, S. DE SOLLA, M. MCMASTER, S. BROWN, J. SHERRY	Occurrence, Levels and Distribution of Cyanobacterial Toxins in Ontario's Municipal Drinking Water and Drinking Water Sources, 2004-2010 J. KINGSTON
13:40	Fate of Anthropogenic Cyclic Volatile Methylsiloxanes in a Wastewater Treatment Plant D. WANG, M. AGGARWAL, T. TAIT, S. BRIMBLE, G. PACEPAVICIUS, L. KINSMAN, M. ALAEE, S.A. SMYTH	Assessment of Human and Veterinary Pharmaceuticals Contamination at River Basin Scale and Study of their Treatability by Activated Carbon Process S. PIEL, O. THOMAS, S. BLONDEAU and E. BAURES	Phenology of Amphibian Breeding in Relation to Pesticide Exposure in Ontario K. PALONEN, S. DE SOLLA, J.STRUGER	Cyanobacteria and Cyanotoxins Breakthrough and Accumulation in Three Drinking Water Treatment Plants in Quebec A. ZAMYADI, S. MACLEOD, N. MCQUAID, S. DORNER, S. SAUVÉ, M. PRÉVOST
14:00	Partitioning of a Suite of Chlorobenzenes (1,2,4,5-tetrachlorobenzene, pentachlorobenzene, and hexachlorobenzene) to Aldrich Humic Acids and Municipal Wastewater Treatment Plant Colloids K.N. MCPHEDRAN, R. SETH, K.DROUILLARD	Pilot Scale Study for the Control of Disinfection By-Products Using Pre-coagulation Ozone in Warm Water Conditions L. ARISS, S. NDIONGUE, D. BORIKAR, T. HEWLETT, L. MOORE	Can Diatom Biomonitoring be Used as a Supplement in Water Chemistry Programs? C. GONCALVES	Design and Development of Universal Molecular Probes for the Geosmin Synthase in Cyanobacteria and Actinomycetes O. KUTOVAYA,S. WATSON
14:20	B R E A K & P O S T E R / E X H I B I T O R S E S S I O N – Main Mall			

Tuesday, February 21, 2012

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14:50	Occurrence And Treatment Of Polybrominated Diphenyl Ethers In Canadian Wastewater Treatment Plants M. KIM, P. GUERRA, M. THEOCHARIDES, K. BARCLAY, S.A. SMYTH, M. ALAEE	Optimization of Biofiltration for the Minimization of Disinfection By-Product Formation K. DUPUIS, I. DOUGLAS, R. DELATOLLA	Water Quality of Streams in Agricultural Watersheds of Southwestern Ontario: Seasonal Patterns, Historical Comparisons, and the Influence of Land Use M. MOHAMED	Toxic Cyanobacteria Blooms along the Southern Embayments of Lake Ontario, NY: History and Current Status G. BOYER, K. PERRI, J. SULLIVAN, A. HOTTO, X. YANG AND M. SATCHWELL
15:10	Characterizing Micellar Enhanced Ultrafiltration for the Removal of Sulfonamide Antibiotics from Wastewater R. BROWN, P. CASHIN, H. CHUNG, E. BUNCEL, G. VANLOON, V. BALAKRISHNAN, K. EXALL	Factors Affecting Total Chlorine Decay and NDMA Formation in Modified Pipe Loops: Pipe Materials, Orthophosphate and Flow Conditions H. ZHANG, S. ANDREWS	Examination of Variation in Water Quality During High Flow Events in Urban and Suburban Tributaries T. LABENCKI, D. BOYD	Extreme Inter-annual Variability in Cyanobacterial Blooms in an Urban Drinking Water Supply, Quebec (Canada). D. ROLLAND, W. VINCENT, I. LAURION, S. BOURGET, A. WARREN
15:30	A Study on Ozone Treatment of Municipal Wastewater Effluent and Oxidation of Chemicals of Emerging Concern S. SINGH, R. SETH, S. TABE, P.YANG	NDMA Formation from Pharmaceuticals-Impact of Water Matrix and Prechlorination R. SHEN, S. ANDREWS	The Dynamic of the Urban Stream Contamination R. VEDOM	Increases in Algal bloom reports in Ontario from 1994 to 2010: did the trend continue in 2011? J. WINTER, A. DESELLAS, R. FLETCHER, L. HEINTSCH, A. MORLE, L. NAKAMOTO, M. PALMER, K. UTSUMI
15:50		Organic Matter and Disinfection By-products in the Grand River Watershed R. HUTCHINS, S. SCHIFF	iSTREEM? - a web-based river chemical concentration estimation model capable of determining where and when to monitor for consumer product chemicals P. DELEO, S. DYER, X. WANG	Predicting the risk of proliferation of the benthic cyanobacterium *Lyngbya wollei* in the St. Lawrence River D. LÉVESQUE, A. CATTANEO, C.HUDON, P. GAGNON
16:30 to 18:30	POSTER SESSION AND RECEPTION at the Holiday Inn, 3063 South Service Rd, Burlington *Directions at end of Program*			

Wednesday, February 22, 2012

	AUDITORIUM	SOUTH SEMINAR	NORTH SEMINAR	GUEST LOUNGE
	Contaminants of Emerging Concern Adrienne Bartlett & Ève Gilroy	**Research and Advances in Wastewater Treatment** Jane Challen Urbanic and Lori Lishman	**Rural and Agricultural Water Stewardship** Gabrielle Ferguson	**Harmful Algal Blooms and Source Water Impacts** Sue Watson, Jennifer Winter and Lewis Molot
8:50	Strategies for Assessing the Aquatic Risk from Emerging Contaminants D. MACKAY	Quantifying Nitrification Kinetics at Low Temperatures Using Moving Bed Biofilm Reactors (MBBR) V.HOANG, R. DELATOLLA, A. GADBOIS	Validating and Demonstrating Best Management Practices to improve water quality on Ontario Farms G. FERGUSON	Development and Field Application of a Multiplex PCR Approach for Improved Monitoring of Harmful Algal Blooms F. NGWA, C. MADRAMOOTOO, S. JABAJI
9:10	Hazard Screening of Substances of Emerging Concern R. HULL, S. KLEYWEGT, T. FLETCHER, J. SCHROEDER	TOC and TN removal of Synthetic Slaughterhouse Wastewater using Biological Treatment in Anaerobic-Aerobic Systems C. LECOMPTE, M. MEHRVAR, E. QUIÑONES-BOLAÑOS	Water Stewardship Actions under Environmental Farm Plans P.SMITH, C. BIBIK, J.LAZARUS, D. ARMITAGE, C. BRADLEY-MACMILLAN, M.KINGSTON, N.CHERNY, A.GRAHAM	Defining the 'Sweet Spot': N:P and Iron Conditions Promoting Cyanobacterial Proportion in Ontario Lakes R.J. SORICHETTI, I.F. CREED, C.G. TRICK
9:30	Perfluorochemicals (PFCs): How Monitoring Data for Emerging Contaminants can Support Drinking Water Guidance Values and Emergency Response S. KLEYWEGT	Characteristics of Effluent Organic Matter and its Influence on Hydroxyl Radical Scavenging Capacity J.GRANT, R. HOFMANN	Spatial Analysis of Adoption of Nutrient Management Related Best Management Practices in Ontario, April 2005 - March 2010 E. WOYZBUN	Modelling Cyanobacteria dominance: How useful are the complex mathematical models? Y. SHIMODA, R. YERUBANDI, G.B ARHONDITSIS
9:50	Contamination of Perfluorooctane Sulfonate and Other Perfluorinated Compounds Downstream of an International Airport, Hamilton, Ontario S. DESOLLA, A. DESILVA, R. LETCHER	Optimization of Aqueous Polyethylene Oxide Photodegradation using Response Surface Methodology S. GHAFOORI, M. MEHRVAR, P.K.CHAN	Evaluating Rural Best Management Practices at the Site and Watershed Scales in Huron County M. VELIZ, W. YANG, J. LAPORTE	The Phosphorus-Ferrous Eutrophication Model: the Role of Anoxia and Internal Loading in Cyanobacteria Dominance in Four Small Soft Water Lakes and Hamilton Harbour, Ontario M. VERSCHOOR, S. MCCABE, L.A. MOLOT, GUIYOU LI, S.B. WATSON, A.M. PATERSON, D.L. FINDLAY, M. PATERSON AND P.J. DILLON
10:10	B R E A K & P O S T E R / E X H I B I T O R S E S S I O N – Main Mall			

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	Contaminants of Emerging Concern Adrienne Bartlett & Ève Gilroy	**Research and Advances in Wastewater Treatment** Jane Challen Urbanic and Lori Lishman	**Research and Advances in Stormwater Management** Hazel Breton	**Harmful Algal Blooms and Source Water Impacts** Sue Watson, Jennifer Winter and Lewis Molot
10:40	Nanosilver in the Aquatic Environment: Should We Be Concerned? C. METCALFE	Advanced Oxidation Process Intensification in Multilamp Sonophotoreactor M.MOHAJERANI, M. MEHRVAR, F. EIN-MOZAFFARI	Evolution of Stormwater Management H. BRETON	Comparison of Phytoplankton Variable Fluorescence from Three Pulse Amplitude Modulated (PAM) Fluorometers J. MAJARREIS, S. WATSON, AND R. SMITH
11:00	Effects of Anthracenedione and Azo Dyes on Survival and Growth of *Hyalella azteca* A. BARTLETT, L. BROWN, V. PALABRICA, V. BALAKRISHNAN	Treatment of Fish Farm Sludge Supernatant by Aerated Gravel Beds and Steel Slag Filters – A Pilot-scale Study S.BRIENT, M. KÕIV, Y. COMEAU	Cyanide in Urban Snowmelt and Winter Runoff K. EXALL , Q. ROCHFORT, R. MCFADYEN AND J. MARSALEK	Nitrogen Fixation Strategies in Cyanobacteria under Different Light Regimes H. ANDREWS, T.BROWN, R.BOURBONNIERE, S. WATSON
11:20	Assessment of the Aquatic Toxicity of Four Sulfonamide Antibiotics Using the Freshwater Amphipod *Hyalella azteca* A. BARTLETT, L. BROWN, J. TOITO, V. BALAKRISHNAN	Enhancement of the Mesophilic Anaerobic Digestion of TWAS, PS, and Scum B.YOUNG, R. DELATOLLA, R. SHERIF, K. KENNEDY	A Review of the Strategies for the Control and Treatment of Combined Sewer Overflows (CSOs) M. MOSLEMI, R. FARNOOD	Relative Strengths of Taxonomic Versus Functional Groups in Explaining Variation in Phytoplankton Communities Along a Trophic Gradient J. BERGERON
11:40		Effect of High Temperature Due to Joule Heating on Biosolids Electro-dewatering Kinetics and Microbial Inactivation T.N. DANESHMAND, P.BIYELA, R.J.HILL, R.GEHR, D.FRIGON	Low Impact Development Stormwater Management: Design, Construction and Monitoring B. BISHOP, R. MOORE	Algal Dynamics as Indicators of Water Quality in the Florida Everglades: Lessons Learned and Applicability to Great Lakes Wetlands A.J. BRAMBURGER, E.E. GAISER
12:00	LUNCH-Main Mall POSTER & EXHIBITOR SESSION: "Meet and Greet"			

Wednesday, February 22, 2012

	AUDITORIUM	SOUTH SEMINAR	NORTH SEMINAR	GUEST LOUNGE
	Nanotechnology in Water Treatment and Sampling Applications Anming Hu and Frank Gu	**Research and Advances in Wastewater Treatment** John Gibson and Yaldah Azimi	**Great Lakes Nearshore Water Quality Issues** Veronique Hiriart-Baer & Jacqui Milne	**Harmful Algal Blooms and Source Water Impacts** Sue Watson, Jennifer Winter and Lewis Molot
13:00	Fast Synthesis of Large Scale High Performance TiO_2 Nanowire Membranes for Water Treatment A. HU, X. ZHANG, P. H. PHAM, D. LUONG, S. KURDE, R. LIANG, H. HUANG, K. OAKES, N. C. BOLS, M. SERVOS, Y. ZHOU	Investigation of Biological Solids Produced by MBBR Systems M.SOLEIMANI, R.DELATOLLA, R.NARBAITZ	Setting Great Lakes Water Quality Targets to Manage Nearshore Algal Issues M. THORBURN	Bay of Quinte Harmful Algal Bloom Initiative: Developing a Monitoring and Long Term Management Programme and Addressing Beneficial Use Impairments S. WATSON, S.OGUNLAJA, J. MUNRO, B. KEENE
13:20	Antimicrobial Efficacy of Photocatalytic TiO_2 Nanowire Membranes on Escherichia coli D. LUONG, X. ZHANG, A. HU, P. PENG, R. LIANG, S. KURDI, K. OAKES, M. SERVOS, Y. ZHOU	Phosphorus Control During Primary Treatment at the Lou Romano Water Reclamation Plant K. FREUND, R. SETH, and P. HENSHAW	Fine-scale Nutrient Enrichment in an Oligotrophic Environment Undergoing Oligotrophication: the Rural Shores of Lake Huron T. HOWELL	Central Algoma Freshwater Coalition: Facilitating Science & Informed Stewardship Practices in Rural Lakeside Communities L. PALUMBO, P. ANTUNES, G. NURNBERG, S. WATSON
13:40	Magnetically Recyclable Superparamagnetic $Fe_3O_4/SiO_2/TiO_2$ Hierarchical Nanospheres for Photocatalytic Water Treatment T. LESHUK, S. LINLEY, F. GU	Phosphate Uptake in Co-precipitation Systems Targeting Low Phosphate Concentrations D.CONIDI, W. PARKER, D. HOUWELING, S. SMITH, P. SETO AND S.MURTHY	Modeling of Circulation and Tracer Distribution in Western Lake Ontario and Hamilton Harbour J. ZHAO, Y. R. RAO	PANEL DISCUSSION
14:00	Evaluating Nanomaterial/Fish Virus Interactions to Understand the Potential of Nanomaterials to Modulate Pathogen Removal in Wastewater Treatment P.H. PHAM, A. HU, K. OAKES, S.X. TANG, N.C. BOLS	The Effect of Floc Properties on UV Disinfection of Wastewater Effluents Y.AZIMI, G.ALLEN, R. FARNOOD	Effect of Beaver Dams on Coastal Marsh Water Chemistry in Eastern Georgian Bay A. FRACZ, P. CHOW-FRASER	
14:20	BREAK & POSTER / EXHIBITOR SESSION – Main Mall			

Wednesday, February 22, 2012

	AUDITORIUM	SOUTH SEMINAR	NORTH SEMINAR	GUEST LOUNGE
	Nanotechnology in Water Treatment and Sampling Applications Anming Hu and Frank Gu	**Research and Advances in Wastewater Treatment** John Gibson and Yaldah Azimi	**Great Lakes Nearshore Water Quality Issues** Veronique Hiriart-Baer & Jacqui Milne	**Harmful Algal Blooms and Source Water Impacts** Sue Watson, Jennifer Winter and Lewis Molot
14:50	Investigation of the Roles of Active Oxygen Species in Photodegradation of the Heterocyclic Aromatic Chemical Compound Methylene Blue in TiO_2 Photocatalysis Utilizing a 365nm UV Lamp S. KURDI, A. HU, H. HUANG, R. LIANG, P. PENG, Y. ZHOU	CFD Modeling for Floc Breakage in Orifice Flow A. FERNANDES, J. GIBSON,Y. LAWRYSHYN, R. FARNOOD	Occurrence and Predictive Correlations of *E. Coli* and *Enterococci* at Sandpoint Beach (Lake St. Clair) Windsor, ON and Holiday Beach (Lake Erie), Amherstberg, ON K. MCPHEDRAN, R.SETH, R. BENJANKIWAR	PANEL DISCUSSION CONTINUED
15:10	Preparation of Whey Stabilized ZnO Nanoparticles for Degradation of Bisphenol A, an Endocrine Disrupting Compound in Water D.P. MOHAPATRA, S.K. BRAR, P. PICARD, R.D. TYAGI	Use of Linoleic Acid to Enhance Anaerobic Sulphate Reduction in Semi-Continuous Reactors T. BISWAS, R. SETH, N. BISWAS	Microbial Source Tracking of Fecal Pollution Sources at Region of Niagara Beaches T. EDGE, S.HILL, H.SCHELLHORN, S.WONG, R.ZHENG, A. O'BRIEN, I.ANDZANS, G.HUDGIN	
15:30	A Review of Applications of Nanofiber Membranes in Water and Wastewater Treatment S. TABE, T. MATSUURA	TOC removal of a Secondary Effluent of Synthetic Slaughterhouse Wastewater using UV/H_2O_2 C. LECOMPTE, M. MEHRVAR, E. QUIÑONES-BOLAÑOS	Virulence of *Escherichia coli* in Receiving Waters Impacted by Wastewater Effluents M. YIP WOON SUN, T. EDGE, D. FRIGON, A. MAZZA, L. MASSON, R. GEHR	
15:50				
16:10	PRESENTATION OF PHILIP H. JONES AWARD & CONCLUDING REMARKS-Auditorium			

Plenary Presentation

Emerging Contaminants: Why are we always playing catch up?

CHRIS METCALFE

Environmental and Resource Studies, Trent University, Peterborough, ON

ABSTRACT: In Canada, we are rarely at the forefront of research on contaminants of emerging concern in the environment. As a result, our regulatory agencies are usually developing regulations and mitigation strategies that respond to contaminants that have already been released into the environment. Moreover, we usually must rely on research conducted in EU countries, the USA, or increasingly, China to inform our decision makers of the hazards of these emerging contaminants. The obstacles that impede our progress and mean that we are constantly playing "catch up" in expanding our knowledge about contaminants of emerging concern include: 1) analytical barriers, 2) regulatory barriers, and 3) institutional and organizational barriers. The importance of these barriers will be illustrated using case histories for chemicals that were of emerging concern in the past and chemicals that are of concern right now.

Climate Change and its Implications for the Water Industry

Chair: Michael Lywood, AMEC Environment & Infrastructure

Session Description

Climate change will have significant impacts across Canada. While the severity of the impacts will vary with geography, one change that will be widespread is higher temperatures, both air and water. This will result in alterations in stream flow and runoff, evaporation rates, agricultural consumption and shifts in urban demands in response to population change.

This session will focus on the social, economic, and infrastructure implications/impacts of climate change to Canada's water industry – municipal and natural resource industries - and strategies for adaptation to the new norm in the near term (5 to 10 year) and over the life cycle of the investment.

Causes and Solutions of the Urban Heat Island

M. HULLEY,[1*] G. ZUKOVS[2]

[1] *Royal Military College of Canada*
[2] *XCG Consultants Limited*

This presentation provides an overview of causes and potential solutions for the urban heat island. A brief analysis of historical temperatures for New York City, NY, and Toronto, ON, are provided as illustrative examples. In each case, the increase in average annual temperature in the city core is significantly greater than average annual temperature increases in surrounding, less developed, areas. Factors contributing to the problem, including urbanization and existing building practices, are discussed and a number of potential mitigation strategies, focusing primarily on the potential benefits achieved through implementation of Low Impact Development measures, are discussed. As well, potential benefits of cool roofs, alternative paving surfaces, and urban vegetation are discussed. Example numerical tools designed to support cost benefit analysis of possible mitigation measures, such the screening level model MIST, are reviewed.

[*] Presenting author; michael.hulley@rmc.ca

Climate Change and Water Utilities: The Role of Economics in Encouraging a More Sustainable Use of Water

D. P. DUPONT[1*]

[1] *Brock University, Department of Economics*

Economics is concerned with how to make the best use of scarce resources such as water. In Canada, as other places, the price of water delivered to customers is not determined within a competitive market. Instead, consumers pay administrative prices that focus upon looking backwards in order to cover past distribution and infrastructure costs. Importantly, these prices do no reflect future opportunity costs of water. One serious outcome is that prices for delivered water are too low. As a consequence, consumers use too much water and have little, if any, incentive to conserve on its use. This leads to apparent rising demand for water and a concomitant need to expand costly water treatment and delivery infrastructure. Climate change is predicted to lead to greater variability in available water supply and is likely to increase the pressures facing water utilities. Consideration of increasing pressure has led to a growing interest in rate setting and the role of water prices in encouraging conservation and water use efficiency
Recent work using economic modeling with Canadian data provides two important lessons. First, over time and using data from metered customers, we have found that the demand for water does respond to rising prices, as economic theory would predict. Using a spreadsheet-level model using a ten-year horizon dataset on prices and household consumption from an Ontario region has been used to simulate the impacts on demand growth of a number of alternative pricing approaches. The no-price increase scenario (where water prices are frozen in real terms) predicts a doubling of water demand over the next forty years while an aggressive water pricing scenario (where real water prices are simulated to rise by 3.38% per annum) predicts that water demand will rise by less than ten percent over the same time period. Second, the lessons from this modeling exercise are supported by an examination of data on household decisions to make watersaving
retrofit decisions such as the use of low-flow showerheads and low-flow toilets.
Such decisions have been found to be very strongly and positively influenced by rising water prices, as well as pricing structures that are volumetric. Overall, this work reveals that demand side management tools such as changing the structure and level of water prices are successful in encouraging both conservation and water efficiency goal by providing incentives for customers to alter their water using behaviour. Adopting these types of tools will assist water utilities in meeting the challenges of climate change.

*Presenting author; Diane.dupont@brocku.ca

Managing the Impact of Climate Change on Municipal Source Water Supply

L. GYUREK,[1*] S. CRAIK,[1] S. NEUFELD[1]

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Protecting the quality and quantity of the raw water supply is a key component of EPCOR's multi-barrier approach to drinking water treatment. This approach focuses on the protection and management of the upstream watershed with the understanding that this can improve or prevent deterioration of raw water quality entering treatment plants. In this watershed management model water supply has been considered to be a constant and planning has focused on mitigating risks to water quality, i.e. Best Management Practices for agriculture or urban/rural stormwater management.

With predicted changes in climate regimes and a better understanding of natural hydroclimatic variability in surface waters, water utilities such as EPCOR are reconsidering the assumption of a static water supply. Recently, EPCOR has supported a collaborative research project led by Dr. David Sauchyn, namely the Prairie Adaptation Research Collaborative. This project was able to estimate the hydroclimatic variability of the North Saskatchewan River for the last one thousand years and predict the effects of possible future climate change on water yield. This work identified that long periods of water scarcity were not infrequent and the impacts of climate change could include: changes in annual stream flow and timing; possible large declines in summer stream flow and higher winter flows; increased likelihood of severe drought; changes in water quality due to more frequent runoff events; and increased aridity in semiarid zones. These findings have allowed EPCOR to better assess future risks to Edmonton's drinking water supply and source water quality, and to also further develop risk mitigation strategies.

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Greenhouse Gases From and Impact of Climate Change on Wastewater Treatment Plants

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Wastewater treatment plants (WWTPs), as other industries, produce greenhouse gases (GHGs), affecting climate which in turn leads to increased intensity rain events resulting in influent shocks to WWTPs. This interaction was studied using modeling and field measurements. Nitrous oxide (N_2O) is a powerful GHG produced during nitrogen removal, while carbon dioxide (CO_2), methane (CH_4) and energy consumption also contribute to GHG emissions. A bioreaction model considering N_2O production by both heterotrophs and autotrophs was built and implemented in a whole plant model to study the way process control can reduce GHG emissions. The open-loop plant performance was compared with a traditional ammonia (NH_4^+)-DO cascade controller and a separate dissolved oxygen (DO) control strategy in which a DO controller was applied to each aerobic tank. The plant performance was evaluated in terms of GHG emissions, effluent quality and operation cost. Results showed that traditional strategies should be re-assessed while new strategies need more discussions when adding GHG emissions as a measure of plant performance. Experimental data were collected in an aeration tank of the Eindhoven WWTP, the Netherlands. The measured N_2O emissions were compared to on-line data recorded by plant sensors. A different variation pattern of N_2O emissions was found under wet compared to dry weather conditions; a relationship was identified between N_2O emission and aeration flow rates, proving the usefulness of setting up new strategies to balance N_2O production with aeration energy consumption and pollutant removal e.g. NH_4^+.

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Climate Change Vulnerability Assessment for Municipal Stormwater and Wastewater Infrastructure for the City of Welland, Ontario, Canada

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It is speculated that Ontario may in the future experience changes in the frequency and/or severity of extreme weather as well as changes to average climate over several decades or more due to climate change influences. These changes are expected to affect natural, social and built infrastructure, potentially having significant socio-economic consequences. Most often, climate change assessments have focused on a range of mitigation options related to energy use such as reducing greenhouse gas emissions, encouraging public transport and energy efficiency at all scales in the community. More recently, though, the focus in the industry has shifted toward adaptation, recognizing how a community and its infrastructure must adapt to changing climatic conditions.

The principal objective of this study has been to identify those components of Welland, Ontario's wastewater and stormwater collection systems that are at risk of failure, damage and/or deterioration from extreme climatic events or significant changes to baseline climate design values. The nature and levels of risk have been determined in order to establish priorities for remedial action. The vulnerability assessment framework has been based on the Engineers Canada Protocol, termed PIEVC (Public Infrastructure Engineering Vulnerability Committee) while concurrently developing rainfall Intensity-Duration-Frequency information for future project time frames, namely: 2020 and 2050.

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Implementing a Project Sustainability Management Framework

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Global climate change issues have resulted in a renewed focus on sustainability. Because sustainability is context sensitive and can be defined many ways, a key challenge that organizations face is ensuring that their project and operations contribute positively to global sustainable development and at the same time effectively demonstrate their commitment to reducing their environmental footprint.

Current sustainability approaches can either focus on one specific aspect, such as water, biodiversity, GHG emissions, energy, etc., or can provide an extensive list of potential issues and initiatives. Effectively implementing sustainability requires a practical, flexible and manageable system to identify sustainability issues for each project

AMEC has developed an innovative Project Sustainability Management (PSM) framework that helps integrate client sustainability requirements as well as the general principles of sustainability into projects managed by AMEC. For our clients, this PSM framework can also be used to guide them in completing a detailed assessment of a proposed project, and develop specific goals to document and clearly demonstrate in an auditable manner to internal and external stakeholders that sustainability is built-in, not bolted-on. The PSM framework can also be used to focus on a specific initiative including water (conservation, management, protection, etc.) and can guide the organization and assist in articulating to stakeholders their ongoing commitment to ensuring sustainability.

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Contaminants of Emerging Concern

Co-Chair: Ève Gilroy, Green House Science
Co-Chair: Adrienne Bartlett, Environment Canada

Session Description

Over the last few decades, the development of increasingly sensitive analytical methods has permitted the widespread identification and detection of numerous "emerging contaminants" in aquatic systems, which in turn has generated concerns regarding the risks that these compounds may pose to environmental and/or human health. In order to properly assess and manage these risks, it is essential to obtain information on the fate, exposure, and effects of contaminants of emerging concern on non-target organisms, and the goal of this session is to highlight the latest research related to these issues. This session covers the measurement, occurrence, fate, effects, and risk assessment of emerging contaminants, including compounds such as pharmaceuticals, personal care products, fluorinated compounds, brominated flame retardants, current use pesticides, siloxanes, and nanomaterials.

This session is mainly targeted towards members of the scientific community (e.g., scientists, graduate students) conducting research on contaminants of emerging concern.

Key themes:

- Advances in analytical method development
- Occurrence of chemicals of emerging concern in the aquatic environment
- Environmental fate (mobility, transformation, persistence)
- Toxicity of emerging contaminants to aquatic organisms
- Risk assessment and/or regulation of emerging contaminants

Strategies for Assessing the Aquatic Risk from Emerging Contaminants

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There is an incentive to assess new and emerging contaminants for the risk they may pose to aquatic ecosystems and humans. The conventional approach is to compare their properties with established P, B, T, (Persistence, Bioaccumulation, Toxicity) criteria. There are several problems with this pass/fail approach including the lack of, or uncertainty in property data. Indeed it can be argued that the PBT approach to assessing hazard can be flawed.

Here we outline a strategy for assessing risk rather than hazard using minimal data, simple models and an analysis of sensitivity and uncertainty. The key data include molecular structure, the "three solubilities", pKa, estimates of degradation half lives in key media including organisms, mode of entry to the environment and an estimate of discharge rate. The strategy is illustrated for chemicals that have the potential to cause risk in the aquatic environment. It is shown that some "non-PBT" substances can pose an appreciable risk and some "PBT" substances can pose negligible risk

It is concluded that from a regulatory viewpoint it is preferable to proceed to an assessment of tentative risk rather than assign priorities based on hazard.

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Hazard Screening of Substances of Emerging Concern

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The concentrations of a variety of chemicals in various media in the Great Lakes Basin were reviewed by the International Joint Commission's (IJC's) Work Group on Chemicals of Emerging Concern, from which a summary report was prepared: Review of Chemicals of Emerging Concern and Analysis of Environmental Exposures in the Great Lakes Basin. The report highlighted monitoring data for over 300 chemicals in water, sediment and biota, however, did not address the ecological significance of the chemicals. To meet part of its commitment under Annex 2 (Harmful Pollutants) of the Canada-Ontario Agreement Respecting the Great Lakes Basin Ecosystem (COA), the Ontario Ministry of the Environment has undertaken a hazard screening project to evaluate the ecological significance of the targeted chemicals from the IJC report. The goal is to identify a list of substances not currently the focus of Annex 2 that may be targeted for future COA programming.

The project was conducted in phases. The first phase evaluated substances measured in Canadian waters, detected in at least 10% of samples, <10 samples and had maximum measured concentrations above an ecological criterion. The second phase is evaluating the remaining substances in the list. Where no environmental criteria were available, benchmarks were developed. Generally, the results of the hazard screening assessment showed that concentrations of contaminants are below those associated with conventional toxicological effects, such as mortality, growth and reproduction. Conclusions about priority substances (hazard quotient >1) and their sources to the Great Lakes, as well as uncertainties in the screening project will be presented.

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Perfluorochemicals (PFCs): How Monitoring Data for Emerging Contaminants Can Support Drinking Water Guidance Values and Emergency Response

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Perflourochemicals (PFCs) are a family of chemicals that have been used to make products that are resistant to heat, oil, stains and grease. Common applications include non-stick cookware, stain-resistant carpets and fabrics and components of aqueous fire fighting foams (AFFFs). These chemicals are very persistent in the environment and are toxic according to the Canadian Environmental Protection Act. Thus, to determine the potential levels and occurrence of PFCs in Ontario source and finished waters, the Ministry collected 33 samples from eight (8) water treatment plants and analyzed the samples for 10 PFC parameters by liquid chromatography/tandem mass spectrometry (LC/MS-MS). The most frequently detected compounds were PFOS (Perfluorooctane sulfonate (C8)), PFOA (Perfluorooctanoic acid (C8)), PFHxS (Perfluorohexane sulfonate (C6)) and PFNA (Perfluorononanoic acid (C9)) with concentrations measured in the ng/L (or parts per trillion) range. This monitoring data provided baseline levels of PFCs in Ontario source waters to compare to an emergency situation involving contaminated source water with AFFF. The outcome of the response was the development of health-based drinking water guidance values for PFOS and PFOA by Health Canada.

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Contamination of Perfluorooctane Sulfonate and Other Perfluorinated Compounds Downstream of an International Airport, Hamilton, Ontario.

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Per- and poly-fluorinated compounds (PFCs) are used in a wide variety of industrial, commercial and domestic products. This includes aqueous film forming foam (AFFF), which is used by military and commercial airports as fire suppressants. A preliminary assessment prior to this study, revealed very high concentrations (> 1 ppm wet weight) of perfluorooctane sulfonate (PFOS) in snapping turtle (*Chelydra serpentina*) plasma collected in 2008 from Lake Niapenco in southern Ontario. In order to ascertain the source of these high PFOS concentrations, we conducted a spatial survey of water, amphipods, and shrimp in Lake Niapenco and the Welland River, downstream of the John C. Munro International Airport, Hamilton, Ontario. PFOS dominated the sum PFCs in all substrates (e.g., >99% in plasma of turtles downstream the airport, and 72 to 94% at all other sites). PFOS averaged 2223±247 (SE) ng/g in turtle plasma from Lake Niapenco, and ranged from 9.0 to 171 elsewhere. Mean PFOS in amphipods and in water were 518±84 ng/g and 130±44 ng/L downstream of the airport, and 19±2.7 ng/g and 6.8±0.5 ng/L at reference sites, respectively. Concentrations of selected PFCs declined with distance downstream from the airport. Perfluoroethylcyclohexane sulfonate (PFECHS), a cyclic perfluorinated acid used in aircraft hydraulic fluid, was also discovered in biota and water downstream the airport. Recent sampling of fish downstream the airport by the MOE resulted in consumption restrictions due to PFOS. Although there was no documented spill event or publicly reported use of AFFF associated with a fire event at the Hamilton airport, the airport is likely a major source of PFC contamination in the Welland River.

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Nanosilver in the Aquatic Environment: Should We Be Concerned?

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Engineered nanomaterials (EN) are being increasingly used in consumer products, including textiles, electronics, photovoltaics, pharmaceuticals and cosmetics. Because of its antibacterial properties, silver nanomaterials (nAg) are currently the most widely used EN in various consumer products, such as additives to socks, underwear and other clothing, shoe liners, adhesive bandages, antibacterial sprays, food storage containers, laundry additives and paints. It is likely that nAg is entering the aquatic environment from discharges of domestic and industrial wastewater. Recent investigations show that nAg and dissolved silver (dAg) are being washed into domestic wastewater though laundering of fabrics containing nAg and from there, nAg may enter the municipal sewage stream of wastewater treatment plants (WWTPs). Although, there are no currently published data on the concentrations of nAg in surface waters impacted by wastewater discharges, a recent study using a predictive model indicated that nAg may enter surface water at low part per billion concentrations through discharges from WWTPs. Once released into surface waters, nAg may induce toxic effects on aquatic organisms. Our recent studies have shown that exposure to nAg at ppb concentrations can inhibit the growth of natural communities of bacteria and algae in water collected from ponds, streams and lakes. Early life stages of amphibians (i.e. tadpoles) and fish, and Daphnia appear to be less sensitive to the toxic effects of nAg. These studies indicate that the effects of nAg on the aquatic environment might be mediated by ecosystem level effects, such as reduced productivity and altered nutrient cycling.

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Effects of Anthracenedione and Azo Dyes on Survival and Growth of *Hyalella azteca*

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Very little toxicological data are associated with the 2600 medium-priority chemicals listed in Canada's Chemicals Management Plan (CMP). This study assessed several of these compounds to determine effects on survival and growth of the freshwater amphipod, Hyalella azteca. Four-week, water-only, static-renewal toxicity tests were conducted with three anthracenedione dyes (Acid Blue 80, Acid Blue 40, Acid Blue 129) and three azo dyes (Disperse Orange 13, Disperse Yellow 7, Sudan Red G). The anthracenedione dyes showed little/no toxicity to Hyalella. Acid Blue 80 was non-toxic to survival or growth of Hyalella up to 10,000 µg/L (the highest concentration tested). Acid Blue 40 and Acid Blue 129 demonstrated some toxicity to Hyalella, with four-week LC50s estimated to be 13,500 and 6470 µg/L, respectively. Growth was not affected by Acid Blue 40, but was weakly affected by Acid Blue 129, with a four-week EC25 of 1950 µg/L. The azo dyes were more toxic to Hyalella. Four-week LC50s for Disperse Orange 13, Disperse Yellow 7, and Sudan Red G were 632, 117, and 30 µg/L, respectively. Growth was affected by Disperse Orange 13, with a four-week EC25 of 894 µg/L, but was not affected by the other azo dyes tested. Dye toxicity reported here was calculated using nominal concentrations; however, based on previous data, measured dye concentrations are expected to be substantially less than nominal (30-50%). These toxicity data will be used in CMP risk assessments to determine if dyes could impact freshwater ecosystems downstream of textile dying facilities or municipal wastewater outfalls.

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Assessment of the Aquatic Toxicity of Four Sulfonamide Antibiotics Using the Freshwater Amphipod *Hyalella azteca*

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Sulfonamide antibiotics are among the most commonly prescribed types of antibiotics in use; however, there is a paucity of data available to conduct risk assessments of the impacts of these compounds on the environment. The goal of this study was to assess the aquatic toxicity of four sulfonamide antibiotics to *Hyalella azteca*, an invertebrate species that is ubiquitous in North American freshwaters, sensitive to a wide variety of contaminants, and widely used in toxicity testing. Juvenile *Hyalella* were exposed for four weeks in static-renewal, water-only systems to nominal concentrations ranging from 0.14-19 μM for sulfaguanidine, 0.31-39 μM for sulfathiazole, 0.30-38 μM for sulfamerazine, and 0.1-12 μM for sulfasalazine. Survival was evaluated weekly, and both survival and growth were measured at the end of the test. Four-week LC50s (measured concentrations) for sulfaguanidine and sulfathiazole were 0.90 μM (190 μg/L) and 1.6 μM (420 μg/L), respectively. Sulfamerazine data were variable, with LC50s occurring over almost a 10-fold range (1.3-12 μM, or 350-3200 μg/L). Growth was also affected by sulfaguanidine, sulfathiazole, and sulfamerazine, but was a less sensitive estimate of toxicity than survival, with EC50s of 2.6, 13, and 17-20 μM (550, 3400, and 4600-5400 μg/L), respectively. Sulfasalazine showed no effects on survival or growth at any concentration tested, up to 13 μM (5000 μg/L). With the exception of sulfasalazine, sulfonamide toxicity increased with exposure duration. Relative sulfonamide toxicity to *Hyalella* was as follows (from most to least toxic): sulfaguanidine > sulfathiazole > sulfamerazine > sulfasalazine. The effects observed in this study occurred at levels well above those typically found in municipal wastewater effluent, but within the range reported for localized areas receiving agricultural run-off.

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Contaminants of Emerging Concern - Advances in Wastewater Treatment (Joint Session)

Co-Chairs:
Shirley Anne Smyth, Environment Canada
Mehran Alaee, Environment Canada
Paula Guerra, Environment Canada
Scott Dunlop, Environment Canada
David Kim, Environment Canada

Session Description

This is a joint session of the Contaminants of Emerging Concern and Wastewater Treatment sessions.

Comparison of "in silico" and Environmental Measurements for Identifying New, Emerging, and Re-emerging Chemicals of Concern

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A wide range of organic chemicals (~350 substances not including structural isomers/congeners) have been reported in air, waters, waste effluents, sediments and biota in the Great Lakes region over the past 15 years (see Klecka et al RECT 2010). The major classes of detected are current use pesticides (CUPs), pharmaceuticals, steroids and hormones, alkylphenol ethoxylates, antioxidants, synthetic musks, perfluorinated chemicals, and halogenated and organophosphate flame retardants. Most of the chemicals have been registered since the 1980s under Food and Drug and Pesticide legislation, the Toxic Substances Control Act inventory or Canada's Domestic Substances List, and therefore might be better termed "re-emerging" rather than "emerging". Their recent identification in environmental media is mainly the result of application of innovative analytical chemistry with a focus on structural analogs of previously identified compounds and application of new techniques such as LC-MS/MS. But this list represents only a small fraction of the possible chemicals that could be present in effluents and tributaries entering the Great Lakes. There are thought to be more than 30,000 "industrial" organic chemicals in wide commercial use (>~1 t/y) as well as about 3000 pharmaceuticals and 1000 CUPs. If their possible degradation products, byproducts, and impurities, are included the list of individual analytes expands enormously. Recently, Howard and Muir (EST 2010;2011) identified 610 organics from a list of 22,263 commercial chemicals and also 364 out of 3193 pharmaceuticals that had potential for persistence and bioaccumulation in the Great Lakes region. Most of the 350 substances previously measured in the Great Lakes region were among the 974 chemicals we identified independently, indicating the value of applying "in silico" approaches provided that structural information is available.

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Wastewater Treatment Plant Inputs of Emerging Pollutants to the Atmosphere

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Wastewater treatment plants (WWTPs) are potential emission sources for emerging pollutants such as per- and polyfluoroalkyl compounds (PFASs), polybrominated diphenylethers (PBDEs), volatile methyl siloxanes (VMSs) and industrial organo-phosphorus (OPs). These emerging pollutants have recently generated intense scientific interest because of their widespread distribution, as well as their persistent, bioaccumulative and toxic properties. To assess their emissions to air from a WWTP, 12 sorbent-impregnated polyurethane foam (SIP) disk passive air samplers were deployed at a WWTP in Ontario in summer 2009. The SIP disk samplers consisted of PUF disks impregnated with finely ground XAD-4 resin which improves the sorptive capacity of the PUF disks for more volatile and polar chemicals. The target analytes include 22 PFASs, 16 PBDEs, 4 cyclic VMS (cVMS), 3 linear VMS (lVMS) and 10 OPs.

Generally, the target analytes showed elevated concentrations at the WWTP compared to the reference sites**.** For example, ΣPFAS concentrations in air were 3–15 times higher within the WWTP (2300–24000 pg/m^3) compared to the reference sites (600–1600 pg/m^3). Variations in the compound pattern were observed within the WWTP sites. For instance, highest air concentrations of PFASs and VMSs were at the aeration tanks compared to the other tanks (i.e. primary and secondary clarifier) and likely associated with increased volatilization during the aeration process. Yearly emissions estimated using a simplified dispersion model were 2.6 kg/year for ΣPFASs and 60–2100 kg/yr for cVMSs. These results highlight the important role of WWTPs as emission sources of emerging pollutants to the atmosphere.

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Wastewater Treatment Plants as Sources of Perfluoroalkyl Substances to the Aquatic Environment

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Perfluoroalkyl substances (PFASs) are a structurally diverse group of chemicals used in carpets, apparel and packaging products as processing additives during fluoropolymer production and as surfactants in consumer applications. These compounds have a dual hydrophobic and hydrophilic character, resulting in both water and oil repellency. The most studied PFASs are perfluorooctanesulfonic acid (PFOS) and perfluorooctanoic acid (PFOA), having the potential to persist in nature, bioaccumulate, and become toxic. As a result, PFOS was added to the list of persistent organic pollutants (POPs) at the Stockholm Convention in 2009.

Previous studies have shown inefficient removal of PFASs in wastewater treatment plants (WWTPs). Consequently, discharge of WWTPs effluents containing PFASs is one of the principal routes for introducing these compounds into the aquatic environment. PFASs have been detected in tap water from several countries and in aquatic organisms worldwide. Therefore, there is increasing attention on understanding fate and behavior of these compounds in WWTPs. The origin of PFASs in WWTPs may be due to domestic activities, industrial discharges, or other commercial activities.

This study aimed to evaluate levels and behavior of different PFASs, including PFOA and PFOS from 20 WWTPs in Canada. Depending on the treatment process different removal efficiencies and congener composition were observed. In this presentation levels of PFASs in influent and effluent will be presented. Effect of different treatment processes on the fate of these compounds will be discussed.

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Drugs of Abuse in Canadian Municipal Wastewater and Estimates of Community Drug Use

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In this study we evaluated the distribution of selected drugs of abuse, including amphetamines (amphetamine, methamphetamine, MDMA and ephedrine,), cocaine and its metabolite, benzoylecgonine and opioid prescription drugs (codeine, dihydrocodeine, EDDP, heroin, ketamine, morphine, methadone, oxycodone and tramadol) in municipal wastewater from three Canadian cities, and we estimated community drug use from the levels of these compounds in untreated wastewater. This is the first study to evaluate community drug use in cities from North America, and the comparison provided on previously published data from European cities provide some valuable insights into differences between North America and Europe in drug usage as well as between small and large urban centres in Canada. Cocaine was the most widely used illicit drug with a highest median level of 36 doses per day per 1,000 people. For the other drugs, the median doses per day per 1,000 people were all below 20. When comparing the data between the large and small urban centers in Canada, the number of doses per day per 1000 people was higher in the large urban centre, except for oxycodone. In addition, data obtained on the removals of these drugs during wastewater treatment indicated that cocaine and amphetamine-types of drugs were generally removed at > 50%, which is similar to values previously reported in literature for European cities. However, negative removals were observed for most of the opioids. The higher concentrations measured in the effluent relative to the influent were probably due to release of conjugated metabolites during wastewater treatment.

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Impact of Tetracycline on Bacterial Wastewater Treatment Communities

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Pharmaceuticals are often designed to have a biological impact on their targets to effectively provide treatment. It is seldom taken into consideration to what the effects of these drugs have on bacteria in wastewater treatment systems which are a crucial component of the treatment system. They can cause selective pressure on the microorganisms and potentially affect the structure, composition and function of the bacterial community found in the secondary step of the treatment system. The aim of this research is to better understand the impact of external factors such as antibiotics on the composition, structure and function of the microbial population in a municipal wastewater treatment system. The short term objectives of this research will be to determine if tetracycline at environmentally relevant concentrations (1ug/L and 10ug/L) will lead to a community shift in the microbial populations present in the community, to determine if the microbial community can adapt to increasing concentrations of the antibiotic over time, and to determine if nitrifying bacteria (nitrification being the Achilles heel of the treatment system) are inhibited by the presence of the antibiotic. Semi-batch reactors were set up with secondary sludge from a municipal wastewater treatment plant and fed synthetic wastewater at two dilution rates for a period of 4 weeks. Samples were taken every two days to monitor DOC, ammonia, nitrate, nitrite, antibiotic resistance and community fingerprints. Higher dilution rates affected the biomass where the community showed decreased mass and increased flocculation. Community DNA fingerprints showed a shift in the members present when subjected to continuous exposure to tetracycline. Overall, both antibiotic and dilution rates affected the composition of the community.

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Comparison of Four Extraction Methods for Determination of Bisphenol-A in Sewage Sludge

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The extraction of bisphenol-A [BPA; 2,2-bis(4-hydroxyphenyl)propane], from sludge samples is a complex process. In sludge samples, some molecules remain bonded with proteins and other biomolecules, which requires accurate extraction procedures to remove it from particulates and solubilise it. The aim of this study was to compare existing extraction methods and develop a reliable, accurate and fast extraction procedure for the determination of BPA in sewage sludge. Four extraction methods, microwave-assisted extraction (MAE), ultrasonication extraction (USE), accelerated solvent extraction (ASE), high-pressure homogenizer (HPH), were optimized based on temperature, pressure, static time and extraction cycle and then compared for isolation of BPA from activated sludge samples. To validate these extraction techniques, recovery studies were performed using 0.1g dried, homogenized and centrifuged sludge samples from a stable lab-scale activated sludge system and spiked with 1ml of 200ug/L BPA standard solution. Samples were then mixed with 5g of anhydrous sodium sulphate and were extracted with 1:1 (v/v) mixture of acetone and hexane. The extracts were cleaned up and pre-concentrated using solid phase extraction (SPE) method and were analyzed by high-performance liquid chromatography (HPLC) coupled with UV detection. For each modified extraction technique, 12 samples (spiked, un-spiked, spiked non-dried sludge, and blanks) were tested and the recovery results were compared. The results showed that the recovery of BPA in spiked samples ranged from 60 to 90%, and the MAE had the highest recovery among these extraction methods.

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Comparison of Membrane Assisted Solvent Extraction to Static Headspace GC/MS Analysis for the Determination of Volatile Methyl Siloxanes in Wastewater

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Volatile methyl siloxanes (VMS) belong to a group of compounds which are commonly used as precursors in industrial applications and personal care products such as cosmetics and anti-foaming agents. Due to their wide use in these industries they are ubiquitously found in the environment. VMS are volatile oily liquids, comprised of a silicon-oxygen backbone with methyl groups attached to each silicone atom. They form both cyclic and linear compounds with a wide range of molecular weights and properties.

The compounds of interest for this investigation include both the linear and cyclic siloxanes. The current method used to determine siloxanes in wastewater is Membrane Assisted Solvent Extraction (MASE). One of the main problems with MASE is that the more volatile hexamethyldisiloxane (L2) tends to co-elute with the solvent peak which makes it a challenge to quantitate.

Static headspace (SH) analysis, a solvent-less procedure was investigated to overcome the problems seen with MASE. In the absence of a solvent peak in SH analysis it was possible to optimize the L2 peak, resulting in a sensitive method for the determination of L2 in environmental samples. Subsequently a method was developed and successfully applied to determine VMS (L2, L3, L4, L5, D3, D4, D5, D6 and M4Q) found in wastewater. Results from this investigation were compared to those obtained using the more established method, MASE-GC-MS analysis.

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Kinetic Model Development for Enzymatic Oxidation of Aqueous Aromatic Trace Contaminants

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The presence of aromatic compounds with potentially significant biological impacts in waters, even in trace concentration levels, is an emerging environmental topic. Due to their low concentrations and recalcitrant nature, aromatic trace contaminants (ATCs) are not effectively removed using conventional treatment technologies and are frequently detected in surface and ground waters. Several classes of enzymes, including peroxidases and laccases, have been reported to have the ability to catalyze the oxidation of numerous aromatic compounds. Due to their high rates of oxidation, such enzymes have the potential to be used to accomplish the treatment of ATCs. However, the use of these enzymes has mostly been demonstrated in studies involving compounds that are present in industrial wastewaters at elevated concentrations. To-date, their application to the treatment of ATCs at environmentally-relevant concentrations has not been demonstrated. An approach that can be used to explore the feasibility of the application of enzymes for the treatment of ATCs is through the modeling of reaction kinetics, particularly in the low substrate concentration range. Laccase from Trametes versicolor was selected as the biocatalyst in this investigation because this enzyme has demonstrated excellent treatment potential and has been used in previous studies on a wide range of substrates. Phenol was selected as a model ATC since it is one of the most common industrial pollutants and most studied of laccase substrates. Experiments was carried out at pH 5, 25oC for 3 hours period with initial phenol concentrations ranging from 0.5 to 40 μM and applied enzyme activities ranging from 0.92 to 9.2 U/mL. A simplified kinetic model was developed and used to investigate the impacts of each variable on the reaction kinetics. A more comprehensive model demonstrated an excellent ability to predict the time course of treatment of phenol for the full range of enzyme and substrate concentrations. The model is now being extended to examine the treatment of other ATCs including estradiol, triclosan and cumyl phenol.

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Fate of Anthropogenic Cyclic Volatile Methylsiloxanes in a Wastewater Treatment Plant

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Cyclic volatile methylsiloxanes (cVMS) - octamethylcyclotetrasiloxane (D4), decamethylcyclopentasiloxane (D5), and dodecamethylcyclohexasiloxane (D6) - are used in a number of commercial applications, such as intermediates for the polymerization of polyorganosiloxanes, cosmetic and personal care products, defoamers, sealants, adhesives and coatings. Their environmental fate has been evaluated in a typical secondary activated sludge wastewater treatment plant (WWTP). A municipal WWTP serving a domestic and industrial community of approximately 285,900 people and discharging to Lake Ontario was selected for this study. Water samples (influent, primary effluent, and final effluent) and sludge samples (primary sludge and waste activated sludge) were collected at overnight low, morning high, afternoon low, and evening high flows, respectively. Concentrations of cVMS in influents fluctuated with various influent flows, reaching peaks at morning and evening high flows. The aqueous phase removal efficiency was >80% of cVMS. Mackay?s fugacity-based treatment plant model (STP-EX) was used to simulate the fate of cVMS through this WWTP. Due to the unusual combination of hydrophobicity and high volatility of cVMS, the removal from water by partitioning to sludge and volatilization in the aeration tank were estimated to contribute equally to the total removal in this WWTP based on the experimental and modeling results. The morning and evening high influent mass flows of D5 accounted for 37% and 40% of total daily mass, respectively. The morning and evening high influent mass flows contributed almost equally at approximately 40% of the total daily cVMS mass, with D5 accounting for the majority of this loading.

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Partitioning of a Suite of Chlorobenzenes (1,2,4,5-tetrachlorobenzene, pentachlorobenzene, and hexachlorobenzene) to Aldrich Humic Acids and Municipal Wastewater Treatment Plant Colloids

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Municipal wastewater treatment plants (MWTPs) can be a source of exposure to human and ecological receptors for many contaminants of concern through loadings via MWTP effluent discharges to receiving waters. These loadings depend on fate and transport of contaminants through the MWTP process. Submicron size or colloidal organic matter (COM) possess large surface areas that can facilitate binding of hydrophobic organic compounds (HOCs). HOC sorption to colloids has been studied in natural environments; however, few studies have investigated their sorption to MWTP colloids.

The study objective is to improve understanding of partitioning of HOCs to MWTP primary effluent COM. Sorption of three chlorobenzenes (1,2,4,5-tetrachlorobenzene, pentachlorobenzene, and hexachlorobenzene) to 1.5 μm filtrate of primary tank effluents was examined using the gas sparging technique. Six spargers were used in parallel which allowed for concurrent replication of controls and treatments. Chlorobenzenes (CBs) are a diverse chemical suite with widely varying physico-chemical properties presenting an ideal choice for better understanding of partitioning behaviour. Sorption of CBs to standard Aldrich humic acids (AHA) was conducted for comparison.

Results show significant sorption of all CBs to effluent COM. Sorption behaviour was different as compared to AHA when normalized to organic matter. AHA sorption behaviour was similar to literature values and followed typical HOC binding. In contrast, no clear trend of sorption behaviour with effluent COM was observed, contrary to expected trends based upon physico-chemical properties. Implications of results will be discussed and potential further study recommended.

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Occurrence and Treatment Of Polybrominated Diphenyl Ethers in Canadian Wastewater Treatment Plants

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Detection of polybrominated diphenyl ethers (PBDEs) is ubiquitous in the environment as a result of their extensive use as flame retardants over the last four decades. Concern about their presence in the environment is increasing since they were globally classified as hazardous substances to human and environmental health. According to their chemical structure, 209 different PBDE congeners can exist however, BDE-47,-99 and -209 are predominantly detected at highest levels in the environment since these congeners were the principal BDE congeners in commercial products. In 2006, the Government of Canada implemented the Chemicals Management Plan, including a monitoring program for chemicals categorized as persistent, bioaccumulative, and/or inherently toxic to human and/or environmental health. This report is a part of the monitoring program conducted on PBDEs from twenty Canadian wastewater treatment plants (WWTPs) consisting of four aerated lagoons, two facultative lagoons, four primary treatment, eight secondary treatment and two advanced treatment plants. Results showed that the incoming concentrations of PBDEs to WWTPs varied widely from 21 to 1009 ng/L whereas PBDE levels leaving WWTPs to watersheds ranged from 3 to 266 ng/L. The occurrence of PBDEs was influenced by industrial wastewater input and seasons rather than community size. PBDE treatment varied over the type of WWTPs and median values of removal efficiencies were 96% (aerated lagoon), 97% (facultative lagoon), 70% (primary treatment), 91% (secondary treatment) and 96% (advanced treatment). BDE-209 was the predominant congener in influent and effluent samples accounting for 41 and 31 % of total PBDEs, respectively.

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Characterizing Micellar Enhanced Ultrafiltration for the Removal of Sulfonamide Antibiotics from Wastewater

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The removal of pharmaceutical and personal care product chemicals by conventional wastewater treatment is typically inefficient and in many cases is poorly characterized. Micellar enhanced ultrafiltration (MEUF) has been proposed as a new method for removing these contaminants, based on the increasing use of ultrafiltration and related technologies in wastewater treatment. We have characterized the association of a series of sulfonamide antibiotics with micelles as a model system for MEUF. The sulfonamides include a variety of compounds that are too small to be removed by conventional ultrafiltration and too water soluble to be removed by common adsorption methods.

We have developed methods to characterize the specific interactions of the sulfonamides with micelles and relating binding constants to properties of the sulfonamide and surfactant molecules, including log K_{OW} and charge parameters. We used a semi-equilibrium dialysis method to demonstrate physical sequestering of sulfonamides behind a dialysis ultrafiltration membrane. Binding constant values were determined by measuring concentrations on either side of the membrane under specific conditions. The locus and orientation of binding in micelles were determined by proton nuclear magnetic resonance (^{1}H NMR) spectroscopy. Relatively hydrophilic sulfonamides coordinated weakly with the charged outer layer if opposite charges were available. The strongest binders were hydrophobic sulfonamides that penetrated deeper into the micelle interior while still coordinating with the charged headgroups. Our results indicate that it may be possible to use conventional properties of molecules to predict MEUF efficiency for a wide range of contaminants that might be found in wastewater.

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A Study on Ozone Treatment of Municipal Wastewater Effluent and Oxidation of Chemicals of Emerging Concern

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Municipal wastewater treatment plant (MWWTP) discharges are a major source of several chemicals of emerging concern (CECs), including endocrine disrupting chemicals (EDCs) and pharmaceutical and personal care products (PPCPs). Conventional wastewater treatment processes are not efficient in removing the CECs. The long-term effect of these compounds on human health is still unclear. However, CECs in wastewater discharges have been linked to feminization of vertebrates such as fish, reptiles, birds and mammals. This is a cause of concerns and prompts to take precautionary measures. MWWTP discharges are also a major source for pathogenic microorganisms.

Ozone is a very powerful oxidant and its efficacy for disinfection is well established. However, process related issues and cost had prevented its widespread use. Recent research indicates ozone to be effective in the oxidation of several CECs from wastewater matrices. Hence, there is a renewed interest in its application for wastewater treatment to achieve dual objective of disinfection and chemical oxidation. The effectiveness of ozonation is strongly influenced by wastewater characteristics and process variables. Continued research is needed to establish the effect of variables on the effectiveness of the process and develop strategies for better process control. In the present study, a 4 L/min pilot plant has been set-up at the Little River Pollution Control Plant, Windsor, for ozonation of secondary treated wastewater effluent. Experiments were conducted to examine the effect of ozone treatment on wastewater characteristics, disinfection, and transformation of CECs including several pharmaceuticals and EDCs. The results and their implications will be discussed.

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Great Lakes Nearshore Water Quality Issues

Co-Chair: Veronique Hiriart-Baer, Environment Canada
Co-Chair: Jacqui Milne, Environment Canada

Session Description
Nearshore environments are highly productive ecotones where much of the terrestrially derived organic and inorganic material is processed. They are vital ecological links between watersheds, tributaries, wetlands, groundwater and lake offshore waters and provide valuable ecosystem services such as drinking water and wildlife habitat. Nearshore environments are also vulnerable to anthropogenic stressors and nuisance algal growth, beach closings and habitat loss are but a few symptoms diagnostic of nearshore ecosystem disruptions. This session will focus on understanding ecosystem processes related to water quality management in the nearshore zone. Papers covering all levels of organization, from molecular to organism to ecosystems are encouraged.
Keywords: Nearshore; water quality; ecosystem processes.

Establishing Great Lakes Water Quality Targets To Manage Nearshore Algal Issues

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The Great Lakes nearshore zone is a precious resource that provides water for drinking, industrial uses, and recreational activities while at the same time receiving wastewater effluent and run-off from both urban and agricultural areas. The nearshores of Lake Huron, Lake Erie and Lake Ontario are all experiencing harmful and or nuisance algal issues as a result of ecosystem changes. In order to effectively manage these nearshore algal issues new ecosystem restoration targets need to be identified, that considers landbase, nearshore and offshore processes. The IJC and various U.S. and Canadian environmental agencies are recommending that the new Great Lakes Water Quality Agreement (GLWQA) consider setting additional, specific water quality targets for the protection of the nearshore zone of the Great Lakes to ensure the current and future health of the ecosystem, ecological services, and economic sustainability for Great Lakes communities and residents. This talk summarizes some of the challenges associated with identifying and setting appropriate targets for the nearshore of the Great Lakes.

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Fine-scale Nutrient Enrichment in an Oligotrophic Environment Undergoing Oligotrophication: the Rural Shores of Lake Huron

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A defining feature of the coastal environment of southeastern Lake Huron is the proximity of intensive agriculture to a shoreline that is heavily used for recreation and residential development. Fouling of the shoreline by algae and a presumption of nutrient enrichment in the nearshore has been a source of public complaint over parts of the coastline in recent years. Levels of total phosphorus in the offshore have been falling over the same approximate time frame. The highly oligotrophic conditions of the lake implies that the nearshore interface with the offshore is a nutrient deficient region of high water clarity where external inputs of biologically available phosphorus are expected to evoke strong biological responses. Previous nearshore monitoring has suggested that strong variability in water quality occurs along the shoreline but may not extend into the broader nearshore making the detection of nutrient enrichment by conventional vessel-based surveys uncertain. In 2010 spatial patterns in nutrient levels extending from the shoreline to five kilometers offshore were examined over 30 km of coastline. Tracers of connectivity between the adjacent land and lake were used to identify areas of nutrient input over the shoreline. Here we examine evidence for the assertion that shoreline and tributary runoff impacts nutrient levels at the shores of Lake Huron and further examine the features of nutrient gradients extending from the sometimes perturbed shoreline zone to the highly oligotrophic offshore.

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Modeling of Circulation and Tracer Distribution in Western Lake Ontario and Hamilton Harbour

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The three-dimensional hydrodynamic Estuary Lake Coastal Ocean Model (ELCOM) was used to study the water circulation and contaminant dispersion in Western Lake Ontario and Hamilton Harbour. To asses the model performance, we first simulate the circulation and temperature distribution of the lake in 2006 and compare the model results with the observations made in the lake during this period. The model showed considerable skill in reproducing the thermal structures and circulations. The simulated currents are used to examine the transport and dispersion of passive particles in Western Lake Ontario and Hamilton Harbour. Numerical results demonstrate that the movements of passive tracers are primarily controlled by the wind-driven currents.

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Effect of Beaver-Dam Impoundments on Water Chemistry of Coastal Marshes in Eastern Georgian Bay

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Coastal Marshes of eastern Georgian Bay are naturally dystrophic systems with water quality reflecting the ion rich waters of Georgian Bay and the ion poor water from the shield landscape. Past research has examined the effect of landscape variables on the water chemistry of these coastal marshes but the influence of a biotic factor such as a beaver is unknown. Marshes form along the convoluted shoreline of granite bedrock and as a consequence can have a narrow outlet that connects them to the open bay. Beavers have been observed to build dams across this outlet, impounding the water changing the hydrology and associated water chemistry. Our goal is to determine whether or not the presence of a beaver dam will have an effect on the water chemistry of the coastal marsh. During the summer of 2010 and 2011, 33 marshes were sampled, 15 of which had beaver impoundments built at the outlet of the coastal wetland. Water-chemistry parameters included total phosphorus, soluble reactive phosphorus, total nitrate nitrogen, total ammonia nitrogen, chlorophyll a, total suspended solids, pH, and conductivity. Additionally, colour and dissolved organic carbon were measured in 2011. We found that a disconnection of a coastal marsh from Georgian Bay will have a significant effect on water chemistry variables driven by lake processes such as conductivity, pH and sulphate. We also observed distinct variation in water chemistry between coastal marshes and beaver impounded coastal marshes. Our results can help refine the set of criteria used to determine reference water-quality conditions for coastal wetlands in the Georgian Bay Biosphere Reserve.

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Occurrence and Predictive Correlations of *E. Coli* and *Enterococci* at Sandpoint Beach (Lake St. Clair), Windsor, ON and Holiday Beach (Lake Erie), Amherstburg, ON.

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Point and nonpoint sources contribute to contamination of surface waters by human pathogens. These pathogens exist at low concentrations and are difficult, expensive, and/or impossible to easily detect, therefore, Fecal Indicator Bacteria (FIB) are used as surrogates in identification of fecal contamination. Most common FIB are *Escherichia coli* (*E. coli*) and *Enterococcus spp.* (*Enterococci*) Ontario guidelines specify a level of ≤100 *E. coli*/100 mL at recreational beaches to protect from adverse health effects from exposure to water-borne pathogens.

This study investigated of *E. coli* and *Enterococci* over 30 days at Sandpoint Beach (Windsor, ON) and Holiday Beach (Amherstburg, ON). Three 100 mL samples were collected daily for each of *E. coli* and *Enterococci* for analysis by Colilert® and Entrolert®, respectively. These methods are approved by US EPA and included in *Standard Methods for the Examination of Water and Wastewater*. Physico-chemical and site specific parameters were taken on-site and wind observations were taken from Environment Canada archives.

Results indicate that *E. coli* and *Enterococci* populations were dynamic and well correlated at both beaches ($p<0.05$; ANOVA). Pearson's *r* correlations of parameters indicate that both populations correlate with turbidity and wave height ($p<0.10$; ANOVA). However, various other parameters such as rainfall, water temperature, and wind direction were also correlated for some data. Despite being geographically close and therefore having similar meteorological data, both beaches exhibited markedly different FIB, turbidity, and wave height data. Beach specific data must be considered for any future predictive applications.

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Microbial Source Tracking of Fecal Pollution Sources at Region of Niagara Beaches

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Environment Canada's National Water Research Institute, McMaster University and the Region of Niagara are collaborating to investigate water quality at Niagara beaches. An initial focus has been to apply microbial source tracking tools to identify sources of human sewage contaminating beaches, as these fecal pollution sources are generally regarded to present the highest human health risks. During the 2010 bathing season, a total of 2096 water samples were analyzed across 15 beaches on Lake Ontario and Lake Erie. Water samples were analyzed to enumerate *E. coli* and detect the HF183 DNA marker for human *Bacteroidales* strains of bacteria. The highest *E. coli* concentrations were measured at Garden City Beach in St. Catherines (mean=286 cfu/100mL; max=4500 cfu/100mL) and Queen's Royal Beach in Niagara-on-the-Lake (mean=257 cfu/100mL; max=4160 cfu/100mL). The HF183 DNA marker for sewage was most commonly detected at Queen's Royal Beach (43% of sampling days) and Garden City Beach (31%). This DNA marker was also frequently detected in some stormwater outfalls and agricultural drains nearby beaches. Investigations focused on 8 of the 15 beaches during the 2011 bathing season. This research is guiding remedial actions that may be needed to improve water quality at some beaches for them to qualify as candidates for Blue Flag status, and to address beach Beneficial Use Impairments in the Niagara Area of Concern. McMaster University's new MacWater Initiative is expanding this research to advance applications of molecular diagnostic tools and wireless real-time water quality monitoring tools for assessing water quality in the Niagara Region.

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Virulence of *Escherichia coli* in Receiving Waters Impacted by Wastewater Effluents

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To better understand the effects of UV disinfection on the occurrence of virulence and antibiotic resistant genes in E. coli found in municipal wastewaters and their receiving waters, DNA microarrays were used to conduct virulence genotyping and profiling. The microarrays consisted of 348 virulence genes and 98 antibiotic resistance genes. 540 E. coli isolates were collected in May 2011 from 6 locations at the Skyway Wastewater Treatment Plant (Burlington, Ontario) and the Hamilton Harbour, which is the receiving water body for the plant?s effluent. Samples were also collected from an avian nesting area to distinguish between wild birds and municipal effluents as possible sources of virulent E. coli isolates. Preliminary results show that a high percentage (34.6%) of all of the isolates collected at the treatment plant and in the harbour carried a set of virulence-related genes corresponding to a given pathotype, which is similar to previous studies of wastewaters and natural waters. An unexpectedly high proportion (8%) of Shiga toxin-producing E. coli (STEC) were found in the isolates collected from municipal wastewater before UV treatment. After treatment, no STEC were detected in the discharged plant effluent or in the harbour, suggesting that UV disinfection is effective at controlling the environmental discharge of STEC pathogens from municipal wastewater. Also, 50% of the STEC isolates harboured at least one antibiotic resistant gene from the aminoglycoside, ?-lactam, phenicol, trimethroprim and tetracycline groups. There was no increase of the occurrence of STEC in the avian nesting area.

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Harmful Algal Blooms and Source Water Impacts: Causes, Consequences and Controls

Co-Chair: Sue Watson, Environment Canada
Co-Chair: Jennifer Winter, Ontario Ministry of the Environment
Co-Chair: Lewis Molot, York University

Session Description

Harmful Algal Blooms (HABs) are an increasing concern in lakes and rivers throughout the world. Although algal blooms can be natural phenomena, they have expanded as an issue in Canada over the last several decades in terms of both extent and public perception They have major socioeconomic and ecological impacts – costing the USA, for example, an estimated ~ $2 – 4.6 billion /yr in response monitoring, fisheries, tourism, public health & advisory, lost revenue & property value. Blooms of cyanobacteria are of particular concern in freshwater systems because of their potential for toxins (cyanotoxins) which impact human and animal health and can affect freshwater ecosystem processes. However, non-toxic algal taxa also produce harmful blooms. Thick mats of Cladophora and Lyngbya are becoming increasingly problematic in inshore areas of the Great Lakes and elsewhere. Many algae (including cyanobacteria) and other microorganisms (e.g. Actinomycetes, fungus) release noxious taste and/or odour causing compounds that have major negative impacts on the public and the drinking water industry.

This session will have three parts;

I. HABs: causes and monitoring (who, why, field detection and monitoring methods) Papers are invited that focus on research into HAB species, their ecophysiology, metabolites and and toxicity, environmental factors promoting their dominance and methods used for bloom and toxin detection and monitoring (from molecular to remote sensing),

II. HABs: consequences and controls (toxins, treatment, risk management, nutrient management, public outreach, stewardship etc.) This session invites papers dealing with trends in algal bloom reporting, costs and approaches to bloom risk management strategies, treatment and long term remediation and management and public outreach/stewardship.

III. Panel discussion (open to public) to further explore algal bloom issues in Canada.

Evidence on Human Health Risk Resulting From Exposure to Harmful Algal Blooms; Specifically Cyanobacteria and Cyanotoxins

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The question of human health risk resulting from exposure to cyanobacteria and their toxins has been one of longstanding and impassioned discussion at all levels of government and across various organizations with a common public health interest. Review of evidence for human health risk resulting from exposure to cyanobacteria and cyanotoxins can be used in decision-making about the need for, and design of, interventions to reduce risk.

This work provides a critical review of the current human health and exposure evidence resulting from recreational water, drinking water, and food. With a primary target audience of decision-makers at the municipal and provincial levels, the current scientific literature was reviewed to obtain a scope of the issue, identify pertinent concerns, determine relevance of concerns, and to discuss measures for limiting human exposure and best management practices for controlling blooms and exposure to cyanotoxins.

A stepwise process was followed for the review. The evidence was assessed with respect to its merit to answer the research question and the methodology used for the review. Comments on the evidence, findings and potential policy directions are provided. A potential framework for use in determining the value of the evidence for different potential human health effects is presented.

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Occurrence, Levels and Distribution of Cyanobacterial Toxins in Ontario's Municipal Drinking Water and Drinking Water Sources, 2004-2010

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The Ontario Ministry of the Environment's Drinking Water Surveillance Program (DWSP) has monitored for cyanobacterial toxins in untreated source water and treated drinking water at selected municipal drinking water systems in Ontario since 2004. From 2004-2010, nearly 1100 samples were collected at 18 drinking water systems. These samples were analyzed using liquid chromatography – (electrospray ionization) tandem mass spectrometry [LC-(ESI)MS/MS] to quantify the concentration of microcystins -LA, -LR, -RR, and –YR, nodularin and anatoxin-A. Cyanobacterial toxins were detected in only 0.4% of treated drinking water samples from two drinking water systems. Concentrations were very low and on the one occasion when microcystin-LR was detected, the concentration was 25 times lower than the ODWQS. In untreated source water, there was a rate of detection of 42% in the samples that were collected at 12 drinking water systems. Microcystin-LR was most frequently detected variant in untreated source water and the maximum concentration was 3.4 μg/L. The next most frequently-occurring cyanobacterial toxins were microcystins-RR and –LA, with maximum concentrations of 1.2 and 0.29 μg/L, respectively.

This paper discusses the occurrence, levels and distribution of cyanobacterial toxin detections in untreated source water and finished drinking water in Ontario from 2004-2010.

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Cyanobacteria and Cyanotoxins Breakthrough and Accumulation in Three Drinking Water Treatment Plants in Quebec

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The detection of cyanobacteria and their associated toxins has intensified in recent years in drinking water sources in Quebec. The objectives of this study were to: (1) monitor cyanobacteria and cyanotoxins breakthrough and accumulation in full-scale treatment processes and to identify the key factors influencing the accumulation of toxic cells in drinking water treatment plants (DWTPs); and (2) propose monitoring and operational solutions to manage and if possible prevent this accumulation.
In three full scale Quebec DWTPs (summer-fall of 2008 to 2011), water samples were taken at raw water, after the addition of coagulant and powdered activated carbon, after clarification, within the clarifier sludge bed, after filtration and after chlorination, for cyanobacterial taxonomic enumeration/identification, and cyanotoxins analysis. Also, a novel procedure was introduced for in vivo monitoring of water quality after each process.

Cyanobacteria entered the plants and formed highly toxic scums over the clarifiers of the DWTPs with up to 10331.2µg/L of total microcystins (9180.0µg/L MC-LR). Furthermore, elevated cyanobacterial cell numbers (4,700,000cells/mL) and total microcystins concentrations up to 40µg/L, accumulated in the sludge bed of the clarifiers of the DWTPs. Breakthrough of cells and toxins in filtered water was also observed causing increase in filtered water turbidity. A total microcystins concentration of 2.47µg/L (1.74µg/L MC-LR) was measured in chlorinated drinking water. Infiltrated cyanobacterial cells and toxins from environmental bloom were more resistant to chlorination than results obtained using laboratory cultured cells and dissolved standard toxins. In vivo cyanobacteria monitoring is essential for adequate treatment adjustment to prevent these events.

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Design and Development of Universal Molecular Probes for the Geosmin Synthase in Cyanobacteria and Actinomycetes

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Geosmin (trans-1,10-dimethyl-trans-9-decalol) is a potent earthy-smelling sesquiterpene which is singularly responsible for the global majority of reported taste and odour (T&O) episodes in drinking and recreational water and major economic losses to commercial, farmed and sports fisheries through fish tainting. Geosmin is produced by a range of microorganisms, most notably cyanobacteria and actinomycetes, but to date, effective and proactive management has been hindered by our inability to identify the major biological sources, and develop sensitive methods for early warning of T&O events. The main goal of this study, therefore, has been to develop a taxon-specific real-time PCR assay which allows i) an early warning of potential geosmin releases and identification of the likely sources; ii) the development of a threshold criterion that can be used to evaluate the level of risk of a T&O outbreak, and iii) control and treatment of T&O episodes. We have developed a rapid molecular assay for the detection and quantification of geosmin synthase (*gsm*) in cyanobacteria and actinomycetes from both cultures and environmental samples. These probes will provide powerful diagnostic tool for managing potential T&O episodes. To date, the molecular probes for *gsm* in cyanobacteria have been successfully developed and tested. Using the probes we were able to detect *gsm* in both geosmin producing cultures and environmental samples with a range of geosmin levels. From our initial work, we show that the dominant geosmin producers among cyanobacteria in Bay of Quinte are represented by *Anabaena lemmermanii*. Lake Erie sample analysis revealed that the majority of geosmin producers in the central basin are closely related to *Anabaena ucrainica*. In contrast, geosmin producers from Sandusky River of the Lake Erie western basin are most closely associated with *Lyngbya* spp.

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Toxic Cyanobacteria Blooms Along the Southern Embayment's of Lake Ontario, NY: History and Current Status

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Toxic blooms of cyanobacteria are commonly observed in the western basin of Lake Erie, Missisquoi Bay of Lake Champlain, and in the Bay of Quinte, Lake Ontario. During these blooms hepatotoxic peptides called microcystin(s), or neurotoxin such as anatoxin-a, may be produced by one or more of several species of cyanobacteria. Less is known about the occurrence of cyanobacterial toxins in other embayments of Lake Ontario. Starting in 2001, we have periodically sampled both embayment and nearshore waters along the southern shore of Lake Ontario for the presence of cyanobacteria toxins. In general – the levels of observed toxins in these locations have been relatively low and rarely exceeded the WHO guidelines for either drinking water or recreational contact. However this dramatically changed in 2010 and 2011 when high levels of microcystin toxins, exceeding 100 ug per liter in 2010 were observed in Greater Sodus Bay near Rochester. These blooms were accumulated by the wind along the northern shore of the Bay and posed a potential hazard to human contact. In response, the New York Department of Health closed several site to recreational contact. These blooms also caused major economic disruption to the region, forcing the cancelation of housing reservations and a visitor exodus during the busy Labor Day holiday weekend. The spatial and temporal distribution of this bloom, its putative causative organism, as well as environmental and other factors leading to its occurrence will be discussed.

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Extreme Inter-Annual Variability in Cyanobacterial Blooms in an Urban Drinking Water Supply, Quebec (Canada)

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Lake Saint-Charles provides drinking water for more than 230 000 residents in Québec City. From Fall 2006 onwards, cyanobacterial blooms have been observed in the lake and have created water quality concerns. Our research aims to identify the dominant causal factors of cyanobacterial blooms in this lake by way of analysis of the spatial and temporal variations in phytoplankton community structure, and their relationships with environmental variables. Over a period of 5 years we have made measurements of phytoplankton biomass, species composition, physical and chemical variables (temperature, oxygen, conductivity, pH, turbidity, and various forms of nitrogen, phosphorus and carbon). Meteorological data (wind, precipitation, temperature) have also been obtained. The analysis of phytoplankton community revealed large variations, both spatially and over time. The north basin of the lake had consistently higher concentrations of bloom-forming cyanobacteria (Microcystis aeruginosa and Anabaena flos aquae) than the south basin. The dominant taxa of phytoplankton were extremely variable, both throughout the period of sampling each year, and among years. The spatial and temporal occurrence of cyanobacteria was significantly correlated with total phosphorus and total nitrogen concentrations. Although many variables showed little change among years, there were large differences in meteorological parameters in terms of amplitude, frequency and intensity, which likely played a secondary role in controlling the trajectory of phytoplankton succession toward dominance by specific taxa. Our data underscore the need for improved monitoring and forecasting of cyanobacterial biomass and species, and the dynamic nature of noxious blooms in terms of amplitude, spatial distribution, and composition.

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Increases in Algal Bloom Reports in Ontario from 1994 to 2010: Did the Trend Continue in 2011?

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We observed a significant increase in the number of algal blooms reported each year in Ontario, Canada from 1994 to 2010 ($P < 0.001$), with increases beginning in the mid-2000s. The greatest rate of increase was in blooms of cyanobacteria ($P < 0.001$). We attributed this trend to increases in nutrient inputs in some areas which promote the growth of algae, factors associated with climate warming which may exacerbate bloom conditions, and an increase in public awareness of algal blooms and associated issues. The increasing trend in cyanobacterial bloom reporting continued in 2011. Several of the lakes from which blooms were reported were characterized by higher median spring total P concentrations (15 ?g/L) compared to a dataset from 1074 Ontario lakes (9 ?g/L). In the absence of more detailed water chemistry data, land use around lakes experiencing blooms was explored to determine whether there were any common characteristics. The proportions of different land use types were analyzed around twelve lakes on the Canadian Shield experiencing cyanobacterial blooms and around twelve nearby lakes from which no blooms had been reported. Principal component analysis (PCA) revealed that six of the lakes with blooms were distinct from the other lakes based on their surrounding land use. Three were separated along a gradient of a greater proportion of human settlement, and others along a gradient of more pasture and cropland. This approach shows promise for identifying lakes that may be at risk for cyanobacterial blooms based on their surrounding land use.

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Predicting the Risk of Proliferation of the Benthic Cyanobacterium *Lyngbya wollei* in the St. Lawrence River

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Harmful proliferations of the benthic cyanobacterium *L. wollei* have been reported with increasing frequency in the last 30 years in rivers, lakes, reservoirs, and springs in North America. We determined *L. wollei* 's distribution over a 250-km stretch of the St. Lawrence River (SLR; Quebec, Canada), to elaborate a predictive models of its presence-absence (Bayesian Model Averaging of logistic regression) and of its biomass (Regression Tree Analysis) based on chemical and physical environmental conditions. In 2008, *L. wollei* was observed at 37 of the 113 sites sampled reaching a biomass > 1 g DM m^{-2} at only 18 sites. *L. wollei* was generally found downstream of the inflow of tributaries draining farmlands, in plumes flowing along the SLR shoreline, characterized by high DOC (+ effect), low TP (- effect) and low DIN:TDP ratio (- effect). These environmental variables best predicted the occurrence and biomass of *L. wollei*. Validation of the predictions on an independent dataset (2006-2007) comprising 184 samples from two SLR fluvial lakes revealed that the overall risk of *L. wollei* occurrence in the SLR was successfully forecasted by our models, which correctly predicted its absence in 72-92% of cases. Our study contradicts the classic linkage between eutrophication and harmful algal proliferation because *L. wollei* thrived under reduced nutrient concentrations, yet it highlights the complexity of biotic interactions favoring potentially heterotrophic, diazotrophic cyanobacteria, which lead to a simplified, less productive ecosystem.

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Development and Field Application of a Multiplex PCR Approach for Improved Monitoring of Harmful Algal Blooms

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Increasing incidences of potentially toxic cyanobacteria in freshwater bodies pose significant challenges for water quality management in Canada and globally. The co-occurrence of morphologically indistinguishable toxic and non-toxic strains within the same bloom makes their monitoring and control particularly challenging. This has necessitated the development of sensitive and specific tools for discriminating toxic from non-toxic cyanobacterial species.

In this study, a multiplex real-time quantitative polymerase chain reaction (qPCR) approach was developed and tested for its sensitivity and specificity at detecting and estimating potentially toxic cyanobacterial from the Anabaena, Microcystis and Planktothrix genera. The oligonucleotide primers and probes utilized were designed to target portions of the microcystin synthetase gene E (mcyE) that encode the synthesis of the unique Adda moiety of microcystins in the three target genera.

Laboratory evaluation showed the developed assay to be highly sensitive and specific at detecting and quantifying targeted species. Indeed, the assay standards for the Anabaena, Microcystis and Planktothrix reactions attained efficiencies above 96%, with coefficients of determination of respectively 0.993, 0.992 and 0.995. Additionally, the assay detection limit was generally below 4 mcyE copies per reaction for all three cyanobacterial genera investigated. Analysis of water samples from the Missisquoi bay, Quebec resulted in detection and estimation of target toxigenic cyanobacterial strains in water samples even when cell numbers were still below the limit of detection for most conventional detection methods. Thus, this robust method provides simultaneous detection, differentiation, and quantification of toxigenic cyanobacteria that otherwise cannot be accomplished by other currently used monitoring approaches.

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Defining the 'Sweet Spot': N:P and Iron Conditions Promoting Cyanobacterial Proportion in Ontario Lakes

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Freshwater cyanobacterial harmful algal blooms (CHABs) are publically associated with large eutrophic lakes. In the past decade, increasing observations of CHABs in small oligotrophic lakes within the Laurentian Great Lakes basin have been documented. This may suggest changes in factors influencing cyanobacterial bloom formation. We investigated biogeochemical drivers of cyanobacterial proportion within lakes in the Algoma Highlands of central Ontario. We sampled the same 25 unmanaged lakes during peak algal biomass from 2009-2011 for [P], [N], and [Fe] (determinants of biomass and biodiversity) and assessed the algal community composition using established methods in flow cytometry (FCM). The ratio of N:P versus cyanobacteria revealed a distinct "sweet spot" in cyanobacterial abundance (around N:P=13). Algal communities containing the greatest proportion of cyanobacteria (>10%, where greatest variation among lakes is observed) occurred within a narrow range of Fe^{3+} availability (pFe21-pFe23) and in lakes with significantly higher [inorganic N] ($p<0.01$) and [NO_3^-] ($p<0.01$) compared to lakes with <10% cyanobacteria in the algal community, which had significantly higher [organic N] ($p<0.001$) and [TP] ($p<0.001$). Our findings suggest an increased susceptibility of oligotrophic lakes to CHAB formation when nitrogen supplies shift from organic to inorganic (NO_3^-) forms.

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Modelling Cyanobacteria Dominance: How Useful are the Complex Mathematical Models?

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Simple models have significant contribution to the development of ecological theory. However, these minimalistic modeling approaches usually focus on a small subset of the causes of a phenomenon and neglect important aspects of system dynamics. In this study, we use a complex aquatic biogeochemical model to examine competition patterns and structural shifts in the phytoplankton community under nutrient enrichment conditions. Our model simulates multiple elemental cycles (org. C, N, P, Si, O), multiple functional phytoplankton (diatoms, green algae and cyanobacteria) and zooplankton (copepods and cladocerans) groups. It also takes into account recent advances in stoichiometric nutrient recycling theory, and the zooplankton grazing term is reformulated to include algal food quality effects on zooplankton assimilation efficiency. The model provided a more realistic platform to examine the functional properties (e.g., kinetics, growth strategies, intracellular storage capacity) and the abiotic conditions (temperature, nutrient loading) under which the different phytoplankton groups can dominate or can be competitively excluded in oligo-, meso- and eutrophic environments. Our analysis suggests that the intergroup variability in the minimum cell quota and maximum transport rate at the cell surface for phosphorus along with the group-specific metabolic losses can shape the structure of plankton communities. We also use classification tree analysis to elucidate aspects (e.g., relative differences in the functional group properties, critical values of the abiotic conditions, levels of the other plankton community residents) of the complex interplay among physical, chemical, and biological factors that drive epilimnetic plankton dynamics. Finally, our study highlights the importance of improving the mathematical representation of phytoplankton adaptive strategies for resources procurement (e.g., regulation of transport kinetics, effects of transport kinetics on the kinetics of assimilation, relationship between assimilation and growth) to effectively link variability at the organismal level with ecosystem-scale patterns.

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The Phosphorus-Ferrous Eutrophication Model: the Role of Anoxia and Internal Loading in Cyanobacteria Dominance in Four Small Soft Water Lakes and Hamilton Harbour, Ontario

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Evidence suggests that the supply rate of ferrous iron (Fe(II)) from anoxic sediments plays a major role in the displacement of eukaryotic phytoplankton by cyanobacteria in eutrophic freshwaters. We hypothesized that the onset of cyanobacteria dominance depends on internal loading of Fe(II) from anoxic sediments reaching hypolimnetic waters adjacent to the metalimnion. Temporal relationships between hypoxia (a proxy of anoxia), internal loading of Fe(II) and total phosphorus (TP), and onset of cyanobacteria dominance were investigated in four soft water lakes in central Ontario (oligotrophic Blue Chalk, mesotrophic Three Mile, eutrophic Brandy), artificially eutrophic Lake 227 in northwestern Ontario and hard water, eutrophic Hamilton Harbour. Cyanobacteria dominance occurred in all lakes during at least part of the summer except Blue Chalk. Development of hypolimnetic hypoxia and internal loading of Fe(II) and TP adjacent to the metalimnion preceded the onset of dominance in all lakes except in Three Mile where TP increased after. Onset of cyanobacteria dominance occurred in June in the soft water lakes but two months later in Hamilton Harbour, possibly because the latter's much higher sulfate concentration may have restricted Fe(II) diffusion from anoxic sediments via iron sulfide precipitation. Internally loaded nutrients were observed in shallow waters deep enough to stratify in Hamilton Harbour. These inshore regions may provide critical habitat for acquiring nutrients because of closer proximity of anoxic sediments to the metalimnion. Results suggest that controlling anoxia is the key to minimizing blooms; hence, loading targets for P and oxygen-consuming substances should ensure that hypolimnetic sediments are oxidized to the greatest extent practical to reduce both productivity and the risk of bloom formation.

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Comparison of Phytoplankton Variable Fluorescence from Three Pulse Amplitude Modulated (PAM) Fluorometers

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Variable fluorescence (Fv/Fm) of Photosystem II (PSII) is the difference between maximal and minimal fluorescence normalized to the maximal fluorescence. It measures the quantum efficiency of PSII, which is sensitive to environmental stressors. Pulse amplitude modulated (PAM) fluorometers (including DivingPAM, WaterPAM, and PhytoPAM) measure Fv/Fm and are becoming useful phytoplankton monitoring tools.

Phytoplankton samples were collected from stations in all basins of Lake Erie during two cruises in July and September 2011. Dark-adapted Fv/Fm was measured using the DivingPAM, WaterPAM and PhytoPAMs. Fv/Fm from the different PAMs did not have a 1:1 correspondence. Results from the WaterPAM and PhytoPAM were positively correlated. DivingPAM results were uncorrelated with the other two and displayed lower values overall. DivingPAM results seemed to indicate some sort of stress affecting PSII, while other PAM results did not suggest strong stress.

This suggests that the Fv/Fm measured from one PAM is not directly comparable to results from another. Results might have been influenced by differences in sample preparation methods for the different instruments and the different excitation and measuring wavelengths of the instruments. It is, therefore, inappropriate to assume that different PAMs yield the same results; this is especially important when synthesizing the results from many different studies.

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Nitrogen Fixation Strategies in Cyanobacteria Under Different Light Regimes

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Some cyanobacteria have the ability to fix atmospheric nitrogen (N_2) and out-compete other non-fixing cyanobacteria and eukaryotic algae when biologically available sources of N are depleted (ammonia, nitrate, or urea). Nitrogenase, the enzyme responsible for nitrogen fixation, is inhibited by oxygen, and thus fixers must enable anaerobic conditions to support this process. Nostocalean cyanobacteria achieve this through the production of specialized non-photosynthetic cells (heterocysts) at intervals along their filaments, which support N_2 fixation using the energy derived from ATP produced by photosynthesis by adjacent cells. For these taxa, fixation in most cases is light-dependant. Some non-heterocystous cyanobacteria are known to use alternative strategies – carrying out fixation and photosynthesis in spatially distinct zones within the cell, in temporally segregated series throughout the day or limiting fixation to dark periods at night or non-illuminated environs. However it is not known how widespread this capacity is amongst different taxa

The Lower Great Lakes (notably Lake Erie) and other waterbodies have a diverse assemblage of heterocystous and non-heterocystous cyanobacteria, some of which produce noxious blooms and cause widespread impairment. Evidence points to phosphorus as the primary nutrient driving these outbreaks, but studies have also shown periods of N-defiency among the plankton community, and it is not known to what extent N_2 fixation plays a role in enabling the dominance and success of cyanobacteria during these N-depleted periods. The purpose of this experiment was to evaluate N_2 fixation among select bloom forming cyanobacteria isolates grown under different light regimes, many of which were derived from the Lakes or other local waterbodies. The species included non-heterocystous filamentous taxa, colonial non-fixers (Chroococcales) and two heterocystous species. Strains were grown in batch cultures using a 2x2 N and light treatment design (low and high N; continuous illumination and 16:8 light:dark cycle). Late stage exponential growth cultures were harvested for pigment and biomass measures, and N_2 fixation carried out using the acetylene reduction method. We hypothesised that cyanobacteria containing heterocysts have the most efficient means of pairing fixation and photosynthesis within the same morphological unit and that these strains would provide the most N_2 fixation per unit biomass.

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Relative Strengths of Taxonomic Versus Functional Groups in Explaining Variation in Phytoplankton Communities Along a Trophic Gradient

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This study tests the hypothesis that phytoplankton taxonomic and functional classifications are predictable in lakes of a similar trophic level. This was examined using short-term seasonal changes in phytoplankton communities in four urban lakes of close proximity but with a range of TP concentrations. Data were analyzed with RDA to test whether the communities differed among these lakes using i) taxonomic and ii) functional groupings. The species assemblages of each lake were evaluated for trophic 'indicator species', as have been used by many other studies. In addition, the data were used to test the Paradox of Enrichment, which predicts similar communities in lakes of a similar enrichment level.

RDA of both taxonomic and functional groupings resulted in spatial separation of all the lakes. This suggests distinct phytoplankton communities are present in each lake, even in Bethel and Minnow Lake, which had very similar average TP levels. It was also found that lakes with different trophic levels often contained similar species and functional groups. These data, therefore, supported the growing literature showing that nutrients, notably TP, are not the only variables driving phytoplankton assemblages, with many other environmental parameters equally important in controlling the community composition. Unexpectedly, the functional groupings were only slightly better explained by the environmental variables, suggesting that, although these functional groupings have a vital role in the ecological use and understanding of phytoplankton data, taxonomic data is also equally important when examining the drivers of seasonal change in Sudbury urban lakes.

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Algal Dynamics as Indicators of Water Quality in the Florida Everglades: Lessons Learned and Applicability to Great Lakes Wetlands

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Like the Great Lakes/ St. Lawrence River system, the Florida Everglades is a large, estuarine river that drains a large, complex network of lakes and wetlands. The Everglades also represents a large, tropical analogue to sensitive karstic wetland systems within the Great Lakes basin. Here, we examine Everglades periphyton and benthic diatom dynamics along gradients of phosphorus, flow, and hydroperiod, and demonstrate the unique "upside-down estuary" responses of calcareous periphyton communities to these stressors. Interestingly, periphyton diatom communities of coastal alvar wetlands around the Great Lakes show high levels of similarity to those of tropical karstic systems, and are home to several species previously thought to be Everglades endemics. The periphyton community of the Everglades is well-studied, and we propose that algal monitoring programs conducted in the Florida Everglades can provide a basis for understanding the effects of phosphorus, water level fluctuations and changing climate on the sensitive alvar wetlands of the Great Lakes.

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Bay of Quinte Harmful Algal Bloom Initiative: Developing a Monitoring and Long Term Management Programme and Addressing Benficial Use Impairments

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Many Great Lakes Areas of Concern such as the Bay of Quinte (BQ) are demonstrating increasing episodes of erratic and severe blooms of cyanobacteria and associated toxins, taste-odour (T&O) and beach fouling. Since 2004, our collaborative monitoring programmes have detected intermittently high levels of cyanobacterial toxins and T&O in BQ, particularly at some inshore sites. These impairments have direct relevance to several Beneficial Use Impairments (BUIs) listed for the Bay, which is a source of drinking water for several major municipalities and (an indeterminate number) of individual users, and an important recreational and fishery resource. However, conventional phosphorus-based management models and remedial targets fail to predict or address these impairments, demonstrating a critical need for a detailed risk assessment and revaluation of current management tools - but despite long-term monitoring records, major data gaps remain. Algal biomass often shows asynchronous peaks along the Bay and little relationship to nutrients or water quality at long-term term monitoring sites. Current nutrient loading estimates are largely based on infrequent data from major tributaries and wastewater facilities, and overlook external and internal sources such as small tributaries, storm sewers and sediments - which recent evidence indicates may be significant.

Following an initial scoping exercise in 2009, the BQRAP HABs programme was developed to more specifically to characterize the spatial and temporal variation in phytoplankton biomass, taxa, toxins and T&O, identify the key factors (nutrients, light, temperature etc.) driving bloom episodes and use this information to assess and provide a recommendation(s) on current BUIs. This included the establishment of focal monitoring sites representative of key zones within the Bay which were sampled for physico-chemical and biological parameters over the entire year. Sites were selected to evaluate offshore, inshore and beach areas, along with surficial sediments and selected water treatment plant intakes. In addition, biweekly monitoring of both large and small tributaries was carried out. The results of this study show annual episodes of significant bloom impairment at inshore sites, where toxin and T&O can greatly exceed recreational guidelines and odour threshold levels. Both planktonic and benthic biota may contribute to levels of impairment or represent seeding areas for blooms. Bloom events are intermittent, and possibly moderated by climatic, hydrologic and shoreline effects such as urban wastewater discharge. A generally poor relationship between water quality at open water monitoring sites and shoreline events may be related to episodes of extremely high particulate nutrients in windblown shoreline scums. These and other biological nutrient transport

vectors may significantly modify the distribution and sequesterment of nutrients predicted by conventional 'mixed reactor' models.

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Central Algoma Freshwater Coalition: Facilitating Science & Informed Stewardship Practices in Rural Lakeside Communities

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Harmful Algal Blooms (HABs) are of increasing concern in lakeside communities. Within the Central Algoma region alone, cyanobacteria blooms are responsible for the impairment of at least seven lakes. The deterioration in water quality has resulted in lakeside owners and cottagers becoming increasingly concerned about decreases in property values, restrictions placed on waterfront use and recreational activities, and negative impacts on tourism and fishing. In response to these concerns, the Central Algoma Freshwater Coalition (CAFC), which represents a partnership among public and private representatives, was formed in 2008. A primary goal of CAFC is to detect, identify, monitor and manage HABs in the Central Algoma region that are caused by cyanobacteria microorganisms that have the potential to be toxic or cause noxious odours along shorelines and in drinking water supplies.

The coalition promotes responsible lake stewardship practices among local residents and encourages landowner participation in science-based research and monitoring opportunities (eg, through the Ministry of the Environment (MOE)'s Lake Partner Program and CAFC-led projects). Since 2009, CAFC has performed biweekly sampling on Desbarats Lake to determine the underlying cause of recurring algal blooms and has successfully reported two cyanobacteria blooms this inland lake, which was later confirmed positive by the MOE. To date, CAFC has a membership base of 38 individuals and has 17 inland lakes being routinely tested by volunteers. The coalition encompasses over 100km of the Algoma region and includes 13 municipalities, four of which financially support CAFC initiatives.

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Nanotechnology in Water Treatment and Sampling Applications

Co-Chair: Frank Gu, University of Waterloo
Co-Chair: Anming Hu, University of Waterloo

Session Description

An important current societal concern is the effective decontamination of wastewater and unpurified water from natural sources. The traditional methods of water filtration and disinfection, while still effective at removing many contaminants, are becoming less viable in the total purification process. Recent research has revealed the presence, and hazardous nature, of harmful organic compounds present in many water supplies which are unable to be removed by traditional purification strategies. These harmful contaminants include endocrine disrupting compounds and pharmaceutical drugs as well as by-products of manufacturing processes and certain pathogenic microorganisms, which are recalcitrant to filtration and chlorination. This information regarding the nature of contamination in our water supply mandates the introduction of new, efficient and effective water purification technologies capable of removing these pollutants. Here we seek to review and summarize significant recent research development on magnetically separable particles for use in water treatment, and highlights the many ways nanotechnology and separation technology is currently being employed to treat polluted water.

Fast Synthesis of Large Scale High Performance TiO_2 Nanowire Membranes for Water Treatment

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Conventional methods to hydrothermally synthesize large scale TiO_2 nanowires require from three to seven days of treatment at 190^{o}C with 10 M NaOH solution. We developed an innovative method to grow high quality TiO_2 nanowires in only 15 hours. While processing at a higher temperature can dramatically speed up the growth of TiO_2 nanowires, synthesis near 250^{o}C results in production of the anatase phase while higher temperatures result in rutile phase production. For TiO_2 nanowires fabricated at 250^{o}C, the photocatalytic degradation rate of methylene blue is about 2 times higher than those nanowires synthesized at 190^{o}C and 3 times higher than commercially-available TiO_2 nanoparticles (P25). Microstructural characterization shows that TiO_2 nanowires have a higher crystallinity when growing at a higher temperature. Small amount of rutile phase embedded in anatase phase could trap free charged carriers and reduce their recombination rate. High performance TiO_2 nanowire membranes also display a high efficiency to deactivate *E. coli* in photocatalytic antibacterial experiments and antiviral effect in disinfection of viral haemorrhagic septicemia virus (VHSV), a virus producing high mortalities in fish aquaculture worldwide.

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Antimicrobial Efficacy of Photocatalytic TiO_2 Nanowire Membranes on *Escherichia coli*

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The use of nanomaterials as an antimicrobial agent has been an area of active research in recent years. It is believed nonmaterials can damage bacterial cell walls and cytoplasmic membranes by producing reactive oxygen species during photocatalytic reactions. The antimicrobial efficiency of a high performance TiO_2 nanowire membrane was investigated on the Gram-negative bacteria *Escherichia coli* (*E. coli*). Cells in Luria-Bertani (LB) broth were passed through the TiO_2 membranes and further exposed to a 365 nm solar UV lamp over various time intervals. Bacterial growth was quantitated by examining the number of viable cells that formed colonies on LB agar plates. Inhibition of *E. coli* growth to < 100 cells/mL was consistently observed when starting concentrations did not exceed ~ $8.6x10^6$ cells/mL. Both TiO_2-UV activated and non-UV activated TiO_2 nanowire membranes strongly inhibited cell growth. Treatment of cells with non-UV activated TiO_2 membranes in the absence of light conditions revealed that the TiO_2 nanowire membranes produced were able to exhibit strong antimicrobial properties in the presence of ambient light conditions.

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Magnetically Recyclable Superparamagnetic Fe3O4/SiO2/TiO2 Hierarchical Nanospheres for Photocatalytic Water Treatment

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Magnetic separability is a promising technology with great potential impact to the field of water purification. The implementation of magnetically responsive functionality can impart enormous added value to existent materials suffering from inherent inability or difficulty to be removed from water after treatment, especially colloidal nanoparticles. Magnetic separability offers an economical and practical solution to this issue whereby an active material coupled to a magnetic particle may be used for water treatment and subsequently easily removed from the purified water via magnetic separation. Herein we discuss a method for creating magnetically separable, light active composite nanostructures, intended for use in photocatalytic water purification. The ability of the particles to remove contaminants from wastewater was examined by observing the particles' ability to remove methylene blue from solution. Furthermore, the magnetic separability and recyclability of the particles was shown by the application of a permanent magnet and the removal of methylene blue from solution in consecutive trials, respectively. We anticipate the application of this technology to advanced water treatment in the future.

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Evaluating Nanomaterial/Fish Virus Interactions to Understand the Potential of Nanomaterials to Modulate Pathogen Removal in Wastewater Treatment

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As nanomaterials rapidly become a part of modern industrial economies, they have the potential to impact wastewater in two fundamentally different ways. Firstly nanoparticles are being engineered and studied for the purpose of improving the treatment of wastewater and protecting the receiving environment. Secondly as nanoparticles become increasingly used in commercial products, they are more likely to be environmental contaminants themselves and enter wastewater treatment plants where their actions are largely unknown and could be either detrimental or beneficial. One important function of the sewage treatment process is to remove and/or kill viral pathogens, such as the poliovirus. Therefore, we have studied the interactions between a fish virus, viral hemorrhagic septicemia virus VHSV, and several kinds of nanomaterials. VHSV was used because fish viruses pose no hazard to the researcher, have properties similar to pathogenic human viruses, are found in water, and are a problem in their own right. The nanomaterials were silver nanoparticles and nanowires, single-walled carbon nanotubes (SWNT), multi-walled carbon nanotubes (MWNT) and Titanium dioxide (TiO_2) nanoparticles and membranes. Silver nanomaterial had no effect on the virus. Of three types of functionalized SWNT, only NH_2-SWNT reduced VHSV titer; NH_2-MWNT did not have significant effect. The VHSV/TiO_2 interactions were complex. Current research indicates that concurrent exposure to UV and TiO_2 enhanced VHSV killing if the UV was long wavelength but protected if the UV was shortwave. These results suggest that among the plethora of nanomaterials promising agents for aiding the removal of pathogenic viruses from wastewater can be found.

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Investigation of the Roles of Active Oxygen Species in Photodegradation of the Heterocyclic Aromatic Chemical Compound Methylene Blue in TiO_2 Photocatalysis Utilizing a 365nm UV Lamp

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A 365nm wavelength UV lamp was used in the photocatalysis of TiO_2 nanowires to degrade methylene blue. The TiO_2 nanowires are grown with 1.2g P25 nanoparticles at 250^oC for 24 hours resulting in the production of the anatase phase, and show amplified degradation of methylene blue compared to conventional nanowire growth methods. Hydroxyl radical (HO•), positive holes (h^+) and hydrogen peroxide (H_2O_2) active oxygen species were investigated to understand the mechanism of methylene blue photodegradation. The quenchers used for the analysis include isopropyl alcohol (i-PrOH), potassium iodide (KI), and catalase respectively. The rate constant that was obtained using pseudo first-order kinetics was shown different decreases via the three pathways. The degradation path of methylene blue was thus discussed.

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Preparation of Whey Stabilized ZnO Nanoparticles for Degradation of Bisphenol A, an Endocrine Disrupting Compound in Water

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The growing urbanization has led to the release of toxic organic compounds into the water system, including Endocrine Disrupting Compounds (EDCs). The EDCs are defined as "exogenous substances or mixture that alters function(s) of the endocrine system and consequently causes adverse health effects. Bisphenol A (BPA) has been identified as EDC by the U.S Environmental Protection Agency (EPA). There is an urgent need for developing cost-effective, in-situ treatment technologies for destruction of organic compounds including BPA from water. ZnO nanoparticles are relatively inexpensive and provide photo-generated holes with high oxidizing power due to wide band gap energy. Sience ZnO has almost same band gap energy (3.2 eV) as TiO_2, its photocatalytic capacity is anticipated to be similar to that of TiO_2.

The primary objective of this work was to prepare ZnO nanoparticles and to study the effect of these nanoparticles on changing the viscosity and zeta potential value of water and simultaneous degradation of bisphenol A. Whey material was used as the dispersant in the preparation of the nanoparticles. The ultrafast method (15 s per sample) used for analysis of BPA in water is based on the Laser Diode Thermal Desorption/Atmospheric Pressure Chemical Ionization (LDTD/APCI) coupled to tandem Mass Spectrometry (MS/MS).The whey stabilized nanoparticles displayed much less agglomeration with greater BPA degradation power than those prepared without a stabilizer. The sample with whey stabilized nanoparticle showed lower viscosity and higher zeta potential value in the medium leading to higher degradation of BPA as compared to nonstabilized one. At a dose of 0.1 g L^{-1}, the whey stabilized ZnO nanoparticles were able to degrade 95% BPA from medium as compared to 74% with nonstabilized one.

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A Review of Applications of Nanofiber Membranes in Water and Wastewater Treatment

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Elelctro-spun nanofiber membranes (ENMs) are a new generation of membranes that offer significantly higher fluxes at similar rejection. ENMs are made using an electro-spinning device that accumulates nano-size fibers on a plate. The final shape of ENMs is flat sheet that can be made in MF or UF configurations.

ENMs have porosities in the range of 80% compared to 1 – 5% for conventional MF/UF membranes. This allows higher flux at lower cross-membrane pressure drop and makes ENMs suitable for many water and wastewater treatment applications. In this presentation, the preparation methods for ENMs will be introduced and select applications of ENMs will be discussed as follows.

Use as Pre-filter: ENMs can be placed before RO and NF membranes as a protective barrier that removes suspended solids from water. The removal is done at pressure drops as low as 0.5 psi and increases the life span of the RO/UF membranes.

Use as Substrate in Thin Film Composite (TFC): ENMs can replace conventional UF membranes that are used as substrate in TFC membranes. The porous structure of ENMs reduces the overall resistance to the permeation of water, thus, increasing the flux and reducing the operating pressure, which result in lower cost of water treatment by TFC.

VOCs Removal: carbonized large-pore ENMs act as adsorbent rather than a filter. In this application, ENMs function like GAC except the former are more efficient due to larger surface area to volume ratio.

Membrane Distillation: the commercial application of membrane distillation is prohibited by relatively low flux of conventional membranes. Lab-scale experiments have indicated that flux can be increased by using ENMs instead of conventional MF membranes. The higher flux allows for larger water production at similar footprints.

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Research and Advances in Drinking Water Treatment

Co-Chair: Ron Hofmann, University of Toronto
Co-Chair: Souleymane Ndiongue, Walkerton Clean Water Centre

Session Description

This session will focus on research and development in drinking water treatment processes and approaches to drinking water supply. Subjects may include, but are not limited to:

- treatment options for emerging contaminants
- evolving treatment technologies and process combinations (e.g., advanced oxidation, membrane filtration, biofiltration)
- distribution system quality
- small system approaches

List of sessions

Comparison of 4 Media Types for Traditional and Biofiltration Treatment Goals: Assessment of Rough Engineered Media and Implications for Filter Media Choice

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The type of filtration media to be used is an important consideration for filtration processes, in general, and in particular for biologically active filtration [BAF]. Previous studies have shown that the use of spherical rough engineered ceramic media [REC] for rapid sand filtration can provide improved turbidity removal and lower headloss when compared to conventional filtration media (anthracite and sand). However, it is not known whether or not REC provides these benefits when used in biologically active filtration and no comparisons of REC to GAC, a filtration medium commonly used in BAF, have been reported. Pilot scale biofilters containing REC, coal-based GAC, wood-based GAC, and anthracite were set-up at a full scale WTP to provide a comparison of biofilter performance using different types of filtration media.

Filter performance is being monitored through measurements of filter run time, headloss, and the removal of turbidity, particles, and biodegradable organic matter [BOM]. Preliminary results indicate that filters containing REC provide 30% longer filter run times than filters containing GAC and 18% longer run times than anthracite when used in BAF, while providing excellent turbidity removal (effluent turbidities <0.1 NTU). Comparisons of filter performance, including BOM removal, for part of the winter 2011/2012 season will be presented.

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Optimization of Dissolved Air Flotation for Drinking Water Treatment Through CFD Modeling

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Dissolved air flotation (DAF) is a process for separation of solid particles from water by the injection of air bubbles. Historically, the design of DAF systems has been based on simple hydrodynamic models with maximum loading rates in the order of 5-10 m/hr. More recent pilot plant testing demonstrated that higher loading rates were possible, with excellent solid removal at rates as high as 41 m/hr, but with increased bubble carryover to the filters that can cause air binding. Computational fluid dynamics (CFD) models can be used to provide a better understanding of high rate DAF to solve the bubble carryover problem. In this study, a CFD model was used to investigate the effect of different air fractions and flow rates on bubble carryover in a generic DAF system. Results show that increasing the amount of air in the system improves the bubble removal by increasing the average bubble size and also generating beneficial back and forth horizontal flow layers (stratified flow). Conversely, increasing the flow rate leads to greater bubble carryover by disrupting the stratified flow pattern. Ongoing work is now exploring how loading rates may be increased by altering the DAF tank?s geometry.
This presentation highlights how CFD can be used for optimization of design and operation of DAF. The presentation will be of interest to water treatment professionals involved in the optimization of DAF, or in how CFD may be used to optimize water treatment processes in general.

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Assessment of Human and Veterinary Pharmaceuticals Contamination at River Basin Scale and Study of their Treatability by Activated Carbon Process

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The study is conducted in Brittany, the first agricultural region of France. In this area, surface water accounts for eighty percents of the drinking water resource. The biggest Brittany's watershed is the Vilaine's basin, which covers two thirds of the region (10,500 km²). The main river named the Vilaine is about 220 km from its source to its mouth and crosses a big city of approximately 210,000 inhabitants, Rennes.

The first step was the assessment of the contamination of the Vilaine's basin by pharmaceuticals. To that end three sampling campaigns have been realized in 2010 and 2011 on thirty one stations strategically chosen on the overall basin. Twelve human and seven veterinary substances have been analysed on each station with UPLC-MS-MS method.

Secondly the treatability of the five more frequently detected substances (caffeine, carbamazepine, sulfamethoxazole, iopromide and oxazepam) was studied with laboratory experiments. Efficiency of four types of powdered activated carbon (PAC) and of a fluidized activated carbon (FAC), extracted from a CarboPlus P pilot developed by SAUR R&D, has been observed. Experiments have been carried out at several AC doses (PAC: 10 mg/L, FAC: 1, 3 and 4 g/L), at different contact times (15, 20, 30, 90 minutes) and also with two types of matrices (raw water and clarified water). FAC appears to be more efficient than PAC. Abatements obtained with FAC are relatively high, between 64 and 99%, but varied according to the substances. No difference between both matrices has been observed.

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Pilot Scale Study for the Control of Disinfection By-Products Using Pre-coagulation Ozone in Warm Water Conditions

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The purpose of the study was to find the optimal treatment for a small water treatment plant that uses a surface water source with high organics (5 to 6 mg/L DOC) and low turbidity (0.5 to 6 NTU). Pre-coagulation ozone, enhanced coagulation and granular activated carbon (GAC) filtration were investigated as treatment options to reduce disinfection by-products (DBPs). The full study consisted of two phases which investigated the formation of DBPs in cold water and warm water conditions. This presentation will cover the results of Phase 2 and will compare them with Phase 1 results previously presented at the 46th Central Canadian Symposium on Water Quality Research.

During Phase 2, four trial runs were conducted using the dual train conventional pilot plant, with ozone incorporated into one train. Simulated distribution system disinfection by-product (SDS-DBPs) experiments were conducted using chlorine dosages ranging from 2.5 to 5 mg/L and 4 day detention time.

The results showed that, when enhanced coagulation was not performed, ozone used with GAC filtration had the lowest levels of THMs for 4 and 5 mg/L of chlorine added. However, all THMs results were higher than 100 µg/L. Enhanced coagulation made it possible to lower the THMs to below 100 µg/L. For a chlorine dosage of 4 mg/L, the THMs were 95 µg/L for the anthracite filter without precoagulation ozone and 90 µg/L for the anthracite filter with precoagulation ozone. For the same dosage of chlorine, the THMs were 88 µg/L and 82 mg/L for GAC filtration without and with precoagulation ozone respectively. All conditions tested resulted in THMs higher than 80 µg/L.

Without enhanced coagulation, all HAAs were found equal or greater than 60 µg/L. Enhanced coagulation lowered the HAAs to below 60 µg/L regardless of the treatment applied.

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Optimization of Biofiltration for the Minimization of Disinfection By-Product Formation

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Disinfection by-products (DBPs) are known carcinogens. In water treatment, DBPs are formed when organic matter reacts with chlorine during the disinfection process or with residual chlorine in the distribution system. Biofiltration has become an increasingly popular technology capable of reducing organic matter and hence diminishing the quantity of DBPs formed. This study characterizes organic matter removal and the potential for DBP formation during the operational cycle of two full-scale sand/anthracite biofilters at the Britannia Purification Plant, Ottawa. DBPs measured in this study are trihalomethanes (THMs) and haloacetic acids (HAAs). Environmental Scanning Electron Microscopy (ESEM) and Confocal Laser Scanning Microscope (CLSM) in combination with live/dead viability staining were used to analyze biofilter media before and after backwashing. The percent coverage of the biofilm on the media and the fraction of live/dead bacteria present in the biofilm were quantified. The work demonstrates that the potential for DBP formation decreases as the operational cycle proceeded; that is, the greatest potential for DBP formation was achieved immediately following the backwash event and the least potential for DBP formation was achieved at the end of the cycle just prior to backwashing. At all times during the filter cycle, the potential for total THM formation was reduced during biofiltration. However, the potential for total HAA formation was observed to be reduced immediately following backwashing and increased towards the end of the backwashing cycle; thus indicating that biofiltration initially reduces the potential for total HAA formation and in turn increases its formation during the filter cycle.

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Factors Affecting Total Chlorine Decay and NDMA Formation in Modified Pipe Loops: Pipe Materials, Orthophosphate and Flow Conditions

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Chloramine has recently received growing attention by water utilities due to the requirements to comply with regulations for halogenated DBPs from chlorination (THMs and HAAs). However, the application of chloramine as a secondary disinfectant may cause the formation of N-nitrosodimethylamine (NDMA), the occurrence of nitrification and/or increased corrosion rates. The objectives of this study were to evaluate the impacts of pipe materials in the absence and presence of orthophosphate and flow conditions on chloramine decay and NDMA formation in modified pipe loops for a range of water quality and chloramination conditions.

This paper will present key results from pilot-scale modified pipe loop experiments which have examined interactive effects of pipe materials (iron, copper, lead and PVC) with orthophosphate on total chlorine decay and NDMA formation under stagnant, laminar and turbulent flow conditions. Total chlorine decay generally increased with increases in flow velocity in the four investigated pipe loops. Orthophosphate affected total chlorine decay by influencing metal corrosion and/or nitrite formation with the extent of these impacts being dependent on the pipe materials and flow conditions employed. Pipe material exhibited different effects on NDMA formation under different flow conditions. Consistent trends were observed in regards to the catalytic effects of copper and iron during NDMA formation.

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NDMA Formation from Pharmaceuticals-Impact of Water Matrix and Prechlorination

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N-nitrosodimethylamine (NDMA) has attracted great interest in recent years as an emerging disinfection by-product (DBP) in chloraminated drinking water systems because of its potential carcinogenicity at ng/L concentration levels. A large amount of research effort has been invested in identifying potential NDMA precursors. The authors have found in previous studies that some amine-based pharmaceuticals present at environmental levels could form observable levels of NDMA under practical disinfection conditions, providing a possible link between the occurrence of trace-level pharmaceuticals in source water and the potential for adverse health effects via the formation of carcinogenetic DBPs in finished drinking water.

This follow-up study investigates the NDMA formation kinetics from selected pharmaceuticals in both lab-grade water and real water matrices. The results suggest that the matrix components affect the NDMA conversion from selected pharmaceuticals by inhibiting the initial contact with chloramine and slowing down the reaction. Further experiments are being conducted to determine the impacts from primary disinfection. Compared with chloramine alone, the application of pre-oxidation may modify or destroy the parent pharmaceuticals and release transformation products that may or may not react with the subsequent secondary disinfectant. Other research has shown that NDMA formation in general may be reduced by pre-oxidation, but this may not be true when using pharmaceutical-based NDMA precursors. It has been observed in recent experiments that the addition of prechlorination significantly reduced the ultimate NDMA conversion from ranitidine, while it increased the conversion from sumatriptan. Further experiments are ongoing to look into this impact in real water matrices.

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Organic Matter and Disinfection By-products in the Grand River Watershed

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During the disinfection of drinking water, chlorine reacts with dissolved organic matter (DOM) to produce potentially harmful disinfection byproducts (DBPs). Trihalomethanes (THMs) and haloacetic acids (HAAs) are major types of DBPs and have been shown to be toxic. In the Grand River watershed, chlorination of surface water for drinking is potentially harmful to human health. The communities of Ohsweken and Brantford get 100% of their drinking water from the Grand River. Drinking water surveillance program (DWSP) data from 1998 to 2004 was analyzed to investigate potential risks. After treatment and chlorination, levels of THMs were ≥50µg/l; a level shown to increase the risk of various types of cancer when exposed over several decades. DBPs in drinking water are reported as an annual average in Ontario. However, seasonal changes are an important consideration. In the Grand River, the summer and fall seasons have higher DOM concentrations than late winter and spring, which peak in the late fall or early winter. DBPs may be higher during these seasonal peaks in DOM. Br^- from STPs can react during treatment to form more toxic brominated halomethanes (BHMs) which are not currently tested for or regulated.

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Research and Advances in Stormwater Management

Chair: Hazel Breton, Conservation Hamilton

Session Description

Three streams have been identified to provide insights into Urban Runoff Water Quality

Stream 1 will look at what scientific work that has been conducted to assess water quality issues from urban sources. This will include a variety of sources of pollution including stormwater runoff, stormwater ponds, stream erosion, spills etc. using a variety of parameters to illustrate impact.

Stream 2 will focus on solutions to the issues raised in Stream 1. This can be in the form of research and management approaches (e.g. Integrated Watershed Management). In the last couple of years many advances have been made in trying to considerably reduce impacts, developing innovative solutions where problems exist, and looking at multi-objective solutions to address other impacts such as climate change, increased growth and failing infrastructure etc. Case studies illustrating innovative solutions could also be presented.

Stream 3 will focus on implementation issues, including looking at opportunities that are available for paying for stormwater management, how can council/public be made aware of new concepts and so gain acceptance for innovative approaches etc.

Questions that these sessions will answer include:
1. What are the water quality issues associated with urban runoff?
2. What are the solutions being used to offset impacts?
3. How do we implement these solutions to ensure long-term sustainability?

Evolution of Stormwater Management

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No abstract available

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Cyanide in Urban Snowmelt and Winter Runoff

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Ferrocyanide compounds are added to road salts as non-toxic anti-caking agents. In illuminated aquatic environments, the salts dissociate and transform to toxic free cyanide, which can then be lost through volatilization. Free cyanide has been detected in runoff from salt storage facilities and in urban snow and snowmelt, but its potential to damage aquatic environments is not well understood. Between 2007 and 2009, we measured cyanide concentrations in three types of urban water samples: runoff from parking lots after deicer application; runoff from an urban snow disposal site; and stormwater ponds. Since the MDLs achieved were higher than the guideline levels for protection of aquatic life, the actual number of exceedances of the guideline could not be determined, but the trends observed confirm that areas receiving direct runoff after deicer application are of the greatest concern. Over the past two winters, we have continued our evaluation of cyanide in winter runoff by measuring free and total cyanide concentrations in samples of bridge deck drainage from the Skyway Bridge in Burlington, Ontario. Preliminary data from this study, relating winter event conditions, road salting and cyanide concentrations in runoff, will be presented.

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A Review of the Strategies for the Control and Treatment of Combined Sewer Overflows (CSOs)

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The existing research aims to review various technologies available for the control, treatment, and disinfection of combined sewer overflows (CSOs). CSOs are the overflows that are formed during heavy rainfalls when the stormwater exceeds the capacity of the combined sewer system. CSOs contain various quantities and types of contaminants such as pathogens, suspended solids, toxic pollutants, floatables, oxygen demanding compounds, oil and grease. Hence, the discharge of combined sewer overflows into a river, stream, lake or ocean can result in severe contamination of the receiving water and this is believed to be a major threat to the environment and human health. CSO discharge has also adversely affected a majority of the Areas of Concerns in the Great Lakes region.

The aim of this study is to investigate, review and evaluate the current CSO treatment strategies in order to create a comprehensive database for the better understanding of CSO issues and the need for developing novel, efficient and cost-effective technologies to address CSO concerns.

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Low Impact Development Stormwater Management: Design, Construction, and Monitoring

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The application of stormwater best management practices has undergone several changes over the years, in particular since the requirements for water quality controls joined those for flood and erosion controls in the early 1990's. The guidelines and documents published by various Government bodies, Conservation Authorities, and research initiatives, have also evolved over these past two decades. New technologies have been developed, and previous technologies have been modified, with the result that the array of available practices has increased. One sub-set of practices, Low Impact Development (LID) stormwater management, focuses on lot-level and conveyance best management practices, i.e. source and conveyance control as opposed to end-of-pipe controls.

This presentation documents several recent case studies from the Hamilton area, in which the current Low Impact Development Stormwater Management Planning and Design Guide (CVC/ TRCA 2010) has been consulted, and techniques applied to the design and construction of LID Stormwater Management measures. Each example has its unique site constraints and objectives that have influenced the design of the preferred solution. In some of the cases, a monitoring program has commenced, with the objective of collecting performance data for the various measures.

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Research and Advances in Wastewater Treatment

Co-Chairs:
Jane Challen Urbanic, Environment Canada
Lori Lishman, Environment Canada
John Gibson, Environment Canada
Yaldah Azimi, University of Toronto

Session Description

Water quality and water quantity issues are becoming more important around the world. Different geographical areas require different approaches to wastewater treatment depending on population pressures and environmental considerations. We invite submissions that demonstrate the breadth of wastewater treatment research underway in Canadian universities, industry and government. Possible topic areas are given below, but submissions on other wastewater treatment topics are also welcome.

Topic areas:

- Innovative treatment technologies (e.g. optimizing energy usage)
- Removal of legacy and emerging contaminants in wastewater treatment
- Microbiology, disinfection and their by-products
- Solids treatment and management

Quantifying Nitrification Kinetic Rates at Low Temperatures Using MBBR

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Ammonia is one of four deleterious constituents released from wastewater treatment plants (WWTPs) that have been proposed for regulation by the Federal Government of Canada (Canada Gazette, 2010). Ammonia removal in conventional Canadian WWTPs is currently limited or non-existent in winter months. Numerous studies along with practical experiences have identified the sensitive nature of nitrifying bacteria to low temperatures as the cause for loss of nitrification (Sharma & Ahler, 1976; Zhu & Chen, 2002; USEPA, 2003). Attached growth processes have shown great promise in achieving sufficient ammonia removal at temperatures below 4°C. Specifically, moving bed biofilm reactor (MBBR) technologies has shown to be a feasible upgrade or replacement technology in existing WWTPs (Andreottola et al., 2000; Flemming et al., 2006).

Treatment lagoons represent approximately 70% of the treatment systems currently operated for wastewater treatment in Canada (USEPA, 2003). The performance of MBBR upgrade systems in Canada to treat ammonia has been well demonstrated at numerous operating lagoons; however the MBBR systems have been installed to treat wastewater exiting from the
first pond of multiple pond lagoon treatment systems where the temperature drop is limited. The optimum C/N ratio for nitrification exists at the end of the last pond where the temperature may drop to 1ºC during the winter months. The purpose of this research project is to quantify the kinetic rate of nitrifying bacteria at a temperature of 1ºC for a time period that represents a Canadian winter.

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TOC Removal of Secondary Effluent of Synthetic Slaughterhouse Wastewater using UV/H_2O_2

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The UV/H_2O_2 process, one of the most widely advanced oxidation processes (AOPs), is an effective technology for industrial wastewater treatment. The degradation and detoxification of pollutants in the UV/H_2O_2 process rely on highly reactive species, hydroxyl radicals ($^{\bullet}OH$), produced from the reaction of the H_2O_2 with the UV light. The advantages of UV/H_2O_2 process include a large range of applications, enhancing the degradation of pollutants, accelerating the rate of oxidation with great potentials for disinfection, and thorough mineralization of pollutants in wastewater. A photoreactor (Siemens, SL-1S) with the total working volume of 1.35 L (8 cm external diameter and 34 cm length) was used for the UV/H_2O_2 process. A UV lamp (output power: 6 W, wavelength: 254 nm, and diameter: 2.5 cm), covered by a quartz sleeve, was inserted into the center of the cylindrical photoreactor. The UV/H_2O_2 process was studied to treat a secondary effluent of synthetic slaughterhouse wastewater with total organic carbon (TOC) loadings of 57.59–140.91 mg/L in batch mode. The results revealed a reasonable efficiency to treat the synthetic slaughterhouse wastewater. Up to 75.22% TOC removal was obtained for an influent concentration of 57.59 mgTOC/L at the hydraulic retention time (HRT) of 180 minutes with H_2O_2 concentration of 900 mg/L. Although these methods are effective in wastewater treatment, they are expensive if applied alone. An optimum molar ratio dosage of 14.03 $mgH_2O_2/mgTOC_{in}$ was also found for the UV/ H_2O_2 process Therefore, a good alternative is to combine biological treatment and AOPs.

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Characteristics of Effluent Organic Matter and its Influence on Hydroxyl Radical Scavenging Capacity

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Effluent from municipal wastewater plants is the primary source of contaminants such as pharmaceuticals and personal care products in our waters. The need to control these contaminants requires advanced treatment technologies such as advanced oxidation processes (AOPs). In wastewater, effluent organic matter (EfOM) is a major scavenger of hydroxyl radicals generated by AOPs, which reduces the hydroxyl radical concentration available for the oxidation of target compounds, potentially affecting the AOP efficiency. Soluble microbial products (SMPs) generated during biological treatment in the wastewater systems are the major constituent of EfOM and distinguishes one water from another. SMP formation is influenced by variations in treatment processes leading to variability in the characteristics and scavenging capabilities of EfOM. Certain properties of EfOM may be key factors to the scavenging potential of EfOM and its influence on the efficiency of AOPs in different matrices, and may result in the effluent of one type of treatment process being more amenable for implementing AOPs.

Conventional activated sludge (CAS) and membrane bioreactors (MBR) are the systems most commonly used for wastewater treatment. This research examines whether MBR effluents compared to CAS effluents may be more easily treated using UV/H_2O_2 AOP. The scavenging capacities of a CAS and MBR matrix were determined, coupled with EfOM characterisation using UV_{254} absorbance, specific UV absorbance (SUVA), resin fractionation, liquid chromatography-organic carbon detection and fluorescence excitation-emission matrix analyses. Both matrices showed similar distribution of EfOM components; however, the MBR contained a higher humic and hydrophobic content. Initial results also suggest that the MBR effluent has a higher scavenging capacity than the CAS, although the organic carbon concentration was lower. Ongoing work will evaluate additional effluents to validate initial findings and identify the key factors that influence scavenging capacity. This is important for identifying treatment options to reduce background scavenging so AOPs can be feasibly used in wastewater systems. With the proposed CCME Wastewater Systems Regulations, this work may also provide an option for plants to reduce the environmental risks associated with the discharged effluent and the number of effluent discharge objectives that may be required.

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Optimization of Aqueous Polyethylene Oxide Photodegradation using Response Surface Methodology

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Most of the synthetic water-soluble polymers from industrial effluents are discarded into aqueous environment. Therefore, they can reach conventional sewage disposal systems and subsequently contaminate water resources. Due to their water solubility, they have received less attention in general public in comparison to packaging plastics which are visibly discarded in environment. In recent decades, advanced oxidation technologies (AOTs) have been applied successfully to degrade recalcitrant pollutants in wastewater. In this study, advanced oxidation of aqueous polyethylene oxide (PEO) by UV/H_2O_2 process was investigated in a batch recirculation system. The response surface methodology (RSM) involving central composite design (CCD) combined with quadratic programming was investigated for the experimental design, analysis, and optimization. The effects of initial concentration of PEO, initial H_2O_2 dosage, pH, and recirculation rate as independent variables on the total organic carbon (TOC) removal as the process response were studied. The results indicated that the initial PEO concentration, the initial H_2O_2 dosage, and pH had considerable influence on the TOC removal efficiency. The recirculation rate had no effect on the response function. At the optimum condition of 10 mg/L polymer, 780 mg/L H_2O_2, pH 3, and 0.5 L/min recirculation rate, 84% TOC removal was achieved after 150 min according to the developed quadratic model. High correlation between observed and predicted data confirms the validity of the model.

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Advanced Oxidation Process Intensification in Multilamp Sonophotoreactor

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Advanced oxidation processes (AOPs) is one of the technologies used for treating polluted sources of drinking water and industrial wastewaters usually using a combination of different oxidants. Intensification of AOPs leads to higher oxidizing radicals (especially hydroxyl radical) generation and consequently leads to greater treatment efficiency. In the present study different advanced chemical treatment techniques such as UV/H_2O_2, US/UV/H_2O_2, photo-Fenton, and sono-photo-Fenton processes were studied in a multilamp sonophotoreactor. Methyl orange has been selected as model compound. The degradation and mineralization efficiencies were evaluated for different initial H_2O_2 concentrations, initial Fenton reagent concentrations, and the configuration of UV lamps. Addition of Fenton reagent enhanced the process efficiency remarkably and complete degradation was achieved within the first 15 min of photo-Fenton processes. Moreover, more than 80% total organic carbon (TOC) removed in the first hour of treatment. Photo-Fenton processes is the cyclic electron transfer (conversion of ferric/ferrous ions) leads to higher hydroxyl radical generation. Sono-photo-Fenton performed higher efficiency comparing with photo-Fenton process. Increasing Fenton reagent concentration resulted in greater mineralization efficiency. Initial H_2O_2 concentration showed a beneficial role in higher organic degradation up to a point (optimal H_2O_2 concentration). Three different configurations of UV lamps were used to find the impact of UV lamps configuration on process efficiency. The closer the UV lamps provided higher light intensity in the photoreactor center but the shadowing effect lessened the synergetic effect.

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Treatment of Fish Farm Sludge Supernatant by Aerated Gravel Beds and Steel Slag Filters – A Pilot-Scale Study

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The commonly used strategy to reduce pollutants from the effluent of fish farms is separating the solids (feces, uneaten food, etc.) from water through physical settling. Once collected and settled, however, fish sludge still presents an environmental problem mainly due to the management of the nutrient-rich sludge supernatant. The objective of our experiment was to obtain a high removal of phosphorus, organic matter and nitrogen from the sludge supernatant in hybrid system with aerated gravel beds and steel slag filters.

The pilot-scale on-site experiment for the treatment of the supernatant was operated at the fish farm "Les Bobines" in East Hereford, Quebec. The treatment sequence consisted of two aerated filter beds (AFBs; HRT_V=2.0 d; loading rate 5.5 kg $BOD_5/m^3/yr$ and 1.1 kg $TKN/m^3/yr$), a sequential sacrificial slag filter (SSF; HRT_V=3.5 h) and three parallel two-stage up-flow slag columns (SCs; with different HRTV of 40, 24 and 9h).

During 8.5 months of experimentation, the supernatant had median concentrations of 364 mg COD/L and 154 mg TSS/L, 15.8 mg TKN/L and 5.3 mg TP/L. The removal efficiency of AFB was 95% of COD, 97% of TSS, 90% of TKN and 32% of TP. An extra 21% TP was removed in the FSS and most of the remaining TP (96%) in the SCs giving a final median value ranging from 0.10 to 0.17 mg TP/L. The results of this on-site experiment confirmed the high efficiency of a low loaded aerated filter bed for organic matter oxidation and nitrification. The downstream sacrificial slag filter and columns showed a high efficiency in bringing down the effluent TP (to less than 0.20 mg TP/L).

Further experimentation will be conducted to increase the loading rate to the AFBs by ~10 times or even to remove them completely to test the efficiency and longevity of the slag filters fed with an effluent that will be less pre-treated.

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Enhancement of the Mesophilic Anaerobic Digestion of TWAS, PS, and Scum

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Scum is in an integral component of the solids management in wastewater treatment plants (WWTP) throughout Canada and it is composed of fats, oils, grease, and other entrained floatable materials that are collected during the primary clarification step in WWTPs. The material is either pumped with the use of a vacuum truck to be transported to landfills, sent to an incineration facility, or distributed to the anaerobic digestion feed of the WWTP. The majorities of WWTPS that have anaerobic digestion facilities concentrate the scum by use of conventional heating and distribute it to the anaerobic digesters. Current literature unfortunately does not address or quantify the impact on biogas production of implementing scum in the anaerobic digestion process.

The goal of this study is to quantify and enhance the biogas production at the Robert O. Pickard Environmental Centre, located in Ottawa, ON, through codigestion of scum with thickened waste activated sludge (TWAS) and primary sludge (PS) undergoing mesophilic anaerobic digestion.

The study investigates the temperature of the concentrator and the holding time in the concentrator in biological methane potential (BMP) tests and semi-continuous lab-scale reactors at hydraulic retention times of 15 and 20 days. Optimizing the pretreatment conditions, we have

Achieved 23% and 18% increase in biogas production through addition of scum to PS and TWAS, respectively.

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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 the microbiological requirements for class A or B biosolids. Accordingly, class A biosolids must have fecal coliform counts below 1000 MPN per g of total solids and enteric virus counts below 1 PFU per g total solids among other requirements. In Canada, the regulations for land application in all provinces are inspired from the ones of the US-EPA. In this Study, a laboratory scale electro-dewatering unit was used for 8 min cycle tests on sludge from five different treatment plants. Sludge temperature increased from room temperature to about 100°C during dewatering due to Joule heating. To study the effect of this temperature increase on the performances of the process, electrodes were also cooled such that the maximum temperature did not exceed 50°C. Results with standard electrodes showed that total coliforms and F^+-RNA coliphages (surrogate indicator for enteric viruses in this study) were inactivated to levels below their detection. However, when cooled electrodes were used, no significant inactivation of pathogen indicators were observed. In addition, although on average 15% more electrical energy was consumed by cooled electrodes than by standard electrodes, dewatering with cooled electrodes produced approximately 20% less filtrate on average. This demonstrates the dual beneficial effect of Joule heating on the electro-dewatering process. First, it enhances the dewatering kinetics of dewatering. Second, it supports the production of Class A biosolids.

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Investigation of Biological Solids Produced by MBBR Systems

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Lower production rate of solids in attached growth moving bed bioreactor (MBBR) systems as compared to conventional activated sludge systems makes them an attractive choice for municipal wastewater treatment (Kulikowska et al. 2007 also H.Odergaard et al. 1994). On the other hand, the solids produced by MBBR systems operating at high organic loadings have poor settling characteristics (Odegaard et al. 2000). In addition the production of biosolids in MBBR systems is currently not well defined and requires additional investigation.

Three identical MBBR reactors were operated under the same DO concentration, influent pH, and volume of Kaldnes media. In the first phase of the study, different loading rates were applied to the reactors to investigate the effects of loading rate on the particle size distribution (PSD) and settling characteristics of the produced solids. In the second phase of study, loading rates were kept the same in all three reactors and HRT was varied in the three reactors to compare the produced solids. PSD analysis of the produced biological solids was measured using a Brightwell Digital Particle Analyzer (DPA) with a detection range of 2-400 μm. The mass of the particles larger than 400 μm was measured by filtration. The decantation index ((TSS0-TSS30min/ TSS0)*100), SVI, TSS and VSS were used to measure the settling potential of the produced biological solids and the mass of volatile and suspended solids. This study demonstrated that HRT and loading rate play an important role in PSD and settling characteristics of the produced biosolids of MBBR systems.

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Phosphorus Control During Primary Treatment at the Lou Romano Water Reclamation Plant

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Phosphorus plays a key role in eutrophication. Accordingly, regulations limit the amount of phosphorus in wastewater discharge from municipal wastewater treatment plants. A large portion of the phosphorus present in municipal wastewater can be removed during primary treatment, especially when chemical precipitation is used. However, phosphorus is also an essential nutrient for microorganisms responsible for biological treatment. Lou Romano Water Reclamation Plant, located in Windsor, Ontario, currently uses chemically-assisted primary treatment for enhanced phosphorus and solids removal. Subsequently phosphoric acid is being added to meet the demands of the secondary biological aerated filter (BAF) treatment process.

Forms of phosphorus in wastewater are typically categorized as orthophosphates, acid-hydrolyzable phosphates and organic phosphates. These vary in bioavailability, with the soluble orthophosphates considered to be the most bioavailable. Initial testing has indicated significant amount of soluble orthophosphates to be present in influent wastewater, almost all of which is being removed during chemically-assisted primary treatment. Factorially designed jar test experiments are planned to investigate the effect of chemical dosages (alum and polymer) on solids and phosphorus removal during primary treatment. The goal of the research is to examine if some of the phosphorus being removed during primary treatment could be salvaged for use while still remaining within the solids loading limit of the BAF process. Results obtained and their implications will be discussed.

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Phosphate Uptake in Co-precipitation Systems Targeting Low Phosphate Concentrations

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Achieving low phosphorus (P) concentrations in wastewater treatment plant effluents is becoming increasingly important. The use of chemical P removal with iron(III) salts to achieve these low concentrations has been shown to be characterized by rapid equilibrium precipitation of hydrous ferric oxides occurring simultaneously with co-precipitation of phosphate (PO_4^{3-}), followed by a slower kinetic removal as a result of chemisorption. The effects of pH, dosing, mixing and aging conditions, as well as water chemistry, dictates the extent to which these mechanisms perform. Model development has increased the ability to predict residual PO_4^{3-} concentrations; however, existing models do not include all mechanisms responsible for P removal to ultra low levels. Currently, there is a lack of information on P removal mechanisms in transient processes and dynamics typical of wastewater treatment. In particular, there is limited information that describes the effect of solids aging and the rates of adsorption and desorption of soluble P. Preliminary data of a multiphase project aimed at resolving issues related to PO_4^{3-}uptake in co-precipitation systems when extremely low PO_4^{3-}concentrations (i.e.<50ug/L) are targeted are presented. This involved identifying the impact of solids residence time (SRT) on PO_4^{3-} uptake from water and a characterization of the desorption of P from solids generated over a range of SRTs commonly employed in practice. The work will be used to enhance models of PO_4^{3-} uptake in co-precipitation systems operating under steady-state and transient conditions, which can lead to more accurate prediction of optimum chemical dosage for P removal to ultra low levels.

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The Effect of Floc Properties on UV Disinfection of Wastewater Effluents

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Flocs generated in the activated sludge process that are carried through the secondary clarifier can significantly decrease the effectiveness of ultraviolet (UV) disinfection of wastewater. This effect is detected in a typical UV dose-response curve where there is a sudden drop in the decrease in the survival ratio of organisms with increasing UV dose. In order to improve UV disnfectability, it is important to understand the factors that influence this phenomenon.

Based on flocs having a double layer structure composed of a compact inner core surrounded by a loose outer shell, it was hypothesized that the compact cores have a major role in the tailing phenomenon. Hydrodynamic shearing and mechanical sieving were applied to extract the inner cores and their UV inactivation kinetics was compared to that of flocs. The results showed that cores are more resistant to UV disinfection, and may be the main cause of tailing

The structure and composition of flocs was varied by changing the secondary treatment conditions. The UV disinfectability of flocs from an enhanced biological nutrient removal (BNR-UCT) system was compared to those from a conventional activated sludge (CAS) system. The results showed that the BNR-UCT flocs were easier to disinfect, and despite their less integrated structure were mechanically stronger than the CAS flocs. Flocs generated under CAS systems of various sludge retention times (SRTs) were also compared in terms of UV inactivation, and no significant difference was found once flocs of similar size were compared.

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CFD Modeling for Floc Breakage in Orifice Flow

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Reducing the size of aggregate wastewater particles can increase the effectiveness of UV treatment. Passing secondary effluent through an orifice has been shown to be effective at lowering particle size. Experimental results also indicate that variations in the orifice geometry can change particle breakage at a given pressure drop. CFD modeling is used to better understand system dynamics, and suggests that breakage occurs in the sharp acceleration region approaching the orifice. The route of approach of the particles to the orifice also appears to impact breakage, where the particles which must travel radially as well as axially to enter the orifice are most likely to break. These results obtained from CFD are compared with experimental data from laboratory tests in which wastewater particles are injected at various radii into the main pipe flow before the orifice. Also, as part of the CFD optimization of this process, refined models are used for considering variations in the parameters of the orifice geometry to maximize particle breakage with minimal energy use. This process has the potential to improve throughput of UV systems for the disinfection of hard-to-disinfect wastewaters.

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Use of Linoleic Acid to Enhance Anaerobic Sulphate Reduction in Semi-Continuous Reactors

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Acid Mine drainage (AMD) has severe adverse effects on aquatic environment due to its low pH and high metal concentrations. Conventional treatment methods are either not so effective or too expensive to be economically attractive. AMD has high sulphate concentrations which can be reduced to sulphide by anaerobic sulphate reducing bacteria. Metal removal from AMD through biogenic sulphide precipitation as an alternate treatment method has the potential for being both effective and economically viable. However, diversion of a fraction of electron fluxes from the organic carbon substrate towards methane production has been a major challenge. This has prompted research on finding methanogenic inhibitors to divert the electron fluxes towards sulphate reducers to achieve higher sulphide yield. Use of LCFAs over other chemical or physical methods of methanogenic inhibition is attractive because of their lower cost and easy availability. A recent batch study has indicated that it may be possible to use LCFA to selectively inhibit methogens and divert electron fluxes towards sulphate reduction.

The objective of the present study is to investigate the efficacy of Linoleic acid (LA), a LCFA bearing 18 carbons and 2 double bonds, in diverting electron fluxes from methanogenesis towards sulphate reduction in semi-continuous reactors. The reactors were operated as continuously stirred tank reactors (CSTRs) at 37 oC. The combined effect of LA and COD/ sulphate ratio has been examined. The results obtained and their implications will be discussed.

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TOC and TN Removal of Synthetic Slaughterhouse Wastewater Using Biological Treatment in Anaerobic-Aerobic Systems

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Slaughterhouses produce large amounts of wastewater during the slaughtering process and periodic cleaning of residual particles. Composition of slaughterhouse wastewaters varies according to the industrial process and water demand; however, these wastes usually contain high levels of organics. The biological treatment of a synthetic slaughterhouse wastewater was studied using an anaerobic baffled reactor (ABR) and aerobic activated sludge at a laboratory scale with total organic carbon (TOC) loadings of 0.03–1.01 g/(L.day) and total nitrogen (TN) loadings of 0.01–0.19 g/(L.day). The flow rate range was from 2.63 to 10.51 mL/min. The results revealed that combined anaerobic-aerobic processes had higher efficiency to treat the synthetic slaughterhouse wastewater. Up to 96.29% TOC removal and 75.15% TN removal was obtained for an influent concentration of 639.44 mgTOC/L at the hydraulic retention time (HRT) of 7 days and a flow rate of 4.21mL/min. Although anaerobic treatment is efficient, complete stabilization of the organic matter is not possible by anaerobic treatment alone as the effluent produced by anaerobic treatment contains solubilised organic matter, which is more suited for treatment using aerobic processes or anaerobic–aerobic systems. Thus, later post-treatment using aerobic treatment is necessary to meet the standards. Moreover, for the biological removal of nutrients (N and P), an adequate combination of anaerobic and aerobic processes is essential.

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Risk Management in Drinking Water Quality and Environmental Pollution Control

Chair: Roland Bradshaw, Associated Engineering

Session Description

A common theme in the public sector is an emerging understanding that the current levels of investment do not address deteriorating or inadequate infrastructure to meet current environmental protection and public health needs. This is brought about by natural infrastructure decay but also changes in economic and/or population growth.

Managing risk in the face of limited resources has long been an implicit component of asset management in the public sector yet increasing pressures ranging from financial constraints to low rate tolerability have created a climate in which the public sector has to negotiate spending on capital investment and maintenance schemes in light of acceptable levels of risk. Over- or under-engineering facilities with the presumption of screening out all risk or tolerating excessive levels of risk are no longer acceptable for stakeholders.

Many argue that a sustainable long-term approach is required to assess and bridge the funding gap that is determined by level of service expectations. This approach places level of service expectations and risk management at the centre of public and environmental health management and the availability and quality of risk assessments at the centre of decision making.

This session will explore the application of risk assessment in decision making and invites practitioners and academics to share their experience with risk analysis and assessment in the context of public and environmental health strategies.

List of sessions

Making the Source Water Events-based Approach Operational: A Screening Method

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Ontario's Clean Water Act (2006) and the Director's Technical Rules define how land use activities are categorized as ?Significant? Drinking Water Threats (SDWT), which subsequently binds land owners to comply with the Source Protection Policies (SPP). The technical rules prescribe three options to elevate an activity to a ?significant? threat level: (1) the vulnerability-based threat-based approach; (2) the issues-based approach if drinking water quality limits have been exceeded or trend toward it; and (3) the events-based approach, which can use numerical modeling to assess how potential spills can impact on the drinking water supply. For the events-based approach, an activity must fulfill a number of conditions: (a) it must be located in a ?large? water body, (b) it must be identified by the Source Protection Committee, (c) water from the spill location must impact on the intake, as determined with particle tracing; and (d) this impact must exceed drinking water limits, as determined with a water quality model or similar analysis.

From the practical perspective of Source Water and Conservation Authorities, the events-based approach may allow to increase the scope of SPP in order to protect drinking water sources. However, an extensive modeling study in combination with litigations around uncertainty can cost more than implementing a risk reduction measure, for example an upgrade of a storm management pond. In such cases, the use of screening methods for impacts of spills, combined with precautionary implementation of risk reduction measures in compliance with SPP, can be a more cost-effective option to protect water than the reliance on in-depth water quality studies.

We present a screening approach that combines hydrodynamic current modeling with water quality modeling, in order to identify SDWT under the events-based approach cost-effectively.

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Computational Modelling in Site-specific Risk-assessment for Trace Metals: Forging the Path Forward

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Trace metal contamination of soil and water is of global concern. To ensure the protection of aquatic and terrestrial life, computational models are often used in environmental risk assessment. Models based on metal speciation chemistry provide guidance for cases where: generic guideline values for total metal concentrations may result in unnecessary remediation of sites for which metal concentrations are high but non-toxic; in toxicity identification and evaluation (TIE) investigations where the chemical(s) causing toxicity is not known; for prioritizing remedial actions for contaminated sites, and; in choosing chemical amendments for reducing toxicity.

In this paper, a case study will be shown where a modified version of the Windermere Humic Aqueous Model (WHAM) is used as an alternative to the Biotic Ligand Model (BLM) for calculating the partitioning of metals (and toxicity) within aquatic systems. While both WHAM and the BLM are based on competition and complexation reactions for dissolved metals in solution, WHAM calculates metal binding based on a heterogenous array of functional groups on the binding surface and also takes into consideration the concentrations of all solution components, rather than a select few (e.g., Ca, Mg, SO_4^{2-}, NO_3^{2-}, Cl^-). While computational models used in risk assessment should aim to simplify the system by including only parameters that influence the output, oversimplification can also limit predictive accuracy for applied scenarios involving multiple-metals. In this respect, the computational approach of WHAM appears to provide both the needed flexibility in terms of complexity and predictive accuracy.

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Introducing Layer of Protection Analysis for Water Safety Risk Assessments

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Population growth and public demands for an increasing level of service place pressure on our existing infrastructure, infrastructure which is already beginning to show the signs of its age. Ageing infrastructure and its inherent risk of failing to provide safe and reliable services requires a management approach that will identify and prioritize risks and supports decision makers in taking the correct course of action whilst satisfying time and cost constraints.

Conceptualizing a risk assessment framework requires a clear definition of risk that relates an asset to its ability to maintain a required standard of service. This can relate to asset and operational performance in four principal areas:

- Service quality from an asset.
- Capacity of assets and networks available to meet demand (Availability).
- Reliability of assets and networks to supply services.
- Customer satisfaction.

In this paper, we introduce Layers Of Protection Analysis (LOPA) as a powerful analytical tool for assessing the adequacy of protection layers used to mitigate process risk for water supply systems. LOPA builds upon well-known process hazards analysis techniques, applying semi-quantitative measures to the evaluation of the frequency of potential incidents and the probability of failure of the protection layers. LOPA is a semi-quantitative methodology that can be used to identify safeguards that meet the independent protection layer (IPL) criteria such as treatment units, standard operating procedures and incident response procedures.

Building on the example of a water treatment process review, in this paper we introduce the methodology and fundamental concepts of LOPA for the water industry.

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Effectiveness of *E. coli* Biofilm for Prevention of Concrete Deterioration in Wastewater Treatment and Collection Structures

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Microbial influenced concrete deterioration (MICD) in wastewater treatment plants and sewer collection systems is a very costly problem that can cause severe damages to concrete structures. MICD is a process in which sulphur oxidizing bacteria (SOB) accelerate concrete deterioration by producing sulphuric acid on the surface of concrete. In this study, *Escheria coli DH5α* biofilm was grown on a concrete surface to control and minimize MICD. The effectiveness of the biofilm was quantified by accelerated chemical acidification tests. MICD was also achieved biologically using two different types of SOB bacteria which reduce the pH of the medium to as low as 3. Scanning electron microscopy (SEM) was used to assess the biofilm growth, attachment and the deterioration of concrete. Confocal scanning laser microscopy was utilized to measure the thickness of biofilm on the concrete surface as well as the proportion of live and dead bacteria in the biofilm before and after chemical and microbial acidification. In order to determine the severity of the concrete deterioration, calcium concentration measurements and elemental mapping were used. The results of the study showed that the biofilm with a thickness of 20-40 μm can easily form on the concrete surface and the thickness remains similar after acidification. It was also shown that the presence of biofilm as an effective protective barrier inhibited the growth of SOB bacteria and prevented the pH drop due to the SOB activity. Overall, the results indicated that the presence of the *E. coli DH5α* biofilm better protected the concrete from microbially and chemically induced deterioration.

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Cyanobacteria Transport: Cyanobacteria Movement and Hydrodynamic Effects on the Vulnerability of a Drinking Water Intake

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Many surface waters are affected by toxic cyanobacteria presenting a health risk for exposed communities. Tools are needed to improve cyanobacteria bloom prediction to plan treatment responses and mitigation strategies.

In 2008, a project was initiated by École Polytechnique to investigate cyanobacterial occurrence in drinking water treatment plants: (Phase1) determine weather conditions influence in blooms occurrence; (Phase2) study the vulnerability of the drinking water plant which is dependent on the interaction of lake stratification and mixing, cyanobacterial community migration, and the intake position and depth. In Phase2, a model of plant vulnerability to toxic events is being developed based on lake hydrodynamics, wind strength and direction, light climate and their effects on cyanobacterial growth strategy and buoyancy.

A coupled hydrodynamic-cyanobacterial growth model has been developed based on the SIMPLE algorithm. In-vivo probes have been installed in Missisquoi Bay situated in the northern region of the Lake Champlain (2007-2011) to monitor bloom-related variables, including the fluorescence of phycocyanin, chlorophyll-a, pH, temperature, dissolved oxygen and turbidity

On an annual scale, there were large differences among years in the incidence and toxicity of blooms. But more importantly, on a daily scale, there was clear evidence of downwind buildup of toxic biomass. Lake hydrodynamics were shown to be critical for both the accumulation of cyanobacteria and the formation of dense surface scums. Thus, a hydrodynamic model including meteorological conditions, sediment mixing and diurnal stratification would be useful as a component of an early warning system for cyanobacteria growth and transport to drinking water intakes.

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Surface and Groundwater Quality

Co-Chair: Veronique Hiriart-Baer, Environment Canada
Co-Chair: John Spoelstra, Environment Canada

Session Description

As human populations grow, so do the pressures on our water resources. This is challenging our ability to sustain and enhance surface and groundwater quality. As we improve our understanding of the sources, transport, transformation and sinks of contaminants (e.g. nutrients, metals) through our water networks we become better equipped to strategically manage these vital natural resources. Technological and computational advances have created a number of diagnostic methods and tools to identify contaminant sources and track the evolution of, and ecosystem response to, contaminants as they make their way through our aquatic environments. In this session, papers are encouraged on aspects of contaminant source identification, transport and fate (biogeochemistry) including advances in diagnostic/monitoring methods and approaches are encouraged. Topics related to surface and groundwater quality are of interest, and especially those involved with groundwater-surface water interaction.

Keywords: Surface water; groundwater; contaminant biogeochemistry.

List of sessions

Environmental Selection of Phenotypic Diversity in *E. coli*

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Environmental *E. coli* are subject to diverse selective pressures, and these pressures can aid in bacterial survival by selection of beneficial mutations that affect cell characteristics, including the ability to utilize poor carbon or to survive in stress. Therefore, genomic mutations that impact *E. coli* phenotype are of interest. Phenotypic diversity of *E. coli* isolates collected from Hamilton Harbour, Lake Ontario, was surveyed, and the contribution of mutations in *rpoS*, a stress-related sigma factor gene, to phenotypic diversity was examined. Biofilm production, *r*ed, *d*ry *a*nd *r*ough (RDAR) morphology, and growth on TCA cycle intermediates and weak acids were determined for 192 (or a representative subset thereof) environmental *E. coli* isolates. Naturally-isolated RpoS mutants were identified using two RpoS-dependent phenotype tests and confirmed with *rpoS* sequencing, and RpoS mutants were also selected using a laboratory selection method. For biofilm and RDAR phenotypes, most isolates with substantial biofilm formation correlated with a positive RDAR morphotype. The amount of biofilm produced, however, differed across isolates, with six out of 37 isolates forming significantly more biofilm compared to laboratory *E. coli* and nine out of 37 isolates having undetectable levels of biofilm after 48h incubation. A range of growth ability on poor carbon sources was also identified, from 2.6% of isolates able to grow on formate to 17.7% able to grow on acetate. Although not typical of *E. coli*, eight isolates were further able to utilize citrate. RpoS mutants of environmental *E. coli* exhibited a consistent phenotype (low biofilm, low RDAR, and ability to grow on poor carbon). Therefore, considerable phenotypic diversity is evident in isolates of the same species subjected to different environmental conditions. We show that some of this phenotypic diversity can be attributed to mutational selection, as is the case with *rpoS* mutations.

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Spatial Variation of Groundwater Contaminants Discharging to an Urban Stream, Barrie, Ontario

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Urban groundwater is subject to many sources of contamination, which collectively can be considered as diffuse contamination. This poses a toxicity risk to aquatic ecosystems, especially benthic organisms, and may contribute to eutrophication. The objective of this study was to assess and attempt to quantify the small-scale spatial variation of groundwater contaminant concentrations along an urban stream in Barrie, Ontario. Drive point sampling was used to take groundwater samples from both banks of the stream at i) depths of about 0.5 m below the stream bed at a spacing of 10 m along a 500 m reach, and ii) depths of about 0.05 m at a spacing of 5-10 m at 19 locations (a subset of the larger reach). For one 25-m section, paired piezometers (0.1 and 0.4 m depths) were installed at 4 positions, on both banks, and were sampled for groundwater biweekly to monthly for seven months. Groundwater concentrations of soluble reactive phosphorus, ammonium, iron, and volatile organic compounds were high, often above the guidelines for aquatic life, at various locations along the stream. Concentrations varied by orders of magnitude between sampling locations along the stream, at the same location at different depths, and across the stream width (1-3 m). These findings suggest that benthic organisms in urban streambeds may experience large concentration gradients of groundwater-sourced contaminants. This small-scale variation also has implications for monitoring of diffuse groundwater contaminants along urban streams.

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Risk to Benthic Organisms (Juvenile Mussels) from Road Salt in Groundwater Discharging to an Urban Stream

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Road salt applied in urban environments may infiltrate with melt water and be transported by groundwater to local streams, potentially exposing aquatic organisms to toxic levels of chloride throughout the year. Burrowing invertebrates, such as juvenile freshwater mussels may be especially at risk. In this study, chloride concentrations in shallow groundwater below an urban stream were measured in summer and compared to results from acute (96 h) sodium chloride toxicity tests performed with newly released (<1 week) juvenile *Lampsilis siloqueodea* (Fatmucket). Toxicity tests revealed a chloride EC50 and EC10 of 1507 and 734 mg/L, respectively, demonstrating that these early life stage freshwater mussels are among the most chloride sensitive invertebrates. Screening of groundwater at 10-m intervals along a 800-m section of stream (76 sample locations), at depths of 25-75 cm below the sediment surface, revealed chloride concentrations ranging between 20 and 3600 mg/L, with an average of 860 mg/L, compared to 20-30 mg/L for the stream water. These were highly correlated with sodium. About 17% and 42 % of the groundwater locations had chloride concentrations at or above the laboratory measured EC50 and EC10. Further detailed sampling indicated that salt concentrations were often in a similar range at 5 to 10-cm depth, which corresponds to the zone inhabited by juvenile mussels and other endobenthic organisms, as at the deeper depths mentioned above. These findings suggest that discharge of road-salt-impacted groundwater may impair mussel habitat across substantial portions of this urban stream.

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Assessment of Contaminated Groundwater Effects on Benthic Invertebrates in Streams

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In many urban areas, streams receive groundwater contaminated with a range of substances, often from long-lasting legacy sources. Ecological impacts of these discharges are of concern but not well known. Among stream biota, invertebrates in the hyporheic and surficial sediment zones are expected to be the most exposed and show the greatest responses to groundwater contaminants. However, assessing exposure and effects of contaminants from this pathway is difficult due to the rapid dilution of upwelling groundwater in the stream, the partial confounding of contaminant and dissolved oxygen concentrations, and effects of other natural and human factors on the stream. In a study of a Nova Scotian stream exposed to chlorinated solvents, petroleum hydrocarbons, metals, and chlorides in groundwater, multiple locations were sampled and assessed for porewater contaminant concentrations, various habitat attributes (including subsurficial dissolved oxygen concentration and sediment particle sizes), surficial macroinvertebrate community composition, hyporheic invertebrate community composition, and in situ toxicity of water at the sediment-water interface to *Hyalella azteca*. Results suggest that hyporheic but not surficial invertebrate communities could be affected by chlorinated solvents and chlorides, and that in situ toxicity could be related to chlorinated solvents. Effects of multiple potential stressors on stream invertebrates remains to be resolved and confirmed.

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Fluorescence Analysis of Natural Organic Matter (NOM) in Shallow and Deep Groundwaters on a Canadian Shield Sampling Site: Influence of pH and Salinity

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Fluorescence spectroscopy aided with a spectral resolution routine such as PARAFAC is a leading tool to analyze Natural Organic Matter (NOM) in waters. This routine separates spectra into humic-like, fulvic-like and protein-like components, which, in turn, can help interpret the NOM dynamics in environmental systems. Despite these advances, the technique is limited, because fluorescence reflects the optical properties, and not the chemical properties of NOM.
In this work, a systematic fluorescence analysis is presented for samples taken at two locations on the Canadian Shield, one shallow set, and the other set at depths to ~650m. These samples were perturbed for pH (7 or 8 \"titration\" points from pH 4 to 10) and salinity (7 salinity points, up to 3 per mil salt content). The fluorescence signals, separated into components by PARAFAC, are tracked as a function of these sample perturbations. The fluorescence signals for the three spectral regions were reproducible for the humic- and protein-like components, but less so for the fulvic-like components. Surprisingly, the fluorescence signals of the 3 components from the pH titration showed no clear change with pH, as would be expected with a classic titration. Changes of salinity only had a small impact on the fluorescence signal, i.e., a ~2.7% to 3.4% signal decrease for each salinity unit for the 3 components. This small perturbation would not likely have a significant impact on the spectral interpretation of NOM in these systems. Other implications of the fluorescence changes with pH will be discussed.

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The Impact of Eutrophication on Mercury Cycling in Lake 227 at the Experimental Lakes Area in Northwestern Ontario

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Both globally and throughout Canada, high methyl mercury (MeHg) concentrations in freshwater fish are of major concern as MeHg is a bioaccumulative neurotoxin. Although we are beginning to understand the factors controlling MeHg production in freshwater lakes, the impacts of environmental disturbances, such as eutrophication, on Hg cycling are not known. As part of a larger project examining controls on eutrophication, we are studying the impacts of eutrophication on Hg cycling and MeHg production in the artificially eutrophic Lake 227 at the Experimental Lakes Area in northwestern Ontario. In addition to 40 years of ancillary data, Lake 227 is ideal for this study as it has an anoxic hypolimnion which may be an important zone of microbial MeHg production. To determine sources and losses of inorganic Hg(II) and MeHg from the lake, we are using a mass balance approach including: detailed lake profiles to determine the water column pools of inorganic Hg(II) and MeHg, Hg(II) and MeHg inputs via precipitation, and losses of Hg from the lake via gaseous elemental Hg(0) evasion and MeHg photodemethylation. In addition, rates of MeHg production are being determined using state-of-the-art Hg stable isotope experiments. 2010 results suggest that eutrophication has a dramatic impact on the Hg cycle in Lake 227. For example, the zone of high MeHg concentrations migrated up the water column throughout the summer following the zone of anoxia, suggesting MeHg is being produced in the anoxic hypolimnion. 2011 results will be presented in the context of numerous other water chemistry parameters.

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Tracking the Source of Contamination of Wheatley Harbour: An Exercise in Multivariate Statistical Analysis

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Elevated PCB concentrations in Wheatley Harbour are suspected to have originated from industrial waste disposal and/or discharges from nearby fish processing through discarding of PCB-contaminated fish remains, yet until now, this hypothesis has remained unverified. In the context of a study readdressing the health of wild fish populations in the Canadian Areas of Concern, we determined whole-body PCB (Σ PCBs) concentrations in brown bullhead (Ameiurus nebulosus) from Wheatley Harbour. Mean Σ PCBs in brown bullhead from Wheatley Harbour were ~250 ng/g ww, compared to ~40 ng/g ww for brown bullhead from two reference sites: Hillman Marsh, a conservation area on Lake Erie, and Turkey Creek, a tributary of the Detroit River. To test the hypothesis of fish waste as the cause of the observed PCB contamination of Wheatley Harbour brown bullhead, a Principal Component Analysis was used to compare the brown bullhead PCB congener data to equivalent data for Lake Erie walleye, Lake Erie sediment, and industrial Aroclor mixtures. The relative contribution of each Aroclor to the overall PCB congener pattern was calculated using the conjugated gradient method. The high similarity between the congener signatures for Lake Erie walleye and Wheatley Harbour brown bullhead supports the hypothesis of contamination from the fish processing industry.

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Phenology of Amphibian Breeding in Relation to Pesticide Exposure in Ontario

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Amphibians often are exposed to pesticides while breeding in agricultural landscapes, and the timing of breeding may affect their exposure. The phenology of amphibian lifestage (egg, tadpole, metamorph, adult) varies among frog species, as does their behaviours (calling, breeding, postbreeding). Our objective was to identify the relative exposure to pesticides for each lifestage and behaviour. Using frog calling intensities, time to hatch, and time to metamorphosis for eight frog species across Ontario, we estimated the lifestage and behavioural phenologies. Data from Environment Canada's Pesticide Science Fund initiative in Ontario were used to quantify temporal changes in concentrations of pesticides in surface waters. For American toads, leopard frogs and spring peepers, the pesticide concentrations generally increased throughout their three life stages, whereas for bullfrogs and green frogs exposure was highest during the egg stage. Generally the concentrations peaked post breeding for early breeders and during breeding for late breeders, and thus pesticide residues were highest during the tadpole or metaphorph stage for late breeders. Data relating pesticide exposure with amphibian lifestage and breeding behaviour is important for assessing risk, and for designing appropriate exposure regimes for toxicological studies.

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Can Diatom Biomonitoring be Used as a Supplement in Water Chemistry Programs?

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The introduction of algae biomonitoring in Ontario brings with it an opportunity to expand and improve our surface water quality monitoring programs. Current users, such as municipalities and conservation authorities, will soon be able to employ a strategic approach to employ diatom biomonitoring as a supplement for water chemistry sampling. Although uncommon in Ontario, diatom community analysis is routinely employed in European countries, to focus water chemistry resources at the most impacted locations. Strong correlations between the diatom community composition and many water chemistry parameters, including chloride, phosphorus, and nitrates are well documented. In Quebec, diatom biomonitoring is gaining popularity, and is used both as a measure of biological integrity and to assess overall water quality. Sampling sites are pre-screened using an analysis of the diatom community composition, and follow up water chemistry analysis is restricted to sites where the diatom community indicates a strong impact has occurred. Through pre-screening, fewer costly water quality analyses are conducted, while valuable information about water quality, as experienced by the biological community, is gained.

In light of the successful use of diatom biomonitoring in Quebec and elsewhere, it is proposed that the sampling frequency for water chemistry at monitoring stations where there is a continuous record of stable water chemistry could be reduced, and replaced with less frequent diatom community sampling to maintain records of water quality. Following this approach could free up resources and lab allocations to sample at new sites or to focus more intensive sampling on problem areas.

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Water Quality of Streams in Agricultural Watersheds of Southwestern Ontario: Seasonal Patterns, Historical Comparisons, and the Influence of Land Use

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Southwestern Ontario is a region of intense crop and livestock production. The impacts of these agricultural activities on water quality is a concern for the health of the streams flowing through these regions, as well downstream receiving waters, including large rivers with drinking water intakes and the Great Lakes. We examined 15 streams in agriculturally-dominated regions of Southwestern Ontario. In this work, we report on the seasonal patterns in the loadings and concentrations of total phosphorus (TP), nitrite + nitrate (NO_2+NO_3), suspended solids (SS), and *Escherichia coli* (*E. coli*) in these study streams. We compared stream loading estimates from the present work to a study of agricultural streams in the same region approximately 30 years ago (PLUARG), and consider the influence of land use on loadings and concentrations of TP, NO_2+NO_3, SS, and *E. coli*. There were marked seasonal patterns in nutrient concentrations and loads, with a majority of annual loads of TP, NO_2+NO_3, and SS delivered in winter and early spring, with low loading of these substances during summer. In contrast, *E. coli* loads were highest during autumn while concentrations were at their peak in midsummer to early autumn. We found that several estimates of loading between our study and those of PLUARG were similar, while in several other cases, our loading estimates were appreciably higher than those found by PLUARG. Relationships between land use and water quality suggest that cattle and poultry density in the study watersheds were positively related to TP and *E. coli* concentrations.

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Examination of Variation in Water Quality During High Flow Events in Urban and Suburban Tributaries

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An intensive event-based monitoring effort has been implemented in Hamilton area watersheds to improve characterization of water quality and pollutant loads to the harbour in support tributary source modelling and harbour eutrophication modelling. Since July 2010 sampling has been undertaken at three near tributary mouth locations as well as the inflow point from an urban marsh (Cootes Paradise) using remotely triggered ISCO automatic water quality samplers equipped with bubblers to provide a continuous record of water levels. Use of this technology has allowed 24 hour flow-weighted composite samples to have been collected for more than 70 precipitation, spring freshet and base flow events thus far and additional samples will be taken during the spring of 2012. Hourly samples spanning the 24 hour composite period have also been analyzed for a subset of sampling events to allow analysis of short-term variability in water quality during large precipitation events. This presentation examines the results of these hourly through-event samples analyzed for suspended solids, nutrients and metals. Results generally include pre-storm conditions (baseflow), and samples on the rising limb, peak, and falling limb of the hydrograph. These data provide insight into contaminant dynamics in urban and suburban tributaries and the observed patterns will inform potential strategies for achieving loading reductions.

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The Dynamic of the Urban Stream Contamination

R. VEDOM*

In order to analyze the dynamics of water quality of two adjoined watersheds of the Great Toronto Area (GTA) (Mimico Creek and Etobicoke Creek) in comparison with the Credit River located outside GTA, the Harmonized Frequencies Analysis (HFA) was used. Daily concentrations of chlorides, copper, total dissolved solids (TDS), and turbidity were obtained from the relation of their sampled concentrations with the corresponding dynamic components of flow: base, inter, and storm ones. Obtained this way daily concentrations were then processed like all other hydro-meteorological variables of this spacetime revealing their individual dynamic structures.

Results reveal that the urban streams have very similar dynamics of water quality in their base and storm components. There is the common process of the contaminants accumulation in groundwater (base component) indicating strong correlation between the variables of adjoined watersheds. This relation is stronger during the warm periods (R up to 0.95). Similarity in dynamics of the storm components are more pronounced during the cold period. Better correlation between corresponding components (base, inter, and storm) of the more urbanized watersheds than the less ones indicates unification of both quantitative and qualitative water regimes of the urbanized watersheds. The less urbanized watershed of Credit River has much higher correlation (R up to 0.99) between the variables of its own dynamic components.

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iSTREEM? - A Web-based River Chemical Concentration Estimation Model Capable of Determining Where and When to Monitor for Consumer Product Chemicals

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iSTREEM? is a publicly-available, web-based computer model that predicts the concentration of a chemical used in down-the-drain products in the effluent of more than 9,000 wastewater treatment plants throughout the continental United States, their resultant mixing zones and downstream river reaches and at drinking water intakes downstream of wastewater discharges (http://www.aciscience.org/iSTREEM.aspx). The model has been scaled at both the national level (e.g., approximately 28,000 river reaches covering over 200,000 river miles) and at the regional/watershed scales (e.g., Great Lakes basin; Willamette River basin, OR). By estimating freshwater exposures, the model permits scientists to understand where the greatest chemical risks may lie and how to best develop environmental monitoring programs. Likewise, it is a tool that can be utilized in setting public policy regarding freshwater discharges and pollution prevention. Currently the model is limited to streams within the contiguous 48 states of the U.S., but future plans include expansion to incorporate Canadian water-bodies and utilities so that its reach is truly continental and can better reflect the connectivity of watersheds that cross the U.S. and Canadian border, such as the Columbia and Red Rivers as well as the Great Lakes basin. The presentation will cover the development, algorithms, databases and structure of the model. In addition, a case study will illustrate how simulations for consumer product chemicals compare to target values developed by the Oregon Department of Environmental Quality (DEQ) and monitoring data from 52 wastewater treatment facilities studied under the Oregon DEQ Priority Persistent Pollutant program.

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Rural and Agricultural Water Stewardship

Chair: Gabrielle Ferguson, OMAFRA

Session Description

Water management is complex because water has so many functions. It takes an interdisciplinary effort to bring about robust, enduring and realistic actions that can assure each of us we are "doing the right thing". Business and lifestyle choices in the rural and agricultural landscape effect water quantity and quality. Making positive choices starts with a good understanding of water use followed by science based options for effective water management. This session will include topics such as water use efficiency, water quality, nutrient management, social factors affecting BMP adoption, evaluation of BMPs and collaborative approach to sub-watershed management. Come learn of how community stewardship creates synergy towards water quality improvements through examples.

Validating and Demonstrating Best Management Practices to Improve Water Quality on Ontario Farms

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The sciences of agronomics, hydrogeology, soils, social behaviour, economics and environment join together to evolve robust water quality solutions to complex biophysical and temporal farm production systems. Best Management Practices are not stagnant so there is a constant need to feed progressive ideas to innovative farm managers who tweak small plot and laboratory research into farm scale practical husbandry. It is through the collaborate efforts of scientists, agronomists and farmers that real understanding of how to implement actions that improve water quality can be made.

Projects that validate and demonstrate best management practices are in place across the province of Ontario. These projects investigate solutions to regulatory, production, economic and environmental obstacles. As information becomes available this science is used to support policy, programs and practices for the support of agriculture production systems that protect water quality.

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Water Stewardship Actions Under Environmental Farm Plans

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The Canada-Ontario Environmental Farm Plan (EFP) is an education and risk assessment tool that assists farmers in developing customized Action Plans to address the key environmental risks on their farms. During 2010-11 an evaluation of the effectiveness of the EFP was undertaken. A confidential survey of 189 Ontario farmers with Environmental Farm Plans revealed high levels of implementation of actions and significant investments of time and money to reduce risks to water quality and improve environmental conditions. On average, producers have completed or are implementing 65% of their Action Plans, up from 54% in 1999. The topic areas with the highest level of completion are Disposal of Farm Wastes, Soil Management, and Pest Management, Horticultural Production and Water Wells. Producers have invested about $69,600 per farm (73% of their own funds) in agri-environmental activities and spent 130 hours of their time per farm. These measures are much higher compared to a similar survey in 1999. 95% of farmers reported environmental improvements on their farm operations: 74% saw improvement to soil quality, 71% noticed improvement to water quality, 63% found improvement to family health and safety, and 48% saw improvement to fish and wildlife habitat. The survey also allowed assessment of the influence of socio-economic factors on actions taken. A series of recommendations suggest improvements to the EFP program to further assist farmers in implementing their EFP Action Plans.

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Spatial Analysis of Adoption of Nutrient Management Related Best Management Practices in Ontario, April 2005 - March 2010

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The Canada-Ontario Environmental Farm Plan (EFP) partnership undertook a spatial analysis of the adoption of nutrient management Best Management Practices (BMPs) in Ontario. The purpose of the analysis was to determine the effectiveness of the EFP as a place-based assessment tool for targeting or accelerating BMP project adoption in geographic areas at risk of elevated nutrient levels and to contribute to the measurement of the performance of the EFP and the Canada-Ontario Farm Stewardship Program (COFSP).

The analysis utilized data from the COFSP database for farms receiving funding for BMP projects from April 2005 to March 2010 and from the 2006 Census of Agriculture. Data were summarized at a municipal and watershed scale. Crop related nutrient management BMPs were analyzed in relation to the area of farmland receiving fertilizer. Livestock related nutrient management BMPs were analyzed in relation to the amount of manure and manure nutrients produced.

The spatial and regression analysis found that there is a high correlation between the number of nutrient management related BMPs adopted across the province (whether crop or livestock related) and the areas where there may be increased risk of elevated nutrients in the environment (whether from fertilizer application or manure production). The EFP and COFSP help target the adoption of livestock and/or crop nutrient management BMPs in municipalities with the highest production of manure or use of fertilizer in the province.

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Evaluating Rural Best Management Practices at the Site and Watershed Scales in Huron County

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The complexity of Great Lakes near-shore water quality issues calls for an integrated assessment of adjacent watersheds. Expanded from previous community watershed stewardship efforts, the Crops and Creeks, Watershed Based Best Management Practices Evaluation (WBBE, Huron) project is evaluating economic decision making and the environmental effects of multiple best management practices (BMPs) in pilot watersheds.

In this 75 km^2 area there are 14 small watersheds that range in size from 1 to 25 km^2. In watersheds north of Bayfield (40 km^2 area), 35 BMPs or community projects were undertaken in 2008 and 2009. To meet the project objectives, farmers in pilot watersheds in the Ausable Bayfield jurisdiction have been encouraged to adopt additional BMPs and to provide data on inputs/outputs of crop and livestock production system and BMP related changes (*e.g.,* revenue and costs). Information collected from the landowners regarding the costs and benefits of the BMPs will provide some insights to the economic decisions that are made at the farm-scale that influence interest in BMPs. We have also established test plots to determine the environmental efficacy of erosion control structures, cover crops, conservation tillage and reduced nitrogen application to improve predictability of existing watershed hydrological models.

The land management information, combined with water quantity and quality monitoring in the pilot watersheds, will help to determine the environmental efficacy of the BMPs at the site and watershed scales. The combined monitoring and modelling exercise will provide land and watershed managers with enhanced environmental and economic information about BMP implementation.

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Poster Presentations

	Session [a]	Authors [b]	Title
1	CCG	M. ANTHONY, M. FARROW, C. PIRIE	Climate Change Action Plan
2	EMC	D. MUIR, H. LEE, T. PEART, C. TEIXEIRA, A. SETT, J. STRUGER, S. BACKUS	Organophosphorus Flame Retardants and Benzotriazoles in Open Waters and Tributaries of the Great Lakes
3	EMC	J. ANDERSON, J. GUCHARDI, D. HOLDWAY	The Acute and Chronic Effects of Hydroxypropyl-β-Cyclodextrin on American Flagfish (*Jordanella floridae*) over One Complete Life-cycle
4	EMC-WWT	F. CLOUTIER, L. CLOUZOT, P. VANROLLEGHEM	A Modelling Tutorial to Predict the Removal of Emerging Contaminants in Wastewater Treatment Plants
5	GEN	J. GUCHARDI, R. KRAUSE, R. ORREGO, D. HOLDWAY	Vitellogenin Detection in Rainbow Trout (*Oncorhynchus mykiss*) Using Cryotechniques and Immunofluorescence
6	GEN	Z. PANDELIDES, R. ORREGO, J. GUCHARDI, D. HOLDWAY	Dehydroabietic Acid (DHAA) Alters Energy Metabolism and theEffects of E2 in Rainbow Trout (*Oncorhynchus mykiss*)
7	GEN	L. BEYGER, J.GUCHARDI, D.HOLDWAY	Does Holding Back Juvenile Rainbow Trout Growth Using Restricted Rations Affect Copper Toxicity Tolerance?
8	GEN	C.H. BARRETT, P.M.C. ANTUNES, K. TAILLON, K. KIM, S-J. AN,	Use of Multiple Lines of Evidence to Support Sediment Remediation and Management Decisions for the St. Marys River Area of Concern
9	GEN	R. BRADSHAW	Introducing Pollution Trading based on Willingness to Pay
10	HAB	A. MORLEY, J. WINTER	Algal blooms in Ontario: Incidences and Response
11	HAB	J. KINGSTON	Occurrence, Levels and Distribution of Cyanobacterial Toxins in Ontario's Municipal Drinking Water and Drinking Water Sources, 2004-2010
12	HAB	T. DECOLA, P. DECOLA, S.B. WATSON, S. OGUNLAJA, T. EDGE AND I. KHAN	Localised Differences in Dressenid Mussel Populations and Associated Biofilms and Pseudofaecal Material in the Bay Quinte: Implications for Drinking Water and Source Management
13	HAB	J. MCLAUGHLIN, I.F. CREED, C.G. TRICK	Bioassays as Tools for Improved Algal Bloom Screening
14	HAB	E.A. STELZER, D.H. DUMOUCHELLE, D.S. FRANCY	Assessment of Water-Quality Conditions, Cyanobacteria, and Microcystin Toxin in Grand Lake St. Marys, Ohio
15	NNT	R. LIANG, A. HU, X. ZHANG, D. LUONG, K. OAKES, M. SERVOS AND Y. ZHOU	TiO_2 Nanowire Membranes for Pharmaceutical Degradation in Wastewater
16	SGQ	C. HAMILTON, M.WOUDNEH, G.WANG, R.GRACE	LC – MS/MS Analysis of Naphthenic Acids in Environmental Analysis
17	SGQ	V.B. HEWLETT, S. NDIONGUE, L. MOORE	Monitoring Surface Water Quality of Inland Lakes Prone to Cyanobacteria
18	SGQ	J. THOMAS AND M. MOHAMED	Spatial, Temporal, and Host Source Distribution of Waterborne Protozoa Isolated from Urban and Rural Streams
19	SGQ	T.Y. KIM, R.E.H. SMITH, P. J. DILLION	The Spatial and Temporal Patterns of Planktonic Production - An Emphasis to Contribution of Non-summer Production to Annual Photosynthesis in a Large Oligo-mesotrophic Lake
20	SGQ	A.TODD, G.KALTENECKER	Warm Season Chloride Concentrations in Stream Habitats of Freshwater Mussel Species at Risk
21	SGQ	M. ELEKTOROWICZ, Z. KEROPIAN	Indian Mustard (*Brassica juncea*) as a Buffer Preventing Leaching of Lithium to Surface and Groundwater
22	WWT	D. YANG, B.C. ANDERSON, A.CHOUINARD	Multi-functional Wetlands and Landscape Design to Advance Chinese Ecological Infrastructure Development

Climate Change Action Plan

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The affects of Climate change will change the way of life for Aboriginal people in Canada. Aboriginal Affairs and Northern Development Canada (AANDC) is dedicating resources to help Aboriginal communities adapt to our changing environment, through its Climate Change Adaption Program (CCAP).

Priorities:

Coastal Erosion: shoreline erosion due to rising sea level, storms, and reduction in sea ice;

Permafrost Degradation: increase in the depth at which ground remains permanently frozen resulting in decreased ground stability, saltwater intrusion in coastal areas, release of contaminants, changes to surface/groundwater interaction, and other effects;

Increased Extreme Weather Events: increase in the frequency and/or severity of extreme weather events including storm surges, heat waves, storms (ice, rain, wind, snow), tornadoes, and droughts;

Changes to Water Resources: changes in timing and type of precipitation, lake/river levels, peak flows, and water temperature which affect the availability and quality of water for human use (drinking water, navigation, irrigation, etc.);

Changes to Ice Dynamics: changes in the timing, extent, and quality of lake and river ice resulting in reduced operating season for winter roads and changes in other on-ice activities; and,

Changes to Ecosystem Structure and Function: changes in the range, distribution, and viability of species resulting in habitats shifting upslope and to the north, biodiversity shifts, disruptions from invading species, loss of species, disease and pest outbreaks.

AANDC encourages experts to be part of that adaption planning, working in partnership with communities, businesses, university research centres and government, to empower communities in the development and implementation of their adaption plan.

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Organophosphorus Flame Retardants and Benzotriazoles in Open Waters and Tributaries of the Great Lakes

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Triaryl/alkyl phosphate, tris(haloalkyl) phosphates (TAAPs/THAPs) and benzotriazoles (BTZs) are of interest as contaminants in Great Lakes waters because they are high production volume chemicals with relatively high log K_{ow}s. Production of TAAP/THAPs increased by 11% in the USA and 57% in Asia from 2005 to 2008 due to their use as replacements for the brominated flame retardants. BTZs are widely used as corrosion inhibitors, and in aircraft deicing fluids and as UV absorbers in polymers. All 3 classes are thus directly emitted to the environment via volatilization and abrasive losses from polymers and indirectly via poor removal in waste water treatment. TAAP/THAPs were extracted from 1L water samples using solid phase cartridges and then analysed by LC-MS/MS using positive Electrospray Ionization (ESI+). Nine TAAP/THAPs were found in municipal wastewater (MWWTP) treatment plant influent and effluent samples at low ng/L to mid μg/L levels, with tris-butoxyethyl-phosphate (TBEP) and tris-chloroalkyl phosphates (TCEP, TCPP, TDCP) present at highest concentrations. TBEP, TCEP, TCPP, and TDCP were also the major TAAP/THAPs at the 3 mid lake sites in Lake Ontario (west, central and eastern basins) at <1 to 200 ng/L and were detectable at all depths. BTZ and 5-methyl-BTZ were also analysed by LC-MS/MS ESI+. MWWTP effluents had concentrations of BTZ ranging from 0.8 - 4.0 μg/L and MeBTZ from 1.2 - 2.2 μg/L. Near shore waters of Lake Ontario (1 m deep) had BTZ ranging from 24 - 42 ng/L and MeBTZ ranging from 38 - 97 ng/L. Although measurements of other lakes are limited, the results suggest TAAPs/THAPs and BTZs are ubiquitous contaminants of surface waters in the Great Lakes as a result of inflows from municipal wastewaters and tributaries.

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The Acute and Chronic Effects of Hydroxypropyl-β-Cyclodextrin on American Flagfish (*Jordanella floridae*) over One Complete Life-cycle

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The prevalence pharmaceuticals and personal care products in the aquatic environment have been steadily increasing in recent years, and the toxicological impacts of such compounds is poorly understood. One such chemical, hydroxypropyl-beta-cyclodextrin (HPβCD), commonly used in fragrance eliminating products (e.g. Febreeze) and the pharmaceutical industry, has recently been entering the environment through atmospheric and sewage discharge. Being cylindrical in nature and consisting of both a hydrophilic outer region and a hydrophobic inner region, HPβCD is very unique. A relatively large cavity permits the formation of non-covalently bonded inclusion complexes with various other compounds. The objectives of this study are to address the lack of aquatic toxicological information on both the acute and chronic effects of HPβCD to fish. A series of standard 96-h LC_{50} tests of HPβCD were run on various developmental stages of the larval American Flagfish (*Jordanella floridae*). The pending results from these acute toxicity tests will reveal many important toxicological properties of HPβCD. Moreover, the data obtained will provide the basis for a subsequent chronic toxicity life-cycle study on the American flagfish. It is hypothesized that the time to mature as well as the reproductive output will differ from the controls. In addition, examination of the behavioural and developmental aspects of the flagfish will provide significant insight into the environmental risk of HPβCD. Both LC_{50} and the preliminary life-cycle results are pending and will be discussed.

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A Modeling Tutorial to Evaluate the Fate of Emerging Contaminants in Wastewater Treatment Plants

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The influent of wastewater treatment plants (WWTPs) contains various emerging contaminants originating from pharmaceuticals and personal care products, other chemicals used in households, etc. Several studies have shown that these compounds can negatively affect living organisms. Most WWTPs were built to remove organic matter and nitrogen and therefore were not designed to treat other specific pollutants. Nevertheless, some WWTPs are able to achieve high removal efficiencies for the non-recalcitrant emerging contaminants. Their removal from wastewaters depends on the treatment trains, the operating conditions and the physicochemical properties of the pollutants. Their main removal processes are volatilization, biodegradation, and sorption. A modelling tutorial on micropollutants was created as part of a CWN-workshop that was held in Quebec City in June 2011 for students and young professionals.

Modeling and simulation were carried out in the software tool WEST® (www.mikebydhi.com) to represent the dynamics and fate of pollution in different wastewater unit processes. The models were developed as part of the ScorePP project and a CWN project on the removal of emerging contaminants in different treatment trains. As examples, the removal efficiencies of 17α-ethinylestradiol (EE2), trichloroethylene (TCE), and bis(2-ethylhexyl) phthalate (DEHP) were studied under dry and wet weather in five wastewater treatment trains: conventional activated sludge (CAS), nitrifying activated sludge (NAS), biological nutrient removal (BNR), CAS + sand filtration, and enhanced primary clarification + ozonation. In the end, this easy-to-use tutorial allows to easily predict the fate of selected emerging contaminants in various types of treatment trains.

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Vitellogenin Detection in Rainbow Trout (*Oncorhynchus mykiss*) Using Cryotechniques and Immunofluorescence

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Vitellogenin (VTG) is an egg yolk precursor protein which can be used as a biomarker of exposure to estrogenic xenobiotics found in the environment. Produced in the liver, this protein can be detected in the blood using an enzyme linked immunosorbent assay (ELISA). Once in the gonadal tissue, it can be detected within the cells using immunofluorescence (a specific type of immunohistochemistry, IHC) in paraffin embedded or frozen tissue sections. Detection using traditional "paraffin section histology" has been criticized due to extensive tissue processing which can compromise antigen integrity. Using immunofluorescence in conjunction with "frozen section histology" can preserve antigens for antibody recognition. This project analyzed gonadal tissue of twelve sexually mature rainbow trout using paraffin and frozen section histology and immunofluorescence. The two techniques of tissue and section preparation were compared for efficacy and section quality. The method for detecting VTG with immunofluorescence on frozen sections was optimized. Results were qualitatively compared to blood VTG levels, as well as the known sex and maturation stage of each fish. Frozen section histology proved to be a useful technique yielding sections which were comparable to paraffin section histology. Immunofluorescence was effective at detecting VTG within oocytes with the fluorescence intensity correlating to oocyte maturity. Frozen section histology and immunofluorescence will be useful for detecting VTG induction in fresh gonadal tissue of rainbow trout exposed to estrogenic xenobiotics in both environmental and laboratory settings.

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Dehydroabietic Acid (DHAA) Alters Energy Metabolism and the Effects of E2 in Rainbow Trout (*Oncorhynchus mykiss*)

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Recent studies have shown that dehydroabietic acid (DHAA), a resin acid present in pulp and paper mills, affects liver energy metabolism and may have anti-estrogenic effects in fish. A chronic-exposure toxicity experiment using immature rainbow trout (*Oncorhynchus mykiss*) was conducted in order to assess the endocrine disrupting and liver metabolic effects of the wood extractives DHAA and β-sitosterol (BS) regularly present in pulp and paper mills and the model estrogen 17β-estradiol (E2). It was found that exposure to 5 ppm of E2 significantly increased hepatosomatic index (HSI), vitellogenin (VTG) and plasma sorbitol dehydrogenase (SDH). This latter effect was reduced by mixing E2 with DHAA, indicating that DHAA does not cause its anti-estrogenic effects indirectly due to liver damage. Exposure to 5 ppm of DHAA caused significant increases in liver citrate synthase (CS), and liver ethoxyresorufin-O-deethylase (EROD) activity after 7 days, however, the fish returned to control values by 28 days. The results of the study indicate that DHAA may alter energy metabolism as well as alter the effects of E2 in juvenile rainbow trout.

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Does Holding Back Juvenile Rainbow Trout Growth Using Restricted Rations Affect Copper Toxicity Tolerance?

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Toxicity testing is a common method of practice when trying to establish guidelines and regulations for acceptable limits of chemicals being received in the environment. The aim of this research was to determine if some of the variability in LC_{50} values found in the literature for the same toxicants is due to researchers and/or hatcheries maintaining (zero growth) fish for extended periods of time prior to exposure. A standard 24-h flow-through LC_{50} of 44.5 µg/L (± 3.54) was determined for larval rainbow trout (~1.8 g wet weight) continuously exposed to copper. Another 24-h continuous flow-through LC_{50} of 50.4 µg/L (± 3.98) was determined after 21-d of holding at restricted rations (0.4 % body weight /day). The rainbow trout were approximately 2.1 g wet weight. There was no significant difference seen between these two LC_{50} values. Following another 21-d of holding at restricted rations, fish were ~2.8 g and a 24-h continuous flow-through LC_{50} of 66.5 µg/L (± 1.41) was calculated. This final LC_{50} value was significantly different ($p \leq 0.05$) compared to the first and second values. The significant difference in the final LC_{50} value was likely due to the modest growth of the juvenile trout. Based on these findings, it is highly unlikely that the variability in LC_{50} values in the literature is due to the holding history of stock populations, including the use of restricted rations.

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Use of Multiple Lines of Evidence to Support Sediment Remediation and Management Decisions for the St. Marys River Area of Concern

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The St. Marys River connects Lake Superior and Lake Huron and is often referred to as the "Hub of the Great Lakes." Since the early 1900s the river has received industrial and municipal wastewater, which has resulted in sediment contamination with petroleum hydrocarbons, polycyclic aromatic hydrocarbons, oils/grease, and metals such as chromium, iron, and zinc. Because of the extensive contamination and other environmental concerns, the St. Marys River was designated as one of 43 Areas of Concern (AOC) under Annex 2 of the 1987 Canada-US Great Lakes Water Quality Agreement. The agreement requires the development of a Remedial Action Plan (RAP) for AOCs. Under the Canadian portion of the RAP, science-based evidence is being collected in support of the Canada-Ontario Decision-Making Framework for Assessment of Great Lakes Contaminated Sediment. This includes an assessment of sediment toxicity, benthic community structure, pore water chemistry, surficial and at-depth sediment chemistry, modeling of sediment transport and fate, and geotechnical assessment of the sediment profile with depth.

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Introducing Pollution Trading Based on Willingness to Pay

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This paper describes an environmental situation relating to pollution of a water course and introduces market-based evaluation model to internalise externalities. The model uses the concept of ?willingness to pay? to evaluate social and environmental costs of pollution to stakeholders and allows for the trade-off between cost and risk in allocating pollution entitlements in a quantitative pollution trading model.

One of the key defining problems with externalities such as pollution impacts is the lack of ownership of common resources (air, water, etc.). In the 1980?s, a new worldview has emerged in economic theory that common resources are in fact no different from any other economic resource and as such should be assigned exclusive ownership rights that are traded on economic markets.

Human activity produces a vast amount of wastewater that would pollute aquatic systems if not adequately treated. In our market model, two scenarios were developed, firstly, the ownership transfer of the common resource to a polluter and secondly, the ownership transfer of the common resource to any other riparian water user who depend on a clean water resource.

This paper presents a mathematical model to demonstrate that regardless of who assumes ownership over the common resource, the public trading of pollution certificates based on willingness to pay and cost benefit analysis will always result in the same optimal price and rate of pollution.

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Algal Blooms in Ontario: Incidences and Response

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Cyanobacteria, commonly known as "blue-green algae", are a type of photosynthetic bacteria commonly found in freshwater bodies. When conditions are favourable, growth accelerates and cyanobacteria can accumulate within the surface water body as a "bloom" or as a "scum" on the water's surface. These blooms are a seasonal phenomenon, usually occurring in the late summer and early fall and tend to occur repeatedly in the same water bodies. Common genera of cyanobacteria identified in Ontario Lakes are *Microcystis*, *Anabaena*, *Oscillatoria* and *Aphanizomenon*. These genera are potential producers of algal toxins; including microsystin-LR which may cause liver damage to humans and other mammals, and for which the Ontario drinking water quality standard is a maximum acceptable concentration of 0.0015 mg/L (O. Reg 169/03, schedule 2).

The Ontario Ministry of the Environment has developed a comprehensive protocol for responding to occurrences of cyanobacteria blooms in Ontario lakes. The protocol ensures clarity of roles and responsibilities and effective management of these incidents.

In this presentation we will provide an introduction to cyanobacteria blooms in Ontario lakes and review the Ministry of the Environment's response protocol to algal bloom incidents.

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Occurrence, Levels and Distribution of Cyanobacterial Toxins in Ontario's Municipal Drinking Water and Drinking Water Sources, 2004-2010

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The Ontario Ministry of the Environment's Drinking Water Surveillance Program (DWSP) has monitored for cyanobacterial toxins in untreated source water and treated drinking water at selected municipal drinking water systems in Ontario since 2004. From 2004-2010, nearly 1100 samples were collected at 18 drinking water systems. These samples were analyzed using liquid chromatography – (electrospray ionization) tandem mass spectrometry [LC-(ESI)MS/MS] to quantify the concentration of microcystins -LA, -LR, -RR, and –YR, nodularin and anatoxin-A. Cyanobacterial toxins were detected in only 0.4% of treated drinking water samples from two drinking water systems. Concentrations were very low and on the one occasion when microcystin-LR was detected, the concentration was 25 times lower than the ODWQS. In untreated source water, there was a rate of detection of 42% in the samples that were collected at 12 drinking water systems. Microcystin-LR was most frequently detected variant in untreated source water and the maximum concentration was 3.4 μg/L. The next most frequently-occurring cyanobacterial toxins were microcystins-RR and –LA, with maximum concentrations of 1.2 and 0.29 μg/L, respectively.

This paper discusses the occurrence, levels and distribution of cyanobacterial toxin detections in untreated source water and finished drinking water in Ontario from 2004-2010.

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Localised Differences in Dressenid Mussel Populations and Associated Biofilms and Pseudofaecal Material in the Bay Quinte: Implications for Drinking Water and Source Management

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Invasive dressenid (zebra, quagga) mussels have profoundly affected the water quality and food web structure in the Great Lakes since the 1990s. Dressenid populations vary with conditions such as depth, food availability, temperature, substrate and prevailing current. They can establish extensive beds composed of active and dead mussels of different size and age (and filtering capacity), biofilms (on mussel shells), attached algae, cyanobacteria and microbiota (actinomycetes, fungi, heterotrophic bacteria, micrograzers etc) and loosely associated pseusdofaecal material. While there have been a number of surveys across the Lakes for dressenid abundance and age/size/species distribution, there is little information about the nature of the associated biofilm material. This is an important data gap, since this attached biota may represent a significant source of taste-odour (T&O) for some inshore areas such as the Bay of Quinte (Lake Ontario). In addition, pseudofaecal material may represent a source of enteric pathogens which may threaten drinking water supplies.

Our primary goal, therefore, was to evaluate differences in dressenid mussel populations and biofilm material at two inshore locations located ~5 km apart in the Bay near major drinking water intakes, and pathogen levels in the associated material. In this preliminary study, we evaluated the coverage and nutrient content of the material on the dressenid shells at the two locations which experience different levels of T&O impairment. The first intake (Pt Anne) is located ~103 m offshore at 2.5 m depth in a naturally sheltered cove with limited flushing and a bottom substrate of mostly large flat limestone rock. The second intake (City of Belleville) is ~490 m offshore at 5.4 m depth in a well flushed area in the navigational channel of the Bay with a silty bottom substrate. Dressenid mussels and overlying water samples were collected by divers from each site using a 30 cm^2 template. Mussels were speciated, weighed and divided into size categories (< 1.0cm, 1.0 - 1.5cm, 1.5 - 2.0 cm and < 2.0 cm). All specimens were scraped 5 times, and this material was collected in a final volume of 300mL distilled water. This material was analysed for particulate nutrients (P,N and C) and examined under the microscope for cyanobacterial taxa. Overlying water was analysed for both particulate nutrients and chla, while pseudofaecal material was collected using sterile syringes and analysed for microbial indicators (*E. coli*, total coliform, total heterotrophic bacteria, *Enterococcus*).

Our results showed significant differences in the mussel communities and associated biofilms among sites, with higher density, size and biofilm content at the more protected Pt Anne site. Belleville had a lower mussel density (2500 vs. 8000 animals/m2),

average mussel weight (0.5 vs. 1g) and size (1.2cm vs. 1.4cm) and mass per unit length than Pt Anne. Between-site variation in weight and size may also have reflected the marked differences in species distribution even within this small coastal region. We observed an approximate even distribution of both quagga and zebra mussels at Belleville while all specimens at Pt Anne were quagga mussels. Organic and nutrient content of the biofilm per unit weight differed significantly, with a higher organic C and P content at Pt Anne. Overlying water showed similar nutrient content between the two sites but the suspended chlorophyll levels were significant higher at Pt Anne (2.5 vs 19.7ug/L). Biofilms did not exhibit any significant numbers of cyanobacteria at either site but contained amorphous organic material, fungi and bacteria. Both sites showed very low numbers of the typical microbial indicator *E. coli* in the pseudofaecal material*; which,* however, contained higher counts of total coliform and *Enterococci* at Belleville, suggesting influence from sewage outfall at this site, although it is farther offshore than Pt. Anne. These differences point to the importance of highly localized shoreline influences which have a potentially significant effect on the structure and composition of the littoral benthic community with important implications for water quality and drinking water integrity.

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Bioassays as Tools for Improved Algal Bloom Screening

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The spatial variability of algal blooms in Ontario's freshwater lakes provides a challenge for investigators seeking to assess the biological impacts of toxic and noxious bloom events. Several small-scale bioassays have been developed for detection of freshwater pollutants, but few attempts have been made to modify these assays for the purpose of freshwater algal compound analysis. Two assays (the RTgill-W1 cell line and erythrocyte lysis) were optimized to develop fast, reliable, low volume, and high throughput screening methods of toxic and noxious freshwater algal compounds. Both bioassays have been evaluated through the use of various analytical standards (eg. Microcystin-LR, 2,4-Heptadienal) and extracts from laboratory cultures to assess their sensitivity to the toxic and noxious compounds commonly produced in Ontario lakes. A number of these compounds have been determined to be suitable for detection by these bioassays, suggesting that these assays may be appropriate for the assessment of non-specific algal blooms. Successful adaptation of these assay methods will improve the screening efficiency and capacity for investigators of water quality and bloom dynamics.

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Assessment of Water-quality Conditions, Cyanobacteria, and Microcystin Toxin in Grand Lake St. Marys, Ohio

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Grand Lake St. Marys, the largest manmade lake in Ohio, is used for recreational activities and as the drinking-water supply for the City of Celina, Ohio. This shallow lake (generally less than 2.5 meters deep at the summer pool elevation) has been placed under recreational advisories for the past few years due to harmful algae blooms, including during the entire 2011 recreational season. A 3-year study (2011-13) by the U.S. Geological Survey and the Ohio Water Development Authority was initiated to develop and utilize new tools to better understand the spatial and temporal occurrence of cyanobacteria, nutrients, and microcystin production in the lake. One large buoy continuously measuring pH, temperature, specific conductance, dissolved oxygen, and chlorophyll *a*, as well as five marker buoys measuring temperature, were installed during 2011. Additional field measurements were made around the perimeter of the lake. Water samples were collected five times during the field season at buoy locations. Samples were analyzed for nutrients, major ions, trace elements, mircocystin, cyanobacteria species identification, phytoplankton biomass, and zooplankton. Additionally, the cyanobacterial community was identified by use of quantitative polymerase chain reaction (qPCR) on three levels: total cyanobacteria, total *Microcystis*, and the presence of genus-specific microcystin toxin genes for *Microcystis* and *Planktothrix*. Preliminary results indicated that total cyanobacteria, total *Microcystis*, and *Planktothrix* toxin gene levels were consistent throughout the season (May-August).

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TiO_2 Nanowire Membranes for Pharmaceutical Degradation in Wastewater

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Pharmaceuticals in wastewater are an emerging global problem, and the development of cost–effective methods facilitating their removal would be of great advantage. TiO_2 nanowire membranes have been fabricated as a means to increase photodegradation rates under UV exposure. UV illumination of predominantly anatase-phased TiO_2 nanomembranes, excites the membrane and generates electron-hole pairs, which produce hydroxyl radicals from adsorbed molecular oxygen. These hydroxyl radicals are able to oxidize pharmaceuticals present in wastewater. The membranes were investigated for photocatalytic oxidation and mineralization of a number of pharmaceuticals, such as atorvastatin and sulfamethoxazole. The degree of pharmaceutical degradation was dependent on light intensity, amount of photocatalyst, suspension pH, illumination time, and initial concentration. The metabolite degradation pathways and degree of mineralization of these pharmaceuticals were determined using LC-MS and TOC, respectively, under 3h of UV irradiation.

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LC-MS/MS Analysis of Naphthenic Acids in Environmental Waters

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Naphthenic acids are a complex mixture of acyclic carboxylic acids naturally present in hydrocarbon deposits around the world. They are a component of the biogenic background in ground and surface waters of the oil sands region of northern Alberta and are also found in high concentrations in process waters and tailings waters. This paper describes a novel method for the analysis of these acids of general chemical formula $C_nH_{2n+z}O_2$ in ambient and tailings waters using LC-MS/MS. Solid phase extraction is used to concentrate the naphthenic acids, either as a laboratory tool for extraction of grab samples or as a passive sampling step used in POCIS sampling of surface waters. The extracts are derivatized by reaction with 1-ethyl-3-(3-dimethylaminopropyl) carbodiimide hydrochloride (1-EDC·HCl in a pyridine/ethanol solution) to convert the carboxylic acid functional groups on the NAs to their EDC adducts. Analysis of the extracts is performed by high performance liquid chromatography with triple quadrupole detection (LC-MS/MS). Positive ion electrospray is used as the method of ionization with the MS/MS system operated in the Multiple Reaction Monitoring (MRM) mode. Deuterium labeled internal standards added at the beginning of the analysis are used for quantification and pyrene butyric acid is the quantification reference. The concentrations of 60 isomer groups of naphthenic acids ($C_nH_{2n+z}O_2$ with n ranging from 12 to 21 and n ranging from 0 to -12) are reported as pyrene butyric acid equivalents. In this paper we will describe the method, present method validation data and show results for ambient and process waters.

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Monitoring Surface Water Quality of Inland Lakes Prone to Cyanobacteria

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The impact of surface water quality of inland lakes from increased nutrient supply is a growing concern and emerging issue. In recent years, two spring-fed, inland lakes in the Bruce County have been prone to cyanobacterial blooms. These lakes are marl lakes and are mainly spring-fed, which results in hardwater. In marl lakes, carbonates precipitate with phosphate ions, which reduces available phosphorus, ultimately limiting phytoplankton growth.

There has been an increase in nutrient supply to the lakes, but due to the carbonate-phosphate interaction, the lakes can currently resist detrimental effects from the additional nutrients. However, since cyanobacterial blooms have been prevalent in recent years, water quality must be closely monitored to identify vulnerable locations of the lake that are susceptible to cyanobacterial blooms. To monitor the water quality of the lakes, 15 water samples were collected and monitored for surface water quality parameters at several time points during summer 2011. Surface water quality parameters such as, nitrate, orthophosphate, total iron, hardness and turbidity were analyzed for each sample. Overall, the water quality parameters were variable across time and between sample locations, with the exception of hardness. Some sample sites had high nitrate and total iron levels, whereas other sample sites had high orthophosphate levels (0.09 mg/L), which may indicate mesotrophic-eutrophic conditions in those areas. Future investigations will include total nitrogen, total phosphorus and total dissolved iron to clarify the trophic level of the lakes and to distinguish vulnerable areas within the lakes.

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Spatial, Temporal, and Host Source Distribution of Waterborne Protozoa Isolated from Urban and Rural Streams

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Cryptosporidium and *Giardia* are environmental robust protozoan parasites that have been associated with drinking water outbreaks in Canada. Many species of *Cryptosporidium* are host adapted, with two species (*C. parvum* and *C. hominis*) primarily responsible for human infections. To further understand the spatial and temporal distribution of waterborne *Cryptosporidium* and *Giardia*, we conducted a two year study (September 2007 to August 2009) in three tributaries of the Grand River watershed (southwestern Ontario), including an urban, rural/agricultural, and mixed-use watershed. In addition, we used PCR-RFLP and gene sequencing to determine the predominant *Cryptosporidium* species/genotypes present. This technique allows for an understanding of the sources of this contamination, as well as the risk these species pose to human health. While we found that precipitation, turbidity, nutrient levels, and stream discharge were positively associated with indicator bacteria (*E. coli* and enterococci) densities, we observed no relationship between protozoa abundance and these variables. Seasonal trends were similar among watershed types, with peaks in abundance observed in the late summer and fall. Overall, protozoan levels were similar among the urban, agricultural, and mixed-use watersheds. However, genotyping revealed marked differences in host sources in watersheds of varying land-uses. Agricultural watersheds were dominated by genotypes typically found in cattle, while urban watersheds had the highest diversity of *Cryptosporidium* species, with a variety of wildlife as the common source of contamination. Despite the abundance of *Cryptosporidium* in these watersheds, most of the *Cryptosporidium* genotypes observed in these waters were of limited human health risk.

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The Spatial and Temporal Patterns of Planktonic Production- An Emphasis to Contribution of Non-summer Production to Annual Photosynthesis in a Large Oligo-mesotrophic Lake

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Emerging issues such as degradation of water qualities, introduction of dressenid mussels and depletion of oxygen concentrations in the hypolimnion in Lake Simcoe, Ontario prompted a study of phytoplankton primary production in an attempt to improve the lake conditions. The characterization of algal production is critical since, as primary producers, their biomass is positively correlated with production at higher trophic levels in pelagic food webs and oxygen levels. The bulk of this study focuses on the spatial and temporal patterns of planktonic primary production using C^{14} tracer analysis in Lake Simcoe. An emphasis is given to non-summer and nearshore processes because non-summer and nearshore production may contribute significantly to annual production cycle. The integrated water samples were taken from ten water quality stations from August 2010-August 2011 except for January 2011. In winter (Jan-Mar), samples from the Beaverton water treatment plant (BWTP) were also collected. As of now, the results show that total daily areal and volumetric production using incident irradiances range from 31.6 to 1221.8 mg C m^{-2} d^{-1} and 3.5 to 150.2 mg C m^{-3} d^{-1}, respectively for open water seasons. During winter (Feb-Mar), the production varies from 0.1 to158.5 mg C m^{-2} d^{-1} and 0.0343 to 18.8 mg C m^{-3} d^{-1}, respectively. Contrary to the classical seasonal pattern of dimictic meso-oligotrophic lakes, algal production is highest in fall (Sept-Nov) followed by spring (Apr-June). As expected, the overall production is lowest in winter (Dec-Mar).

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Warm Season Chloride Concentrations in Stream Habitats of Freshwater Mussel Species at Risk

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Trends in warm season (May-October) chloride concentrations were assessed in stream habitats of at risk freshwater mussels in southern Ontario. Significant increases in concentrations were observed at 96% of 24 long-term (1975-2009) monitoring sites. Rates of increase ranged from <0.1 to 2.8 mg Cl L^{-1} $year^{-1}$. Contemporary (2005-2009) median and maximum concentrations ranged from 2 to 159 mg L^{-1} and 4 to 261 mg L^{-1}, respectively, and were positively correlated with road density, population density and percent urban and negatively correlated with percent forest. Linear regression showed that concentrations were significantly related to road salt use. Results suggest that long-term salt loading is contributing to a gradual increase in warm season chloride concentrations in at risk mussel habitats. In Ontario, mussel larvae (glochidia) are released into stream water during the warm season. Acute toxicity (24 h EC50) of glochidia from southern Ontario streams has been observed at chloride concentrations as low as 113 mg L^{-1} in laboratory studies, indicating that toxic effects may be occurring at contemporary concentrations. Given the trend toward higher exposure levels, and the sensitivity of glochidia to chloride, recovery strategies for at risk mussels should consider the likelihood of existing and future negative effects from salt loading.

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Indian Mustard (*Brassica juncea*) as a Muffer Preventing Leaching of Lithium to Surface and Groundwater

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Lithium is largely regarded as benign primary material for batteries and therapeutic compound. Its daily intake of 500 $mg.day^{-1}$ is regarded as no affecting human health and growth. Contrary, frequent trials on animals revealed different symptoms of illnesses when its daily feed was supplemented with 50 $mg.day^{-1}$ lithium. Moreover, lithium as an alkali metal is extremely mobile in environment and its leachate from mine tailings cannot be easy stabilized; subsequently, lithium ends in surface and groundwater.

The objective of this research was to find tailing conditions, which are suitable for the *Brassica juncea* (Indian mustard) growth in order to phytoextract and stabilize the lithium. Tested tailing matrices were composed of tailings, peat and dewatered sludge mixed in different proportions. The plants were sowed on five different growth media for 86 days then harvested, cleaned, dried and digested. The lithium concentrations in physiological parts of plants were measured, per dry weight basis using the atomic absorption spectroscopy Analyst 100.

Finally numerous comparisons were drawn on the presence of lithium around the plant rhizosphere (494 $mg.kg^{-1}$), in roots (19.87 $mg.kg^{-1}$), in its stem (91.14 $mg.kg^{-1}$) and in the leaves (626.25 $mg.kg^{-1}$), which provides us the ability to consider the *Brassica juncea* as a suitable plant for phyto-extraction and stabilization of lithium. The best growth was observed in medium composed in an equal proportion of tailings, peat and sludge - components which can be found in abundance in northern mining areas.

Successful use of plants can serve as a buffer system for protection the leachate of lithium toward streams and groundwater.

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Multi-functional Wetlands and Landscape Design to Advance Chinese Ecological Infrastructure Development

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The focus of this research is a typical tract of land severely impacted by flyash heaps left by Chinese coal factories. Faced with an extreme shortage of usable land in China, multi-functional and on-site infrastructure needs to be explored to bring these brownfield sites back into productive use. It is also the desire of the national government of China to focus on rural development in the new 12th Five-Year plan; it is our contention that the western 'big pipe 'approach will probably not be the solution in most parts of rural China. This paper therefore proposes to use a bidirectional wetland system aimed at improving the environment and integrating itself into the fabric of the site, from the perspectives of both form and function.

Making use of the different permeabilities between the flyash and the typical clay underlying the heap, wastewater from neighboring villages can be purified by gravity filtration through the flyash (due to its special molecular structure) and the filtrate can then be reclaimed in depression storage areas distributed within the heap. It has been shown that the heap will extract nutrients from the wastewater during filtration, which would be synchronized with the growing plants of the wetlands. This design also produces a garden-like setting with sculptural earth forms woven into the site history, which also dictate flow-forms.

This research will contribute to a deeper consideration and innovative exploration of constructed wetland design and application for infrastructure and site remediation as well as for recreation of natural landform, to address these environmental challenges in China and elsewhere.

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