CAWQ
ACQE

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

46TH CENTRAL CANADIAN SYMPOSIUM ON WATER QUALITY RESEARCH

Book of Abstracts

Managing Urban Water and Municipal Wastewater

Canada Centre for Inland Waters
Burlington, Ontario

FEBRUARY 22 & 23, 2011

Environment Canada Environnement Canada

Canada

MESSAGE FROM THE PROGRAM CHAIR

On behalf of the organizing committee, it is my pleasure to welcome you to the 46th Central Canadian Symposium on Water Quality Research. This year's theme is "Managing Urban Water and Municipal Wastewater." We have assembled a strong technical program, with session themes covering all aspects of water quality management in urban environments. The goal is to convene a symposium that benefits delegates interested in a wide range of water quality and treatment issues. Fitting with this year's theme, we are pleased to welcome Dr. Jiri Marsalek as our plenary speaker, who will open the Symposium with a presentation on total management of the urban water cycle. We welcome you to Burlington and wish you a successful and informative symposium.

Kirsten Exall
Environment Canada
Program Chair

Plenary Presentation

Managing Urban Waters in the Context of the Urban Water Cycle

Dr. JIRI MARSALEK
Environment Canada

Progressing urbanisation leads to ever increasing concentrations of people in urban areas. Statistics indicate that of the current world population (almost 7 billion people) more than one half live in urban areas and this proportion will be further increasing. The urban population creates demands on water, energy and food, and exerts adverse impacts on the environment, including water resources and their ecosystems. The connectivity among various elements of the urban water system is best described in the context of the urban water cycle. Conflicting demands on water resources, which are further exacerbated by climate variability, make provision of water services to the urban population particularly challenging and need to be resolved by integrated water management. In urban areas, such a management approach is known as total management of the urban water cycle (TMUWC) and encompasses such measures as:

- Integrated stormwater, groundwater, water supply and wastewater management, as the basis for: economic and reliable water supply; environmental flow management (deferment of infrastructure expansion, return of water to streams); urban water-scape/landscape provision; substitute sub-potable sources of water (wastewater and stormwater reuse); and, protection of downstream waters from pollution;
- Reuse of treated wastewater, as a basis for disposing potential pollutants, or a substitute for other sources of water supply for sub-potable uses; and,
- Water conservation (demand management) based approaches, including: more efficient use of water (water saving devices, irrigation practices); substitute landscape forms (reduced water demand); and, substitute industrial processes (reduced demand, water recycling).

While full applications of TWUCM are not yet common, specific elements of this concept have been applied in recent years and will be discussed and documented by examples from studies addressing innovative stormwater management, encompassing such concepts as 'design with nature' and 'low impact development'; water supply focusing on 'soft path for water', rather than just meeting the water demands; wastewater management oriented towards resource recovery; and, the assessment of aquatic habitats in newly created urban waterscapes (e.g., stormwater management ponds).

Table of Contents

Plenary Lecture

Managing Urban Waters in the Context of the Urban Water Cycle

Jiri Marsalek

WSTD, Burlington, Ontario

Progressing urbanisation leads to ever increasing concentrations of people in urban areas. Statistics indicate that of the current world population (almost 7 billion people) more than one half live in urban areas and this proportion will be further increasing. The urban population creates demands on water, energy and food, and exerts adverse impacts on the environment, including water resources and their ecosystems. The connectivity among various elements of the urban water system is best described in the context of the urban water cycle. Conflicting demands on water resources, which are further exacerbated by climate variability, make provision of water services to the urban population particularly challenging and need to be resolved by integrated water management. In urban areas, such a management approach is known as total management of the urban water cycle (TMUWC) and encompasses such measures as:

- Integrated stormwater, groundwater, water supply and wastewater management, as the basis for: economic and reliable water supply; environmental flow management (deferment of infrastructure expansion, return of water to streams); urban water-scape/landscape provision; substitute sub-potable sources of water (wastewater and stormwater reuse); and, protection of downstream waters from pollution;
- Reuse of treated wastewater, as a basis for disposing potential pollutants, or a substitute for other sources of water supply for sub-potable uses; and,
- Water conservation (demand management) based approaches, including: more efficient use of water (water saving devices, irrigation practices); substitute landscape forms (reduced water demand); and, substitute industrial processes (reduced demand, water recycling).

While full applications of TWUCM are not yet common, specific elements of this concept have been applied in recent years and will be discussed and documented by examples from studies addressing innovative stormwater management, encompassing such concepts as ‘design with nature’ and ‘low impact development’; water supply focusing on ‘soft path for water’, rather than just meeting the water demands; wastewater management oriented towards resource recovery; and, the assessment of aquatic habitats in newly created urban waterscapes (e.g., stormwater management ponds).

Advances in Wastewater Treatment

Chairs: Hongde Zhou, Wayne Parker, Hyung-Sool Lee, Sheng Chang

This session will focus on research and development in treatment processes and approaches for both municipal and industrial wastewater. Subjects may include, but are not limited to:

- Development of innovative wastewater treatment processes
- Optimization of wastewater treatment processes
- Enhancements in modeling of wastewater treatment
- Application of existing technologies to new contaminants and waste streams
- Biosolids processing and management
- Studies that provide enhanced insights into existing technologies

Pollution Loadings of Ontario's Municipal Wastewater Plants: Who is Monitoring?

G. MILLER, E. SCHWARTZEL*

Environmental Commissioner of Ontario

This presentation will share the perspective of the Environmental Commissioner of Ontario (ECO) on the adequacy of municipal wastewater regulation in Ontario, as featured in the Commissioner's new Annual Report for 2009/2010.

Municipal wastewater effluents have significant impacts on receiving waters. In Ontario, the lower Great Lakes receive the lion's share of municipal wastewater effluent. A variety of trouble signs on the Great Lakes are warning us to pay some attention to pollution loadings; we are seeing proliferation of algae and problems with closed beaches. However, Ontario's guidelines for effluent quality were established in 1983 and have not been tightened despite very strong population growth over the last generation. This suggests that pollution loadings have been increasing steadily. Unfortunately, it appears that Ontario's Ministry of Environment (MOE) has lost the capacity to measure and track loadings from municipal wastewater facilities, and there has been no public reporting on this key metric since 1993.

MOE has deferred policy development in this area since at least 2004, awaiting the completion of a national strategy for municipal wastewater effluent under the umbrella of the Canadian Council of Ministers of the Environment (CCME). However, effluent limits under the new CCME Strategy are not stringent, and if adopted in Ontario, would merely perpetuate the status quo. To protect water quality and to compensate for population growth, a new approach is needed – an approach that would reduce allowable effluent concentrations over time. The ECO also recommends that MOE monitor and publish annual reports on the quality of municipal wastewater discharges to Ontario's waterways, providing both concentrations and loadings of key pollutants.

*Presenting author; ellen.schwartzel.on.ca

Assessing Titanium Coagulants for Municipal Wastewater Treatment

E. HAMILTON*, R. GEHR

Department of Civil Engineering and Applied Mechanics, McGill University

Using jar tests, titanium coagulants were compared to ferric chloride (FeCl3) and alum (Al2(SO4)3•18H2O) for treating a municipal wastewater. Samples were collected from a plant in Fabreville, Quebec.

The coagulants were compared at doses of 5, 10, and 15 mg (metal)/L. At highest doses, all coagulants performed similarly, except for sludge volume. At the highest dosage, typical removals of total reactive phosphorus, TSS and FC were 94 - 95%, 55 - 78%, and over 80%, respectively, for all three coagulants. Phosphorus, TSS, and FC are regulated by Quebec. The criteria for phosphorus and TSS were met at all doses, but the FC criterion was not; coagulation, however, is not expected to significantly decrease FC counts.

Wastewater treated with the minimum dosage of alum and FeCl3 produced sludge volumes 2.2 and 1.4 times that of the titanium coagulant, respectively. As municipalities are charged by weight of sludge for landfill disposal, a lower rate of sludge production could result in a reduction in costs for the municipality. An additional cost consideration is the proportion of metals in the coagulant dose. Assuming that Al and Fe perform similarly as coagulants, for a unit mass of Fe (in anhydrous FeCl3) added, the equivalent mass of alum (as Al2(SO4)3•18H2O) required would be 4.25 times higher. It is expected that commercial formulations of Ti would require even lower unit doses compared to Fe. Hence the titanium coagulant might be an economical choice for the treatment of municipal wastewaters.

*Presenting author; emmawiffen.hamilton@mail.mcgill.ca

Performance of Reactivated Carbon Nanotubes in Adsorbing Cadmium from Aqueous Solution

A. MAMUN*, M. KHATIB, R. DANIAL

Bioenvironmental Engineering Research Unit (BERU), Faculty of Engineering, International Islamic University Malaysia (IIUM), Jalan Gombak, 53100 Kuala Lumpur, Malaysia

This study was intended to determine the optimum desorption condition to reactivate exhausted cadmium loaded carbon nanotubes (CNTs) for re-adsorption of the same metal cadmium (Cd). The desorption of cadmium ions (Cd^{2+}) by batch mode laboratory experiments was investigated for hydrochloric and nitric acids, where the former gave better desorption compared to the other acid. Initial experiments revealed that hydrochloric acid (HCl) was better than nitric acid (HNO_3) for the desorption of Cd^{2+} from the CNTs. Optimization study was conducted by design expert software using various molarities of HCl, which resulted in pH of 1.39 (0.1 M), pH 2.43 (0.01 M) and pH 3.53 (0.005 M). Contact time of 20, 50, 80, 110 and 140 minutes were used with fixed agitation of 200 rpm to study the effect of time on the desorption process. Statistical model was developed for the optimum desorption process, which provided a regression model with R^2 value of 0.987. The desorbed CNTs were washed with deionized water to remove residual acids and then dried for re-adsorption process. The re-adsorption capacity of cadmium was also determined by batch mode experiments. This study revealed that pH and contact time influenced the desorption and re-adsorption capacity of the CNTs. The optimum condition for desorption was pH 1.39 (0.1 M) hydrochloric acid for 50 minutes agitation. This study also revealed that with this optimum condition, three (3) cycles of desorption process was necessary to remove all cadmium ion from the used CNTs. Re-adsorption capacity of the CNTs, after 3 cycles, was reduced from 8.28 mg/g to 4.23 mg/g. This indicated that about 50% of the adsorption capacity of the CNTs were destroyed or reduced due to the desorption process. Such reduction can also be linked to the destruction of the active sites of the CNT adsorbents.

*Presenting author; mamun@iium.edu.my

Batch and Continuous TOC Removal of Sulfadiazine Solution by External-Loop Airlift Sonophotoreactor

M. MOHAJERANI*, M. MEHRVAR, F. EIN-MOZAFFARI

Department of Chemical Engineering, Ryerson University, 350 Victoria Street, Toronto, Ontario, Canada M5B 2K.

The combination of photolytic and sonolytic process in the presence of H_2O_2 in a 7-liter external-loop airlift sonophotoreactor was used to treat the sulfadiazine solution. The impact of initial H_2O_2 concentration, initial sulfadiazine concentration, pH, ultrasound (US) power, air flow rate, and time was studied in batch mode to find the optimal operating conditions. 72.5% TOC removal (after 90 *min*) and 93% sulfadiazine degradation (after 30 *min*) were obtained under optimal conditions ($[H_2O_2]_o$=700 mgL^{-1}, US power= 65 W, air flow rate= 2 $Lmin^{-1}$, and pH 5.1) when the initial sulfadiazine concentration was 20 mgL^{-1}. The effect sonophotochemical pre-treatment on biodegradability enhancement of sulfadiazine solutions was investigated. The continuous process with three different flow rates (0.1, 0.2, and 0.4 $Lmin^{-1}$) was conducted for 180 *min* to investigate the TOC removal. Lower flow rate resulted in greater residence time and TOC removal. At 0.1 $Lmin^{-1}$, 60% TOC removal was achieved after steady state condition was obtained. An artificial neural network (ANN) model was developed to predict the TOC removal of sulfadiazine solution.

ACKNOWLEDGEMENTS

The financial support of Natural Sciences and Engineering Research Council of Canada (NSERC) and Ryerson University is greatly appreciated.

*Presenting author; mmohajer@ryerson.ca

UV Disinfection of Wastewater Effluents: How to Control the Tailing level, and Improve the Efficiency

Y. AZIMI[1*], G. ALLEN[1], B. CARINS[2], R. FARNOOD[1]

[1] *Department of Chemical Engineering and Applied Chemistry, University of Toronto, 200 College street, Toronto, Ontario, Canada, M5S3E5*
[2] *Trojan Technologies, 3020 Gore Road, London, Ontario Canada, N5V 4T7*

Ultraviolet disinfection is a well established technology for wastewater disinfection, and there's a growing interest due to more stringent restrictions over the toxicity levels of chemically disinfected water. However, the effectiveness of UV disinfection decreases in the presence of microbial aggregates formed in the activated sludge process, referred to as flocs. The presence of flocs, increases energy usage to reach acceptable degrees of disinfection; moreover, it decreases the chances of utilizing the treated water for secondary usages. The effect of particles in UV disinfection could be detected in a typical UV dose-response curve, where at some point by increasing the UV dose the survival ratio of microorganisms exhibits a near plateau or tailing region. In this study, it was aimed to further understand the tailing effect by identifying the UV resistant component in the microbial aggregates. It is hypothesized that in every microbial floc community there are a fraction of flocs that contain physically strong dense cores and the cores are the main cause of tailing. The dense cores were extracted by shearing using a Couette flow, which supposedly separates the loose outer layer from the physically strong cores. Mechanical Sieving and washing was used to obtain various size fractions of the un-sheared flocs and sheared cores. Constructing the UV dose response curves (DRCs) for all samples showed that for un-sheared samples the tailing level elevated for larger flocs, meaning larger flocs were harder to disinfect. For sheared flocs larger than 45 microns the DRCs overlapped, meaning that the kinetics of inactivation became similar. In addition, for all size fractions the sheared particles, which contained a larger fraction of dense cores showed higher tailing levels than un-sheared flocs. Mathematica program was used to fit the DRC data into the double exponential model, and the model parameters were extracted and compared.

[*]Presenting author; yaldah.azmimi@utoronto.ca

Photochemical Kinetics of Poly(ethylene glycol) Degradation in Aqueous Solution

S. GHAFOORI*, M. MEHRVAR, P. CHAN

Department of Chemical Engineering, Ryerson University, 350 Victoria Street, Toronto, Ontario, Canada M5B 2K.

Industrial activities most often result in generation of wastewater containing highly recalcitrant pollutants that are not amenable to biodegradation. Water-soluble polymers are one of these refractory pollutants. Therefore, the possibility of rendering these materials to biologically useful chemical compounds is a challenging task.

In this study, the process of ultraviolet radiation and hydrogen peroxide process (UV/H_2O_2) is investigated to establish the kinetics for the photooxidative degradation of poly(ethylene oxide) as a water-soluble polymer in aqueous solution. Rate expressions are based on free radical mechanisms. Random chain scission is assumed to be the mechanism of chain scission. Continuous-distribution kinetics is applied to model the kinetics of photooxidative degradation of polymers in aqueous solution based on population-balance equations (PBEs). The PBEs are solved by the moment operation which transforms the integro-differential equations into ordinary differential equations that can be readily solved to give the rate coefficients of polymer degradation. The model predictions were in excellent agreement with the experimental data for the photodegradation of poly(ethylene glycol). The kinetic parameters were found using a sequential quadratic programming (SQP) that minimize the error between the model and the experimental data.

ACKNOWLEDGEMENTS

The financial support of Natural Sciences and Engineering Research Council of Canada (NSERC) and Ryerson University is greatly appreciated.

*Presenting author; Samira.ghafoori@ryerson.ca

Fate of Nutrients during the Treatment of Municipal Wastewater by Electrocoagulation

W. HIRZALLAH[1*], M. ELEKTOROWICZ[1], J. OLESZKIEWICZ[2]

[1]*Concordia University*
[2]*University of Manitoba*

Batch experiments were carried out to evaluate the fate of nutrients during electrocoagulation (EC). This treatment was applied to wastewater from one of Quebec's municipalities during the winter season. The collected wastewater was dilute in term of COD, TSS, and nutrients, yet it had a high conductivity, making it a good candidate for an electrocoagulation treatment. The nutrients assessed were phosphorus, nitrate and ammonia. Three variables (treatment duration, current density, and electricity exposure modes) were considered to assess the nutrient fate. The current densities ranged between 10 and 40 A/m^2 and the treatment run durations were 30, 60 and 120 minutes. In each run, four 1.5 litre reactors were operated in parallel, one reactor was exposed continuously to DC current, and other three were connected to automated timers with different variations to interrupt the exposure throughout the experiment. Mixing was mechanically maintained throughout the experiments using a magnetic stirrer bar and no aeration was provided. The lack of oxygen supply resulted in anoxic conditions in the reactor, especially at longer exposure to electricity and at higher current densities.

Results showed relationship between reactors? conditions, and quality of influent and effluent. A total phosphorus removal was observed in all runs. The presence of anoxic conditions coupled with the hydrogen gas production during the EC treatment resulted in abiotic conversion of nitrates to ammonia. Nitrate reduction to ammonia was proportional to the decrease in dissolved oxygen levels. The obtained data can serve in designing EC processes for nutrient treatment in various wastewater treatment plants.

[*]Presenting author; walaa.hirzallah@gmail.com

Interference by the Activated Sludge Matrix in the Measurement of SMP

C. POTVIN*, H. ZHOU

University of Guelph, School of Engineering

Soluble extracellular polymeric substances, otherwise known as soluble microbial products (SMP) can comprise the majority of solids that leave the conventional activated sludge (CAS) plant. Included in this broad category are carbohydrates, DNA, humics, lipids, proteins, and polysaccharides, among others. In order to reduce the concentration of organics that leave a CAS, it is necessary to accurately quantify SMP present in effluent.

Measurement of carbohydrates, humic substances, proteins and polysaccharides has typically been performed using methods validated by Frolund et al. (1996). These methods consist of extraction of SMP from activated sludge, followed by colour development of extracted aliquots. Absorbance of the treated extract is then measured by spectrophotometry, which is in turn correlated to the absorbance of standard solutions containing known amounts of the analyte.

In order to account for matrix effects in activated sludge, an improved means of quantitation of SMPs is proposed. This procedure relies on adaptation of traditional methods by use of the well-known *standard addition* method. Standard addition provides a very good means of quantifying SMP in complex matrices, as it incorporates recovery of analyte from the sample matrix.

In order to investigate matrix effects in activated sludge, carbohydrates, proteins, humics and polysaccharides were measured by use of the *standard-addition* method in tandem with the traditional standard curve method. This comparison was made for two full-scale membrane bioreactors (MBRs), a conventional activate sludge (CAS) plant, and a sequencing batch reactor (SBR). Storage of SMP extract over time was investigated for changes in levels of carbohydrates, proteins, humics and polysaccharides. As well, carbohydrates, proteins, humics and polysaccharides in extract were measured before and after freezing. Matrix effects due to extract dilution were also investigated by measuring carbohydrates, proteins, humics and polysaccharides in SMP extracts at several dilution ratios.

*Presenting author; cpotvin@uoguelph.ca

Novel Submerged Membrane Electro-BioReactor (SMEBR) tested in l'Assomption, QC

S. HASAN[1*], M. ELEKTOROWICZ[1], J. OLESZKIEWICZ[2]
[1] *Dept of Building, Civil and Environmental Engineering, Concordia University, Montreal, QC, Canada*
[2] *Dept of Civil Engineering, University of Manitoba, Winnipeg, MB, Canada*

A new approach is required to treat wastewater that would generate high quality effluent, have a minimal footprint and low cost. A recently developed technology called Submerged Membrane Electro-BioReactor (SMEBR) appears to fulfill these requirements (Elektorowicz et al., 2009). The SMEBR operates based on the interaction between biological processes, membrane filtration, and electrochemical processes.

The pilot unit of SMEBR was placed in the WWTP in the City of l'Assomption (Quebec) to investigate the performance of a new system. A low voltage gradient and a hollow fiber microfiltration membrane (Asahi Kasei Chem. Corp., Japan) were used. The hybrid SMEBR system run under SRT and HRT of 10 days and 11 hours, respectively. The SMEBR was continuously supplied with wastewater redirected from main collector, after screening, without any pre-treatment. The influent COD, ammonia, and phosphorous were variable and ranged between 160 -700 mg/L, 30 -70 mg NH3-N/L, 2 - 10 mg PO43- -P /L, respectively.

When reactor reached equilibrium, the removal of COD, ammonia and phosphorous was around 92%, 99% and 99%, respectively. Furthermore, the monitored trans-membrane pressure has not shown any significant drops which can lead to the conclusion that the membrane fouling was marginal.

Detailed design and technological parameters were determined and showed adequate microbial activity, preventing inhibitory conditions in the electrical field. A decrease of sludge production and an increase its dewaterability was also observed.
The investigations showed that SMEBR system can be successfully applied to large and small scale WWTPs.

Reference:
Elektorowicz M., Bani Melhem K., Oleszkiewicz J, 2009, US Patent 12/553,680
*Presenting author; shw_79@hotmail.com

Novel approach for the reduction of membrane fouling

S. IBEID[1], M. ELEKTOROWICZ[1*], J. OLESZKIEWICZ[2], S. HASAN[1]

[1]*Concordia university*
[2]*university of manitoba*

This research was conducted to evaluate the reduction of membrane fouling rate by applying direct current (DC) field through the activated sludge of membrane bioreactors. Submerged membrane electro bioreactor (SMEBR) of 8 liter-working-volume was operated in parallel with conventional submerged membrane bioreactor (SMBR) to compare the fouling rate at different operating conditions. Experimental runs were operated on continuous flow at different operating conditions to assess relationship on membrane fouling among the following parameters: a) influent composition (high protein, low protein and no protein), b) mixed liquor suspended solids (3000 to 18,000 mg/l), c) membrane flux (in relation to HRT=12.8 h and HRT=24h) under different DC fields.

The results showed that at low MLSS (4000 to 6000 mg/l) and high membrane flux (HRT=12.8 h), DC field presence reduced the fouling rate by 6 times when the reactors were fed with high protein synthetic wastewater and by 2 times when no protein (or low protein) was added into the synthetic wastewater. At MLSS of 6000 to 9000 mg/l and HRT of 12.8 h, the fouling rate was 3 times higher in the SMBR than in the SMEBR even at low and no protein concentration in the influent. At lower membrane flux (HRT= 24 h), the fouling rate was much less than that at higher flux in both reactors, but still for the favor of the SMEBR. This study concludes that SMEBR reduced substantially membrane fouling; particularly, at higher MLSS (>5000 mg/l) and high concentrations of soluble microbial products (protein and polysaccharides). This data can be applied to an optimal designing of SMEBR reactors dedicated to a large range of MLSS characteristics.

[*]Presenting author; mariae@encs.concordia.ca

Spatial and Temporal Foulant Deposition in Submerged Membrane Bioreactors and Their Implication to Irreversible Fouling Mitigation

A. FARQUHARSON[1*], V. ZHANG[1], H. ZHOU[1], M. THEODOULOU[2]

[1]*School of Engineering, University of Guelph, Guelph, Ontario N1L 2W1*
[2]*GE Water & Process Technologies, 3239 Dundas Street West, Oakville, Ontario L6M 4B2*

Long-term, especially irreversible membrane fouling is a critical factor controlling the cleaning frequency and lifespan of membrane modules in submerged membrane bioreactors (SMBR). However, the knowledge about the causative foulants and their spatial and temporal distribution across hollow-fibre membrane modules is scarce. The main objectives of this study were to determine the spatial distribution of foulants on the membrane surface and through the fouling layer, and to evaluate the effectiveness of membrane cleaning procedures.

Experimental work was conducted using two ZeeWeed® 500 MBR pilot plants located at the City of Guelph Wastewater Treatment Plant. After achieving steady-state condition, multiple fouled membrane fibres were harvested at a variety of locations. Additional membrane samples were subject to both maintenance cleaning and recovery cleaning. In addition to the permeability tests, all membrane samples were then characterized using attenuated total reflectance Fourier transform infrared (ATR-FTIR) spectroscopy, transmission electron microscopy energy diffusive x-ray (TEM-EDX) and filtration resistance testing. CLSM analysis in conjunction with staining was used to determine the biofilm thickness and the spatial distribution of living cells, dead cells, proteins, carbohydrates, and lipids.

The results showed that along a fouled membrane fibre, the filtration resistance was higher near the bottom section of the fibre. Both maintenance and recovery cleaning could effectively remove the majority of organic foulants on the membrane surface. However, the accumulation of proteins, carbohydrates and lipids within the membrane was minimally removed, suggesting that they played a key role in long-term irreversible fouling. Furthermore, the deposition of inorganic foulants, particularly calcium and magnesium were identified on the membrane surface even after citric acid cleaning. This indicates that the formation of inorganic precipitates or inorganic-organic complexes can also be an important factor in forming long-term irreversible fouling.

[*]Presenting author; aportela@uoguelph.ca

Using Membrane-Aerated Biofilm Reactor Process for Tertiary Nitrification in Wastewater Effluents

Z. LONG[1*], L. LISHMAN[2], H. ZHOU[1], P. SETO[2], S. LISS[3]

[1]*School of Engineering, University of Guelph, Guelph, Ontario N1G 2W1*
[2]*Environment Canada, 867 Lakeshore Road, Burlington, Ontario L7R 4A6*
[3]*Department of Environmental Studies and Chemical Engineering, Queen's University, Kingston, Ontario K7L 3N6*

Recently, membrane aerated biofilm bioreactor (MABR) process has attracted increasing interest because oxygen is directly diffused into the attached biofilm, resulting in much higher oxygen utilization efficiencies. In addition, the large membrane surface area allows the attachment of much more biomass, while the counter-diffusion of oxygen against other substrates/nutrients provides a spatial stratification of microbial communities across the biofilm depth, which in turn allows for the simultaneous removal of organics and nitrogenous compounds in a single biofilm. Nevertheless, most studies have been conducted with synthetic wastewater at bench-scale. The difficulties were encountered to maintain an optimum biofilm thickness that is sufficient to provide enough oxidation capacity while not causing excessive resistance to oxygen mass transfer. The objective of this study was to examine the feasibility of tertiary nitrification using two ZeeLung MABR pilot plants. For comparison purpose, both secondary effluent and tap water spiked with ammonia were tested. The effects of the key operational parameters, including ammonia loading, HRT, DO/air flow rate, mixing conditions and membrane cleaning, were examined in terms of nitrification efficiency and oxygen transfer.

The results show that different influents had different nitrification efficiencies. Mixing was identified as one of the key operational parameters for effective biofilm attachment and growth. An optimum mixing intensity existed because sufficient mixing must be provided to minimize the oxygen transfer limitation while excessive mixing would cause the detachment of biofilm. By properly controlling the mixing intensity, a removal efficiency of ammonia over 88% was achievable (see Fig. 1).

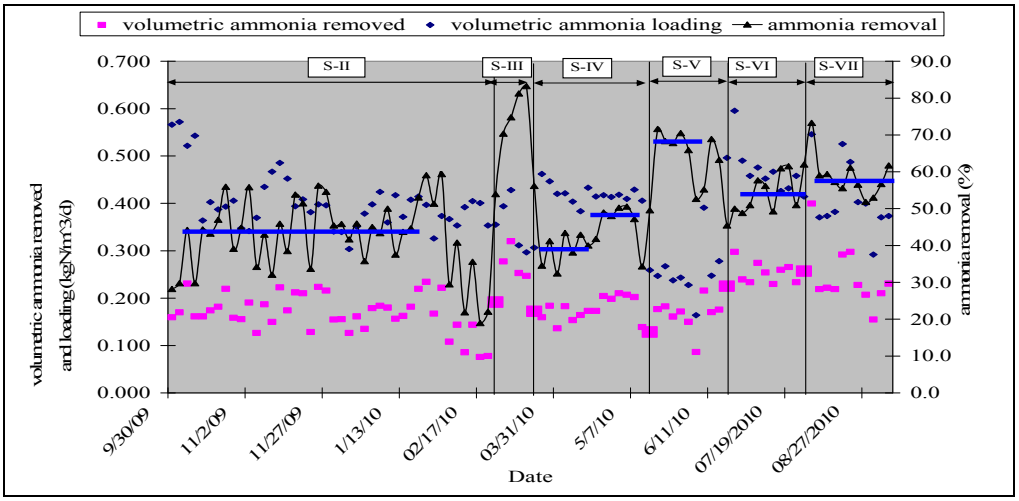

Figure 2. Ammonia removal from secondary effluent.

*Presenting author; zlong@uoguelph.ca

Foaming Formation in Submerged Membrane Bioreactors for Municipal Wastewater Treatment

V. ZHANG[1*], H. ZHOU[1], S. LISS[2], M. THEODOULOU[3]

[1]*School of Engineering, University of Guelph, Guelph, Ontario N1L 2W1*
[2]*School of Environmental Studies, Queen's University, Kingston, Ontario, Canada, K7L 3N6*
[3]*GE Water & Process Technologies, 3239 Dundas Street West, Oakville, Ontario L6M 4B2*

Excessive foaming is one of serious problems to operate biological wastewater treatment plants. This is particularly true for submerged membrane bioreactors (sMBR) due to 1) vigorous aeration necessary to scour membrane surface, 2) high concentration of biomass in the bioreactor and 3) retention of almost all suspended solids and many macromolecules formed from biological activities. Thus, the objectives of this research were: 1) to develop the methods that could be used to measure foam production, 2) to examine the growth behaviours of two key foaming microbes, *Microthrix parvicella* (*M. parvicella*) and *Gordonia* species (*G. spp*.), and 3) to evaluate the effects of main influent quality and operating parameters on foam production and foaming bacteria growth.

A series of experiments were conducted using two ZeeWeed®-10 MBR pilot plants operated at hydraulic residence time of 4.5 h while differing the sludge retention time of 8 and 25 d, respectively. Foam accumulated on the top of bioreactor was collected daily to measure its mass and volume. The content of *M. parvicella* and *G. spp*. in activated sludge and foam samples were quantified by using a quantitative real-time PCR (qPCR) method in terms of 16S rRNA gene copies. COD, MLSS and particle size distribution were measured according to Standard Methods.

The results confirmed that sMBR had more severe foaming than conventional activated sludge processes. Foam production increased with SRT. Furthermore, the foaming was initiated at a relative count of foaming bacteria to total *Eubacteria* at 0.15% in sMBR, as compared to the reported threshold of 3% for conventional activated sludge processes. *M. parvicella* was identified to be the dominated foaming bacteria in spring and early summer, while *G. spp*. in summer and fall.

[*]Presenting author; xzhang@uoguelph.ca

Biological Phosphorus Removal with Partial Nitrification at Low Temperature

Q. YUAN, J.A. OLESZKIEWICZ*

Dept. of Civil Engineering, University of Manitoba, Canada, R3T 5V6

Partial nitrification and biological phosphorus removal appear to hold promise of a cost-effective and sustainable biological nutrient removal process. Up to now most research focused on partial nitrification alone while overlooking biological phosphorus removal. Several researches concluded that the NO_2-N produced from partial nitrification will significantly inhibit P uptake which will have negative impact on overall phosphorus removal. The objective of this study was to 1) examine the performance of phosphorus removal in a partial nitrification process at low temperatures, 2) investigate the operational conditions which inhibit the growth of NOBs.

Pilot sequencing batch reactors were operated under Anaerobic/aerobic configuration for 8 months. It was found that biological phosphorus removal can be achieved in an SBR system, along with the partial nitrification process. Sufficient volatile fatty acids supply is the key for enhanced biological phosphorus removal. This experiment demonstrated that partial nitrification can be achieved even at low temperature with high dissolved oxygen (>3 mg/L) concentration. Shorter solid retention time for nitrite oxidizing bacteria (NOB) than ammonia oxidizing bacteria due to the nitrite substrate limitation at the beginning of aeration cycle was the reason that caused NOB washed out. Controlling SRT, therefore, can be used as a strategy for the SBR operated at cold climate to achieve partial nitrification. In addition, the presence of nitrite hindered the aerobic P uptake by PAOs and the aerobic P uptake is more sensitive to nitrite than anaerobic P release.

*Presenting author; oleszkie@cc.umanitoba.ca

Regrowth of Bacterial Pathogen in Biosolids after Electro Dewatering

M. GUL-E-HINA*, D. FRIGON, P. BIYELA

McGill University

Land application of biosolids from activated sludge wastewater treatment plant (WWTP) is an attractive disposal solution. However, it is tightly regulated in USA and in Canada; and biosolids need to meet specific microbiological qualities specified by the US-EPA class A or B classification for pathogen loads that can be land applied. As the regulations specify meeting the regulations at the time of land application, recent investigations have characterized the regrowth of bacteria during sludge storage. These investigations found higher regrowth levels in centrifuge dewatered biosolids compared to belt press dewatered biosolids. This study examined bacterial regrowth potential in electro-dewatered biosolids. It has been found that Escherichia coli is inactivated at levels of X-Y log during a typical 8-min electro-dewatering cycle, which potentially classifies these dewatered biosolids as class-A. The extent of aerobic E.coli regrowth in electro-dewatered sludge was assessed for samples from a local WWTP and electro-dewatered using a lab-scale unit. As a control, non-dewatered heat inactivated biosolids were also analysed. The sludge samples were placed in bottles close with their lid or with cheese-cloth. The bottles were incubated at room temperature and continuously mixed by rolling. Regrowth was monitored by enumerating E. coli in samples taken every 24 hours; at the time of sampling the lid-closed bottles were aerated for 10 minutes to ensure aerobic conditions. It was observed that there is an increase of 1-1.2 log in number of E.coli in 7 days for both bottle closures and both sludge treatments (electro-dewatered and heat-inactivated).Further experiments are being conducted to understand the factors supporting the regrowth potential and to determine the anaerobic regrowth potential of E. coli.

*Presenting author; gul-e-.hina@mail.mcgill.ca

Natural Freeze-Thaw Treatment of Biosolids

B. ORMECI*, J. DIAK

Carleton University

Sludge dewatering is one of the most challenging processes during sludge treatment. Particularly in cold climates, sludge dewatering becomes a major problem for treatment plants because mechanical equipment such as centrifuges and filter presses are difficult to maintain and operate. Freeze-thaw technology works on the principal that ice crystals grow by incorporating water molecules only. Because the structure of ice crystal is highly organized and symmetrical, it cannot accommodate any other atoms or molecules. Each ice crystal continues to grow as long as water molecules are available. All other impurities and solids are forced to the boundaries of the ice crystal, where they become compressed or dehydrated. During thaw, the meltwater drains away between the consolidated particles leaving a dewatered sludge.

The goal of this study was to evaluate the effectiveness of freeze-thaw conditioning on RBC sludge generated at a remote mining exploration facility located in Northern Quebec. The site is only accessible by air, and there is very limited opportunity for transportation which limits the treatment options. Freeze-thaw conditioning was considered as one of the effective and low-cost options. A pilot-scale freezing bed that can fit in a freezer truck was designed and built, and sludge samples were flown in from the site once every two weeks during the summer months. Sludge was frozen in layers of approx. 10 cm to ensure complete freezing. Several sludge characteristics such as total solids, volatile solids, COD, and dewaterability of sludge were measured before and after freezing. In addition, fecal coliform and Salmonella numbers in sludge were also quantified using EPA Methods 1681 and 1682. The results show that freeze-thaw treatment is effective in conditioning and dewatering RBC sludge as a simple, sustainable, and cost-effective method, and a containerized freezing bed can be installed on site.

*Presenting author; banu_ormeci@carleton.ca

Pathogen Inactivation During Electro Dewatering of Biosolids from Secondary Wastewater Treatment

T. NAVAB DANESHMAND*, G. E-HINA, R. HILL, R. GEHR, D. FRIGON

McGill University

Recent cost increases for the disposal of biosolids produced during secondary wastewater treatment requires the implementation of more efficient dewatering technologies. The electro-dewatering process uses an electrical field to increase the sludge dryness from 15% to 30-50% while using less than 30% of the energy required by a heat dryer for the same performance. This study aims at identifying the pathogen inactivation mechanisms during the process. First, the effects of varying electrolyte additives (CaCl2 and Ca(NO3)2) and their concentration, and varying maximum voltages (40, 50 and 60V) were investigated for an 8-minute dewatering cycle. It was observed that increasing the maximum voltage from 40 to 60V led to (i) an increase in final dryness, (ii) an increase in cake temperature, and (iii) an increase in Escherichia coli inactivation. In a second experiment, the dewatering cake was separated in four layers along the vertical axis to determine gradients between the anode (top) and the cathode (bottom) using Ca(NO3)2 and max voltage of 60V. The pH increased from 2 near the anode to 8 near the cathode. Total Solids varied on average from 44.5% in the top layer to 21.7% in the bottom layer. The inactivation of E. coli was similar in all layers with 5-6 logs of inactivation. Inactivation was positively correlated with the duration of the dewatering experiment, which in turn was correlated with the energy input and the final cake temperature. Thus energy inputs, cake temperature or both could be responsible for E. coli inactivation, but low pH (~2) does not seem to explain inactivation. This research will provide the necessary information to guarantee the level of inactivation necessary by the electro-dewatering process to produce biosolids of Class A quality (US-EPA classification) for application to agricultural lands.

*Presenting author; tala.navabdaneshmand@mail.mcgill.ca

Effect of Hydrocycloning Activated Sludge for Sludge Reduction on Floc Morphology

F. L. CÔTÉ[1]*, M. MANSOUR-GEOFFRION[1], P. L. DOLD[2], D. LAMARRE[3], A. GADBOIS[3], S. DÉLÉRIS[4] and Y. COMEAU[1]

[1]*Department of Civil, Geological and Mining Engineering, Ecole Polytechnique of Montreal, P.O. Box 6079, Station Centre-ville, Montreal (Quebec), Canada H3C 3A7*
[2]*EnviroSim Associates, McMaster Innovation Park, 175 Longwood Rd South, Suite 114A, Hamilton (Ontario) Canada L8P 0A1*
[3]*John Meunier Inc., 4105 Sartelon Street, Saint-Laurent (Quebec), Canada H4S 2B3*
[4]*Anjou Recherche—Veolia Environnement, Chemin de la Digue, BP 76, 78603 Maisons-Laffitte Cedex, France*

Sludge production at biological wastewater treatment plants (WWTPs) may be reduced by increasing sludge retention time (SRT). As SRT is increased, grit (ex. sand, silt) from the influent accumulates in the sludge but does not contribute to pollutant removal and may lead to premature wear of mechanical equipment. Grit can be removed from activated sludge by hydrocycloning, enabling WWTPs to operate at higher SRTs and to reduce sludge production. Hydrocycloning activated sludge to remove grit, however, may break activated sludge flocs and reduce their density , affecting the floc morphology and sludge settleability. The purpose of this study was to determine the effect of hydrocycloning activated sludge on floc morphology and size.

Twenty one experimental runs were performed on sludge samples from 8 biological WWTPs in the Montreal area. Sludge was pumped to a 13 mm diameter hydrocyclone and samples of hydrocyclone feed, underflow and overflow streams were analysed using an AxioZeiss 40 microscope at 100X magnification. Microscopic observations were carried out according to Eikelboom (2000) and Jenkins *et al.* (1993) using the following criteria: floc strength, shape, size, structure and filament index (FI). Microscopic results were compared to particle size distribution measurements obtained by laser diffraction (Malvern MasterSizer S).

Floc sizes observed under the microscope were similar to those determined by laser diffraction. Floc sizes in the hydrocyclone underflow were greater than those in the overflow, indicating the hydrocyclone separated flocs based on particle size. There was no change in floc morphology in 90% of experimental runs, indicating floc integrity was conserved for most sludge samples despite the high centrifugal forces in the hydrocyclone. In 40% of the runs with a high filament index (greater than 3), activated sludge flocs were less robust and large filamentous flocs were broken down into many smaller-sized flocs.

Microscopic observations of sludge samples were useful in determining the effect of sludge hydrocycloning on floc morphology. In most cases, the hydrocyclone had little or no impact on floc morphology, indicating that the use of such devices may not impact sludge settling. With filamentous sludges, however, it was observed that large filamentous flocs were broken down after being hydrocycloned, potentially improving sludge settleability. Further studies on the effect of reduced sludge density due to hydrocycloning on settleability need to be conducted.

REFERENCES

Eikelboom D.H. (2000) Process control of activated sludge plants by microscopic investigation. IWA Publishing, London, U.K.

Jenkins, D., Richard M.G., Daigger G.T. (1993) Manual on the causes and control of activated sludge bulking and foaming, 2nd ed. Boca Raton, FL: Lewis Publishers Inc.

*Presenting author; fannie.lcote@polymtl.ca

Thermo-chemical Pretreatment of Sludge for Volatile Sulfur Compounds Control in Anaerobic Digestion

B. DHAR[1*], G. NAKHLA[2], M. RAY [1]

[1]*University of Western Ontario, Chemical & Biochemical Engineering*
[2]*University of Western Ontario, Civil and Environmental Engineering*

Biological treatment of wastewater produces a huge amount of waste activated sludge (WAS). Although anaerobic (AD) digestion is a widely accepted and popular sludge stabilization process, conventional anaerobic digestion still has some limitations. Anaerobic digestion of WAS is difficult compared to primary sludge due to the rate-limiting hydrolysis step. The quality of biogas is also of major concern, as presence of volatile sulfur compounds (VSCs) such as hydrogen sulfide (H2S), mercaptans in biogas may contribute to corrosion in combustion engines and create unpleasant environment in wastewater treatment plants. Pretreatment of sludge prior to AD is a common approach to increase the solid reduction and biogas production in anaerobic digestion. Various pre-treatment techniques including chemical, thermal, and mechanical methods have been widely reported in the literature for waste activated sludge solubilisation through cell disruption and making organics such as protein, carbohydrate, volatile fatty acids available for microbial consumption. Although, the effects of thermal-chemical pretreatment of sludge on anaerobic digestion are studied extensively, earlier studies conducted on pretreatment mostly concentrated on the improvement of solid reduction and biogas production, and very limited information is available on the reduction the various sulfur containing odorous precursors in influent and corrosive VSCs control in biogas.

The research project investigated the impact of thermal pretreatment at 60oC in presence of chemicals (H2O2+FeCl2) on continuous mesophilic anaerobic digester operated at 10 days solid residence time (SRT). The chemical dosages were used based on the dissolved sulfide (S2-) concentration in raw waste activated sludge. The objectives were to evaluate the impacts of pretreatment on: a) various sulfur containing compounds such as dissolved sulfide, sulfate, and bound proteins, b) sludge solubilisation, c) solids reduction, d) VSCs control in biogas, and e) biogas production.

*Presenting author; bdhar2@uwo.ca

Rebate Beer as a Co-Substrate for Anaerobic Digestion of Dairy Manure

S. MASSEN*, H. SALSALI, E. MCBEAN

School of Engineering, University of Guelph

An investigation into the feasibility of using rebate beer (RB) as a co-substrate for the anaerobic digestion of dairy manure (DM) was conducted for consideration in a brewery waste management program. Rebate beer has high soluble $CBOD_5$ concentrations (greater than 12,000 mg/L) that are readily accessible to microorganisms. The experimental procedure involved a 12L bench-scale, cylindrical PVC digester maintained at mesophilic temperatures (35°C) by a temperature controller with a 24 day hydraulic retention time. The digester feedstock consisted of a mixture of rebate beer and dairy manure diluted with water to maintain an organic loading rate of 1 kg_{VS}/m^3/day. A 50% DM/50% RB and 75% DM/25% RB blend (by volume) were tested against a 100% DM control feed stock. Effluent samples were withdrawn daily. Various parameters including pH, operational temperature, alkalinity (HCO_3), volatile fatty acids (VFA), total solids (TS) and volatile solids (VS) were measured regularly. Gas volume produced during anaerobic digestion was recorded by a wet-tipped gas meter. The quality of the biogas was determined with a Gas Chromatographer. The volatile solids reduction for all blends exceeded a minimum of 29% for the majority of the digester's operation. An increase in methane yield was observed with rebate beer blends. The ratio of VFA/HCO_3 was below 0.3 for both the 75% DM/25% RB and 100% DM control blends which demonstrated stable digester operation; effluent VFA concentrations were near zero. The 50% DM/50% RB blend had variable results; the first trail failed as the VFA/HCO_3 ratio was too high. The inability to secure a consistent dairy manure feedstock for the first trial may have been a contributing factor. The second 50% DM/50% RB exhibited more stable results and did not fail. The volume and quality of biogas increases with higher proportions of rebate beer added to dairy manure. However, rebate beer increased the duration for the digester to achieve steady state operation, perhaps due to the higher activity of the feedstock. The study indicates improved mesophilic anaerobic digestion of dairy manure with rebate beer as a co-substrate in volumes 25% or less. A mutually beneficial partnership between local farmers operating digester facilities and brewers seeking competitive waste beer disposal options is feasible.

*Presenting author; smassen@uoguelph.ca

Flow Cytometry for Functional Analysis of Heterotrophs in Wastewater Treatment Systems

B. GUO*, D. FRIGON

Department of Civil Engineering & Applied Mechanics, McGill University, Montreal, Quebec, Canada

Characterizing heterotrophic microbial populations in activated sludge wastewater treatment systems using observable biomarkers is a first step in understanding their ecological functions and dynamics. This is necessary information to solve problems of bulking and foaming, and to engineer a community which will specifically produce valuable polyhydroxyalkanoates (PHA) for bioplastics. We propose that one important marker is the level of RNA in the cell, which depends on the maximum rate of growth during the feast (presence of extra electron donors) and famine (absence of electron donors) cycles experienced in plug-flow reactors. Another important marker is the level of PHA in the cell.

A method was developed to characterize these markers on a cell-by-cell basis using a rapid and sensitive flow cytometric method with fluorescent dyes to stain for RNA (RNASelect), PHA (Nile Red), and DNA (7-aminoactinomycin D); the latter being the marker for biomass level. The method was validated against five strains representing a wide coverage of bacterial diversity: *Escherichia-coli* K-12*, Rhodococcus jostii* RHA1*, Bacillus subtilis, Cupriavidus necator* DSM428 and DSM 541 (a non-PHB producing mutant of DSM428). Cells growing exponentially at different rates were produced by cultures in LB medium, or in mineral medium containing glucose, succinate or acetate. For all except DSM428, the ratios between the RNA and DNA signals were positively correlated with growth rates. However, the average RNA/DNA ratios were similar for all strains tested despite a five-fold change in the average tested growth rates. When the method was used to characterize samples from seven activated sludge wastewater treatment systems, the RNA/DNA ratio correlated with the presence of PHA. We suggest that this correlation represents a functional characterization of heterotrophic bacteria. We are now expanding our analysis by cell sorting and using 16S rRNA genes targeted molecular techniques to identify the composition of heterotrophic functional sub-populations.

*Presenting author; bing.guo@mail.mcgill.ca

Improvements in Wastewater Effluent Quality - Upgrade and Expansion of the Lou Romano Water Reclamation Plant, Windsor Ontario

P. DRCA*

Corporation of the City of Windsor

Prior to 2007, the City of Windsor's Lou Romano Water Reclamation Plant (LRWRP) was the largest and one of the last remaining primary chemical physical wastewater treatment plants in the Great Lakes basin. The plant discharges directly to the Detroit River, one of 43 areas of concern identified by the International Joint Commission (IJC) requiring remedial action with respect to water quality. Realizing the need to upgrade the LRWRP to secondary treatment, the City initiated a 2 year study in 1994 to investigate innovative alternatives to conventional secondary treatment in an effort to determine the best process for their needs and to minimize wastewater treatment plant expansion costs. The outcome of this study resulted in the selection of the biological aerated filter (BAF) as the preferred solution for the City's need to upgrade the LRWRP to secondary treatment.

In 2005, the City commenced with an upgrade and expansion of the LRWRP that included the expansion of primary treatment rated capacity from 163,700 m3/d (36 MIGD) to 272,800 m3/d (60 MIGD) and the construction of a BAF facility for secondary treatment with a rated capacity of 218,000 m3/d (48 MIGD). The plant is designed to handle a peak flow of two times the rated capacity. In addition, the City has replaced chlorination with UV light for disinfection. The $110,000,000 upgrade and expansion of the LRWRP is the largest single project ever undertaken in the history of the City of Windsor.

This presentation will review the LRWRP's MOE issued Certificate of Approval and focus on the improvement in plant effluent quality (concentrations and loadings of conventional wastewater parameters) resulting from the upgrade and expansion of the facility.

*Presenting author; pdrca@city.windsor.on.ca

Regression Analysis to Find the Effects of Reduced Aeration in Biological Aerated Filter

R. RAY,* P.F. HENSHAW, N. BISWAS

Department of Civil & Environmental Engineering, University of Windsor, Windsor, Ontario, Canada N9B 3P4

Biological aerated filter (BAF) is a submerged, aerated, fixed film reactor where biological organisms are used to remove organic matter and ammonia, and suspended solids are filtered out by granular media. Reducing the aeration rate, and cost, was the incentive for this research.

A series of tests were conducted at different airflows in a specific cell at the Lou Romano Water Reclamation Plant to find the lowest possible airflow while maintaining satisfactory ammonia and biological oxygen demand in the BAF effluent. Profiles of temperature, dissolved oxygen, pH, biological oxygen demand, ammonia and nitrate concentration were measured along the height of the cell and at different time intervals during filtration, at four air flow rates varying from 1300 to 1700 m^3/h per cell.

The performance (measured as BOD and ammonia removal after 120 minutes of operation) was correlated to input parameters, such as BOD and NH_3 loading, nominal airflow, water flow rate, pH and temperature to determine whether air flow rate was a statistically significant factor for the performance of the BAF. A backward regression was performed to determine the important variables, first using BOD removal as the outcome, then for NH_3 removal. BOD removal is mainly dependent on airflow to water flow ratio, temperature and BOD concentration of inflow wastewater in the BAF. At a specific water flow rate, the lower airflow rate gives a better BOD removal efficiency in the BAF.

According to the regression analysis, ammonia removal is independent of airflow in this BAF. Ammonia removal capacity depends on ammonia loading between 1300 m^3/h to 1700 m^3/h airflow rate. Most of the ammonia was removed with in the first 50% for both the 1300 m^3/h and 1700 m^3/h nominal airflow rates.

*Presenting author; rayr@uwindsor.ca

Ammonia-oxidizing Archaea in Rotating Biological Contactors

L. SAUDER*, J. NEUFELD

University of Waterloo

Municipal wastewater treatment relies on microbially mediated nitrification for the conversion of toxic ammonia to nitrate. Since their discovery over a century ago, ammonia-oxidizing bacteria (AOB) were believed to be solely responsible for ammonia oxidation in natural and engineered environments. Recent research has challenged this paradigm, with the discovery that Archaea are capable of ammonia oxidation and outnumber AOB in several terrestrial and aquatic environments. Conventional wastewater treatment utilizes aeration basins to promote nitrification; however, many wastewater treatment plants (WWTPs) continue to release ammonia-rich effluent into receiving waters. Where facilities exist, rotating biological contactors (RBCs) provide additional nitrification and result in low-ammonia effluents. Previous research has suggested that ammonia-oxidizing archaea (AOA) exist at low relative abundance in activated sludge; however, no previous studies have investigated AOA in RBCs. This study used quantitative real-time PCR (qPCR) to quantify the ammonia monooxygenase (amoA) and 16S rRNA genes of Bacteria and Archaea in RBCs at the Guelph Wastewater Treatment Plant (Guelph, ON). In addition, the diversity of AOA and AOB was assessed by denaturing gradient gel electrophoresis (DGGE) and DNA sequencing. Our data indicate that AOA comprise a substantial proportion of the ammonia-oxidizing organisms in RBCs designed for nitrification. Both archaeal amoA and 16S rRNA genes increased significantly as ammonium decreased along the flowpath of this tertiary treatment system, implicating ammonia as a critical environmental control for determining the dominant ammonia oxidizers. Archaeal amoA sequences showed limited diversity and clustered with environmental sequences derived from activated sludge from a variety of other WWTPs. This study is the first to detect AOA in RBCs and demonstrate a link between AOA population size and ammonia. Together our data suggest an important role for AOA in producing high quality wastewater effluent.

*Presenting author; lsauder@uwaterloo.ca

Urban Runoff Water Quality: Approaches in Stormwater Management

Chairs: Hazel Breton, Bahram Gharabaghi

Four main topic areas are covered off under this session which include:
- Characterizing Urban Runoff
  Presentations will discuss the sources of pollution to Ontario streams as well as various pollutants conveyed by streams.
- Impacts of Urban Runoff
  Presentations will focus on the impacts of urban runoff and the use of stormwater management to offset these impacts.
- Low Impact Development
  Presentations will review Low Impact Development Stormwater Technologies and evaluate their effectiveness.
- Stormwater Management Ponds
  Presentations will include topics on Bioretention cells, floating wetlands and rehabilitation of a stormwater management pond.
- Climate change
  Presentations will discuss climate change effects on water quantity and quality

Questions that these sessions will answer include:
1. What are the sources of water quality issues associated with urban runoff?
2. What are the impacts from urban runoff and how is stormwater management used to offset these impacts?
3. What are some of the recent types of stormwater management tools available?

Sources of Pollution to our Ontario Streams and Rivers

D. MAUNDER*

Aquafor Beech Limited

There is some thought that the only source of pollution to our local streams and rivers is from non point urban sources (i.e. stormwater runoff) . This paper will address the various sources of flow to our local streams and rivers and will attempt to characterize the impacts.

The initial phase of the paper will present the different sources which include urban and rural sources together with Sewage Treatment Plants . A comparison of the relative inputs from a water balance perspective (low flows, baseflows, and high flows) will be presented. Subsequent phases will deal with water quality issues . In this regard representative values for various pollutants will be provided together with the potential impact of these parameters on the environmental resources . A discussion with respect to the variability of the parameters will also be presented.

The information that will be presented will be taken from numerous local studies undertaken within the GTA and other areas within Ontario. Comparison of several local databases to other external (Canada and the United States) will also be provided. An overview as to the approaches that can be used to estimate flows and water quality loadings (modeling vs. monitoring will also be provided).

*Presenting author; maunder.d@aquaforbeech.com

Urban Tributaries as a Pathway of PCBs, PBDEs, PAHs, and Polycyclic Musks to Adjacent Lake Ontario, Canada

P. HELM[1*], M. ROBSON[2], G. KALTENECKER[1], B. GILBERT[1], L. MELYMUK[2], M. DIAMOND[2], C. BRIMACOMBE[1], T. CHEN[1]

[1]*Ontario Ministry of the Environment*
[2]*University of Toronto*

Urban rivers continue to deliver contaminants such as the legacy polychlorinated biphenyls (PCBs) and current/recent-use chemicals to receiving waters like the Great Lakes where they may persist, bioaccumulate, and impact biota. To investigate the relative roles of urban contaminant fate pathways (atmospheric deposition, tributary, municipal wastewater) to adjacent waterbodies, using Toronto, Canada and Lake Ontario as examples, we measured concentrations for a suite of organic compounds of varying uses and sources and estimated stream loadings. This presentation highlights results for the urban tributary pathway and its contributions relative to atmospheric deposition and municipal wastewater discharges.

Bulk water concentrations of PCBs, polycyclic aromatic hydrocarbons (PAHs), polybrominated diphenylethers (PBDEs), and polycyclic musks (PCMs) were determined in dry and wet weather samples collected from 10 sites in 6 watersheds across the Toronto area in 2007 through 2009. Wet weather events were intensively sampled on 3 occasions to provide an indication of the variability with hydrological change. For all analytes, concentrations were greatest at the downstream sites located in intensively developed urban areas. Median (maximum) concentrations across the downstream sites ranged from 2.2-6.7 (19-144) ng/L for SPCBs, 100-950 (1700-19300) ng/L for SPAHs, 5.1-6.6 (25-46) ng/L for SPBDEs, and 29-1800 (53-5800) ng/L for SPCMs. BDE-209 was the dominant PBDE, while PCMs consisted mainly or HHCB and AHTN. Concentrations of PCBs, PAHs, and PBDEs were higher during wet weather when streams were much more turbid. However, PCM concentrations tended to decline during wet weather, suggesting sewer cross-connections may be a source of PCMs. PCM concentrations were considerably higher in the Don River which receives municipal wastewater discharges.

Stream contaminant loads to Lake Ontario were calculated using USGS's LOADest for the 6 downstream sites. Estimated average annual loads were 2200 kg/yr for SPAHs, 42 kg/yr for PCMs, and 8 kg/yr each for SPCBs and SPBDEs. On a mass basis, the tributaries were the most important pathway for SPAHs, contributing 60% of loads compared to atmospheric and wastewater pathways from urban Toronto. In comparison the tributaries were estimated to contribute 40% for SPBDEs, 20% for SPCBs, and 4% for SPCMs. Urban tributaries are important contributors of compounds with urban sources to adjacent aquatic environments.

[*]Presenting author; paul.helm@ontario.ca

Event-Based Water Sampling in Four Hamilton Harbour Tributaries

T.LABENCKI*

Ontario Ministry of the Environment

Event-based water sampling was initiated in spring 2010 at downstream locations on Red Hill Creek, Indian Creek, and Grindstone Creek, as well as at the Desjardins Canal, with the goal of improving non-point source loading estimates of nutrients and trace metals to Hamilton Harbour. An automatic ISCO sampler (model #6712) and bubbler module (model #730) measuring stream level in 15 minute intervals was installed at each station, as well as an analog phone line connected to a 56K modem to allow for remote communication with each ISCO from a desktop computer. During a targeted event, samples are collected once an hour for 24 hours, with 24-hour flow-weighted composites being submitted to the lab for analysis; for select events, grab samples according to key points on the hydrograph were also submitted for analysis. Preliminary results indicate that total phosphorus (TP) concentrations in 24-hour flow weighted composite samples collected during storm events are about an order-of-magnitude higher than baseflow samples from the same tributary. Also, previous stream monitoring programs based on random grab sampling have underestimated TP concentrations, as concentrations are highest at the hydrograph peak, and have been measured as high as 3,500 ug/L in an urban stream. In addition, data show that phosphate concentrations are highest on the falling limb of the hydrograph, occurring later in the event than the maximum TP concentrations. While this sampling program is a work in progress, it is anticipated that data will not only feed into a critical analysis of what loading reductions are achievable in the watersheds of interest to the Hamilton Harbour Remedial Action Plan (RAP), but data will also help to characterize contaminant concentration trends in tributaries of differing degrees of urbanization and land use

*Presenting author; Tanya.Labencki@ontario.ca

Impacts of Controlled Versus Uncontrolled Stormwater Runoff on Urban Stream Form and Function

C. EVES*

Lake Simcoe Region Conservation Authority

The management of urban stormwater runoff is important to maintaining the health and quality of the receiving waters. Stormwater runoff can impact tributaries by changing stream hydrology, changing channel morphology, degrading water quality, and changing the aquatic habitat by deposition of sediments. Stormwater management facilities are designed to mitigate these impacts by retaining runoff long enough to allow suspended particulate (and associated nutrients) to fall out of suspension and slowly releasing the water to minimize stream hydrological and geomorphic impacts. Therefore, in areas of adequate stormwater control not only would there be measurable improvements in water quality but in stream stability, form and function.

An inventory of stream bank erosion and channel hardening/straightening was conducted within the urban streams in the Town of Newmarket and the City of Barrie in 2008-09. Effects of stormwater management controls on stream form and function was undertaken by comparing the inventory data to locations of existing stormwater management controls. The data also allows for the comparison between stormwater facilities providing quantity control only versus those that provide quantity and quality control.

This study aims to highlight the important role that stormwater controls play in affecting stream form and function in new and existing urban areas if correctly designed and maintained.

*Presenting author; c.eves@lsrca.on.ca

Importance of Water Quality Control in Storm Water Management

A. SINGH*

Credit Valley Conservation Authority

There are four primary objectives of maintaining water quality in the creeks and lakes. These include aquatic habitats, drinking water, esthetics, and recreation. Broadly the pollutants are introduced to the creeks as point or non-point loads. Whereas point source pollutants (industrial or waste water treatment plant) are generally well regulated, the strategies are generally insufficient in regulating non-point source (agricultural and urban) pollutants. The pollutants discharged with the urban runoff produce strong pulses in the receiving streams resulting in high concentrations of pollutants well above guidelines for the protection of aquatic life. Furthermore, the urban runoff brings high loads of pollutants which are ultimately dumped in the Great Lakes deteriorating their water quality.

The current strategies of storm water management require removing of total suspended solids (TSS). However, there are no guidelines for other pollutants of concern. Further, the guidelines for TSS do not specify settling by particle size distribution. Generally the particles that get trapped are of larger size whereas the finer particles stay in suspension and carried away with the flowing water. Since most of the pollutants are attached to the finer sediment particles, they are not retained in the storm water facilities and end in the receiving bodies. Therefore, there is a need to modify the current storm water guidelines and apply Low Impact Development practices to effectively control the pollutants at source. The paper presentation would include water quality findings from some of the studies conducted in the developed and developing sub-watersheds in the Credit River watershed and Lake Ontario Integrated Shoreline Study initiated by Credit Valley Conservation Authority.

*Presenting author; asingh@creditvalleyca.ca

Are Ageing Stormwater Ponds Still Effective? Assessing Maintenance Requirements and the Potential for Hypoxic Nutrient Rerelease

D. LEMBCKE*, B. GINN, S. LYNN, R. BOLTON

Lake Simcoe Region Conservation Authority

Urban stormwater run-off is one of the largest terrestrial sources of nutrient loading to Lake Simcoe and accounts for an estimated 14% of the annual phosphorus load. It is estimated that stormwater management facilities reduce phosphorus loads to Lake Simcoe by 4,262 kg annually. Stormwater facilities treat runoff by trapping and retaining nutrient rich sediments, a feature which over time results in a reduced pond volume and thus a reduced efficiency in particulate (and nutrient) removal. The size of the facility must also be balanced against the tendency for larger water bodies to stratify and develop low oxygen conditions in bottom waters.

A survey of 105 stormwater management facilities across 6 urban areas in the Lake Simcoe Watershed was conducted in 2010, comparing design volume with current volume. The objective of this study was to better assess the performance of these facilities for more accurate estimations in nutrient reductions being achieved, and to examine the frequency of maintenance required to maintain optimal performance. Preliminary results indicate that approximately half of the facilities have accumulated enough sediment so that they no longer operate at the designed efficiency (i.e. a Level 1 pond is reduced to Level 2). In addition, we found that under certain environmental conditions, some stormwater ponds underwent thermal stratification resulting in low dissolved oxygen near the sediment surface, and therefore the potential release of captured phosphorus back into the water column. This study will be used to determine an optimal maintenance schedule for maximizing pond nutrient reduction. A second phase of the project will evaluate various methods of preventing stratification and the associated hypoxic conditions. This in turn will play a valuable role in setting realistic targets and achieving nutrient reductions as directed by the Lake Simcoe Protection Plan.

*Presenting author; d.lembcke@lsrca.on.ca

Evaluation of Low Impact Development Stormwater Technologies and Water Reuse Options for the Lake Simcoe Regions

J. LI[1*], D. BANTING[2], D. JOKSIMOVIC[1], M. WALTERS[3]

[1]*Dept. of Civil Engineering, Ryerson University, Toronto, Ontario, Canada M5B 2K3*
[2]*Dept. of Geography, Ryerson University, Toronto, Ontario, Canada M5B 2K3*
[3]*Lake Simcoe Region Conservation Authority, 120 Bayview Parkway, Newmarket, Ontario, Canada*

In support of the efforts of the Lake Simcoe Region Conservation Authority (LSRCA) to meet its Vision for the Restoration and Protection of Lake Simcoe and its Watershed, Ryerson University conducted a study to evaluate the suitability and effect of implementation of non-conventional wastewater and stormwater control technologies, including low impact development technologies (LID) and water reuse options, within the pre-defined uncontrolled study area where conventional stormwater management practices were not feasible. The aims of the study project were to: identify opportunities for implementation of these technologies, quantify at a planning level the benefits that could be provided in terms of reduced nutrient loadings to Lake Simcoe, and ultimately provide guidance to municipalities within the watershed. Phase I compiled all the existing data and information, summarized the previous studies and projects that had been carried out to date deemed relevant to the project, and carried out a geographic information system analysis (GIS) of the opportunities for implementation of LID (based on suitability criteria such as land use and physical site requirements). Phase II carried out a more detailed study of the usage of LID identified in Phase 1 as being potentially suitable, evaluated the best combinations of LID (and their placement), quantified preliminary costs of their implementation and pollution reduction benefits such as annual nutrient loading reduction, and examined the opportunities for reclamation of wastewater and stormwater in the study area. Additionally, the effects of future development and climatic changes on the overall efficiency of promising solutions were evaluated. The modeling of the pollution reduction benefits was based on the development of hydrologic unit response functions (URF) for different land uses and LID combinations and the aggregation of these URF over the study area using GIS. The study findings indicate that the implementation of the feasible LID such as bioretention cell, rainwater harvesting, greenroof, and downspout disconnection could potentially reduce the nutrient loading from the uncontrolled study area by almost 10%.

[*]Presenting author; jyli@ryerson.ca

Evaluating the Effectiveness of Stormwater Infiltration on Fine Textured Soils

T. VAN SETERS*, D. YOUNG

Toronto and Region Conservation Authority

Low impact development (LID) approaches to stormwater management attempt to reproduce the pre-development hydrologic regime through site planning and engineering techniques aimed at infiltrating, filtering, evaporating and detaining runoff. Stormwater infiltration practices that direct runoff to pervious areas or engineered structures for storage and eventual infiltration are central to these approaches because the infiltration component of the water balance is substantially reduced by urban development. Several field studies on the performance of LID practices have shown large reductions in runoff volumes through infiltration on relatively permeable soils. There have been considerably fewer studies of LID practices applied on fine textured soils. This presentation reviews guidelines relating to stormwater infiltration from cold climate jurisdictions and reports on results from on-going performance studies of underground infiltration chambers, infiltration trenches and permeable pavements installed on fine textured soils throughout the Greater Toronto Area. Results to date indicate that substantial volumes of stormwater can be infiltrated on clay based soils, but effectiveness varies depending on key system design parameters, surficial geology and soil characteristics.

*Presenting author; tvanseters@trca.on.ca

Bioretention Garden Designs for Increased Nutrient Removal

M. RANDALL,* A. BRADFORD

School of Engineering, University of GuelpH

Eutrophication of surface waters continues to be a high priority water quality problem and is accelerated by nitrogen and phosphorous contained in urban runoff. Bioretention gardens are stormwater management practices shown to have consistent removal rates for many contaminants in urban runoff with the exception of nutrients. Recent studies of bioretention soil amendments intended to improve nutrient removal have shown promise, however very few of these studies have been performed in a field setting or on a larger than bench top scale.

In this study, ten vegetated mesoscale bioretention cells were constructed in rainbarrels and doused with synthetic stormwater. The performance of five different bioretention garden soil treatments will be evaluated in terms of nutrient removal. Soil amendments tested in this study include; alum based drinking water treatment residuals, a commercially available oxide-coated media designed for use in stormwater BMPs, a commercially available lanthanum-modified bentonite product designed for direct application to surface waters, and shredded newsprint. Potential drawbacks of each soil amendment including leaching of metals and reduction in hydraulic conductivity will also be presented.

*Presenting author; randallm@uoguelph.ca

An Evaluation of Engineered Media for the Treatment of Stormwater Runoff from a Greenroof

E. CAMM*, M. STONE

Department of Geography and Environmental Management, University of Waterloo, Waterloo, Ontario N2L 3G1

Greenroofs are increasingly being recognized as an effective best management practice (BMP) to reduce the volume of stormwater runoff in urban environments. For some water quality constituents, greenroofs can improve runoff water quality but recent studies demonstrate greenroofs are sources rather than sinks of phosphorus (P). Accordingly, further research is required to evaluate treatment technologies that improve the performance of these BMPs. This study examined the use of two engineered media types to reduce phosphorus loadings from a greenroof located on the Archetype Sustainable House at Kortright in Vaughan, Ontario.

A treatment system was installed to capture stormwater runoff and remove P using sorptive properties of an engineered media. A mass balance approach was used to evaluate pre and post-treatment water quality. Pre and post-treatment water samples were collected for 26 rainfall events from July 11, 2009 to August 25, 2010 and analyzed for soluble reactive phosphorus (SRP), total phosphorus (TP), suspended solids (SS) and total dissolved solids (TDS). Storm events ranged in return frequencies from < 2 years to 25-50 year periods. The results show that the greenroof was a consistent source of P. The volume weighted mean concentrations were 0.769 mg/L and 0.630 mg/L for 2009 and 2010, respectively. The media assessed in 2009 reduced SRP loadings by 32.0% and TP loadings by 25.4%. The media evaluated in 2010, reduced SRP loadings by 82.4% and TP loadings by 86.6%. The greater P removal demonstrated by the 2010 media is attributed to a higher specific surface area and increased P sorptive capacity. Results of this study will help inform the use of sorptive materials in greenroof applications and a wider range of best management practices for stormwater quality treatment.

*Presenting author; ecamm@uwaterloo.ca

Water Quality Performance of Bioretention Cells in Cold Climates

U. KHAN[1*], C. VALEO[1], A. CHU[1], B. VAN DUIN[2]

[1]*Department of Civil Engineering, University of Calgary*
[2]*Water Resources, City of Calgary*

Bioretention cells are an emerging urban runoff management technology. The cells are densely vegetated basins that intercept runoff, before allowing it to infiltrate into the highly permeable growing media. As the runoff travels through the media, a variety of physical, chemical and biological reactions remove contaminants. Most studies of bioretention cells have been conducted in temperate areas, where the effects of cold climates, such as freeze-thaw cycles and reduced chemical and biological activity are not considered.

To test the short and long term performance of bioretention cells, field and laboratory experiments were conducted in Calgary, AB. Synthetic runoff was applied to the field bioretention cell, mimicking different storm events, and was tested for sediment, nutrients and chloride. High contaminant mass removal rates were noted; 91% for sediment, 90% for nutrients and 83% for chloride. Additionally, significant concentration reduction was noted for sediment, BOD and TP. No significant difference was noted in cold climate conditions. Miniature bioretention columns were tested in the laboratory at the University of Calgary. The columns demonstrated significant sediment concentration reduction and high levels of nutrient leaching. This was due to lower than normal influent concentration and nutrient flushing from the growing media. Long term performance experiments were conducted on the laboratory columns, where the equivalent of 20 years of runoff was applied. These experiments showed that sediment capture occurred in the top 20 cm of the columns. BOD and nutrient reduction improved over the 20 year period. Inlet and outlet chloride concentrations were not significantly different over the testing period. The research demonstrated that bioretention cells are a viable option for urban runoff treatment in cold climates and water quality performance (particularly for nutrients) is highly dependent on the media properties of the cells.

[*]Presenting author; utkhan@ucalgary.ca

Floating Wetlands for Enhanced Treatment in Stormwater Management Ponds

A. SHANE[1*], B. ANDERSON[1], B. WOOTTON [2]

[1]*Department of Civil Engineering, Queen's University, Kingston, Ontario*
[2]*Centre for Alternative Wastewater Treatment, Fleming College, Lindsay, Ontario*

Conventional stormwater management ponds are designed to control peak flow and reduce contaminant loads into receiving waters through settling of solid materials. Typical ponds have limited capacity to address the issue regarding treatment of pollutants such as metals, pathogens and nutrients entering waterways. Floating wetlands are a promising technology for increased removal of water-borne contaminants in stormwater ponds. Floating wetlands are buoyant structures containing plants that are hydroponically immersed in water. The test islands for this research will be assessed as treatment systems for water quality improvement through microbial action in the root mass and nutrient translocation to the plant biomass. Studies are currently underway to monitor nutrients (phosphorus, nitrogen as NH_3, NO_3/NO_2), metals and bacteria (*E. coli* and microcystins) to test the efficiency of floating wetlands treatment in mesocosm and large scale studies focused on mimicking stormwater ponds.

For the large scale study, *Typha angustifolia* is being grown on the wetland mats within nine of the fifteen test ponds. This study has a total of two control series and three treatments each with three replicates. A control series and 2 treatment series have inputs of contaminants of varying amounts based on values from stormwater literature. The other control series has no floating wetlands and the 3 treatments all have floating wetlands. This research is monitoring nutrients, metals and pathogens through regular sampling. The mesocosm study consists of twelve 70 L bins mimicking stormwater ponds. This study has two control series and three treatments each with two replicates, and is using the same plants as the large scale study. This study is monitoring the efficiency of floating wetlands for the removal/inactivation of microcystins and *E. coli.*

Data collected during the summer of 2010 from the large scale study as well as preliminary data from the mesocosm study will be presented.

[*]Presenting author; amanda.shane@queensu.ca

Town of Richmond Hill's Pioneer Park Stormwater Management Facility Rehabilitation

J. NEMETH[1*], I. BRUTTO[1], S. FICK[1], B. MCLAREN[1], G. TAYLOR[1], W. WITHERS[1], D. BANNISTER[2], H. REINDERS[3], F. REINDERS[3]

[1] *Town of Richmond Hill*
[2] *R.J. Burnside and Associates Limited*
[3] *R&M Construction*

The Town of Richmond Hill has completed the first major stormwater management facility (SWMF) rehabilitation in Canada. The Pioneer Park SWMF project rehabilitated an existing flood control facility to provide protection to flood vulnerable areas, protect existing infrastructure, enhance erosion control, treat water quality and stabilize and rehabilitate the associated watercourse and fishery. The facility was built in 1985, but no longer met the standards to which it was designed, and further fell short of modern stormwater standards, which is a problem many municipalities are now facing. As a result, key infrastructure was at risk including an important dispatch route for a major area hospital and other emergency services including Fire and Police. Residential properties upstream and downstream of the facility were also at risk of sewer surcharge and flooding.

This presentation will discuss how science, engineering, watershed planning principles and public consultation were used to develop a facility design, which incorporated innovative treatment train technologies and addressed environmental, social and economic opportunities. Construction was completed in August 2010 and already measurable results can be seen. Risk of flooding in the community and damage to municipal infrastructure has been reduced, watercourse habitat conditions have been improved and municipal operations and maintenance has been optimized. Pre- and post- construction monitoring results have shown improvements to stream temperature, water quality parameters such as total suspended solids concentrations, pH and dissolved oxygen. A fisheries assessment will be conducted in 2011 and additional water quality monitoring will proceed between 2011 and 2014.

The Pioneer Park SWMF Rehabilitation was awarded the 2010 Technical Innovation Award by the Ontario Public Works Association and is the Ontario co-winner for the 1st annual Watershed Awards sponsored by the Federation of Canadian Municipalities and the Insurance Bureau of Canada. Please visit www.richmondhill.ca/stormwater for additional information.

*Presenting author; jnemeth@richmondhill.ca

Predicting the Effect of Water Level Decline on Connectivity of Coastal Wetlands in Eastern Georgian Bay, Lake Huron

A. FRACZ*, P. CHOW-FRASER

McMaster University, Department of Biology

Coastal wetlands of eastern Georgian Bay are known to support critical spawning and nursery habitat for the fish community of Lake Huron. Some coastal wetlands can become hydrologically disconnected (stranded) from Georgian Bay when lake elevation drops below the wetland entrance. Loss of connectivity is undesirable because restricted fish access means loss of critical fish habitat. In addition, hydrologically stranded wetlands have very different water chemistry compared with hydrologially connected wetlands and this may have implications for wetland biota. To predict the effect of water level decline on the connectivity of coastal wetlands in eastern Georgian Bay, we randomly selected 103 wetland complexes (>2 ha in size) between Severn Sound and Key River and visited them during 2010. For each site, we determined the sill elevation and calculated corresponding wetland area. Sill elevations ranged from 162.94 m to 176.06 m above sea level (asl). We calculated total area of wetlands that would become hydrologically disconnected as a function of sill elevations. Wetland area is extremely susceptible to water level changes between 173 and 176 meters (asl), and we estimate that just over half of the wetlands of eastern Georgian Bay would become hydrologically disconnected with Georgian Bay if water levels dropped to an extreme predicted water level decline of 174.06 m (asl).

*Presenting author; fracza@mcmaster.ca

Why Melt Indices Have Been Rising at Increasing Rates While Temperature Have Been Rising Steadily

T. DICKINSON*, R. RUDRA, I. AHMED

Water Resources Engineering, University of Guelph, Guelph, Ontario

Temperatures have been rising steadily across Ontario for at least 100 years. The rate of temperature rise is a function of the temperature variable considered. For example extreme daily minimum temperatures have been rising at the greatest rate (about 4 C degrees per 100 years), while extreme maximum temperatures have not risen at all or may have decreased; temperature variables in the middle of the annual range have risen at about 4 C degrees per 100 years. This study focuses on frequency distribution of winter daily minimum temperatures for 15 stations across Ontario, and how these distributions have shifted with rising temperatures over the past 60 years and more. A parameter of these distributions is the number of frost-free days per winter. This number has been discovered to be a function of the rates of increase of minimum temperature, the shape of the frequency distribution of minimum temperature, and the location of the distribution in relation to 0 degree C. It has become clear that as temperatures have been steadily rising, the number of frost-free days has been increasing at an increasing rate. Impacts of these changes include more winter rainfall and less snowfall; and there is a good likelihood of decreasing end-of-winter snow packs and snowmelt volumes, and increasing frequencies and amounts of winter runoff and winter recharge.

*Presenting author; wdickins@uoguelph.ca

Urban Groundwater

Chairs: Craig Johnston, David Rudolph

As urban populations grow, cities that are dependent on local groundwater resources for water are being faced with a myriad of challenges to sustain and enhance both the quantity and quality of the supply. Advances in understanding of groundwater vulnerability and impacts of legacy, current and future contaminated sources on the long term quality of urban groundwater supplies have provided opportunities for strategic management. New insights gained through quantification of recharge distributions, optimization of aquifer production and numerical modeling tools have been critical for the assessment of source sustainability and the future development and permitting of new supplies. In this session, papers are encouraged on aspects of urban hydrogeology including advances in field investigation, numerical simulation, source water protection practices and strategies for sustainability. Topics related to groundwater quality are the main focus however aspects of and groundwater quantity are also of interest.

Screening for the Potential Ecological Hazard Posed by Groundwater Contaminants to Urban Streams in Canada

J. ROY*, G. BICKERTON

Environment Canada

There is little information available on the potential threat that groundwater contaminants pose to aquatic ecosystems in urban environments. In this study, a rapid screening approach for detecting groundwater contaminants, and providing data to estimate the ecological hazard they may pose, was applied to eight urban streams (reaches from 100 to >1000 m) in Canada. For each stream, groundwater samples from below the stream bed (typically 25-75 cm) were collected using a drive-point mini-profiler at intervals of 10-15 m along the stream and were subsequently analysed for general chemistry and a wide range of common and emerging urban contaminants. Identified contaminants included benzene and other petroleum hydrocarbons, fuel oxygenates (e.g. MTBE), pesticides, artificial sweeteners, and various chlorinated solvent compounds. In addition, elevated levels of nitrate, phosphate, some heavy metals, including cadmium and arsenic, and elevated chloride (likely indicating road salt) were detected. Most streams had many different types of contaminants, often overlapping over small stretches, and together often covering substantial portions of the monitored reach (> 90% in some cases). Given the coarse spatial detail provided by the sampling, contaminant concentrations should only be considered as estimates of the range of concentrations actually occurring at each site. However, a crude assessment based on detections of solely anthropogenic contaminants and comparisons between measured and aquatic life guideline concentrations was attempted to provide some insight into the potential hazard posed to the stream ecosystem. The findings provide support to this screening approach for delineating areas of potential ecological concern within urban streams and identifying possible sources of groundwater contamination in urban settings. They also suggest that the presence of multiple groundwater contaminants may be a more common threat to the aquatic ecosystems of urban streams than currently perceived.

*Presenting author; jim.roy@ec.gc.ca

Artificial Sweeteners in Groundwater as Potential Tracers of Urban Wastewater and Other Sources

D. R. VAN STEMPVOORT*, J. W. ROY, S. J. BROWN, G. BICKERTON

Water Science and Technology Directorate, Environment Canada, Burlington, Ontario, Canada

The artificial sweetener acesulfame was detected in groundwater at all eight of the Canadian urban sites investigated, often in concentrations at the µg/L-scale. Three other artificial sweeteners, saccharin, cyclamate and sucralose, were detected in some urban groundwater samples, though the detection limit for sucralose was much higher than for the others. In a municipal wastewater plume at Jasper, Alberta, acesulfame was strongly correlated with chloride and was positively correlated with other wastewater-related contaminants. This sweetener has potential to be a good tracer of wastewater impacts on groundwater that have occurred within the past two decades, since the introduction of the use of this sweetener in Canada. At Barrie, Ontario, adjacent to an old landfill, saccharin was the most abundant sweetener in many samples. Overall the results suggest that analyses of sweeteners may provide useful information on contaminant sources and groundwater conditions in urban settings.

*Presenting author; dale.vanstempvoort@ec.gc.ca

Groundwater Velocity Estimates for Fractured Bedrock Using Multiple Types of Borehole Tests and the Cubic Law

B.L.PARKER[1], P.QUINN[1*], K.BELAN[2], P.PEHME[1] and J.A.CHERRY[1]

[1]*University of Guelph, School of Engineering*
[2]*Schlumberger Water Services, Waterloo, ON*

Groundwater travel time, which is an important in the assessment of contaminant behavior in aquifers and source water protection, is usually based on estimates of the average linear groundwater velocity (V). In porous granular media, V is easily obtained by dividing the Darcy flux (q) by the groundwater flow- effective porosity, which is approximately 0.3 for most non-indurated geologic deposits. Therefore in these deposits, V is only a factor of 3 greater than the Darcy flux. However in fractured rock, V can exceed q by orders of magnitude because the effective fracture porosity is typically extremely small. Although it is generally recognized that V in fractured rock can be relatively large, very few V values are reported in the bedrock aquifer literature. This presentation shows an approach using borehole tests for estimating V in fractured rock exemplified by studies conducted in the dolostone aquifer providing most of the water supply for Guelph, Cambridge and some smaller communities in Ontario. This method is based on the Cubic Law to obtain values of hydraulic aperture from high resolution transmissivity (T) measurements using straddle packer tests and identification of the number of hydraulically active fractures in each borehole test interval. In the packer test procedure applied to each test interval, four types of test are conducted: constant head steps, slug, constant flow pumping and recovery so that the T values are obtained using four different mathematical models to enhance reliability. Also T values are obtained for the FLUTe K profiling method. The number of active fractures in each packer test interval is obtained from assessment of several lines of evidence including: borehole image logs, FLUTe K profiling, temperature profiling inside lined holes and analysis of the flow- regime characteristics of constant head step packer tests. For the dolostone aquifers in Guelph and Cambridge, which has been shown to have bulk fracture porosity comprised of ubiquitous interconnected fractures, this approach provides local V values of several meters per day, which converts to travel times over large areas, where municipal wells have pumping influence, on the order of kilometers per year. These large groundwater velocities and the estimates of hydraulic apertures in the dolostone have important implications for contaminant behaviour, including potential for rapid virus transport and recognition that the approach for travel time analysis commonly applied in source water protection for granular aquifers is not appropriate for fractured rock.

[*]Presenting author; pquinn@uoguelph.ca

Three Dimensional Characterization of the Fracture Network in the Guelph Dolostone Aquifer for Understanding Contaminant Behaviour

J.D. MUNN[1*], B.L. PARKER[2], J.R.KENNEL[3], and S.W.CHAPMAN[2]

[1]*University of Guelph, School of Environmental Sciences*
[2]*University of Guelph, School of Engineering*
[3]*S.S. Papadopulos & Associates, Inc*

It is well established that in studies of contaminants in fractured rock, understanding and predicting contaminant fate and transport requires the discrete fracture network (DFN) approach in which identification of essentially all hydraulically active fractures and features is critical. This presentation shows application of a methodology for characterizing and describing the fracture network in a dolostone aquifer beneath the City of Guelph that supplies most of the municipal water supply. This methodology involves continuous coring of vertical and angled holes in which numerous different tests are conducted to identify fractures and their characteristics. The starting point is the visual description of the rock lithology and core features using a system designed to minimize bias and standardize the types of observations from core to core within a quantitative framework. The next stage involves borehole geophysics including oriented image logging (e.g. ATV) to identify fractures and their orientations. Though these visual methods can determine the presence and orientation of fractures, they cannot distinguish permeable features from those impermeable. To identify which features are permeable and, of those, which show active flow under ambient conditions, hydraulic tests are conducted in the boreholes including: temperature logging inside lined holes, FLUTe hydraulic conductivity profiling, and straddle packer testing. The 'visual evidence' from a combination of vertical and angle holes shows that the fracture network consists of frequent bedding parallel and high angle fractures, which is consistent with the hydraulic evidence indicating strong 3D hydraulic connectivity in a network of dense fractures. When fracture networks based on field evidence are used in a DFN model for groundwater flow and contaminant transport with matrix diffusion (Fractran), the simulated plumes have the style of the contaminant distributions (i.e. TCE) in the study area as determined from rock core analyses. This demonstrates a strong degree of monitorability due to the close fracture spacing and high connectivity in the network.

[*]Presenting author; jmunn@uoguelph.ca

Viral Contamination and Attenuation in Fractured Bedrock Groundwater Aquifers

C. FARROW*, E. McBEAN, H.SALSALI

University of Guelph

Biofilms consist of agglomerations of microorganisms, as well as their excreted products, attached to inert surfaces. The ability of a biofilm to reduce the magnitude of viral contamination is dependent on a variety of factors which are difficult to monitor and control in a field study.

This issue is of interest since there is potential for migration of viruses through fractured bedrock which may result in exposure of contaminants to consumers. This paper describes an investigation of the attenuation rate of viruses by biofilms, where these biofilms may develop within fractured bedrock. The flow rate, surface conditions and aperture in experiments were maintained to investigate attenuation rates with relative repeatability.

The viral detection method employed was the double agar layer (DAL) method in which plates of E-coli were subjected to water samples with varying levels of MS-2 coliphage. Presence of clearings within the bacterial lawn were indicative of viral presence. Log phase dilutions allowed the concentration of MS-2 within the water sample to be accurately determined. Single pass trials, as well as cyclic tests, have shown reduction in viral concentration ranging from 20-50%. Decreased flow rate, and thus increased contact time, displayed higher removal percentages as expected.

*Presenting author; cfarrow@uoguelph.ca

Tracking changes in groundwater base flow due to urbanization through high resolution stream gauge data

P. THOMPSON*, W. ANNABLE

Department of Civil and Environmental Engineering, University of Waterloo

The quantification of groundwater base flow volumes is a challenging problem. Base flow volumes are frequently used to address issues of environmental low-flow characterization, water resources in drought conditions, both surface water and groundwater model calibration, and water quality assessments. Most contemporary estimate techniques often result in at best, order-of-magnitude estimates. This problem becomes even more complex in urban watersheds where permeability can vary not only spatially throughout the effective catchment area but also temporally as land-use change occurs. Hydrograph separation is a commonly employed method for estimating base flow volumes. Stream flow discharge hydrographs are divided into base flow and surface runoff components and the net contribution to groundwater flow is calculated. Most studies attempting to quantify base flow volumes in urban catchments have made use of daily mean averaged discharge data. The increase in impervious catchment area due to urbanization results in a larger relative peak stream discharge, decrease in lag time between rainfall and stream discharge events, and a more complex falling hydrograph rendering many of the conventional methods of quantifying groundwater base flow with daily data suspect. Recently extracted Water Survey of Canada data has allowed the creation of a high resolution instantaneous stream flow dataset dating to the late 1960s for many Ontario gauge stations. Utilizing this record, urban and semi-urban catchments in southern Ontario have been analyzed. Base flow separation methods, as well as event based methodologies have been applied to this dataset to track subtle changes to groundwater infiltration and interflow over time. Temporal changes to urban land area and road length were calculated for each watershed through detailed air photo analysis conducted with ArcGIS spanning the previous 50 years. This allows for the comparison of base flow trends to changes in the catchment landscape. In addition, the suitability of traditional base flow separation algorithms for use in urban areas is considered, as are the advantages of high resolution discharge data.

*Presenting author; pjthomps@uwaterloo.ca

Harmful Algal Blooms

Chairs: Sue Watson, Jennifer Winter

Nuisance growths of algae and algal blooms are a 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. Blooms of cyanobacteria are of particular concern in freshwater systems because of the potential of many species to produce toxins. Toxins produced by cyanobacteria (cyanotoxins) impact human and animal health and can affect freshwater ecosystem processes. Several species of cyanobacteria and chrysophytes also release noxious taste and/or odour causing compounds that can have major negative impacts on the public and the drinking water industry. In this session we will explore trends in algal bloom reporting, hear about research into the environmental factors that promote algal blooms, learn more about the detection of algal toxins and algal toxin monitoring, and explore management concerns and approaches. We will end the session with a panel discussion to further explore algal bloom issues in Canada.

Algal bloom reports in Ontario from 1994 to 2010

J. WINTER*, A. DESELLAS, R. FLETCHER, L. HEINTSCH, L. NAKAMOTO, A. MORLEY, K. UTSUMI

Ontario Ministry of the Environment

The Ontario Ministry of the Environment provides an algal identification service as part of the response to algal bloom events. We've been tracking the samples that have come in to our algal monitoring group since 1994. Over the period from 1994 to 2010, we noted a significant increase in the number of algal blooms reported each year ($P < 0.001$). There greatest increase was in blooms of cyanobacteria ($P < 0.001$). The lakes from which blooms of cyanobacteria were reported were characterized by higher median total P concentrations (15 µg/L) compared to a dataset from 1074 Ontario lakes (9 µg/L). However, the lakes experiencing blooms ranged in total P concentrations with 26 % being classified as oligotrophic (with spring total P <10 µg/L). This indicates that an array of factors contributed to bloom occurrence. The most common taxa of cyanobacteria identified were Anabaena, Aphanizomenon, Microcystis, Gloeotrichia and various Oscillatoriales. The remaining samples were dominated filamentous green algae, or occasionally by chrysophytes, dinoflagellates or diatoms. We also noted geographic and seasonal trends in the blooms reported. Most of the increase in the number of cyanobacterial blooms was accounted for by lakes within the boundary of the Ministry's northern region, primarily in its southern range. Samples are now also coming in for analysis later into the fall than they did during the 1990s; bloom identification requests consistently extended well into November in recent years. We attributed these trends 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.

*Presenting author; jennifer.winter@ontario.ca

Temporal Patterns of Hypolimnetic Dissolved Oxygen, Phosphorus and Iron in Three Small Lakes in Central Ontario and Hamilton Harbour

M. VERSCHOOR[1*], S. MCCABE[1], L. MOLOT[1], A. PATERSON[2], S. WATSON[3]

[1]*York University*
[2]*Ontario MInistry of the Environment*
[3]*Environment Canada*

Cyanobacterial blooms are a seasonal phenomenon in freshwaters, and can present significant health, ecological, and aesthetic problems. Recently, there has been an increase in the number, severity, and distribution of such blooms in southern Ontario and Quebec. A number of mechanisms have been brought forward to explain cyanobacterial dominance, but one that receives less attention yet may be more significant in mesotrophic and oligotrophic systems is the ability of iron to act as a limiting nutrient. Because cyanobacteria have higher iron requirements than eukaryotic algae and can only transport ferrous Fe, biogeochemical processes that increase the supply of iron, in particular ferrous iron, may shift the phytoplankton community towards cyanobacterial dominance. A study of temporal patterns of hypolimnetic anoxia and internal loading of Fe and TP in several eutrophic and oligotrophic lakes in 2008-2010 suggest that increased ferrous iron levels adjacent to the metalimnion may trigger the onset of cyanobacterial blooms.

[*]Presenting author; verschm@yorku.ca

Status of ELISA for Microcystin Analysis in Drinking Water

C. LO[1*], J. PARMAR[1], J. LI[2]

[1] *Ministry of the Environment, Laboratory Services Branch, Etobicoke, Ontario, Canada*
[2] *Ryerson University, Environmental Applied Science and Management, Toronto, Canada*

In the past several years, enzyme-linked immunosorbent assay (ELISA) had proved to be invaluable in the analysis of microcystins in surface water samples. However, the analysis of drinking water samples is regulated under the *Safe Drinking Water Act, 2002, c. 32, s. 62* (SDWA). The act specifies that laboratories must be licensed to perform drinking water tests. With respect to the "*Protocol of Accepted Drinking Water Testing Methods*" any new test methods must receive accreditation before it can be added to the laboratory licence. The only exception is that the Ontario Ministry of the Environment (MOE) has designated director(s) under the SDWA, who may authorize a test without accreditation for a limited period of time in certain circumstances.

The MOE laboratory has been actively promoting the analytical method for microcystins based on ELISA technology. The ELISA method E3469 version 1.0 was implemented in September 2009, for the testing of surface water but not for drinking water. In this version, semi-quantitative results were reported as ELISA indices. In March 2010, method E3469 was audited and accredited by the Canadian Association for Laboratory Accreditation (CALA). Version 1.2 was released on August 19, 2010. In version 1.2, results are reported as "total microcystins" in µg/L. This updated version was added to the MOE's drinking water testing licence as a screening method in August 2010. In October 2010, the method passed another audit by the Standards Council of Canada (SCC). Assay validation documentations, a crucial prerequisite for accreditation, will be discussed.

In 2010 the ministry's laboratory has reduced by more than half the work load of testing drinking water using the expensive liquid chromatography (electrospray ionization)-tandem mass spectrometry [LC(ESI)-MS/MS] method. In contrast, the material cost of the new ELISA Method E3469 is approximately $9.00 per sample. Most importantly, ELISA allows laboratories without [LC-MS/MS] capabilities to participate in monitoring microcystins in drinking water.

In the summer of 2010 two additional laboratories were licensed to use microcystin ELISA to test drinking water. In 2010 five laboratories participated in the proficiency testing program for microcystin ELISA. Hopefully more laboratories will be licensed in the future.

ELISA technology allowed the province to develop a new strategy to manage blue-green algae threats in drinking water. On August 5, 2010, the MOE Safe Drinking Water Branch issued Standard Operating Procedure (DW.6.02.03.01) for "Response to Reported Blue-Green Algae Event and Microcystin Analysis for O. Reg. 170 Systems". The province's response strategy is now centered on sending water samples to a private licensed laboratory for ELISA testing. ELISA screening for microcystin is now accepted and implemented province-wide.

[*]Presenting author; Ching.lo@ontario.ca

Cyanobacterial Toxins in Untreated Source Water and Finished Drinking Water in Ontario (2004-2009)

J. KINGSTON*

Environmental Monitoring and Reporting Branch, Ontario Ministry of the Environment

The Ontario Ministry of the Environment's Drinking Water Surveillance Program (DWSP) has monitored for cyanobacterial toxins in untreated source water and finished drinking water at selected municipal drinking water systems in Ontario since 2004. The purpose of this survey is to collect baseline data on cyanobacterial toxins for trend analysis and to compare microcystin-LR results with the Ontario Drinking Water Quality Standard (ODWQS) of 1.5 µg/L (O. Reg. 169/03).

From 2004-2009, more than 4500 results were collected at municipal drinking water systems and analyzed for the presence of the cyanobacterial toxins Anatoxin-A, the Microcystin variants -LA, -LR, -RR, and –YR and Nodularin. Cyanobacterial toxins were detected in only 2 of the nearly 2300 finished drinking water sample results and microcystin-LR was never detected above the laboratory's minimum detected limit in finished drinking water. In untreated source water, there was a rate of detection of 18.8% in the more than 2200 sample results that were collected.

This paper discusses the occurrence and spatial distribution of cyanobacterial toxin detections in untreated source water and finished drinking water in Ontario from 2004-2009.

*Presenting author; Jillian.Kingston@ontario.ca

Satellite Remote Sensing of Potentially Harmful Algal Blooms in Lake of the Woods

C. BINDING[1*], T. GREENBERG[1], J. JEROME[1], R. BUKATA[1], G. LETOUMEAU[2]

[1]*Aquatic Ecosystem Management Research Division, Environment Canada, Canada Centre for Inland Waters, 867 Lakeshore Rd., Burlington, Ontario, L7R 4A6, Canada*
[2]*Water Quality Monitoring and Surveillance, Science and Technology Branch, Environment Canada, 105 McGill, Montréal, Québec, H2Y 2E7, Canada*

Lake of the Woods is an inland water body bounded by both the US and Canada and is under significant water quality pressures from recurring cyanobacteria blooms. Its remote location combined with the hydrologically complex nature of its waters, makes adequate *in situ* monitoring of the lake difficult. The presentation aims to demonstrate the potential of MERIS satellite imagery for monitoring algal blooms on the lake. Optical properties of Lake of the Woods waters were measured and a full assessment of MERIS chlorophyll products carried out during an intense surface algal bloom in September 2009. Images are shown to adequately identify the bloom and are used to track the evolution of the bloom across the lake. Evidence is presented of the effects of variable depth distributions of cyanobacteria on the surface signal seen by the sensor; imagery suggests that day to day variations in wind-induced mixing have a profound impact on surface algal biomass as detected by remote sensing.

[*]Presenting author; Caren.Binding@ec.gc.ca

Linking Drinking Water Source Protection to Nutrient Management through Paleolimnological Analysis in Callander Bay, ON.

T. KARST-RIDDOCH[1*], S. MILLER[2], N. HUTCHINSON[1]

[1]*1. Hutchinson Environmental Sciences Ltd., Bracebridge ON.*
[2]*North Bay Mattawa Conservation Authority*

Source Water Protection Planning Studies undertaken in 2007 identified eutrophication and related cyanobacterial proliferation as threats in Callander Bay of Lake Nipissing, the drinking water supply of Callander ON. Callander Bay is physically constrained from complete mixing with Lake Nipissing and this, plus stormwater runoff, treated sewage discharge, septic systems, agricultural activities and potential internal loading were identified as sources that could be managed to reduce phosphorus levels in the bay.

A paleolimnological analysis was undertaken to identify the time course and relative magnitude of changes in nutrient status in the bay to guide assessment of the problem. Callander Bay became slightly more eutrophic over 250 years of European settlement, with phosphorus concentrations increasing from ~17 to ~20 ug/L between 1650 and 1950. Concentrations increased to ~30 ug/L and average lake water levels dropped by ~0.2m over the five years following construction of the Portage Dam at the outlet of Lake Nipissing in 1950, showing that large scale changes in water levels may be as important as local watershed factors in governing trophic status. Phosphorus concentrations have remained stable in the past 50 years.

Although the paleolimnological analysis overestimated phosphorus concentrations in the Bay, it provided a clear demonstration of the timing and magnitude of changes over time and showed that, while nutrient abatement initiatives in the watershed are unlikely to change the basic eutrophic nature of the Bay, they may be able to reduce the potential for formation of cyanobacterial blooms. A nutrient budget was subsequently completed and showed the most likely targets for nutrient remediation. The sporadic appearance of the blooms suggests a climatic signal may also be important.

[*]Presenting author; tammy@environmentalsciences.ca

Harmful Blooms in Recovering Systems: Are our Management Models Missing the Targets? Bay of Quinte Revisited

S.B. WATSON[1*], M. BURLEY[2], J. RIDAL[3], N. IRVINE[4]

[1]*Environment Canada, CCIW Burlington ON*
[2]*Fisheries & Oceans Canada, CCIW Burlington ON*
[3]*SLREIS Cornwall ON*
[4]*Quinte Conservation, Belleville ON*

Many Great Lakes Areas of Concern are increasingly demonstrating erratic and severe inshore blooms of cyanobacteria, some of which produce toxins and taste-odour. Conventional remedial targets fail to predict or address these impairments, demonstrating a critical need for detailed, long term data to conduct a risk assessment and revaluate current management models. This paper presents a synthesis of comprehensive study of blooms, toxins and taste-odour carried out since 2004 in the Bay of Quinte to assess the temporal and spatial range of these impairments. Along with long-term open water monitoring sites, sampling and analyses were designed to evaluate inshore and beach areas that have not been previously investigated, and where there is a far higher risk of human contact. The results of this study show annual episodes of significant impairment from harmful blooms at beach and inshore sites, where toxin and taste odour can exceed guidelines and odour threshold levels by several orders of magnitude. Taxonomic and fluorescence data indicate that both planktonic and benthic biota may contribute to levels of impairment or represent seeding areas for blooms. These 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.'

[*]Presenting author; Sue.Watson@ec.gc.ca

Environmental Modelling

Chairs: Cheng He, Ferdous Ahmed

This session deals with Environmental Modeling, which, in the broader sense, can be defined as concepts or computational and mathematical procedures dealing with any aspects of the environment. However, for the purpose of any conference, the meaning of the term is essentially defined by the submitted papers. For this conference, we are particularly interested in the movement of water and contaminants therein.

The papers of this session will deal with subjects as diverse as hydrology and hydrodynamics, data analysis and numerical methods, water and wastewater modeling, etc. Recent use of numerical models in the area of watershed management, climate change and water quality treatment will be highlighted.

We shall see how the science is used to support policy – and how the policy is implemented. Translating science into a language understandable to non-experts is a challenge. Furthermore, convincing policy makers to take action based on science which may be vaguely understood by various stakeholders is a difficult process. We shall see how local regulating agencies deal with the conflicting interest and opinion of various stakeholders. After all, the benefit of scientific research is limited by its proper application.

Estimation of Local Water Budget for Ecology and Stormwater Management

B. SM[1*], G. SWITZER[2]

[1] *Credit Valley Conservation, 1255 Old Derry Road, Mississauga, Ontario, L5N 6R4*
[2] *Nottawasaga Valley Conservation Authority*

An innovative technique has been applied to develop a physically distributed and calibrated hydrologic model using EPA HSPF software. The objectives of the model are to estimate groundwater recharge and the Tier 2 Water Budget for the NVCA and SSEA watersheds. HSPF is basically a lumped hydrologic model. The PEST auto-calibration (Doherty, 2008) technique is applied to calibrate HSPF parameters. A total of 375 parameters were calibrated using PEST and simulated streamflows of 17 WSC gauge stations. The present HSPF model is discretized into subwatershed, catchment and subcatchment. It uses land use/cover, Hydrologic Soil Group (HSG) and small size climate zone to represent physical and spatial distribution of hydrologic responses. Each of the subcatchment is further discretized into 46 Unit Response Functions (URFs), which are developed from combinations of land use/cover and HSG. The URFs represent both rural and urban land use/cover in Ontario. The rural URFs represent agricultural crop/pasture, forest, hummocky, open place, water body and wetland land use/cover. The urban URFs include Low/Medium/High Density Residential, Industrial, Commercial, Education/other Institution, Park/Open Place, Highways and Roads land uses. To capture spatial distribution of climate data, the subwatersheds are divided into 64 climate zones. It uses over 50 climate stations' data to estimate climate data at centroid of each climate zone.

As each of the URFs is effectively a "sub-model", the HSPF model can estimate hydrologic responses of the URFs using local climate data. The model parameters were calibrated and adjusted not only to calibrate with observed streamflows but also to estimate reasonable groundwater recharge and actual evapotranspiration. The estimated recharge was applied to a FEFLOW groundwater model of the NVCA and SSEA watersheds. Since the NVCA and SSEA watersheds were divided into 64 climate zones, long-term annual average (1970-2005) water budget components include recharge were estimate for the 46 URFs in each climate zone. The estimated water budget represents local physical and climate conditions. The result of the study indicates that the hydrologic responses and water budget significantly vary across the climate zones of the NVCA and SSEA watersheds. It would be more appropriate to apply the local water budget for ecology and stormwater management.

[*]Presenting author; baharsm@creditvalleyca.ca

Numerical Simulation of Storm Surge on Lake Winnipeg

P. CHITTIBABU*, R. YERUBANDI

Aquatic Ecosystem Management Research Division (AEMRD), Water Science and Technology Directorate, Environment Canada, 867 Lakeshore Rd., Burlington, ON, Canada L7R 4A6

A high resolution unstructured grid two dimensional finite element model (ADCIRC) was applied to simulate the storm surge on Lake Winnipeg associated with the October, 2010 extra tropical storm. Wind and pressure fields from the high resolution North American Mesoscale (NAM) forecast model was used to drive the hydrodynamic model. The model results were compared with the observed water levels at several stations. The model was able to simulate 0.6 to 1.5m storm surge at several stations in the Southern basin of Lake Winnipeg. Model results are further analyzed to characterize the seiches after the storm and transport of water between the north and south basins of Lake Winnipeg.

*Presenting author; padala.chittibabu@ec.gc.ca

Modelling of Hydrodynamics and Water Quality in Lake of the Woods

W. ZHANG*, Y.R. RAO, S.B. WATSON, P.CHITTIBABU

Water Science and Technology Directorate, Environment Canada

Lake of the Woods (LOW) is characterized with highly complex morphometric features and large spatial variations in water quality parameters. A hydrodynamic model in conjunction with semi-empirical eutrophication modelling framework have been applied to the lake during the period from 2000 to 2009 to assess the interactions among physical, chemical and biological properties of LOW. The hydrodynamic model with high spatial resolution was calibrated by using flow measurements in 2009. The lake was divided into six segments to represent the lake's spatial environment for the water balance analysis and eutrophication model. The exchange flows across each segment determined from circulation patterns were incorporated into multiple-segments eutrophication model. The eutrophication model includes phosphorus cycle and phytoplankton dynamics. The calibrated results of water quality variables are in reasonable agreement with the observed data of total phosphorus and chlorophyll-a. The model reproduced spatial and temporal distribution features of water quality parameters, such as total phosphorus gradient decreased from the south segment to the north segment. Because of the differences in hydrodynamic and topographic characteristics, the central and south segments resembled shallow lakes with strong variability of TP concentrations and phytoplankton biomass, whereas two relatively isolated segments in the north are characterized with lower phytoplankton biomass and less variability of TP concentrations.

*Presenting author; weitao.zhang@ec.gc.ca

A Comprehensive Approach to Receiving Water Assessments

T. ROUMELIOTIS[1*], D. SINCLAIR[1], N. HUTCHINSON[2]

[1]*AECOM*
[2]*Hutchinson Environmental Sciences Ltd.*

Regulatory approvals for Water Pollution Control Plants (WPCP) normally require a receiving water assessment to evaluate the influence of the plant discharge on the receiving watercourse. The requirements of the receiving water assessment will typically depend on the environmental regulatory body responsible for issuing the necessary approvals.

In 2007-08, the County of Norfolk undertook a receiving water assessment in support of a proposed capacity increase for their Town of Simcoe WPCP. The provincial regulatory body was consulted in order to develop a comprehensive program that ensured specific aspects of the receiving water environment were considered and characterized, including the size of the mixing zone and the receiving water quality within and beyond the mixing zone. The overall approach carried out was a marriage of detailed field investigations and surface water modeling. The field investigations included reach-specific physical stream characterization for input to the assimilation model, water quality sampling, benthic invertebrate sampling, stream discharge measurements and a mixing zone delineation using dye tracer testing, conductivity measurements and sewage parameters. The CORMIX model was used to quantify the extent of lateral and longitudinal mixing and predict water quality in the near field. Qual2K, a 1-dimensional river model, was used to predict water quality in the Lynn River beyond the point of complete mixing to a point 3 km downstream of the WPCP outfall.

The results of the field investigation were used to refine and verify the results of the modeling exercises, which showed rapid initial mixing and assimilation of ammonia and little downstream oxygen sag. Both approaches, in concert, resulted in a receiving water assessment that was well received by both the client and the regulatory body, supported plant expansion and effluent quality improvements and has since been used as a framework for completing other receiving water assessments in the area.

[*]Presenting author; tara.roumeliotis@aecom.com

A Geochemical Model for Predicting of Lead Dissolution in Drinking Water

A. HASSAN[1*], E. KIM[2], I. ZHANG[2], C. ROBINSON[1], J. HERRERA[1]

[1]*Department of Civil and Environmental Engineering, University of Western Ontario.*
[2]*University of Western Ontario.*

Although lead bearing plumbing materials are no longer used in new water distribution systems, high lead levels in drinking water are still a major concern for many municipalities where a portion of the distribution system is partially serviced in by lead pipes. Laboratory and modeling studies have been conducted to investigate the transformations and dissolution of lead scales collected from pipes used in the water distribution system of the city on London, ON. Dissolved lead concentrations and scale chemical transformation processes have been analyzed in the laboratory at different pH and residual chlorine values. Based on these results a geochemical model has been developed using the modeling platform PhreeqC.v.2.16.03 to simulate lead dissolution from lead scale. Dissolution experiments using pure lead compounds (hydrocerussite, cerussite, lead (II) oxide, lead (IV) oxide) were also conducted to validate the model. The model is valuable tool for providing insight and conducting sensitivity analyses to predict lead dissolution and scale transformation, and thus concentrations of lead in drinking water for different water quality conditions.

[*]Presenting author; ahassa44@uwo.ca

Comparative Biofilm Modelling of Biological Nutrient Removal from Landfill Leachate Using Circulating Fluidized Bed Bioreactor (CFBBR)

A. ELDYASTI*, M. ANDALIB, H. HAFEZ, G. NAKHLA, J. ZHU

The University of Western Ontario, London, Ontario, Canada

Steady state operational data from a pilot scale circulating fluidized bed bioreactor (CFBBR) during biological treatment of landfill leachate characterized by COD, TSS, TKN, and TP concentrations of 1260, 265, 390, and 7 mg/L, respectively at empty bed contact times (EBCTs) of 0.55, 0.49, and 0.41 d and volumetric nutrients loading rates of 1.9-2.6 kg COD/(m3•d), 0.6-0.8 kg N/(m3•d), and 0.010-0.016 kg P/(m3•d) were used to calibrate and verify a developed process model. A comparative modeling of CFBBR system treating landfill leachate was performed using AQUIFAS® and BioWin® softwares. The models were first calibrated with one set of data and then, were validated using two sets of experimental data at different loading rates.

AQUIFAS® was capable of predicting most of the performance parameters such as effluent TCOD, SCOD, BOD, SBOD, TKN, NH4-N, NO3-N, TP, PO4-P, TSS, and VSS with an average percentage errors (APEs) of less than 4%. BioWin® was found to predict the effluent characterizations with an APE of 10% but under-predicted the BOD and SBOD for various runs by 30%. Furthermore, efficient reactor arrangement using both models predicted anoxic and aerobic biofilm thicknesses of 160-200 and 500-580 μm in the riser and downer, respectively compared to 120 and 600 μm observed experimentally.

Although both calibrated models, confirmed the advantage of the CFBBR technology in treating the landfill leachate at low carbon to nitrogen ratio of 3:1 and achieving COD, nitrogen, and phosphorus removal efficiencies of 85%, 80%, and 70%, respectively, AQUIFAS® was superior in predicting the anoxic and aerobic biomass concentrations with an APE of 10%, as compare to 30% for BioWin®. Thus, the AQUIFAS® biofilm diffusion model was found to be more reliable and accurate than BioWin® in modeling fixed film systems due to better prediction of reactor biomass, effluent quality, and process performance parameters.

*Presenting author; aeldyast@uwo.ca

Statistical Modelling of Nonpoint Source Pollution from a Tropical Urban Residential Area

A. MAMUN[1*], M.Z. ALAM[1], D. DARUS[1], A. IDRIS[2]

[1]*Bioenvironmental Engineering Research Unit (BERU), Faculty of Engineering, International Islamic University Malaysia (IIUM), Jalan Gombak, 53100 Kuala Lumpur, Malaysia*
[2]*Department of Chemical & Environmental Engineering, Faculty of Engineering, Universiti Putra Malaysia (UPM), 43400 UPM Serdang, Selangor, Malaysia.*

Quantification of the pollutants generated due to rainfall-runoff process is tedious and expensive. On the other hand, the characteristics of runoff quality also depend on the landuses and rainfall patterns. Such difficulties can be simplified by the development of reliable and easy to use non-point source (NPS) regression models. Information on the statistical models for the estimation of NPS or diffuse pollution loading in many tropical countries, including Malaysia, is not available yet. Therefore, local data was used to develop multivariate statistical models to estimate various pollutants from the NPS or diffuse sources of a residential area. The multivariate regression models were developed for total dissolved solids (TDS), total suspended solids (TSS), zinc (Zn) and copper (Cu), which could be used to estimate pollution loading from the urban residential areas having activities and drainage system similar to the study area. Fifty six storm events of various durations and intensities were monitored for the study. It was observed that the rainfall data followed log-normal distribution at 95% confidence level. About 5% of the events had inter-event dry period of less than 19.5 hours and 95% of the events occurred less than a gap of 169.8 hours. Forty six rain events were used to develop the regression models. Calibration and validation were done using another five rain events for each exercise. Models for other parameters exhibited low coefficients of determinations (less than 0.50) and, therefore, considered not useful for the estimation of pollution load form nonpoint sources of a developed urban residential area.

[*]Presenting author; mamun@iium.edu.my

Estimation of Total Phosphorus Loads for a Large, Flashy River of a Highly Developed Subwatershed - Seasonal and Hysteresis Effects

E. M. O'CONNOR[1*], C. MCCONNELL[2], D. LEMBCKE[1], J. G. WINTER[3]

[1]*Surface Water Monitoring, Watershed Management, Lake Simcoe Region Conservation Authority, 120 Bayview Parkway, Newmarket, Ontario, Canada, L3Y 4X1*
[2]*Dorset Environmental Science Centre, Environmental Monitoring and Reporting Branch, Ontario Ministry of the Environment, 1026 Bellwood Acres Road, Dorset, Ontario, Canada, POA 1E0*
[3]*Sport Fish and Biomonitoring Unit, Environmental Monitoring and Reporting Branch, Ontario Ministry of the Environment, 125 Resources Road, Toronto, Ontario, Canada, M9P 3V6*

Estimation of nutrient loads is of crucial interest for the assessment of the links between phosphorus loading and biotic impairment. The challenge for many monitoring programs is to make the best use of available information (flow and concentration data) for load estimations. This study evaluates several total phosphorus loading estimation procedures using long-term (1990-2009) data from a large, highly developed river watershed that flows into Lake Simcoe. The procedure involved the grouping of long-term data into 7-year moving windows, stratifying flow and concentration data, and calculating annual load for the centre-year of each window. A procedure involving seasonal stratification and then further stratification of the winter/spring strata by hydrograph limb was preferred over stratification by flow. The former stratification scheme distinguished groups that were more homogenous with regards to concentration *versus* flow relationships (higher slopes and r^2). Annual phosphorus loads calculated using the Beale Ratio load estimation method ranged from 3,920 to 20,642 kg and were greater than loads calculated using the method historically used to calculate loads to Lake Simcoe (the Midpoint method). It is recommended, for this river, and rivers of other regions with similar characteristics (urban/agricultural subwatersheds affected by seasonality and hysteresis), that sampling aims at capturing the full range of flows of the hydrograph in all seasons. Data stratified by season, hydrograph or flow should be investigated further to identify combinations of these factors; more understanding of the concentration/flow dynamics of a given system and more accurate loads can be acquired.

[*]Presenting author; e.oconnor@lsrca.on.ca

Modelling Pharmaceutical Transport in Canadian Watersheds Using the PhATE Modeling Code

N. HOSSEINI[1*], W. PARKER[2], L. MATOTT[3]

Department of Civil and Environmental Engineering, University of Waterloo, 200 University Ave West, Waterloo, Ontario, N2L 3G1

Pharmaceuticals and personal care products (PPCPs), and endocrine disrupting compounds (EDCs) can have significant adverse effects on the aquatic environment. Modeling the transportation of these chemicals in surface waters plays a significant role in understanding the fate of these compounds in the environment. Therefore, the PhATE (Pharmaceutical Assessment and Transport Evaluation) model was previously developed and applied to estimate pharmaceutical concentrations in the surface waters of 11 watersheds in the United States. In this study, the PhATE model was applied to the Grand River watershed, located in Southwestern Ontario. The climate in Ontario exhibits substantial seasonal variability and previous studies demonstrate considerable seasonal variability in some PPCPs and EDCs concentrations in the Grand River watershed. Accordingly, the PhATE model was adapted to simulate seasonal concentrations of the selected compounds. Several seasonally variable physical, chemical, and hydrological factors were considered, including: average and low flow, treatment plant loading, in-stream decay, and removal efficiencies of lagoons, secondary and tertiary wastewater treatment plants. The considered PPCPs and EDCs included ibuprofen, naproxen, carbamazepine, nonylphenal and DEET (N,N-diethyl-m-toluamide). The selection of these compounds was motivated by the availability of seasonal measured data in the watershed, thereby facilitating a robust assessment of the model. In general, accounting for seasonal variability improved the accuracy of the in-stream concentrations predicted by the PhATE model. Comparison of simulated concentrations with measured data at two previously sampled locations in the Grand River indicates relatively good fits between historical data and corresponding model output; for example, an r2 value of 0.9 was observed for carbamazepine. Overall, the modified PhATE model was capable of accurately simulating pharmaceutical concentrations in the Grand River.

[*]Presenting author; nahossei@engmail.uwaterloo.ca

Biological Assessment of Water Quality

Chairs: Guillaume Tixier, Patricia Gillis

As cities grow, increasing volumes of stormwater and wastewater and their associated contaminants are threatening the quality of receiving waters in and downstream of urban areas. To assess the impact of anthropogenic activities on water quality, examining physico-chemical parameters alone is generally insufficient because of the temporal variability in the chemical stress, the potential additive effects of contaminants and their variable bioavailability in the environment. On the other hand, organisms living in receiving waters are integrative of all environmental conditions at all times. Therefore, biological tools that investigate the health of aquatic organisms at different levels of biological organizations i.e., (sub) individual, population, and community, can provide better insight into the quality of receiving waters. However, current research in this field is facing numerous challenges. For example, most biological indicators require a comparison with a control or reference site which is challenging to find. Moreover, the combined effects of multiple stressors make it difficult to select responsive indicators, and to establish the cause(s) of detected impairments. In addition, the standardization of methods for large-scale assessments is challenged by the natural heterogeneity of the environmental conditions. This session highlights recent advancements in this science, including studies which overcome such challenges.
Subjects of interest for this session:
• Proposal of new biological assessment methodologies
• Development of existing methodologies towards specific application or standardization
• Comparison of methodologies (ex: in situ vs. in vitro)
• Definition of control or reference site
• Identifying stressor-response relationships
• Impact studies of water quality on the biological compartments (Bacteria, Fungi, Plankton, Algae, Macrophytes, Invertebrates, Fish)

Monitoring water quality using an Algae Bioassessment Protocol

C. GONCALVES[1,2*], J. WINTER[3], S. JARVIE[1]

[1] *Ecology Division, Toronto and Region Conservation Authority*
[2] *Graduate Student, Department of Physical and Environmental Sciences, University of Toronto at Scarborough*
[3] *Sportfish and Biomonitoring Unit, Water Monitoring and Reporting Section, Environmental Monitoring and Reporting Branch, Ontario Ministry of the Environment*

The use of algae, and particularly diatoms, in biomonitoring has been extensively used in Europe, New Zealand and even South Africa. North America however, has been slow to apply diatom monitoring as a water quality assessment tool. The Ontario Ministry of the Environment, in partnership with the Toronto and Region Conservation Authority and the University of Toronto, has recently developed and produced an Algae Bioassessment Protocol (ABP) for streams in southern Ontario.

As an effective monitoring protocol, the ABP needed to produce results that are both repeatable and reproducible. We tested the ABP by conducting a repeatability study on 33 sites across southern Ontario. Two samples were independently collected at each site by two separate field crews. All samples were analyzed for taxonomic composition, and evaluated using the Eastern Canadian Diatom Index (IDEC).

Samples were paired to test for differences attributable to sampling crews. No significant differences were found ($p=0.6048$), however there was a difference when paired samples were grouped according to the orientation of the diatom on the substrate ($p=0.0074$). Despite this, there was no difference in the IDEC scores calculated ($p=0.9028$). Differences in diatom community composition were also tested, using the scores from a correspondence analysis of the species data. There were no significant differences in the diatom communities between the paired samples using either Axis 1 scores ($p=0.626$) or Axis 2 scores ($p=0.928$). Regardless of the effect of different samplers, the ABP is robust enough to provide the consistent and comparable results required in an effective monitoring protocol.

This presentation will highlight the unique applications of diatoms in water quality assessments, the results of the repeatability study, and the ability of diatom communities to indicate average water quality in southern Ontario using an existing diatom index.

[*]Presenting author; cgoncalves@trca.on.ca

Diversity and Abundance of Anaerobic Ammonia-Oxidizing Bacteria in the Grand River

P. SONTHIPHAND*, J. NEUFELD

University of Waterloo

The Grand River watershed is the largest catchment within Southwestern Ontario. Both agricultural runoff and wastewater treatment plants (WWTPs) discharge nitrogen in the form of ammonia (NH3) into the Grand River. Anaerobic ammonia-oxidizing (anammox) bacteria can oxidize NH3 to nitrogen gas (N2) under anoxic conditions and we hypothesize that under appropriate conditions, anammox bacteria may may contribute to NH3 oxidation in this freshwater environment. The diversity and abundance of anammox bacteria in freshwater environments impacted by NH3 inputs have not been revealed yet. In this proof-of-principle study, three types of samples (water, sediment and epilithic biofilm) were collected from two sites with differing NH3 inputs (0.05 and 1.04 mg N l-1). Following DNA extraction from all samples, denaturing gradient gel electrophoresis (DGGE) and gene cloning approaches were used to reveal the diversity of anammox bacteria in all samples. Reflecting the anaerobic niche of these ammonia-oxidizing bacteria, anammox genes were only detected in the sediment sample DNA extracts. Neither water nor epilithic biofilm samples revealed the presence of anammox bacteria. Phylogenetic analysis indicated that anammox bacteria from both sites were closely related to known anammox bacteria related to the genus Candidatus Brocadia. Quantitative real-time PCR was used to evaluate the abundance of 16S rRNA genes of these Planctomycetes. From the qPCR results, the sites with low and high NH3 concentrations revealed anammox 16S rRNA gene abundances of 6.96 x 105 ± 1.61 X 104 and 9.74 x 105 ± 2.84 X 104 copy numbers g-1 sediment, respectively. The results confirm that Ca. Brocadia is a common freshwater genus of anammox bacteria and that these bacteria may be key players in NH3 removal within the Grand River sediment. Ongoing research seeks to understand the relative contributions of anaerobic and aerobic microorganisms to ammonia oxidation in this impacted environment.

*Presenting author; psonthip@uwaterloo.ca

Toxicity Testing at Merrick Landfill

A. EVANS[1*], P. CHAMPAGNE[1,2], P. HODSON[3]

1 Department of Civil Engineering, Queen's University
2 Department of Chemical Engineering, Queen's University
3 Department of Biology, Queen's University

Landfill leachate contains an array of contaminants that can negatively affect receiving environments, including fish habitat. The toxicity of landfill leachate to aquatic systems at the Merrick Landfill in North Bay, ON, is a function of several factors including surface water, groundwater and leachate characteristics. To determine the effectiveness of an experimental vertical-flow wetland system and existing natural attenuation zone for the treatment of landfill leachate to a level where the local ecosystem is not affected, toxicity tests with rainbow trout are being conducted. The goal of the toxicity studies is to determine the risk posed to the Little Sturgeon River, which is characterized by its uniquely soft water and high organic and iron content. Changes in measured toxicity of leachate as it flows through treatment systems will identify adjustments to treatment that are needed to reduce impacts on ecosystem health. The results of leachate chemical analyses and toxicity tests will be integrated using principle component analysis (PCA) to determine the source(s) of toxicity, including interactions among various chemical constituents as well as the receiving environment. Toxicity tests will also be used in a Toxicity Identification Evaluation (TIE) approach to validate the results of the PCA analysis. Toxicity tests integrate the interactions of all of the chemical variables characteristic of the leachate and receiving water, and can be combined with the results of leachate treatment system and groundwater studies to determine the degree of treatment required and to optimize the treatment variables.

[*]Presenting author; andrew.evans3@gmail.com

Differential Gene Expression in Rainbow Trout Exposed to the Brominated Flame Retardant TBBPA-DBPE

A. MUTTRAY[1*], T. NEHELI[1], H. PARIKH[2], J. MILLER[1], J. SHERRY[1]

[1]*Environment Canada*
[2]*University of Waterloo*

Tetrabromobisphenol A bis(2,3-dibromopropyl ether) (TBBPA-DBPE) is a flame retardant which was introduced as a replacement for other brominated high-volume flame retardants that showed clear evidence of persistence, bioaccumulation, and carcinogenicity. The Chemicals Management Plan has included brominated flame retardants (BFRs) in the assessment because of their bioaccumulation, inherent toxicity, and persistence in the environment. Although little toxicity data are available, the BFRs as a class have been found to be geno-, hepato-, immuno- and neuro-toxic. A degradation product of TBBA-DBPE, bisphenol A, has endocrine disrupting effects.

The objective of the current research is to determine gene expression effects of TBBPA-DBPE in the livers of juvenile rainbow trout (Oncorhynchus mykiss) after 2, 10, and 21-day exposures to three sublethal concentrations. We employed the Fluorescent RNA Arbitrarily Primed Polymerase Chain Reaction technique (FRAP-PCR) to identify genes that were differentially expressed in rainbow trout after exposure. FRAP-PCR is an open-ended exploratory tool that identifies differences in gene expression without prior knowledge of the affected genes.

A total of 55 FRAP-PCR amplification products were identified as differentially expressed and extracted from the gels. These amplification products were re-amplified, cloned and sequenced. Approximately 51% of the FRAP-PCR products were positively identified using the BLAST algorithm. 31% of the products were unique non-ribosomal genes. We are now using the Ingenuity Pathway Analysis software to categorize the identified gene products into biochemical pathways.

In future research we will use real-time quantitative PCR (qPCR) to confirm that the FRAP-PCR identified genes are differentially expressed. qPCR will allow us to determine gene expression levels in individual fish. The present research will increase our understanding of the molecular mechanisms of toxicity of brominated flame retardants and may contribute to the development of molecular tools for the assessment of sublethal effects in aquatic organisms.

[*]Presenting author; annette.muttray@ec.gc.ca

Determination of Biological Effects of Wastewater Effluent on Frog Tissue Culture Using the C-fin Assay and Transcriptomic Endpoints

P. WOJNAROWICZ*, C. C. HELBING

Department of Biochemistry & Microbiology, University of Victoria, Victoria, British Columbia, V8W 3P6

Pharmaceuticals and personal care products (PPCPs) present a challenge to municipal wastewater treatment facilities. Identification of the best treatment trains for mitigating PPCP effects in the receiving environment is of particular concern as the endocrine disrupting effects of many PPCPs are yet to be fully assessed. There is a need for rapid biological effects assessment tools based upon relevant wildlife species.

Frogs are environmental sentinels and they are very sensitive to hormonal effects. The ability of the frog to respond to estrogenic exposures is superseded only by a dramatic response to thyroid hormone (TH). Metamorphosis from tadpole to adult depends solely on TH. Frogs thus serve as an ideal model for the detection of biological effects due to endocrine disrupting compounds in municipal wastewaters.

We have developed a method to rapidly screen for biological effects in *Rana catesbeiana* tadpoles using the cultured tail fin (C-fin) assay. A typical C-fin assay uses eight premetamorphic tadpoles that are euthyroid, but functionally athyroid. Twelve 4 mm circular tail fin biopsies are individually placed into tissue culture wells containing serum-free medium. Each biopsy is then exposed to different conditions including various effluent concentrations in the presence or absence of TH or estrogen. After 48 h, the biopsies are collected, the RNA isolated, and then quantitative real time polymerase chain reaction (QPCR) is performed on transcripts encoding proteins that are important in hormone- and stress-signaling pathways. The C-fin assay allows for the simultaneous screening of multiple conditions in one individual while maintaining biological variation and complex tissue structure. Changes in transcript levels induced by exposure to effluents relative to unexposed and hormone-treated conditions are indicators of possible deleterious effects. Because gene expression changes precede morphological changes, the C-fin assay and transcriptomic analyses are a much-needed early-warning system for evaluating the biological effects of wastewater effluents.

*Presenting author; polaw@uvic.ca

General/Receiving Environments

Chair: Chris Marvin

This session will include presentations on bacterial monitoring at Ontario beaches, dissolved oxygen and carbon dynamics in lake environments, and receiving water risk assessments.

An Assessment of Arsenic-Iron Removal Plants in the Manikganj District of Bangladesh

R. BRENNAN[1*], E. MCBEAN[1], A. PRAMANIK[2], S. AHMED[1]

[1]*University of Guelph*
[2]*The Society for People's Action in Change and Equity*

Water supply of acceptable quality in Bangladesh is a challenge, given microbial contamination of surface water, the annual cycle of monsoon and drought, and arsenic contamination of groundwater. Arsenic-iron removal plants (AIRPs) are one way of removing arsenic from groundwater for access to better quality drinking water in Bangladesh. AIRPs are of particular interest, given that they are low-cost compared to other arsenic-removal technologies, can be constructed and maintained locally, require no added chemicals, are easy to use, and were developed in Bangladesh. The Society for People's Action in Change and Equity (SPACE), a Bangladeshi non-governmental organization, has installed 105 AIRPs in the Manikganj District of Bangladesh. These AIRPs are designed to serve the drinking water needs of about 20 people, or one extended family.

For this project, we collaborated with a local engineering university, BUET, and the implementing NGO, SPACE, to evaluate the performance of SPACE AIRPs. Performance was evaluated at 21 sites in terms of arsenic removal and was supplemented with microbial data. Performance variability throughout a cleaning cycle and the impact of arsenic, iron, and phosphate on performance were also investigated. The scientific results provide evidence that AIRPs are technically capable of removing arsenic to the Bangladesh standard, and in most cases the World Health Organization guideline, in the study area. On average, 87% of influent arsenic was removed. Given these results, and the fact that AIRPs were generally found to be well-accepted and well-maintained, AIRPs show promise for use in areas with high natural iron where users are concerned with arsenic and/or iron in their drinking water.

[*]Presenting author; ryan.thomas.brennan@uoguelph.ca

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

K. McPHEDRAN[1*], R. SETH[1], AND R. BENJAKIWAR[2]

[1]*Department of Civil & Environmental Engineering, University of Windsor, Windsor, ON*
[2]*Essex Region Conservation Authority, Essex, ON*

Point and nonpoint sources contribute to contamination of surface waters by pathogens found in human or animal feces. Most pathogens exist at very low levels and are difficult and expensive to detect, therefore, Fecal Indicator Bacteria (FIB) are used as surrogates to help identify fecal contamination. FIB generally do not cause illness directly, but may indicate the presence of pathogens. The most common FIB are *Escherichia coli (E. coli)* and *Enterococcus spp.* Ontario water quality guidelines specify a level of ≤ 100 *E. coli* / 100 mL to protect public from adverse health effects from exposure to water-borne pathogens at recreational beaches. Exceedance results in warnings of potential health risk or beach closures.

E. coli at public beaches in Windsor-Essex are monitored weekly as specified in beach management protocol of the Ontario Ministry of Health and Long-Term Care. Samples are taken Wednesday and results available Friday used as a basis for action. However, FIB levels are expected to fluctuate daily dependent on weather conditions. This study was a preliminary investigation of *E. coli* and *Enterococcus spp.* over 30 consecutive days at two beaches, Sandpoint Beach (Windsor, ON) and Holiday Beach (Amherstburg, ON). Three 100 mL samples were collected daily for each of *E. coli* and *Enterococcus spp.* by Essex Region Conservation Authority (ERCA) and delivered to Environmental Engineering (University of Windsor) for analysis of *E. coli* and *Enterococcus spp.* by Colilert® and Entrolert®, respectively. These methods are approved by US EPA and included *Standard Methods for the Examination of Water and Wastewater*. Physico-chemical parameters were taken on-site (water and air temperature, turbidity, and wave height) and wind observations were taken from Environment Canada archives. Preliminary results indicate that *E. coli* and *Enterococcus spp.* populations were dynamic and can be correlated to turbidity and wind directions.

*Presenting author; mcphed2@uwindsor.ca

Dissolved Oxygen Dynamics of an Embayment of the Great Lakes

N. DIEP*, D. BOYD, R. SEIN

Ontario Ministry of Environment

Dissolved oxygen is a critical component of natural ecosystems and severe depletion of dissolved oxygen is a concern as it has the potential to adversely affect aquatic organisms. Dissolved oxygen models are important tools for understanding the potential effects of eutrophication and when applied to an oligotrophic, clear-water embayment of the Great Lakes were found to generally under-predict the extent of the hypolimnetic dissolved oxygen depletion. *In situ* depth profiles and discrete real-time continuous sensors were used to characterize the DO condition of this embayment spatially and temporally. Near-bottom anoxia was observed since 1999 and volume-weight averaged hypolimnetic dissolved oxygen concentrations were below the DO Provincial Water Quality Objectives (PWQOs). Although near-bed anoxia was observed episodically since 1999, the anoxic conditions were observed for > 40% of the 2007 to 2009 summer stratified season. In 2007 and 2008, the hypolimnion was completely anoxic and severe metalimnetic dissolved oxygen depletion was observed. This waterbody is physically dynamic and the hypolimnetic boundary depth was found to fluctuate widely. This embayment's connectivity to the Great Lakes and the site-specific characteristics of this waterbody may pose a challenge to eutrophication modellers.

*Presenting author; ngan.diep@ontario.ca

Determining Large Scale Risk from Available Data - Receiving Water Risk Assessment for Municipal WWTPs in Alberta.

N. HUTCHINSON[1*], C. PRATHER[2]

[1]*Hutchinson Environmental Sciences Ltd.*
[2]*AECOM*

In 2008, Alberta Environment undertook a risk assessment of every WWTP in the Province. It included an engineering (plant infrastructure/operating practices) and an environmental component based on near field and cumulative risk posed to surface water receivers by 325 surface water dischargers. The major challenge was to develop meaningful and repeatable methods for consistent risk assessment with the recognition that useful site specific receiving water data and effluent quality were only available for a few major dischargers. Sixteen risk metrics were developed that used available data to estimate site specific and cumulative risks for each discharger on the basis of comparison of annual effluent loads to annual receiver loads for key conventional effluent parameters (phosphorus, ammonia, nitrate and oxygen demand). Receiver flow was the most important risk factor and was estimated for each site and for key reaches of rivers (for cumulative effects analyses) from Water Survey of Canada long-term flow records at 73 locations in the Province. Long term water quality data were available for 29 Alberta Environment sites and short-term or limited data from 90 Alberta Environment sites. This desktop assessment was favorably validated for a series of sites where there was detailed measurements of environmental responses to discharges. The results produced a series of recommendations for plant upgrades, monitoring and record keeping programs.

[*]Presenting author; neil.hutchinson@environmentalsciences.ca

Advances in Drinking Water Treatment

Chairs: Ron Hofmann, Souleymane Ndiongue

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

Modeling the Efficacy of Substrate Limitation versus Residual Disinfection in Controlling Water Quality Deterioration inside Drinking Water Distribution Systems

P. BIYELA[1,2*], S. PARK[2], B.E. RITTMANN[2]

[1]*Department of Civil Engineering and Applied Mechanics, McGill University, 817 Sherbrooke Street West, Montreal, Quebec, H3A 2K6, Canada*
[2]*Center for Environmental Biotechnology, Biodesign Institute at Arizona State University, 1001 South McAllister Avenue, Tempe, AZ 85287-5701 U.S.A*

The deterioration of drinking-water quality within distribution systems is a serious cause for concern. Extensive water-quality deterioration often results in violations against regulatory standards and has been linked to water-borne disease outbreaks. The causes for the deterioration of drinking water quality inside distribution systems are not yet fully understood. Mathematical models are often used to analyze how different biological, chemical, and physical processes interact and cause water quality deterioration inside distribution systems. We developed a mathematical model, the Expanded Comprehensive Disinfection and Water Quality (CDWQ-E) model, to examine the processes that advance water quality deterioration inside distribution systems. When used to forecast water quality decay trends after treatment and during distribution, CDWQ-E predicted that the extent of bacterial growth and by extension biofilm formation are controlled by organic substrate concentrations in the finished water at the time that it enters the distribution system, the presence of disinfectant residuals, and the water's residence time. To test the validity of the CDWQ-E model as a tool for interpreting and forecasting water quality decay in real distribution systems we collected and analyzed water samples from two full-scale distribution systems that differed in source water types, disinfection, size, and retention time. Bacterial counts increased inside the distribution system. This increase was coupled with the depletion of organic substrates and disinfectant residuals. All these trends were exacerbated by longer retentions times. Without exception the trends observed from experimental studies matched trends predicted by CDWQ-E. The CDWQ-E model fits major water quality trends that can be expected in finished water, including but not limited to bacterial growth, depletion of organic substrates, and disinfectant decay. More than being just a fitting tool, CDWQ-E also offers specific connections between water quality decay trends and the biological and/or chemical processes behind the observed trends.

[*]Presenting author; precious.biyela@mail.mcgill.ca

Magnetic Nanoparticles for Photocatalysis in Drinking Water Treatment

T. LESHUK, F. GU*

Deparmtent of Chemical Engineering, University of Waterloo, Waterloo, ON N2L3G1.

Water quality is a fundamental issue to human health in both the developed and developing world. In industrialized nations such as Canada, chemical contaminants, persistent organic pollutants, and microcontaminants such as endocrine inhibitors, are continual and growing concerns. Furthermore, microbial pathogens recalcitrant to conventional water treatment technologies, such as *Cryptosporidium parvum*, require advanced and alternative methods to be controlled. In the coming years there will be a growing need for novel, efficient, and economical solutions to effectively deal with these concerning contaminants.

Recent advances in nanotechnology have resulted in the development of a wide array of advanced materials exhibiting features and properties unique to the nanoscale, allowing innovative approaches to be applied to challenging problems. In particular, nanofabricated titanium dioxide, a semiconductor photocatalyst, has been extensively investigated for use in water treatment applications, especially for the degradation of otherwise difficult to remove contaminants, due to the highly oxidizing radicals generated in aqueous melieu upon exposure of the material to ultraviolet irradiation. Fundamental challenges have largely prevented practical deployment of this promising technology for water treatment purposes in the past, especially the difficulty in recovering the catalytic nanoparticles from suspension following water treatment, as well as the material's inherently poor efficiency in natural sunlight, requiring expensive electrical ultraviolet illumination to operate effectively.

We report a new approach to address these concerns in the hopes of advancing this nanotechnology toward realistic applications. We are currently endeavouring to couple a visibly light activated form of mesoporous titanium dioxide, chemically doped and sensitized with nanoparticulate quantum dots, with a superparamagnetic nanoparticle core. These composite nanoparticles exhibit photocatalytic efficacy in degrading methylene blue using visible light, and can be easily recovered through application of a magnetic field. Therefore, we envisage that these nanoparticles will be economically recyclable, and possess the ability to efficiently degrade difficult contaminants using only solar illumination.

*Presenting author; frank.gu@uwaterloo.ca

Investigation of Fouling Behaviour Observed with Ceramic Membranes with Typical Drinking Water Treatment Foulants

L. MUNLA*, S. PELDSZUS, P. HUCK

University of Waterloo

Polymeric membranes have been accepted as an effective treatment technology for drinking water treatment. On the other hand, ceramic membrane applications have been limited to more industrial uses mainly due to their high capital cost. Ceramic membranes are able to withstand higher pressures, display a higher chemical resistance, and have a longer lifetime when compared to polymeric membranes. Although overall life cycle costs for ceramic membranes have decreased, making them almost cost competitive with polymeric membranes, foulants of concern and fouling characterization in a drinking water treatment context have not been studied in depth. Since fouling poses a major challenge in any membrane application as it can severely impact productivity, fouling behavior needs to be investigated in order to assess the suitability of ceramic membranes for drinking water production. The objective of this research is to characterize the fouling behavior of ceramic membranes with model solutions representing foulants that have been identified for polymeric membranes. The rejection of these foulants and their influence on the surface properties of the ceramic membrane are investigated. Additionally, the reversibility of this fouling is determined with a hydraulic backwash.

The model solutions used were bovine serum albumin, a protein, alginate to simulate a carbohydrate, silica to simulate colloidal matter, and Aldrich humic acid. Solutions were filtered individually and in all possible combinations using a flatsheet TAMI membrane disc with a molecular weight cut-off of 300 kDa. The experiments ran at constant pressure while flux decline curves were monitored. The extent of the rejection was determined by characterizing feed, permeate, and backwash water. The contact angle, surface roughness using atomic force microscopy, and the surface charge using zeta potential analyzer were studied for the virgin membranes and selected fouled membranes. Knowledge of the fouling behavior of these ceramic membranes will be relevant in assessing more complex feed waters and in optimizing ceramic membrane operation thus improving overall performance.

*Presenting author; ldmunla@uwaterloo.ca

A Study of Nitrification Potential in Two Southern Ontario Drinking Water Distribution Systems

D. B. SCOTT*, M. I. VAN DYKE, W. B. ANDERSON, P. M. HUCK

Dept. of Civil and Environmental Engineering, University of Waterloo, Waterloo, Ontario

In chloraminated drinking water distribution systems, the phenomenon of nitrification can lead to the depletion of the disinfectant residual. Nitrification is a biologically-mediated process in which ammonia is oxidized to nitrite by autotrophic microorganisms, including both ammonia-oxidizing bacteria (AOB) and ammonia-oxidizing archaea (AOA). Nitrite can then be further oxidized to nitrate chemically or by nitrite-oxidizing bacteria (NOB). This work was undertaken to advance knowledge of distribution system nitrification, both generally and in the specific systems included in the study. A sampling campaign was conducted in two southern Ontario distribution systems, followed by batch testing on water samples from these same systems. A notable use of the results from this work was in the evaluation of some models for nitrification. Having reliable models for nitrification can provide early warnings of nitrification episodes and give guidance on system operation to avoid nitrification.

During the field sampling campaign in the full-scale distribution systems there were no severe nitrification episodes but some indicators of nitrification were detected. Some sites saw a small rise in nitrite above base levels, sometimes accompanied by a decline in total chlorine residual. Nitrifying microorganisms were detected both by culture-based and molecular methods (PCR). The latter was able to distinguish AOA from AOB; both were detected in the systems included in this study, with AOB gene counts outnumbering those of AOA at most sites.

This presentation will include some interesting observations made in the full scale distribution systems as well as the outcome of experiments comparing the loss of total chloramine residuals in real water samples where AOB/AOA growth was inhibited. Selected nitrification models found in the literature were compared to the results of the field sampling and batch testing. These models may have the potential to be useful in practice.

*Presenting author; d8scott@uwaterloo.ca

Relationship between Disinfection Byproducts, BFAs and PCPs using Swimming Pools as Model Water Matrices

J.WANG*, S. A. ANDREWS

Department of Civil Engineering, University of Toronto, 35 St. George Street, Toronto, Ontario, Canada, M5S 1A4

Disinfection byproducts (DBPs), such as organic chloramines, THMs, HAAs, and nitrosamines are formed during mandatory disinfection processes in drinking water treatment. Many of these DBPs have been shown to be potentially carcinogenic. Extensive research has been conducted on the occurrence and formation of these DBPs individually during the past decades. However, there has been limited research on their relationships with each other, which may be important for the understanding of their formation mechanisms and, ultimately, for the development of possible improvements in treatment technologies.

The aim of this study was to examine the relationship between several classes of DBPs including: organic chloramines, THMs, HAAs, and nitrosamines. Swimming pool bulk water was used as a background matrix considering its high level of DBPs inside. Personal Care Products (PCPs) and Body Fluid Analogues (BFAs) were spiked into swimming water to investigate their potential to form DBPs under controlled experimental conditions. It has been found that the formation of organic chloramines would inhibit the formation of THMs and HAAs, but did not significantly affect nitrosamine formation, in particular with chlorination. Results of this study improve the understanding about the formation of DBPs from these precursors and provide feasible strategies to minimize DBP formation while maintaining the efficiency of disinfection.

*Presenting author; zhen.wang@utoronto.ca

Pilot-scale Study for the Control of Disinfection By-Products Formation by Precoagulation Ozone

D. BORIKAR*, S. NDIONGUE, L. MOORE, A.T. JAMAL, L. ARISS

Walkerton Clean Water Centre, Walkerton, Ontario

Total trihalomethanes (TTHMs) are major cause of non-compliance with Ontario Drinking Water Quality Standards for municipal residential drinking water systems. This study conducted at the Walkerton Clean Centre is an investigation of the performance of pre-coagulation ozone to control trihalomethane and haloacetic acid formation of a high organics (DOC 5 mg/L) and low turbidity (approximately 1 NTU) source water. Six filter runs were conducted using a dual train conventional pilot plant with an ozone system incorporated into one train. Effluents from filters were sampled and simulated distribution system trihalomethanes and haloacetic acids experiments were conducted. Experimental conditions included chlorine dosages of 3.5- 4 mg/L and detention time of 4-5 days. Total trihalomethanes and halo acetic (HAA_5) were determined at the end of the contact time.

Simulated distribution system experiments conducted using samples taken immediately after anthracite filter indicate that ozone reduced average TTHMs by 15.4%; while the HAAs increased by 29.3% in most of the experiments.

Simulated distribution system experiments conducted using samples taken directly from the new GAC filter did not show any additional benefits of ozone.

*Presenting author;dborikar@wcwc.ca

Tradeoff Between Zebra Mussel Control and Carcinogenic DBP Formation

Z. J. Y. ZHU, B. HARPER*, A. TUTT, E. MCBEAN

School of Engineering, University of Guelph, Guelph, Ontario

Chlorinating water for purposes of disinfection is common practice in water treatment facilities throughout Ontario; however, as chlorine is added, an array of disinfection by-products (DBPs) is formed. Some of these DBPs are carcinogenic. To reduce DBP formation, options include reduction in the precursors of organic matter and/or chlorine dose.

The complicating factor involved in the reduction of DBP formation at some facilities is the existence of large populations of Zebra mussels. Zebra mussels are an invasive species along the Western shores of Lake Erie that impact the ecosystem structure and increase the organic matter in surface water. Many treatment facilities attempt to control Zebra mussels through processes of chlorinating---an anti-fouling procedure--surface water to extensive levels. It is possible that DBPs are unnecessarily elevated during this controlling process.

This paper analyzes the seasonal fluctuations of the formation of DBPs. A regression model is created to predict how DBP levels can be lowered by reducing chlorination dosages. Furthermore, the paper assesses an approach to timing wherein the chlorination for zebra mussel control is accomplished by evaluating the toxicity of chlorination to zebra mussels during the combatable life stage. The multivariate models for TTHMs and HAAs subspecies are created to optimize the chlorination amounts used for zebra mussel control. The results show that when pre-chlorination is lowered during certain months, the average DBP levels can be decreased by approximately 28 percent over the year, which substantially decreases the cumulative cancer risk.

*Presenting author; harperb@uoguelph.ca

Effectiveness of Water Filtration at Lime Softening Water Treatment Plants

B. GORCZYCA*

University of Manitoba

Lime/soda softening plants require high pH levels that are unfavorable for dissolved organic carbon (DOC) removal. As DOC contains most of the pre-cursors of chlorine disinfection by-products many conventional lime/soda softening plants have difficulty meeting standards for trihalomethanes of 100 ppb. Portage la Prairie water treatment plant is facing the above challenges.

The DOC at the plant is removed by two processes: coagulation/softening/sand filtration and Granular Activated Carbon Filtration (GAC). The plant has been experiencing frequent clogging of sand filters and the premature exhaustion of Granular Activated Carbon filters (GAC), which results in ineffective removal of DOC.

Sand filters. Chemical analysis of material deposited on the sand filters at Portage la Prairie water plant indicated that these filters are fouled by calcium carbonate. We observed an increase in the size of particles during the recarbonation and ozonation processes at the plant. However, the laboratory experiments showed no correlations between the pH or ozone dose and number or size of particles. It appears that the cake on the filter media is simply formed by lime softening flocs that are not effectively removed by the clarifiers. Quiescent mixing condition in oversized recarbonation and ozonation units, promote further floc formation which results in an increase in the size of particles and subsequent filter clogging.

GAC filters. This part of the research is aimed at identifying the origin of the premature drop of GAC adsorption capacity. Two hypotheses are currently being investigated:

1) The GAC filters at Portage plant are preceded by the backwash water storage reservoir. The mixing conditions in this reservoir may promote formation of calcium carbonate aggregates which can clog GAC filter.
2) High DOC load on GAC filters may be due to its inefficient removal in the coagulation/softening/sand filtration processes.

Currently detailed analyses of removal of DOC and its fractions throughout the plant are under way. Fractionation of DOC in the water is conducted using a novel Solid Phase Extraction method. The material adsorbed on GAC media is being analyzed using X-ray diffraction and Ion Chromatography Inductivity-Coupled Plasma (ICP). It is expected that the reasons for premature exhaustion of GAC filters will be identified and methods for improved DOC removal suggested very soon.

*Presenting author; gorczyca@cc.umanitoba.ca

Optimization of Dissolved Air Flotation for Drinking Water Treatment through CFD Modelling

B. LAKGHOMI*, R. HOFMANN

Drinking water research group (DWRG), Department of Civil Engineering, University of Toronto

Dissolved air flotation (DAF) is a process for separation of solid particles from water by the injection of air bubbles. Historically, design of DAF systems has been based on trial and error and simple hydrodynamic models. However, the flow behavior and removal efficiency of current high rate DAF systems cannot be explained by the existing hydrodynamic models. As a result, more comprehensive and detailed models of the flow hydrodynamics using computational fluid dynamics (CFD) are required for design and optimization of these systems.

A variety of CFD models have been developed previously to study the flow hydrodynamics of DAF tanks. However, these models were not able to fully predict some flow features that have major effects on the efficiency of the system. The final objective of this study is to provide a better representation of the main features of the flow in a DAF system by combining the complex hydrodynamics and chemical phenomena into a single strong model. After validation of the model in a pilot scale tank using ADV (acoustic doppler velocimetry), the model can be used to improve the efficiency of high rate DAF systems.

The research is in preliminary stage and the presentation will include an introduction to CFD modeling of DAF systems and preliminary CFD results generated to date. The presented results will focus on 2-dimensional air-liquid modeling of a lab scale tank using FLUENT commercial software at different surface loading rates and bubble sizes.

To summarize, the presentation will highlight the importance of CFD modeling of a DAF tank and the type of guidelines it can provide in design and operation of industrial high rate DAF systems.

*Presenting author; b.lakghomi@utoronto.ca

Water Reuse

Chairs: Darko Joksimovic, Kirsten Exall

Although Canada enjoys abundant freshwater resources on the whole, there remain regions with limited water supplies, particularly in periods of drought and high water demands. Other regions are looking for new ways to control wastewater effluent discharges into sensitive receiving waters. Reuse or recycling of treated wastewater reduces effluent discharges into receiving waters and offers a reliable alternative supply of water for applications that do not require high quality water, freeing up limited potable water resources. Common water reuse applications include agricultural and landscape irrigation with reclaimed water, greywater reuse, rainwater or stormwater harvesting, and industrial reuse. This session will focus on current research and case studies in the development and implementation of water reuse projects.
This session will address such subjects as:
• What are some of the approaches to water reuse practiced in Canada, the U.S. and Europe?
• What are some of the water quality, treatment and monitoring challenges in producing reclaimed water?
• How are water reuse projects implemented in different regions of the country?
• What challenges remain in terms of gaining public support and regulatory acceptance for water reuse?

Evaluating the Potential to Reduce Phosphorus Loadings to Lake Simcoe through Water Reuse

D. ARSENEAU[1*], M. WALTERS[2], D. AMMERMAN[1]

[1]*AECOM*
[2]*Lake Simcoe Region Conservation Authority*

Lake Simcoe is one of the largest inland lakes in Ontario and supports a cold-water recreational fishery that is vital to the local tourism economy. Human activity has degraded the water quality in the Lake, creating significant eutrophication from excessive phosphorus loadings. To meet new discharge limits mandated by the Lake Simcoe Protection Act, operating municipalities face costly treatment upgrades at wastewater treatment plants. This study was commissioned to evaluate water reuse as a potentially cost-effective alternative to reduce phosphorus loadings.

The study included a watershed-scale demand screening analysis, quantifying potential reclaimed water demands using irrigation simulations, municipal water consumption and other permitted water taking records. Using the estimated water demands and wastewater effluent characteristics, the total annual phosphorus removed for each reuse application was determined and compared to the appropriate loading targets. Three conceptual reuse scenarios were developed to illustrate the range of implementation alternatives: agricultural irrigation, urban reuse and municipal disposal irrigation. A conceptual hydraulic design was completed and the capital and operational costs were tabulated, with the resultant metric of dollars per kilogram of phosphorus removed (kg P) to gauge effectiveness and allow comparison to other phosphorus reduction initiatives.

The analysis revealed large potential demands for reclaimed water, and associated potential for the reduction of phosphorus discharge, near each of the fourteen wastewater treatment plants. The irrigation of agricultural areas and golf courses yielded the largest potential for phosphorus reductions, with a competitive cost-effectiveness when compared to the installation of tertiary filtration at existing secondary treatment plants. The use of reclaimed water for disposal irrigation and in urban areas was found to be less cost-effective; however, the analysis considered only the cost-effectiveness of reducing phosphorus loadings, and there are many other benefits of water reuse that were not explicitly accounted for.

[*]Presenting author; david.arseneau@aecom.com

Stormwater Reuse and Potential Climate Change Impacts

J. HE[1*], C. VALEO[1], A. CHU[1], N.F. NEUMANN[2]

[1] *Department of Civil Engineering, Schulich School of Engineering, University of Calgary, Calgary, Alberta.*
[2] *School of Public Health, University of Alberta, Edmonton, Alberta.*

Stormwater reuse for irrigating public lands is proposed to reduce pressures on water supplies over a long-term horizon for the City of Calgary. A study was conducted in a residential area located in the southeast quadrant of Calgary to assess this new strategy in a changing climate. This study focused on the stormwater quality of the Inverness Stormwater Pond and the quality of stormwater runoff from a nearby sub-residential area under both current and future climate conditions.

The field work was conducted from 2005 to 2008 to assess and characterize stormwater quality and stormwater runoff quality. Under current climate conditions, the stormwater is considered suitable for reuse as irrigation water. Stormwater quality is correlated with climatological variables, and quality (in particular, microbiological quality) degradation is largely related to rainfall events. Stormwater runoff generated in rainfall events was characterized in terms of event mean values and first-flush (FF) effects. The relationships between stormwater runoff quality and rainfall characteristics were investigated.

In order to assess potential climate change impacts on both stormwater quality and stormwater runoff quality, data-driven modeling approaches including regression and artificial neural network (ANN) modeling were employed. This assessment was conducted under the assumption that models developed based on current observations are still valid under future climate scenarios. The future climate scenarios were generated from a general circulation model using a spatial statistical downscaling model. In the ANN modeling approach (for stormwater runoff quality), partial mutual information based input selection was adopted to determine input variables of ANNs. Results show that a changing climate will likely deteriorate both stormwater quality and stormwater runoff quality, which suggests a higher risk to public health in future climate conditions. The absence of significant FF effects for total suspended solids and microorganisms throw doubt on adopting FF concepts in designing stormwater treatment facilities.

[*]Presenting author; jiahe@ucalgary.ca

Reclaimed Wastewater: Household Views and Acceptability of Alternative End Uses

D. DUPONT*

Brock University - Economics

Climate change may cause more frequent seasonal water shortages. Water-scarce countries use reclaimed household wastewater for subsequent uses that do not require potable water. Potential concerns over health risks and a distrust of one?s water provider may deter countries like the United Kingdom and Canada from adopting these technologies. However, to date there has been no research in Canada to investigate these issues.

This paper reports on results from a 2009 Canadian Internet-based study to better understand potential public acceptance of alternative end uses for reclaimed household wastewater. Survey respondents were queried as to their past experience with water shortages and they then were asked to answer a series of 5-point Likert scale questions to determine their willingness to see reclaimed wastewater used for a series of both indoor and outdoor end uses. Responses were correlated with responses to a series of questions based on the New Environmental Paradigm in order to determine whether environmental beliefs and sensitivities play a role. In addition, respondents were asked a series of questions about their belief in the ability of their water utility to manage potential health risks associated with the use of reclaimed wastewater. Finally, respondents were shown a risk ladder and asked to situate their perceived health risks from the current situation (no reclaimed wastewater use) and to compare these risks with those that might arise from a future situation that involved their municipality using reclaimed wastewater for household toilet flushing.

In general, the public is more accepting of the use of reclaimed wastewater for the subsequent purpose of toilet flushing, however, a number of respondents are completely against the idea because they perceive the potential health risks to be unavoidably high. This suggests that the average Canadian needs to be provided with the real health risk information from credible sources.

*Presenting author; diane.dupont@brocku.ca

Developments in Canadian Water Reuse Standards, Regulations, and Applications

T. VASSOS*

NovaTec Consultants, Inc.

This presentation reviews the current status, trends, and proposed changes in water reuse regulations, guidelines and standards in Canada. This includes a summary of: 1) reclaimed water within the BC Municipal Sewage Regulation (1999) and recently proposed changes; 2) Health Canada (2010) Canadian Guidelines for Domestic Reclaimed Water for Use in Toilet and Urinal Flushing; and 3) CAN/CSA-B128.1-06/B128.2-06 "Design and Installation of Non-Potable Water Systems/Maintenance and Field Testing of Non-Potable Water Systems" and draft CSA B128.3 "Performance of Non-Potable Water Treatment Systems". Recent related US standard initiatives will be reviewed. In addition, three parcel-level (individual building) urban water reuse case studies will be presented including: Quayside Village (North Vancouver, BC); Vancouver Convention Centre Expansion Project; and the Centre for Interactive Research on Sustainability (CIRS) building (University of British Columbia). The examples illustrate the range of technology solutions available for treating greywater and mixed wastewater, the associated operating requirements, challenges, and regulatory issues. The CIRS building also incorporates a rainwater harvesting system for potable water use within the building.

*Presenting author; tvassos@novatec.ca

City of Guelph Residential Greywater Reuse Field Test

W. GALLIHER*

City of Guelph, Water Services Department

The City of Guelph strives to be a leader in water conservation and efficiency. Guiding the City's water conservation efforts are the per capita water sustainability targets of the Guelph Community Energy Plan (CEP) of "using less water and energy per capita than comparable Canadian cities", and the daily reduction targets of City's 2009 Guelph Water Conservation and Efficiency Strategy Update (WCESU), which aims to reduce 2006 average daily water production requirements by 20% (10,600 m3/day) by 2025.

With reference to the City's long standing water conservation program, the impending market saturation of many status quo municipal water demand management programs was forecasted beyond the immediate planning period of the City's WCESU. With this in mind, the WCESU recommended the current piloting of more innovative demand management measures, such as greywater reuse and rainwater harvesting, to build technical and social capacity for these future water conservation programming alternatives. In alignment with these recommendations, the City of Guelph Water Services Department introduced the Residential Greywater Reuse Field Test in early 2009. The objectives of this initiative are to evaluate operation of current centralized residential home based greywater reuse systems, assess homeowner acceptance of residential greywater reuse (and related technologies) as well as define the municipal management framework necessary to best facilitate the future adoption of these technologies.

This presentation will discuss development and implementation of the Residential Greywater Field Test as well as present preliminary findings and lessons learned.

*Presenting author; wayne.galliher@guelph.ca

Water Reuse in Edmonton: The EPCOR-SUNCOR Experience

V. CORKERY*, G. HEISE

EPCOR Water Services Inc.

Water reuse system development poses many challenges as it moves from pilot stage to full scale implementation. The hurdles overcome by EPCOR in the project development, design, approval, permitting, construction and ongoing operation and maintenance of Canada's first full scale industrial wastewater reuse project in Edmonton will be identified and examined.

Both EPCOR and Suncor overcame many technical, financial, social and cultural challenges in the implementation of the 15 Ml/day water reuse system at EPCOR's Gold Bar Wastewater Treatment Plant. The methods used, lessons learned and ongoing action plans will be presented.

*Presenting author; vcorkery@epcor.ca

Water Reuse Developments in Europe

D. JOKSIMOVIC*

Ryerson University, Department of Civil Engineering

Both the demand for water and the distribution of renewable water resources in Europe vary quite widely from northern to southern states. As the demand for water resources has risen by 600% over the second half of the last century, an increasing number of European countries have turned to unconventional sources of water, including reuse of treated wastewater and desalination of seawater. Canada and Europe are both in the process of identifying the potential for water reuse and developing frameworks to facilitate a broader adoption of water reclamation in practice. This presentation will highlight some of the recent developments in Europe, and discuss their relevance in the Canadian context.

AQUAREC was the first major EU-funded project on water reuse that examined the role of water reuse in Europe and aimed at providing guidance in planning, implementation and operation of water reuse projects. The presentation will summarize key achievements of this project, and provide an overview of more resent research efforts in Europe that followed. Methodologies developed as part of the AQUAREC project related to integrated planning of large scale, centralized water reclamation will be highlighted, and illustrated with results of a hypothetical case study in Waterloo, Ontario. The presentation will conclude with an overview of some of the major water reuse schemes recently implemented in Europe.

*Presenting author; darkoj@ryerson.ca

Municipal Wastewater Effluents and Emerging Contaminants

Chairs: Vimal Balakrishnan, Joanne L. Parrott

Municipal Wastewater Effluents (MWWEs) contain a wide variety of natural and industrial products including nutrients, metals, organic chemicals as well as numerous emerging substances. A vast array of pharmaceuticals and personal care products (PPCPs) has been detected in MWWE. One reason for the interest in this issue that pharmaceuticals are designed to elicit biological responses, and so could affect exposed aquatic organisms. PPCPs and other emerging contaminants are generally present in ng/L concentrations, but because they are constantly added to aquatic ecosystems they are considered 'pseudo-persistent'. Fish, invertebrates and microbes will be exposed to low doses of not only these complex mixtures, but also their environmental and biological transformation products, over long time periods, sometimes their entire life cycle.

Detection of PPCPs and other emerging contaminants in MWWE is not easy as the MWWE matrix is complex. Different classes of compounds need different extraction methods, and so data is just now emerging on the variety of PPCPs in Canadian MWWEs.

The session will begin its focus on the chemistry of MWWE (analytical challenges and chemical fate) and will build to the biological effects of MWWE and PPCPs in Canadian environments.

Are Healthcare Facilities Significant Point Sources of Pharmaceuticals?

M. RIAZ UL HAQ[1*], W. PARKER[1], C. METCALFE[2]

[1]*University of Waterloo*
[2]*Trent University*

A Variety of sources contribute to the total load of pharmaceutical active compounds (PhACs) entering into the aquatic environment including pharmaceutical manufactures, individual households, dumps and land fillings, hospitals, nursing homes, veterinary and agricultural sources etc. Healthcare facilities are believed to be the significant point sources because considerable amounts of these compounds are used within these facilities. This study investigates the two different size hospitals and two long-term-care homes effluents for the occurrence and mass flows of selected pharmaceutical compounds and the relative contributions of these compounds to respective downstream wastewater treatment plants.

Twenty-four hour composite samples were collected over the five week days period from each investigated healthcare facility effluent. The downstream wastewater treatment plants influents were also sampled for mass balance calculations. Results support the idea that healthcare facilities may contain elevated concentrations of certain PhACs. The maximum concentrations of the antibiotic compounds detected in the hospital effluents were Sulfamethoxazole (10900 ng/L), Trimethoprim (10300 ng/L), and Ciprofloxacin (1240 ng/L). The maximum concentrations of these antibiotics in the long term care facility effluent were 2300 ng/L, 6500 ng/L and 1470 ng/L, respectively. The concentration of Acetaminophen was detected in levels of up to 134000 ng/L in the hospital and 116000 ng/L in the long-term-care home effluents. The contributions of pharmaceutical loads by healthcare facilities to their downstream WWTPs were found to be affected by the size of the facility, its service spectrum, and the size of the community contributing to the loads of these compounds to the same WWTPs. Relatively higher contributions were observed for antibiotic compounds; the maximum contributions of Ciprofloxacin were 26.6% for hospitals and 37% for long-term-care homes.

[*]Presenting author; riaz.ghazi@gmail.com

Monitoring Chemical Substances in Municipal Wastewater

S. SMYTH*, K. BARCLAY, M. KIM

Environment Canada

The purpose of Canada's Chemicals Management Plan (CMP) is to improve protection of human health and the environment against hazardous chemicals. A key pillar of the CMP is the monitoring and surveillance of levels of chemical substances in the Canadian environment. The wastewater sector has been identified as an important possible release points to the environment for certain substances; therefore the CMP monitoring program includes comprehensive monitoring at selected municipal wastewater treatment plants (WWTPs) across Canada. The purpose of the wastewater monitoring program is to determine the levels of selected chemical substances entering municipal WWTPs, the fate of these substances through the liquid and solids treatment processes, and levels of substances being discharged in WWTP effluents and solids residuals.

Data from the wastewater monitoring program will be used to assess the occurrence of chemical substances in municipal wastewater influents, the degree to which they are already being removed at warm and cold temperatures through different types of typical wastewater treatment processes used in Canada, and concentrations and loadings of substances being released to the environment as a result of municipal wastewater effluent discharges and land application of treated biosolids. These results will be used to improve our understanding and prediction of the fate of chemical substances during wastewater and solids treatment, and to determine if control measures are needed to prevent these substances from entering the municipal wastewater system.

This presentation will describe the monitoring program and show preliminary results of concentrations of polybrominated diphenyl ethers (PBDEs) in municipal wastewater and solids residuals.

*Presenting author; shirleyanne.smyth@ec.gc.ca

Evaluation of Biodegradation Kinetics Models for Microconstituents Under Typical Sewage Treatment Conditions

B. BANIHASHEMI*, R.L. DROSTE

Civil Eng. Dept., University of Ottawa, 161 Louis Pasteur St., Ottawa, ON, K1N 6N5

The occurrence and fate of microconstituents (MCs) in wastewater treatment plant (WWTP) effluents is a growing concern. Mathematical models developed for design and operation of biological wastewater treatment such as those from the International Water Association (IWA) were not concerned with specific chemical compounds. Consequently commercial modeling software for MCs removal have been developed, but models used in these packages for MCs have not incorporated developments in IWA models which present numerous possibilities that have not been evaluated.

The literature was reviewed for the kinetic models that can be used to describe transformation of MCs in an activated sludge process (AS). Volatilization and photolysis of non-volatile MCs was considered negligible. Micropollutants sorption equilibria in sludge have been found to often be modeled by Freundlich isotherms with a coefficient close to 1, which is equivalent to a linear isotherm. It is recommended that sorption should depend on total concentration of solids in AS.

More commonly used biological models have been found to be a first-order formulation dependent only on the liquid phase concentration of chemical or apparent first-order formulation where degradation occurs in both the soluble and sorbed phases and the pseudo first order expressions which take into account the mixed liquor suspended solids concentration (MLSS). However, using these models would lead to a linear increase in the removal rate with the SS concentration independent of sludge activity, but only active biomass can degrade substrates; therefore, studies should incorporate active mass in their formulations. This paper discusses many theoretical models that could be applicable considering coupling with activated sludge models developed by the IWA.

Finally, biodegradation models used in modeling software, such as SimpleTreat, ASTreat, STP, and TOXCHEM+ have been reviewed. Although TOXCHEM+ had the best performance record among the studies reviewed, ASTreat and TOXCHEM+ are recommended for simulating chemical transformations.

*Presenting author; BBANI082@UOTTAWA.CA.

Adsorption and Photocatalytic Degradation of Pharmaceuticals by TiO_2 Nanowires

A. HU[1*], X. ZHANG[2], D. LUONG[2], K. OAKES[2], M. SERVOS[2], Y. ZHOU[1]

[1] *Department of Mechanical Engineering and Mechatronics, University of Waterloo, 200 University Avenue West, Waterloo*
[2] *Department of Biology, University of Waterloo, 200 University Avenue West, Waterloo*

The adsorption and photocatalytic degradation of 14 different pharmaceuticals in the presence or absence of UV was comparatively studied using TiO_2 anatase and rutile nanowires as well as commercially available TiO_2 (P25) nanoparticles. Both anatase and rutile nanowires were grown under environmentally benign hydrothermal conditions. The adsorption isotherm indicates that adsorption is a thermally-activated process, while kinetic studies demonstrate adsorption is usually complete within 30 to 45 min. The nanomaterials evaluated differed in photocatalytic efficiency by compound, with the anatase-phased nanowires being more effective at degrading venlafaxin, lincomycin, norfluoxetine, diclofenac, and trimethoprim, while the rutile phased nanowires were more effective for fluoxetine. The P25 nanoparticles were more effective in degrading atorvastatin, ibuprofen, naproxen,and gemfibrozil, while sulfamethoxazole was strongly degraded by UV. Differences in photocatalytic degradation efficiencies are likely modified by each compounds molecular structure and unique degradation kinetics. These initial studies provide mechanistic insight into the effectiveness of TiO_2 nanowires and nanoparticles for treatment of surface waters containing trace pharmaceutical residues.

[*]Presenting author; a2hu@uwaterloo.ca

Determination of Degradation Products of Selective Azo and Anthracenedione Dyes Under Reducing cCndition

S. SHIRIN*, V. K. BALAKRISHNAN

Aquatic Ecosystem Protection Research Division
Water Science and Technology Directorate, Environment Canada
867 Lakeshore Road, Burlington, ON, L7R 4A6

Sulfonated anthracenedione dyes and selected diazo dyes have been categorized as medium priority compounds under the Government of Canada's Chemical Management Plan (CMP). Two such synthetic dyes are Acid Blue 129 (AB 129) and Disperse Yellow 7 (DY 7), mainly used in textile industries. Both AB 129 and DY 7, as well as other dyestuffs, represent important classes of organic pollutants about which little information is known regarding their environmental fate. Organic compounds can undergo chemical transformations when they interact with environmental matrices; therefore, understanding these transformations is a critical aspect of assessing their environmental fate.

In the current study, both Acid Blue 129 and DY7 were shown to be reduced efficiently in the presence of zero-valent iron. Loss of these dyes were attributed to the adsorption onto the Fe surface followed by chemical transformations via competitive and consecutive pathways. We found that AB 129 produced 2,4,6-trimethylaniline (a potential carcinogen) as well as other aromatic reduction products in which the bioactive anthracene moiety remained intact. Meanwhile, DY 7 produced 1,4-phenylenediamine and other reduced products. Reaction products were identified using accurate masses obtained from high resolution LC-Q-ToF-MS instrumentation. These results will be discussed in the context of elucidating the environmental fate of dyes in the aquatic ecosystem.

*Presenting author; salma.shirin@ec.gc.ca

Fate of Bisphenol A, an Endocrine Disrupting Compound in Wastewater and Wastewater Sludge of Urban Community of Quebec Wastewater Treatment Plant

D.P. MOHAPATRA*, S.K. BRAR, R.D. TYAGI

INRS-ETE, Université du Québec, 490, Rue de la Couronne, Québec, Canada G1K 9A9

The growing urbanization has led to the release of toxic organic compounds into the environment, 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 in an intact organism, or its progeny, or (sub) populations". Moreover, these compounds and many of their metabolites end up in the environment as a result of emission from production sites and direct disposal from households-detected in wastewater (WW) and wastewater sludge (WWS) across Canada. The biggest problem associated with these compounds is their detection (ng or pg level) mainly in media with complex matrix. Bisphenol A (BPA) has been identified as EDC by the U.S Environmental Protection Agency (EPA) and World Wide Fund for Nature (WWF).

The identification and quantification of BPA in WW and WWS is of major interest to assess the endocrine activity of treated effluent discharged into the environment. BPA was measured in samples from Urban Community of Quebec wastewater treatment plant located in Quebec (Canada) using LC-MS/MS method. The results showed that BPA was present in significant quantities (0.07 $\mu g\ L^{-1}$ to 1.68 $\mu g\ L^{-1}$ in WW and 0.104 $\mu g\ g^{-1}$ to 0.312 $\mu g\ g^{-1}$ WWS) in the wastewater treatment plant (WWTP). The treatment plant is efficient (76 %) in removal of BPA from process stream, however, environmentally significant concentrations of 0.41 $\mu g\ L^{-1}$ were still present in the treated effluent. Rheological study established the partitioning of BPA within the treatment plant. Higher BPA concentration was observed in primary and secondary sludge solids (0.36 and 0.24 $\mu g\ g^{-1}$, respectively) as compared to the liquid counterpart (0.27 and 0.15 $\mu g\ L^{-1}$, respectively) separated by centrifugation. Thus, BPA was detected in significant concentrations in the WWTP and it was mostly partitioned in the solid fraction of sludge.

Keywords: Bisphenol A; partitioning; rheology; wastewater; wastewater sludge

*Presenting author; diptiiitkgp@yahoo.co.in

Fate of Pharmaceutical in Municipal Wastewater Treatment

D. SHAVER*, H. SALSALI, E. MCBEAN

University of Guelph, Department of Engineering

Trace levels of many pharmaceutical compounds have been found in surface waters and wastewater effluents across Canada suggesting incomplete removal by current wastewater treatment processes. Hence, before effective removal strategies can implemented, a greater understanding of the fate of the drugs in conventional treatment schemes must be achieved.

Samples were taken from multiple points within the treatment process of three municipal wastewater treatment plants as well as select locations in the sewage catchment system. Twenty four hour composite samples were taken at the plant influent, plant effluent, raw sludge, mixed liqueur, TWAS, digester effluent, and biosolids. Using high-performance liquid chromatography and mass spectrometry, the wastewater was analysed for the beta-blockers Sotalol, Atenolol, Metoprolol, and Proranolol.

It was found that beta-blockers are predominantly removed in the Primary Clarifier where they remain relatively unchanged in the biosolids. Overall Removal rates ranged from 0-66% with some cases of negative removal indicating the drug became more concentrated in the plant effluent.

The study is ongoing and seeks to determine operating conditions that influence the removal of pharmaceuticals as well as provide an understanding of partitioning of the compound during each unit wastewater treatment process.

*Presenting author; dshaver@uoguelph.ca

Occurrence and Removal Efficiencies of Selected Emerging Contaminants in the Detroit River Watershed

S. TABE[1*], V. PILEGGI[1], P. YANG[2], N. FEISTHAUER[1], J. PARROTT[3], S. KLEYWEGT[1], J. SCHROEDER[1]

[1] Ontario Ministry of the Environment – Standards Development Branch, 40 St. Clair Ave. West, Toronto, ON;
[2] Ontario Ministry of the Environment – Laboratory Services Branch, 125 Resources Road, Toronto, ON;
[3] Environment Canada, 867 Lakeshore Road, Burlington ON

The occurrences of more than 200 legacy and emerging contaminants in the Detroit River Watershed (DRW) were monitored over a four months period. The target pollutants covered a wide range of substances from common organics and metals to pharmaceuticals and endocrine disrupting compounds (EDCs). Samples were collected from the influent, interstage, and effluent of two sewage treatment plants (STPs) as well as the intake, transient, and finished water in a water treatment plant (WTP). Also, the efficiencies of the existing treatment trains in the STPs and WTP in reducing the concentrations of the target chemicals were investigated. The STPs use CAS followed by UV disinfection. The WTP uses ozonation and conventional processes. The study was designed to collect baseline data for a more comprehensive research investigating the correlations between STP effluent chemistry and potential environmental impacts.

The results indicated that while approximately 97% of the total load of the target contaminants entering the STP was removed by the treatment processes, a number of them were detected in the effluent at concentrations ranging from PPT to PPB levels. The concentrations of these substances were further reduced in the receiving water through natural processes such as dilution, biodegradation, and sedimentation. At the intake of the water treatment plant some were detected at PPT levels while others were undetectable. The existing water treatment processes reduced another portion of the contaminants. The finished drinking water contained a few of the target contaminants in concentrations ranging from sub- to a few PPT.

The results from the DRW were compared to similar datasets collected independently from two other southern Ontario STPs. In addition, a set of ecotoxicity experiments were conducted on the effluent samples. The results from those two studies are also the subject of two separate abstracts by Pileggi et al. and Parrott et al.

[*]Presenting author; shahram.tabe@ontario.ca

Do Wastewater Treatment Processes Impact the Virulence Risk of *Escherichia coli*?

B. K. BISWAL[1*], A. MAZZA[2], L. MASSON[2], D. FRIGON[1], R. GEHR[1]

[1]*Department of Civil Engineering and Applied Mechanics, McGill University, Montreal, H3A 2K6*
[2]*Biotechnology Research Institute, National Research Council of Canada, Montreal, H4P 2R2*

Wastewater effluents are the primary source of pathogenic bacteria, including *Escherichia coli*, in the aquatic environment. The virulence risk of *E. coli* depends on the acquisition and/or expression of virulence genes which vary according to pathotype. This study evaluated the impact of biological and physicochemical treatment processes on the virulence risk of *E. coli*. As many as 90 *E. coli* isolates from each of the influent and undisinfected effluent samples from four wastewater treatment plants were characterized using DNA microarray technology to determine the impact of activated sludge (AS) or physicochemical treatment processes on the frequency of specific pathotypes, phylogenetic groups and antibiotic resistance genes in the *E. coli* population. The percentages of potentially pathogenic *E. coli* in the influent and effluent of one AS plant were 24% and 13% respectively whereas for another AS plant the percentages were 35% and 30% respectively. However, the percentages of potentially pathogenic *E. coli* in the influent and effluent of one physicochemical plant were 42% and 23% respectively whereas for another physicochemical plant the percentages were 30% and 13% respectively. For the influent and effluent of all four plants, extraintestinal pathogenic *E.coli* (ExPEC) was the most abundant pathotype. The difference in pathogenic levels in the influent and effluent of the two physicochemical plants and one of the AS plants was significant ($P < 0.1$). The concomitant antibiotic resistance gene study revealed that 16% - 66% of both pathogenic and nonpathogenic *E. coli* isolates in the influent and effluent of each plant contained antibiotic resistance genes from the aminoglycoside, β-lactam, phenicol, sulphonamide and tetracycline groups. *E. coli* isolates from effluents contained more antibiotic resistance genes than from influents. Thus this study showed that both types of treatment processes reduced pathogenic levels in the *E. coli* population, but increased the level of antibiotic resistance genes.

[*]Presenting author; basanta.biswal@mail.mcgill.ca

Finding the Needle in the Haystack: Total Estrogenicity Measurements in Guelph Biosolids using the Yeast Estrogen Screen (YES)

J. CITULSKI*, K. FARAHBAKHSH

University of Guelph School of Engineering

In vitro bioassays such as the Yeast Estrogen Screen (YES) allow for the determination of a sample?s total estrogenic potency. Natural and man-made estrogenic substances in wastewater have been implicated as endocrine-disrupting compounds (EDCs), and concern now exists regarding the presence and possible environmental impacts of EDCs in biosolids applied to land for agricultural, silvicultural and land-reclamation purposes. Chemical analyses have identified biosolids as the predominant sink for EDCs in municipal wastewater treatment, yet bioassay testing of biosolids has been comparatively sparse. This is largely because biosolids contain substances that can interfere with or completely block assay responses or cause cell death, yielding inconclusive or unusable results.

Our research has honed sample processing and cleanup techniques that successfully mitigate the interferences and cytotoxicity typically encountered when the YES assay is applied to biosolids. Using these enhanced techniques, the total estrogenicity of biosolids during sequential steps of the City of Guelph wastewater treatment plant?s (WWTP) process train has been evaluated. This represents the first comprehensive, long-term evaluation of total estrogenicity in a full-scale Canadian WWTP. YES assay data will be used in conjunction with WWTP operational, flow and analytical data to establish an ?estrogenicity balance? across the plant. They will also be used to determine the effects of operating conditions on the evolution of estrogenic potency. Studies are also underway to determine the effects of storage conditions on total estrogenicity levels in finished biosolids, as provincial/territorial legislation in Canada places seasonal restrictions on the land-application of biosolids.

*Presenting author; jcitulsk@uoguelph.ca

Extending the Traditional Effluent Quality Assessment Using Trace Chemical Analysis, In-Vitro and Whole-Organism Bioassays

V. PILEGGI[1*], S. TABE[1], N. FEISTHAUER[1], J. PARROTT[2], S. KLEYWEGT[1]
J. SCHROEDER[1], P. YANG[3], P. SETO[2]

[1] *Ontario Ministry of the Environment – Standards Development Branch, 40 St. Clair Ave. West, Toronto, ON*
[2] *Environment Canada, 867 Lakeshore Road, Burlington ON*
[3] *Ontario Ministry of the Environment – Laboratory Services Branch, 125 Resources Road, Toronto, ON*

The final effluent from a nitrifying sewage treatment plant (STP) located in southern Ontario, was assessed over a 6-month period. The assessment went beyond the traditional quality criteria (e.g., $CBOD_5$, TSS, TAN) to include legacy and trace organic contaminants (TrOCs) with known endocrine disrupting compounds (EDCs). *In-vitro* bioassays (estrogenic, androgenic, thyroid) and selected ecotoxicity tests were conducted including: rainbow trout acute lethality (96-h), *Daphnia* magna acute lethality (48-h), fathead minnow survival and growth (7-d), *Cariodaphnia dubia* survival/reproduction (7-d), *Lemna minor* growth (7-d) and *Pseudokirchneriella subcapitata* growth (72-h).

The purpose of this study was to provide a baseline of information for detailed pilot work (underway), to investigate potential correlations among sewage treatment, effluent chemistry and biological (*in-vitro* and/or *in-vivo*) responses. The results of this and subsequent pilot-studies are intended to inform provincial and national policies on reducing the potential impacts of municipal sewage effluent discharges.

During the sampling events, the STP was nitrifying (TAN < 5 mg/L) with nitrates > 5 mg/L and TSS < 20 mg/L. The chemical concentration analysis for legacy contaminants, emerging TrOCs and selected EDCs showed significant variability, with some log-normal distributions of the datasets and with parts of the datasets being below the method detection limits (MDLs). The preliminary ecotoxicity results showed no acute sublethal effluent toxicity following acute or chronic exposure to any of the test species. However the in-vitro screens indicated a weak estrogenic response. In general, the *in-vitro* and *in-vivo* bioassays provided varied and complex responses with no immediately apparent correlation to effluent chemistry.

This baseline study (and related studies; see abstracts by Tabe et al. and Parrott et al.) highlights some of the challenges associated with trying to link, treatment and effluent chemistry with biological responses at full-scale installations. It also demonstrates the need for side-by-side pilot-scale investigations under controlled conditions.

[*]Presenting author; Vince.Pileggi@Ontario.ca

Fathead Minnow Lifecycle Exposure to Two Canadian Municipal Wastewater Effluents.

J. PARROTT[1*], B. BLUNT[1], C. REGAN[1], P. SETO[1], S. BACKUS[1], V. PILEGGI[2], S. TABE[2], N. FEISTHAUER[2], S. KLEYWEGT[2], J. SCHROEDER[2]

[1] *Environment Canada, Burlington, ON,*
[2] *Ontario Ministry of the Environment, Toronto, ON*

Fathead minnows were exposed for a lifecycle to secondary treated municipal wastewater effluents (MWWEs) from two cities in southern Ontario. The MWWEs (1,500 L) were collected weekly and fish were exposed to 70-100% effluent in flow-through aquaria in the lab. Exposures began at the fertilized egg stage, and continued through hatching, maturation and breeding. Fish were sampled at 5 months of age and growth, health and reproductive status were assessed. Pharmaceuticals and personal care products (PPCPs) and endocrine disrupting compounds (EDCs) detected in the MWWEs included in descending order of concentration: bisphenol A, trimethoprim, sulfamethoxazole, carbamazepine, diclofenac (at 1 ug/L to 280 ng/L) and lincomycin, norfloxacin, naproxen, ciprofloxacin, enrofloxacin, erythromycin, ketoprofen, chlorotetracycline and gemfibrozil at lower concentrations (240 to 20 ng/L). Fish grew well in both effluents, but reproduction was decreased in one of the two effluents. Both effluents had similar concentrations of pharmaceuticals, and low free ammonia. The long term effluent exposures show the complex response of fish to the MWWEs, with normal growth, but decreased reproductive output. Studies will continue in 2011 to assess if model-scale advanced effluent treatment (increased nitrification and biological nutrient removal) will decrease conventional contaminants and PPCPs, and possibly decrease or remove the negative effects on fish egg production.

[*]Presenting author; joanne.parrott@ec.gc.ca

Communities to Cells: Assessing Fish Responses to Municipal Wastewater

G. TEREAULT[1*], C. BROWN[1], M. MCMASTER[2], J. BENNETT[2], K. SHIRES[2], B. KNIGHT[2], C. CHENG[2], M. SERVOS[1]

[1]*University of Waterloo*
[2]*Environment Canada*

Municipal Wastewater Effluent (MWWE) is the largest point-source for contaminants to the Canadian aquatic environment. This effluent is a mixture of domestic and industrial wastes, including Pharmaceuticals and Personal Care Products (PPCPs). The purpose of this study is to evaluate the potential impacts of these discharges at various levels of biological organization (fish communities, populations, and individuals) in the Canadian aquatic receiving environment. In 2005 and 2007, field studies upstream and downstream of two municipal discharges assessed fish communities (diversity and abundance), populations and individual responses in terms of growth (condition factor) and reproduction (in vitro sex steroid production, gonadosomatic indices, and gonad, kidney and gill histopathology). Fish community assessments in 2007 and 2008 demonstrated significant alterations in fish abundance, diversity, and changes in the key species of the river fauna downstream of the MMWE discharges. Fish (Greenside Darter [*Etheostoma blennioides*] and Rainbow Darter [*Etheostoma caeruleum*]) collected downstream of the Kitchener and Waterloo municipal wastewater plants had greater condition when compared to reference fish collections. Although fish populations did not display effects to MWWE exposure, individually exposed fish demonstrated physiological alterations in sex steroid productive capacity and male fish demonstrated intersex. Other alterations in histopathology observed included inflammation of tubules in the kidney and stunted gill lamellae. This research will aid in establishing biological criteria for monitoring the effects of MWWE discharges in Canada.

[*]Presenting author; Gerald.Tetreault@ec.gc.ca

Environmental Management Strategies and Frameworks

Chair: Johann (Hans) Biberhofer

Implicit in effective stewardship of environmental resources is the integration of scientific data, economic realities and cultural insight. These components often vary in scale and scope but are requisite to the assessment, selection and implementation of the most appropriate management strategies. The development of these strategies can be guided by existing or transposed frameworks or may be the consequence a new approach explicit to the management objective.

This session will highlight processes for the advancement of effective management strategies, as well as the science undertaken to address specific elements of investigation that contribute to a better understanding of successful environmental stewardship and protection.

Key Subject Areas include:

- Site characterization studies
- Risk assessment
- Analysis of management alternatives
- Decision pathways for the selection of specific management activities or plans

Delineation of Areas for Sediment Management in the St. Clair River using Invertebrate Methyl Mercury Tissue Concentrations

L. RICHMAN[1*], D. MILANI[2], M. HENNING[3]

[1]*Ontario Ministry of Environment*
[2]*Environment Canada*
[3] *ENVIRON International Corp.*

The St. Clair River was identified as an Area of Concern by the IJC in 1985 because of contaminated fish, degraded benthos, beach closures, and other impairments due to poor water and sediment quality. Currently, sediment management options are under review for three Priority Areas. These areas were identified based on the risk of Hg biomagnification in fish through benthic organisms. Methyl Hg tissue data for oligochaetes collected in 2001/2004 were used to estimate maximum exposure of Hg to fish assuming fish foraged exclusively within the study area. Site specific BMFs were generated using local fish tissue concentrations (pike and redhorse suckers) and the oligochaete concentrations. These BMFs were divided into a literature derived fish tissue concentration protective of fish (Toxicity Reference Value: 0.2 mg/kg) to obtain a range of target methyl Hg concentrations in invertebrates protective of fish (0.0125 mg/kg – 0.0154 mg/kg). Using anisotropic interpolation, spatially weighted average concentration (SWAC) of methyl Hg in oligochaetes were calculated (0.020 mg/kg). To lower the SWAC below the target concentrations, locations with oligochaete tissue concentrations greater than 0.025-0.027 mg/kg require remediation.

To better assess the size of the three Priority Areas requiring remediation, additional benthic tissue data was collected in 2010. Concentrations of methyl Hg in oligochaete tissue, with only a few exceptions, exceeded the target concentrations (range: 0.017 -0.050 mg/kg; median: 0.033 mg/kg). The percent methyl Hg in oligochaete tissue ranged from 4-20% (median 8%). Methyl Hg concentrations in oligochaetes were significantly correlated with methyl Hg and total Hg in sediment ($r=0.84$; $p<0.002$ and $r=0.66$; $p<0.04$ respectively). Total Hg in oligochaetes was also significantly correlated with total Hg in sediment ($r=0.89$; $p<0.0001$). Overall, methyl Hg concentrations were consistent in all three Priority Areas with data from 2001/2004. The size of the Priority Areas can be refined using the new data.

[*]Presenting author; lisa.richman@ontario.ca

Comparison of Sediment Management Strategies Developed for Three Canadian PCB-Contaminated Sites

A. BORGMANN[1*], R. JAAGUMAGI[2], N. DIEP[3], M. HENNING[4], N. BENOIT[3], R. SANTIAGO[1]

[1]*Environment Canada*
[2]*Golder*
[3]*Ontario Ministry of Environment*
[4] *ENVIRON*

Historic industrial discharges and spills have been a concern to government agencies because of the tendency for persistent contaminants to settle and accumulate in sediments. Sediment contamination has been assessed at several sites in the Canadian Great Lakes Areas of Concern (AOCs). Some of the contaminants, such as polychlorinated biphenyls (PCBs), have the propensity to bioaccumulate in the tissues of fish and biomagnify in piscivorous wildlife. To explore the reasons for the diverse sediment management strategies developed for sites where PCBs are the main contaminant of concern, three sites are compared: Muddy Creek wetland (Wheatley Harbour AOC; no action), Turkey Creek upstream of Walker Road (Detroit River AOC; dredging to refusal and limited capping), and Lyons Creek East (Niagara River AOC; Monitored Natural Recovery). The maximum PCB concentration reported in surface sediment (0 to 10 cm) found at these sites was 26.8 mg/kg, and the maximum concentration at depth (20 to 50 cm below the surface) was 255 mg/kg. Risk of adverse effects of the PCB-contaminated sediment to local receptors ranged from negligible risk to low risk. Sediment management options were assessed with regard for local uniqueness of the sites, such as seiche action, multiple landowners, and Provincially Significant Wetland designations.

[*]Presenting author; anne.borgmann@ec.gc.ca

The Effect of Agricultural Practice and Storm Events on the Water Quality of First Order Streams in the Beaver Valley Watershed

C.DIELEMAN*, P. CHOW-FRASER

McMaster University, Biology Dept.

Agriculture has long been associated with environmental degradation as a non-point source of pollution. Numerous studies have examined the elevated nutrient and sediment levels expelled from major basins due to agricultural activity and have shown that these contaminants can lead to eutrophication and cause habitat loss and degradation. However, the ecological impacts of specific agricultural practice types have not been well studied. Proper management and monitoring must be conducted at the individual farm scale in order to elucidate the impacts that these specific agricultural practices have on the ecological health of a stream system.

Here we examine the micro-impacts caused by a single farm by studying five crop based and five animal husbandry based sites in the Beaver Valley watershed in Ontario, Canada. Discrete water samples were collected from 2009 to 2010. A two-way analysis of variance indicated a significant effect of land use as well as an interaction between land use and precipitation intensity. These findings suggest that the type of agricultural practice utilized influences the degree of water-quality degradation. More interestingly, storm events increased impacts observed by practices; however, degradation from livestock-based agriculture may be worse then other agricultural land uses. Further research is needed to fully examine the extent of the water-quality differences between land uses during storm events to develop best management practices for not only agriculturalists but also for community and government conservation officials.

*Presenting author; dielemc@mcmaster.ca

Environmental Controls on Carbon Budget and Hydrology of Lake Simcoe: How Much can Process-Based Modelling Explain?

S. ONI[1*], M. FUTTER[2], L. MOLOT[3], P. DILLON[1]

[1]*Trent University*
[2]*Swedish University of Agricultural Sciences*
[3]*York university*

Hydrology is important in controlling dissolved organic carbon (DOC) concentrations and fluxes from soils to surface waters. Changing land use and climatic conditions may impact watershed hydrology by altering the timing and amount of runoff, leading to changes in seasonality of DOC. Changes in runoff, DOC concentrations and fluxes were examined in two study periods 1993-1997 (period 1) and 2007-2009 (period 2) in tributaries draining into Lake Simcoe, the largest inland lake in southern Ontario. The watershed is under increasing pressure from human development resulting in marked land use changes which in turn have altered hydrology and water quality in tributaries draining into the lake. There was an overall increase in DOC concentration and fluxes between the two study periods in tributaries draining into Lake Simcoe. These increases were attributed more to land use changes than climate. However, there is a monotonic increasing trend in air temperature in late summer/early autumn as well as increase in precipitation during winter season, suggesting a possible warmer and wetter condition in period 2 that can be accentuated by land use change. DOC concentration and fluxes exhibited increased variability between the 2 periods and their mean values increased by 5% and 6%, respectively, between the study periods. The increases in carbon fluxes were driven by spring and summer increases. Understanding the seasonal nature of the hydrologic connectivity that mediates DOC production and transport into Lake Simcoe from its catchment may lead to improvements in watershed management.

[*]Presenting author; stephenoni@trentu.ca

Performance Measurement and Verification Partnership - Measuring Progress for Sustainable Water Solutions

J. NEATE[1*], B. DESFORGES[2]

[1]*Strategies for Change*
[2]*Environment Canada, Science and Technology Branch*

The Performance Measurement and Verification Partnership (PMVP) was established by Environment Canada in 2009 as a network for information-sharing on best practices and new developments related to environmental performance benchmarking, measurement, verification and reporting. Members include public and private sector organizations involved in environmental technology investment, funding programs, green procurement and environmental regulation. The knowledge shared within the PMVP network increases awareness and understanding in support of environmentally sound solutions.

This presentation outlines the principles of stakeholder-driven performance measurement, verification and reporting as a mechanism for establishing meaningful baselines and benchmarks, and ensuring the development and implementation of sustainable water solutions. Five main topics are addressed: stakeholder engagement; performance benchmarking; quality-assured performance measurement protocols; independent verification; and transparent reporting. Case studies based on the Canadian, US and European Environmental Technology Verification (ETV) programs will be used to illustrate the effectiveness of environmental performance measurement and verification as a decision support tool in achieving sustainable water objectives.

[*]Presenting author; jhneate@sforc.com

Assessing the Feasibility of Water Quality Trading in the Lake Simcoe Watershed

L. LUONG[1*], G. ZUKOVS[2], M. KIESER[3]

[1]*Ministry of the Environment, Ontario*
[2]*XCG Consultants*
[3]*Kieser & Associates, LLC*

In 2010 the Ministry of the Environment (MOE) released and consulted on a feasibility study for water quality trading in the Lake Simcoe watershed. In general, water quality trading is seen as a way to;

- potentially achieve pollutant reductions in a more cost-effective manner compared to only upgrading sewage treatment plants,
- provide incentives for investment in projects and practices that reduce pollutants and improves water quality, and
- allow time for advanced pollutant reduction technologies to become economically viable.

The Ministry retained a team of experts to prepare the study and provide their opinions. The study reviewed pollutant trading programs in leading jurisdictions and identified options for the structure and delivery of a water quality trading program that could address phosphorus to Lake Simcoe. The report also explores potential principles, trading structures and assesses a variety of water quality trading opportunities in the watershed to assist in reducing total phosphorus loads to Lake Simcoe.

This presentation provides a summary of the feasibility study report and a synopsis of public consultation on the feasibility of water quality trading in the Lake Simcoe watershed.

[*]Presenting author; leo.luong@ontario.ca

Small Systems and Northern Systems

Chairs: Jane Challen Urbanic, Brent Wootton

Small communities across Canada are faced with unique challenges in the treatment and management of water and wastewater, including cost effective technologies, meeting existing or proposed regulations and the education and training of personnel. Communities in Canada's northern region face similar challenges, compounded by extreme temperature and remoteness. This session will address the challenges of these communities and highlight research being conducted in them. Session subjects may include:

- Treatment options for small or northern communities
- Treatment of water or wastewater in cold climates
- The impact of regulations on the management of water and wastewater in small communities

Storage Lagoons as a Means of Pathogen Reduction Rates for Septage

A.OOSTING[1*], D.JOY[1], S. BONTE-GELOK[2], K. RENTSCH[3]

[1] *University of Guelph*
[2] *Ministry of the Environment*
[3] *Ontario Rural Wastewater Centre*

Septage management is an essential component of an overall wastewater management program in rural parts of Ontario. In the past untreated septage was typically land applied, however Ontario has committed to banning this practice unless the septage undergoes some form of treatment before land application. There is a need to explore practical treatments of septage in Ontario which can be used by those involved with septage management. One potential form of septage treatment is during storage of septage in storage lagoons. Preliminary laboratory investigations were successful in showing that pathogen reduction in septage using storage lagoons may be a viable means of treating septage. To examine the use in typical Ontario conditions, three field trials were carried out to examine the reductions in pathogens (i.e. *E.coli*) in fall, winter and summer periods with operating lagoons. The trial periods tried to capture a range of filling and static phases of operation at a typical storage lagoon. Modest to no reductions in bacterial concentrations were found in the trials only experiencing a filling phase while the winter trial, experiencing both filling and static phases, achieved a reduction in terms of CFU/g TS of 0.5 to 1 log. While recognising the results are for only three trials, septage storage has shown to be a possible means of providing modest bacterial reductions in septage and meeting the proposed targets. However, operational practices (i.e. storage duration) need to be considered and studied more in depth before establishing this as an effective method to reduce bacterial levels in septage.

[*]Presenting author; aoosting@uoguelph.ca

Assessing Wastewater Treatment Systems in Canadian Arctic Communities

L. GRACE[1*], M. KELLY[2], J. CHALLEN URBANIC[1]

[1] Aquatic Ecosystems Management Research Division, Water Science and Technology Directorate, Environment Canada, 867 Lakeshore Rd., Burlington Ontario, Canada.
[2]Prairie and Northern Region, Environmental Protection Operations Division, Environment Canada, 5019-52nd Street, Yellowknife NWT, Canada.

Water Science and Technology Directorate (WSTD) is conducting a multi-year study of wastewater treatment systems in communities of Canada's Arctic region. One objective of this study is to collect information to assess the level of treatment currently being achieved and the highest level of treatment attainable in northern communities. The results presented here include data collected between 2008 and 2010 in communities visited in the Northwest Territories, Nunavut, northern Labrador and northern Quebec.

There are 80 wastewater treatment systems considered in this research project. Of these systems, 9% employ mechanical treatment, 9% have no treatment and 82% treat wastewater through passive means (sewage lagoons). At more than half of sewage lagoons, the effluent is further treated in wetlands before discharge into the receiving waters.

WSTD's sampling program consisted of collecting samples of raw sewage influent, treated effluent and effluent treated by wetlands. These samples were analyzed for a variety of parameters including total suspend solids (TSS), biochemical oxygen demand ($cBOD_5$), chemical oxygen demand (COD), ammonia (NH_3) and a suite of metals. *In-situ* measurements of dissolved oxygen, pH, conductivity and temperature were also collected at four sources: the lagoon and its influent and effluent, and the wetland effluent.

Initial results from 11 sites where extensive sampling occurred in 2009 and 2010 indicate considerable removal of TSS and $cBOD_5$ in treated effluent and even greater reductions at sites where wetland effluent polishing is available. Raw sewage influent had a high concentration of solids and biodegradable organic matter, having an average of 370 mg/L TSS and 410 mg/L $cBOD_5$. Average percent reduction in effluent TSS ranged between 48-97% and average percent reduction in effluent $cBOD_5$ ranged between 53-98%. Despite promising reductions in TSS and $cBOD_5$, average effluent concentrations were higher than those expected for secondary treatment.

The results from this study highlight the current effectiveness of lagoon systems in Canada's Arctic while also bringing to light the potential means for improvements to reduce effluent concentrations.

*Presenting author; laura.grace@ec.gc.ca

Phosphorus Removal Performance in Field Scale Slag Filters Providing Secondary Treatment in An Integrated Constructed Wetland Treating Aquaculture Wastewater in Cold Climates

L. SANSFORD[1*], B. ANDERSON[1*], B. WOOTTON[2*], D. BLOWES[3*]

[1] *Queen's University, Kingston, ON*
[2] *Centre for Alternative Wastewater Treatment, Fleming College, Lindsay, ON*
[3] *University of Waterloo, Waterloo, ON*

Constructed wetlands are engineered to provide treatment of wastewaters. While effective in the removal of several water quality parameters, the removal of phosphorus – a problematic nutrient for many receiving waters – by constructed wetlands alone has been shown to be inconsistent and limited. As a result, this research has focused at pairing constructed wetlands with a separate polishing filter consisting of media with high phosphorus adsorption capacity. Among others, blast furnace slag, a by-product of steel production, has been shown to be effective and is a desirable media due to its ready availability.

A subsurface flow constructed wetland paired with a slag filter, treating aquaculture wastewater from a fish hatchery in rural Haliburton, ON, has been in operation since 2008. Despite its demonstrated potential for phosphorus removal, the slag has not been as efficient as expected. Several factors, such as the addition of detritus from outside sources, clogging and preferential flow pathways are thought to be the cause of its poor performance. A tracer test performed on the slag filter after two years of operation confirmed that only 21% of the slag was active.

To address the issue of clogging and preferential flow pathways, two separate slag filters in parallel have been designed to replace the original filter. The first aims to increase the amount of active slag by delivering the water to the slag more uniformly. The second aims to reduce clogging by creating an environment that discourages unwanted precipitates. Lab-scale studies will complement this work to provide comparison to the field results and will also address the relationship of temperature and phosphorus loading on the performance of the slag filters.

Field-scale slag filter performance over two years and tracer study results will be presented. The filter re-design and experimental outline for lab work will also be discussed.

[*]Presenting author; lauren.sansford@ce.queensu.ca

Removal of Pharmaceutical Compounds in a Pilot-Scale Field Demonstration of Ew-Phosphex Wastewater Treatment System

S. I. HUSSAIN[1*], C. J. PTACEK[1], G. BALCH[2], B. C. WOOTTON[2], J. HIGGINS[3], D.W. BLOWES[1]

[1] *Earth and Environmental Sciences, University of Waterloo, Waterloo, ON, N2L 3G1*
[2] *Centre for Alternative Wastewater Treatment, Fleming College, 200 Albert Street South, Lindsay, ON, K9V 5E6*
[3] *Stantec, 160 - 7070 Mississauga Road, Mississauga, ON, L5N 7G2*

An integrated treatment system, which combines Engineered Wetland and Phosphex™ technologies (EW-Phosphex), was installed to treat sewage effluent for final polishing. The system configuration consisted of influent from a conventional septic system, followed by flow through an engineered wetland, to an aerobic oxidation unit, and finally through a Phosphex polishing unit. The Phosphex polishing unit contained steel slag intended for removal of phosphorus and pathogens. The integrated system was monitored in winter 2010 to determine treatment efficiency, including removal of phosphorus, ammonia, nitrate, BOD, faecal coliform, E. coli, metals, metalloids and pharmaceutical compounds. The fate of a suite of pharmaceutical compounds in this integrated system was monitored from February to April 2010, during four sampling events. The pharmaceutical compounds analysed covered a range of octanol-water partition coefficients and acid dissociation constants, and included carbamazepine, caffeine, sulfamethoxazole, ibuprofen, gemfibrozil and naproxen. The average flow rate of the system was approximately 1 m^3 day^{-1} with a residence time of approximately 5 days. Most of the contaminants monitored were effectively removed by the treatment system. The ammonia removal was as high as 79% while the phosphate, BOD, faecal coliform, and E. coli were >99%. At the effluent the trace metal (Pb, Zn, Cd and Cr) concentrations were very low (below the detection limit in most cases). However, some of the pharmaceutical compounds were not removed completely. Carbamazepine was removed during the first sampling event by 47% . Sulfamethoxazole and gemfibrozil were removed during all sampling events except the second one by 22 to 62% and 44 to 96% respectively. Caffeine was removed during the first three sampling events by 77 to 98%. Ibuprofen and naproxen were removed during all sampling events by 47 to 69% and 27 to 47% respectively. Caffeine, ibuprofen and naproxen were consistently removed in most of the sampling events, whereas carbamazepine, sulfamethoxazole and gemfibrozil were not. The variability in concentrations and treatment efficiency observed in the different sampling events might be due to variations in input concentrations or changes in flow rate. Sampling is continuing to provide additional information on treatment efficiencies at different temperatures and flow rates.

[*]Presenting author; sihussai@uwaterloo.ca

Treatability Study of Two Hybrid Passive Systems for Control of Landfill Leachate at Cold Temperature

S. SPEER*, P. CHAMPAGNE, B. ANDERSON

Queen's University Department of Civil Engineering

Leachates produced throughout the process of conventional municipal waste landfilling require treatment prior to release to the receiving environment. The costs of such treatment accrue long after the landfill is closed and is no longer collecting revenue. Passive and semi-passive leachate treatment technologies are an attractive option for leachate management due to their relatively low operating and maintenance costs. These treatment systems are far more site specific than active (i.e. highly mechanical) treatment systems and must be specifically designed for each distinct leachate stream. Passive treatment systems are also strongly affected by regional climate; as operating temperatures decrease, passive treatment system size must increase to maintain effective treatment. To address these issues hybrid passive treatment systems (passive systems preceded by an active treatment process) can be designed to optimize treatment efficiency while minimizing size, as well as operation and maintenance costs. For this study, cold temperature treatment efficiencies were compared between a commercially available semi-passive treatment system and a passive peat and wood shaving biological trickle filter, for eventual incorporation into a planned hybrid passive treatment system at the Merrick Landfill in the City of North Bay, Ontario, Canada. During testing, space constraints in the temperature controlled chamber limited the insulation of the treatment systems, which decreased the overall treatment efficiencies observed; however monitoring of the internal temperature demonstrated that this was independent of influent water temperature. It was therefore concluded that the low treatment efficiencies were due to limited insulation and that with added insulation, efficient treatment could be achieved even at low temperatures (a theory which was confirmed during subsequent in-situ pilot-scale analysis). In this same study comparison of the treatment systems efficiencies with and without active pretreatment of the leachate, demonstrated that the pretreatment system was a useful addition for cold climate operation. It was therefore concluded that either of the systems would be feasible as the treatment component of a hybrid passive landfill leachate treatment system in a cold climate. To ensure that these hybrid passive treatment systems are adequate for leachate treatment in North Bay, Ontario, further testing will be conducted in an on site pilot-scale hybrid passive treatment system.

*Presenting author; thespeer@ce.queensu.ca

Microbial Community Characterization of Cold-Weather Constructed Wetlands Treating Fish Hatchery Waste Exposed to Oxytetracycline.

M. MITZEL[1*], B. WOOTTON[2], and R. SLAWSON[1]

[1] *Wilfrid Laurier University, Faculty of Biology*
[2] *Fleming College, Centre for Alternative Wastewater Treatment*

Constructed wetlands (CWs) are complex treatment environments, requiring an integrative research approach to improve our understanding them. Using community-level physiological profiling (CLPP) and denaturing-gradient gel electrophoresis (DGGE) simultaneously, this research aimed to establish an improved understanding of the functional and structural characteristics of microbial communities within field-scale subsurface-flow CWs operating in cold weather to treat fish hatchery waste. The impact of oxytetracycline (OTC) on the indigenous microbial communities based on their functional and structural profiles was also investigated. Under normal operation, sample points further from the influent are dominated by the microbial communities portraying lower functional capacity and more diverse structural properties compared to areas that initially received hatchery wastewater. However, this community profile was not maintained during antibiotic exposure. Functional fingerprints displayed acute increases after the addition of antibiotic, which was followed by a return to pre-exposure profiles. Conversely, structural fingerprints displayed minor acute responses, but alluded to delayed changes in the proportional abundance of different microbial populations. The changes in structural community profiles also appeared to depend on the type of macrophyte planted (i.e., sedge vs. cattail), although the functional profile did not. These findings illustrate the dynamic and complex nature of microbial communities and may indicate the possibility of long-term effects regarding the sustainability of the microbial community within CWs if exposed to antibiotic contaminants.

[*]Presenting author; mitz7690@mylaurier.ca

The Effect of Freeze-Thaw Temperature Variations on the Transport and Survivability of Pathogenic *Escherichia coli* in Granular Porous Media

A. BHAKTA[1*], S. GHOSHAL[1], and N. TUFENKJI[2]

[1] *Department of Civil Engineering, McGill University, Montreal, Quebec, Canada H3A*
[2] *Department of Chemical Engineering, McGill University, Montreal, Quebec, Canada H3A 2K6*

Surface soils in cold climate regions experience temperature fluctuations during the onset of winter and during spring thaw. Pathogenic microorganisms such as *Escherichia coli* may be introduced to these soils following application of manure, improper disposal of animal waste or surface run-off from fields. The pathogens present in the soil will also be subject to these temperature variations. Microbial pathogens have been known to survive for long periods of time at low temperature and withstand severe environmental conditions. However, there are very few studies examining the effect of freeze-thaw stresses on their transport and survivability.

This study compares the transport in porous media of selected strains of *Escherichia coli* that have been subjected to controlled freeze-thaw cycles with those that have been incubated at constant temperature for the same length of time. The transport studies were performed using laboratory columns packed with sand to obtain bacterial breakthrough curves. Survivability and cell characterization studies were carried out to determine changes in cell viability, membrane damage and culturability due to temperature variations. The temperature and associated environmental changes may alter microbial surface characteristics and survivability and could provide conditions more conducive to their transport, as a result increasing the risk of contamination of groundwater by pathogens.

[*]Presenting author; Arti.bhakta@mail.mcgill.ca

Energy and Sustainability in Water and Wastewater Treatment

Chair: R.D. Tyagi

This session will explore issues of energy and sustainability in water and wastewater treatment, including such topics as microbial electrochemical cells, biodiesel and methane production, algae- and sludge-derived products, and zero discharge wastewater treatment.

Microbial Electrochemical Cells for Wastewater Treatment: Challenges and Outlook

H. LEE*

University of Waterloo

Microbial electrochemical cells (MECs), which generate electricity, hydrogen gas (H2), or valuable chemicalsfrom biomass, have considerable their potential as renewable, carbon-neutral bioenergy. The power generated from MECs, however, is too small to be used for our society up to now. Many researchers have attempted to increase the power output, but one possible conclusion is that large-scale MFCs might not produce useful power. Based on our studies, the main bottleneck seems to be the anodic reaction rate, which is controlled by the substrate-utilization rate of anode-respiring bacteria (ARB). A maximum current density catalyzed by ARB can be estimated at ~14 A/m2 in a substrate non-limiting condition. Another roadblock is the large over-potential, mainly caused by ohmic energy loss for ion transport in liquid and through membrane and by cathode energy loss. Due to the serious over-potential, the maximum voltage output may be only ~ 0.3 V when the current density is near its maximum. Thus, the maximum power density of an MEC may be only about 42 W/m2, which means that we would need about 240 m2 MFC units to provide 1 kW. Despite of these limitations, an MEC can have many useful purposes beyond making electricity alone. One option is to change the end product from electricity to H2 gas. The MEC requires a small energy input for H2 production at the cathode, and the key goal is to minimize over-potentials so that this energy input is as small as possible. To recover a net positive energy benefit from H2-MEC, the applied voltage should be less than ~0.6 V at cathodic conversion efficiency (electrons to H2) above 80% in an MEC. Similar to the MFC, ohmic and cathode over-potentials are significant for energy efficiency in MEC. MECs are advancing rapidly and also have many challenges: e.g., improving the power density in MFC and net energy benefit from H2 in an MEC. To attain true successes, we must first understand ARB metabolic features and the fundamentals of energy losses throughout the MEC system.

*Presenting author; hyungsool@uwaterloo.ca

The Potential of Wastewater and Wastewater Sludge in Biodiesel Production

X.L. ZHANG[1*], S. YAN[1], R.D. TYAGI[1], R.Y. SURAMPALLI [2]

[1] *INRS Eau, Terre et Environnement, 490, rue de la Couronne, Québec, Canada, G1K 9A9*
[2] *U. S. Environmental Protection Agency, P. O. Box 17-2141, Kansas City, KS 66117*

Substitute fuel is in great need due to the predicted scarceness of fossil fuel and its negative effect on environment, such as climate change. Biodiesel as a renewable fuel has greatly attracted global interest. The traditional biodiesel is normally produced from edible oils, which is expensive, energy-intensive, as well as competes with food industries. The large portion of cost and energy input of biodiesel production, which are around 80%, respectively, were from raw material. Therefore, sustainable and abundant raw material is urgently required. Wastewater and wastewater sludge are generated in vast quantities and could be a promising raw material for biodiesel production. In order to investigate the benefit of wastewater and wastewater sludge over the traditional raw materials for biodiesel production, energy balance of the biodiesel production from wastewater and wastewater sludge was evaluated. The results showed that the energy gain in biodiesel production from starch wastewater cultivated microalgae was 13 times greater than that from starch cultivated microalgae in per ton of biodiesel produced. When primary sludge (20% oil content of sludge dry weight), was used as raw material to extract lipids followed by the conversion of lipids into biodiesel, around 5000000 kcal of energy is gained per ton of biodiesel produced. This approach also extensively reduces the sludge quantity for disposal (reduced from 50 to 8 tons). Based on the energy balance, it is predicted that the use of wastewater and wastewater sludge to produce biodiesel is a promising alternative.

[*]Presenting author; xiaolei.zhang@ete.inrs.ca

Enhancement of Hydrogen and Methane Production form Pulp waste using Ultrasonication

E. ELBESHBISHY[1*], H. HAFEZ[2], G. NAKHLA[1]

[1]*Dept. of Civil and Environmental Engineering, University of Western Ontario*
[2]*GreenField Ethanol Inc*

The effect of ultrasonication as a pretreatment method for pulp waste prior to anaerobic digestion for enhancement of hydrogen and methane production is evaluated. Four continuous stirred tank reactors (CSTR) were used in this study, two for hydrogen production (one for unsonicated feed and the other for the sonicated feed) and two for methane production(one for unsonicated feed and the other for the sonicated feed). The ultrasonication pretreatment was conducted by sonicating the pulp waste at specific energies of 5000 kJ/kgTS prior to anaerobic digesters. Based on the results, it is evident that applying the ultrasonication pretreatment prior the anaerobic digestion has a significant impact not only on the hydrogen production rate and hydrogen yield but also on the liquid quality of the effluent of the hydrogen reactors. Moreover the effluent acetate for the sonicated feed was higher then that of the unsonicated feed by about 30%. On the other hand, the methane production of the sonicated feed was higher than that the unsonicated feed by 29%. VSS removal efficiency of the sonicated feed was 22% higher than that of the unsonicated feed.

[*]Presenting author; eelbeshb@UWO.CA

Enhanced Flocculation and Dewatering Using Extracellular Polymeric Substances (EPS) Produced from the Sludge

T. T. MORE[1*], N. V. HOANG[2], S. YAN[1], R. D. TYAGI[1], R. Y. SURAMPALLI[3]

[1]*Université du Québec, Institut national de la recherche scientifique, Centre Eau, Terre & Environnement, 490 de la Couronne, Québec (QC), G1K 9A9, CANADA.*
[2]*Center of Research and Applications of Technology for Environment, Institute of Environmental Technology –VAST, 18, Hoang Quoc Viet, Cau Giay, Ha Noi*
[3]*U. S. Environmental Protection Agency, P.O. Box 17-2141, Kansas City, USA, KS 66117.*

Chemical polymers used for sludge settling and dewatering are very expensive, toxic and pollutant. Thus, recently sludge settling and dewatering by biological, sustainable, non-hazardous, and environment friendly methods have been the main focus of many researchers. In this context, bacterial strain (*Serratia sp.* BS8) isolated from sludge was grown in the pretreated sludge to produce extracellular polymeric substances (EPS) and its bioflocculant potential was investigated. Three types of pretreatment methods were applied such as sterilization, alkali-thermal (pH 10) and acid-thermal (pH 2), at 121^{o}C for 15min. Bioflocculants produced were collected in the form of broth, slime and capsular EPS. Combined effect of calcium (Ca^{2+} of 150mg/L) and EPS dose on kaolin (5g/L prepared in deionized water) flocculation was studied.

Bacterial strain BS8 grown in different pretreated sludge produced different quantity of EPS with different flocculation activity. EPS quantity of 1554 mg/L, 2266 mg/L and 1158 mg/L were obtained in sterilized, alkaline-thermal and acid-thermal pretreated sludge, respectively. Flocculation test results clearly demonstrated that the combination of Ca^{2+} and EPS was improved settling and dewaterability. The highest flocculation activity was observed from EPS produced in the sterilized sludge, followed by alkaline-thermal and acid-thermal pretreated sludge. EPS in different forms exhibited different flocculation characteristics, among them broth (concentration of 1.24mg/L) revealed the best flocculation activity of 79.12% whereas, capsular EPS (concentration of 3.39mg/L) shown the improvement in dewaterability by 52.17% than control (calcium-kaolin suspension without EPS addition).

EPS produced from BS8 strain isolated from sludge and grown in sludge proved to be effective bioflocculant for settling and dewatering at very low concentrations of EPS. The $CaCl_2$ was acted as good conditioning agent with EPS from strain BS8. Production of EPS in the sludge and its application as a bioflocculant is feasible and potentially applicable in wastewater sludge settling and dewatering in near future.

[*]Presenting author; tanaji.more@ete.inrs.ca

Nutrient and Heavy Metal Removal by Microalgae Grown in Secondary Effluent from a WWTP

A. CHAN*, H. SALSALI, E. MCBEAN

University of Guelph

Use of microalgae as a feasible option to remove nutrients (phosphorous and nitrogen) from a wastewater treatment plant discharge is demonstrated. Laboratory-scaled experiments are described which characterize the nutrient removal of total phosphorous and ammonia by three microalgae strains: Chlorella vulgaris, Spirulina maxima, and a naturally growing algae sample found in the wastewaters of a meat processing plant containing Synechocystis sp. (dominant) and Chlorella sp. (common) and a few cells of Scenedesmus sp. Autoclaving the secondary effluent had significant effects on its pH and ammonia concentration. The precipitation and removal of phosphates is strongly positively related to the pH of the solution. Volatilization of ammonia due to an increase in pH is not shown as a dominant contributor to overall removal efficiency. Total phosphorous removal rates reached up to 95.8% and 90.4% for normal and autoclaved, respectively. Ammonia removal rates reached up to 94.6% and 86.2% for normal and autoclaved respectively. These results demonstrate that use of microalgae to remove nutrients in a wastewater treatment plant may prove capable of being a sustainable approach to wastewater treatment.

*Presenting author; achan06@uoguelph.ca

Sustainability with Alternative, Onsite, Wastewater Treatment Technology: *ECOCYCLET* Zero Discharge Wastewater Systems

É. L. BORDELEAU*

Centre for Sustainable Watersheds

The ongoing impact of phosphorus loading in Lake Simcoe is particularly acute. This excerpt form Environment Canada's web portal defines the critical importance of nutrient loading elimination: "The Government of Canada announced $30 million in funding to establish a Lake Simcoe Clean-Up Fund (LSCUF) to provide financial and technical support to implement high-impact, priority projects to reduce phosphorus inputs deemed essential for the restoration of Lake Simcoe and its watershed."

Septic systems remain a significant source of potential nutrient pollution. Even when installed to code and functioning properly, they leach nutrients and pathogens that can contaminate ground and surface waters. Ontario Onsite Wastewater Association's inspection studies show that fewer than 30% of systems are serviced and failure rates range from 30-60%. The Lake Simcoe Region Conservation Authority's Septic System Funding Program lists an approximate 6,300 systems within 300 m of the lake, most of which are over 30 years old.

As part of Centre for Sustainable Watersheds' mandate to protect and preserve Canada's waterways, CSW works with the wastewater industry to facilitate the installation of unique zero discharge systems. With these innovative and sustainable technologies, wastewater is recirculated in lined, closed- loop treatment beds, where appropriate plantings and aerobic processes enhance evapotranspiration. A most recent installation at Lock 41 on the Trent-Severn waterway at Gamebridge will serve public washrooms. This is a busy location for both boaters on the Trent and land-based visitors, en route to lake country via highway 12.

ECOCYCLET systems are typically designed for the evapotranspiration of 10 $L/m^2 \cdot d$ wastewater (yearly average). By means of recirculation and evapotranspiration, the systems achieve complete removal of biochemical oxygen demand, total suspended solids, phosphorus, nitrogen, and pathogens. Continued support for weather and water data monitoring from LSCUF will further the development of these important and zero discharge technologies.

*Presenting author; bordeleau@watersheds.ca

Combined Sewer Overflows

Chairs: Sandra Kok, Jiri Marsalek

This session will focus on research, development and demonstration of treatment technologies for combined sewer overflows, and experiences with planning and implementation of combined sewer overflow control and treatment. Topics may include, but are not limited to:
- performance evaluation of treatment technologies for combined sewer overflows,
- system optimization (e.g., real time control, source controls including inflow/infliltration reduction, sewer rehabilitation, and hydraulic modelling of such measures),
- research on different aspects of CSO treatment (e.g., disinfection, characterization),
- modelling approaches,
- updates on CSO plan implementation and implementation challenges, and
- policy and regulatory approaches.

The City of Port Colborne's Inflow and Infiltration Program: The Development of an Advanced and Sustainable Storm and Sanitary Management System

M. ABRAHAM, R. BRADSHAW, S. NOBLE,* D. WATT

Associated Engineering, 110A Hannover Drive, Suite 208, St. Catharines, Ontario, L2W 1A4

It is estimated that the City of Port Colborne spends approximately $1 million dollars each year treating extraneous flow entering its sanitary sewer system. In the past, these flows have also caused excessive spills at combined sewer overflows (CSO's) and are increasing the number of basement flooding events for residents. Considering the cost saving opportunity as well as the potential to reduce CSO spills and basement flooding events, the City commenced an Inflow and Infiltration Reduction (I&I) Program aimed at finding, quantifying and reducing any source of extraneous flow entering its sanitary system.

In this paper, we communicate the policies, techniques and practices of the I&I Program that have successfully contributed to the advancement and sustainability of Port Colborne's storm and sanitary management system.

The program consisted of several coordinated components that aimed to reduce the sources of inflow and infiltration on private property and within the municipal right of way. From a policy perspective, the program included the amendment of the regulatory framework and sewer use by-laws to support a private property inspection program. This amendment also provided for financial assistance to conduct private property retrofits to remove sources of I&I from private sanitary laterals. From a technical perspective, the data collection and analysis techniques reflect a holistic and systematic approach to defining the extraneous flow problem towards subsequently reducing their contribution to overflow and basement flooding events. This included the monitoring of sewage and storm flows, the inspection of sewers with CCTV equipment and the correlation of storm events with flow patterns.

As a result of this program, the sewer flow data already indicates a softening of peak wet weather flows that is mainly attributed to the disconnection of impermissible flow sources. Further inflow reductions are expected to arise from the strategic sewer rehabilitation and maintenance program that was formulated as part of the program.

*Presenting author; nobles@ae.ca

Chemically Enhanced Primary Treatment (CEPT) for CSO Treatment

G. ZUKOVS*

XCG Consultants Ltd.

Many older Canadian communities are served by systems of combined sewers. These systems were typically designed to discharge directly to receiving waters prior to the widespread advent of wastewater treatment facilities. Once treatment facilities were built, they were regularly overtaxed by wet weather flows directed to the new plants. As a result, in-plant overflows or overflows just upstream of the facility were employed for flow control. More recently, governments have acted to reduce if not eliminate wet weather overflows requiring that treatment plants provide at a minimum the equivalent to primary treatment and possibly disinfection to the majority of flows. This has produced a significant challenge for wastewater facility owners and operators. The standard level of treatment for mechanical plants is now secondary implying a biological treatment component. Traditional biological treatment trains are generally ill suited to respond to the widely and rapidly varying flows and loads associated with wet weather wastewater. This has resulted in interest in physical-chemical means of solids/$CBOD_5$ removal and chemical or UV irradiation based disinfection.

Chemically enhanced primary treatment (CEPT) is one such technology that shows considerable promise for cost-effective solids/$CBOD_5$ removal.

CEPT uses coagulants and flocculants in conventional primary clarifiers to accelerate the process of separating and removing solids. CEPT removes suspended solids and organic material at an overflow rate of two to three times or more that of conventional primary plants, while still maintaining high TSS and $CBOD_5$ removal rates. Potential removal efficiencies range from 75 to 85 percent TSS removal, with proportional removal potential for $CBOD_5$.

CEPT coagulation promotes the formation of larger, heavier particles and flocculation aids the clarification process by aiding the formation of larger flocs that can settle more rapidly. Metal salts, such as ferric chloride or alum, are typically used as coagulants. Cationic or anionic polymers can be used, either in dry form or as emulsions. Jar testing is generally used to establish approximate coagulant and polymer feed rates to achieve intended contaminant removal results.

Figure 1 presents a summary of Canadian, US and international experience for TSS removal for a range of primary clarifier surface overflow rates (SOR) with CEPT. The results are generally from plant scale trials. The results indicate TSS removals up to 80+% are possible and that removals in the range 70% to 80% are possible up to SORs of 5,000 Usgpd/ft^2 (8.5 m/hr.).

The presentation will provide an overview of the CEPT technology, the performance experience with the technology and the practical design and operating factors mitigating CEPT retrofit opportunities.

*Presenting author; georgez@xcg.com

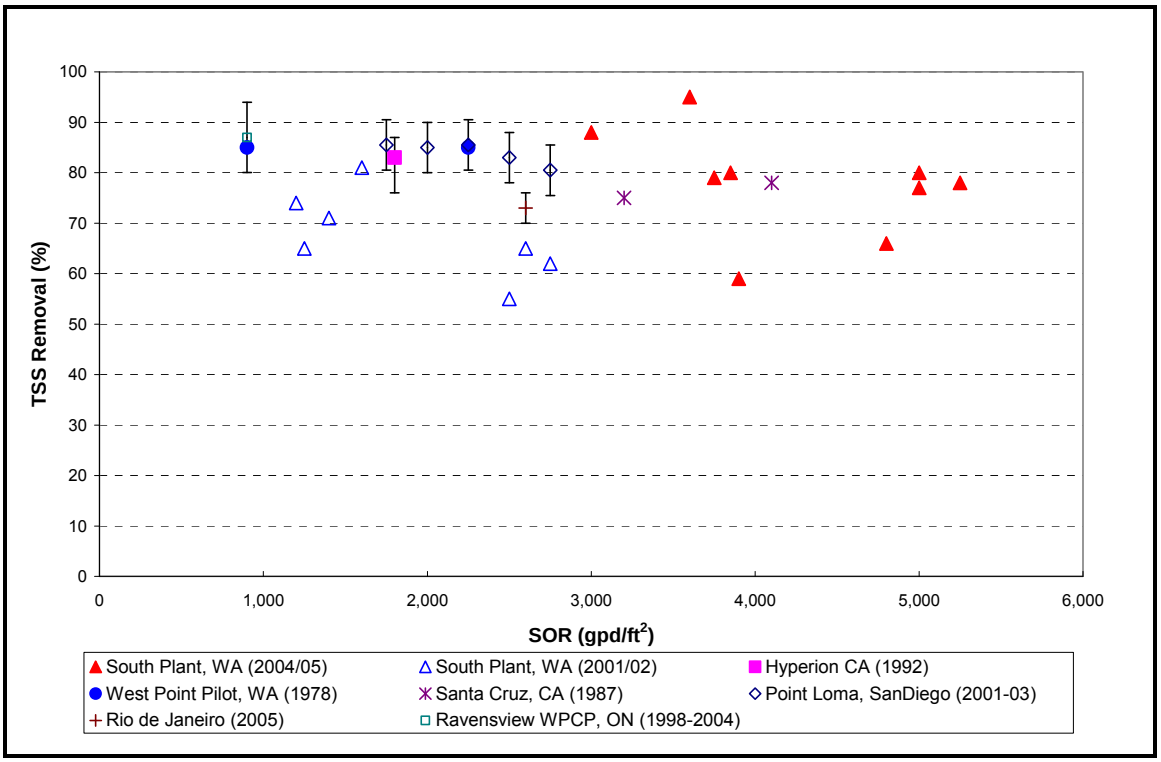

Figure 1: CEPT Solids Removal Efficiency

Combined Sewer Overflow MS Excel Model

L.VESPI*, P.SMELTZER

AMEC Earth and Environmental

AMEC Earth and Environmental was retained by a local municipality to develop a combined sewer overflow (CSO) model capable of quantifying spill rate, volume, duration, frequency and mass loadings at overflow locations along an interceptor system.

The system is designed to convey sanitary and storm flows from the municipal system to the Regional water pollution control plant. Wet weather flows bypass the interceptor into the river via overflow structures. MOE regulation requires the municipality to develop a Pollution Prevention and Control Plan (PPCP) and meet minimum CSO controls. The PPCP was developed several years ago, and some system improvements have since been made. AMEC developed the model to measure volumes and concentrations of contaminants to ensure minimum CSO controls are met.

The model is intended to aid the municipality in reporting CSO volumes and concentrations of contaminants in CSOs. The model uses Microsoft Excel, and contains input files and a main model. The input files comprehensively calculate frequency, average flow and total volume of CSO events at each overflow location based on flow depths in the system. An overflow event is recorded when the level in the interceptor exceeds the elevation of the overflow structure.

The input files are linked to a main model that contains worksheets for each overflow location. Included in the worksheets are pipe characteristic and spill rate information, and a summary of the frequency, flow and volume results from the input files. Also included are mass loadings of contaminants calculated by multiplying predetermined concentrations by CSO volumes at each location.

The model can easily be understood and updated by the municipality, assist them with reporting to the MOE, and determine locations contributing significant amounts of contaminants. Control strategies and management options can be evaluated and implemented to ensure the requirements of the MOE are satisfied.

*Presenting author; lisa.vespi@amec.com

Impact of CSO retention tank emptying on Quebec City's east treatment plant

B. WIPLIEZ*, G. PELLETIER, T. MARUEJOULS, P.A. VANROLLEGHEM, P. LESSARD

Département de génie civil et de génie des eaux, Université Laval, 1065 av. de la Médecine, Québec (Qc) G1V 0A6 Canada. (E-mail: genevieve.pelletier@gci.ulaval.ca)

In the 80's, the St-Charles river in Quebec City was considered a very polluted river due to the presence of a large number of combined sewer overflows (CSO). To reduce CSO events, fourteen retention tanks (RTs), with a total volume of 125000 m^3, have been built since 2003. The fourteen RTs are now in operation and the emptying of these tanks is an operational concern. How do they affect the efficiency of the wastewater treatment plant (WWTP) and thus the quality of its effluent? While theoretical studies have been done on the subject, no field studies on both characterizing those returns and estimating their impact have been done. Thus, this study aims at: (1) characterizing the water quality of a representative RT during its emptying; and (2) simulating the impact of the emptying of the RTs on the WWTP. Two major sampling campaigns have been conducted during the summers of 2009 and 2010. Laboratory analyses of the combined wastewaters released during emptying have shown a typical pattern of total suspended solids (TSS) and chemical oxygen demand (COD) concentrations. TSS are pumped in large amounts during the first fifteen minutes of emptying due to the accumulation of sediments in the pumping well of the RT. A second concentration peak occurs at the end of emptying due to the cleaning system of the RT. Finally, a lower concentration is observed during the middle of the emptying which is, usually, the longest phase. Using SWMM, simulations have been made to evaluate the impact of emptying 10 of the 14 RTs linked to the east WWTP, based on the time of transport (depending on their location) and on the overall hydraulic behavior of Quebec City's main interceptor. Results obtained can lead to the improvement of the emptying sequence of the RTs.

*Presenting author; bastien.wipliez.1@ulaval.ca

Posters

Wetlands as Nutrient Sink and Export: Studies on Mill Creek and Victoria Point Wetlands, Orillia, Ontario

N. KANAVILLIL[1], S. O'CONNOR[1*], D. BALIKA[1], M. DOBLE[1], S. KURISSERY[1], P. LEE[2]

[1]*Lakehead University Orillia Campus, 500 University Avenue, Orillia, ON, L3V 0B9*
[2]*Lakehead University, 955 Oliver Road, Thunder Bay, ON, P7B 5E1*

Ongoing urbanization and effluent discharge into Lake Simcoe have caused depletion of dissolved oxygen concentration leading to the collapse of the natural cold water fishery as well as a decline in overall water quality. Various water quality parameters were investigated in the Mill Creek and Victoria Point wetlands in Orillia, Ontario to evaluate the potential of these wetlands to act as nutrient sink and export system. Ten sampling sites were chosen based on the direction of water flow from the wetlands to the lake. Five sampling sites each were located in Mill Creek and Victoria Point wetlands. Water samples were collected on a monthly interval for 15 months from October, 2009. Samples were analyzed for nutrient concentrations and other water quality parameters including chlorophyll *a*. Among the water quality parameters, phosphorus and chlorophyll showed a reducing trend in the water that left the wetlands, emphasizing the buffering role of wetlands. However, the concentrations of these parameters were higher in wetland water compared to that enters the wetland. This shows the occurrence of nutrient regeneration in wetlands from the degrading biomass. Therefore, wetlands are acting both as nutrient filter and nutrient generation systems. The data also showed the influence of anthropogenic activities on the water qualities, especially in Mill Creek, where, by the time the water reaches Lake Simcoe, the concentration of phosphorus increased possibly due to the inflow of effluent discharge from the waste water treatment plant. Thus, the study provides baseline data that suggests possibilities of wetlands acting as both nutrient filter and nutrient production system and therefore the need to have a constant monitoring strategy on the nutrient outflow into aquatic ecosystems such as lakes.

[*]Presenting author; soconnor@lakeheadu.ca

Caffeine as Anthropogenic Marker of Human-Mediated Phosphorus: A Preliminary Study in the Lake Simcoe Watershed

S. KURISSERY[1], D. BALIKA[1*], D. MITCHELL[2], S. VERENITCH[2], A. MAZUMDER[1], N. KANAVILLIL[1]

[1]Lakehead University Orillia campus, 500 University Avenue, Orillia, ON L3V 0B9
[2]Water and Aquatic Sciences Research Program,University of Victoria, Department of Biology, P.O. Box 3020, Station CSC, Victoria, BC, Canada. V8W 3N5

The Lake Simcoe watershed covers an area of 3,303 km^2 that includes 23 municipalities. There are approximately 35 tributaries emptying water into Lake Simcoe. Lake Simcoe serves a large cottage population during summer months and supports an active tourism industry. It is also known for its high phosphorus levels due to urbanization and other anthropogenic activities happened in recent years. The health of Lake Simcoe, thus, is dependent not only on the cleanup activities but also on the strategies undertaken to reduce phosphorus loading. These strategies include reduction of both point and non-point source phosphorus entry. In this study, we have tested the possibility of using caffeine as an anthropogenic marker of human originated phosphorus into Lake Simcoe. Water and sediment samples were collected on monthly intervals since spring 2010 from 5 different sampling sites located in the north-western part of Lake Simcoe. Samples were analyzed for caffeine and nutrient concentrations including total phosphorus and total dissolved phosphorus. The results showed an increased level of caffeine and phosphorus during summer months compared to spring. The results also showed a fairly high level of phosphorus and caffeine in sampling sites closer to anthropogenic activities. An existence of correlation between caffeine and the total phosphorus in the water would lead to the use of caffeine as a marker for human originated phosphorus in this ecosystem. Completion of sample analysis (which is being done) would generate more data and will prove useful to test the existence of this correlation. Once established, caffeine monitoring may be used as an evaluation strategy to pinpoint human originated phosphorus in this aquatic ecosystem. This will help to devise and adopt proper management/inspection strategies for septic/bed tanks leaks located in the vicinities of Lake Simcoe thereby preventing the input of human originated phosphorus into the lake.

[*]Presenting author; dbalika@lakeheadu.ca

Water Supply and Sanitation in Dhaka City

A. MAMUN* and M. NOOR

Bioenvironmental Engineering Research Unit (BERU), Faculty of Engineering, International Islamic University Malaysia (IIUM), Jalan Gombak, 53100 Kuala Lumpur, Malaysia.

Dhaka is a mega city with the highest population density in the world. The city covers about 154 km^2 area and provides residence for about 7 Million people. The city is highly potential for the economic and infrastructural development. Similar to other developing regions, this city also lacks many essential needs. Among others, water supply and sanitation are of great concern. Ground water is the main source of potable water supply to the city. Although many rivers passes through the city and the surrounding areas, due to lack of fund, surface water treatment facilities could not be constructed. As such, the city relies on the naturally purified groundwater. The city is served by combination of separate and combined sewer system; again, which is not adequate for the city. Lack of proper operation and maintenance make the sewer system inefficient. Most of the rain events cause localised flooding due to blocked and inadequate sewer systems. The only centralised municipal wastewater treatment facility located at Pagla is unable to cope with the amount of wastewater received by the plant. Although the city is developing rapidly for the housing, roads and industries, the infrastructure facilities related to the water supply and sanitation are not given due attention; mainly due to lack of financial support. As a result, the rivers are heavily polluted due to municipal and industrial waste discharges. Recently, the historical Buriganga River is cleaned by removing the contaminated sediments. However, if proper wastewater treatment infrastructures are not built and operated properly the river water quality will remain unacceptable. This poster paper is intended to draw attention of the international donor agencies to look into the water supply and sanitation status of the most densely populated Mega City of the world. It is realised that there should be proper strategic plan, legislative setup and allocation of adequate fund to properly design, build and operate the facilities related to water supply and sanitation.

*Presenting author; mamun@iium.edu.my

A New City Project in Haiti Following the 2010 Earthquake – Planning and Designing Infrastructures for Water and Wastewater

O. TRUDEL-BEAULIEU*, B. CÔTÉ, R. LEDUC, H. CABANA

Department of Civil Engineering, University of Sherbrooke, Sherbrooke (Quebec), Canada J1K 2R1

Haiti has suffered an enormous earthquake in early 2010, devastating the country and leaving its population in precarious conditions namely in terms of housing. Numerous initiatives have since emerged from all over the world to assist in the rebuilding effort.

This project consists in planning, designing and building rapidly a new city of about 5000 people. The city will be located at about 100 kilometers southwest of Port-au-Prince, near the city of Paillant. Housing units and services will be located on the site of the former Reynolds aluminum plant that was shut down in 1992. Construction is to begin early in 2011.

This project is initiated and supported by Vilaj Vilaj, a humanitarian cooperation organisation devoted to the reconstruction effort in Haiti. This organisation places the development of the human being, sustainable development and environmental design at the heart of the new cities (called villages) for the communities. Their program aims to provide assistance to communities in need by promoting quality standards and high responsibility in the construction of integrated villages) for these communities, based on four pillars of sustainable development : social equity, economic health. environmental responsibility, and cultural vitality. The Department of Civil Engineering at the Université de Sherbrooke (UdeS), an architect firm involved in social housing and a construction contractor have joined to support Vilaj Vilaj in planning, designing and building this new village.

However, this is not a conventional new city, as one would observe in North American and other developed countries. The particularity of this village is that the houses will be built from concrete block masonry. These blocks will be used for framing houses to make them habitable by a family of four. Another aim of the implementation of this project is to stimulate the local economy by providing advanced training for Haitians in construction by involving them in rebuilding the country.

This presentation focuses on water and wastewater infrastructure for this project. The UdeS team provides technical expertise for the water and wastewater infrastructures of the new village, based on sustainable development as one of the primary goals for planning and designing. Specifically, water supply, treatment and distribution as well as collection and treatment of wastewater infrastructures are considered. These are planned and designed to facilitate operation and maintenance, and local conditions are taken into account.

*Presenting author; Roland.Leduc@USherbrooke.ca

Quantification of Bacterial Pathogens and Antibiotic Resistance Genes in Treatment Lagoons Receiving Poultry Waste Effluent

C.D. HELT[1,2*], R.L. LEGGE[3], R.M. SLAWSON[2]

[1]*Dept. of Biology, University of Waterloo, Waterloo, Ontario, Canada*
[2]*Wilfrid Laurier University, Waterloo, Ontario, Canada*
[3]*Dept. of Chemical Engineering, University of Waterloo, Waterloo, Ontario, Canada*

The treatment of domestic sewage using natural systems such as constructed wetlands and lagoons is becoming a popular approach for small communities in rural regions. Wastewater from livestock operations and poultry processing plants are known to harbour elevated levels of antibiotic resistant bacteria, which may contribute to the dissemination of antibiotic resistance genes (ARGs). Although antimicrobial resistance patterns have been described using cultivation-based methods, few studies have monitored the prevalence and fate of bacterial pathogens/ARGs in waste lagoons using quantitative real-time polymerase chain reaction (q-PCR). The purpose of this study was to quantify and examine the behaviour of bacterial pathogens (*E. coli, Enterococcus* spp., *Salmonella* spp.) and ARGs (*vanA, blaSHV, ampC*) in a constructed lagoon system receiving poultry waste effluent using q-PCR. *Salmonella* spp., *Enterococcus* spp., and *E. coli* concentrations were highest in the first lagoon receiving post-flocculated effluent, with 7.42 x 10^3, 5.84 x 10^5, and 2.07 x 10^9gene copies/100 mL, respectively. *Enterococcus* spp., and *E. coli* concentrations decreased throughout the treatment system by more than 4 orders of magnitude in the final lagoon, with the exception of *Salmonella* spp., maintaining a final concentration of 5.53 x 10^3 gene copies/100 mL. ARGs were present throughout the year, with *ampC* and *blaSHV* (conferring resistance to β-lactam antibiotics) occurring in highest concentrations in the first receiving lagoon. Preliminary results indicate the presence of *vanA* (conferring resistance to vancomycin) in all sampling locations, with very little decrease throughout the system. This study represents a quantitative characterization of bacterial pathogens and ARGs in a lagoon treatment system, with results indicating the potential for survival and persistence of specific pathogens and/or ARGs. Due to the growing concern surrounding antibiotic resistance, there is clearly a need to improve our understanding of the potential environmental persistence of ARGs in treatment lagoons and the broader aquatic environment.

[*]Presenting author; chelt@sciborg.uwaterloo.ca

Nitrogen Cycling in a River Receiving Domestic Wastewater

E. CEJUDO[1*], R. ARAVENA[1], S. SCHIFF[1], M. MURRAY[1], N. OTERO[2], R. ELGOOD[1]

[1]*University of Waterloo*
[2]*Universitat de Barcelona*

Human activities have impacted ecosystems by incrementing residues from industrial, domestic and agricultural processes in the biosphere. Large amounts of ammonia, nitrous oxide and nitric oxide are being emitted as a consequence of human activities. In nature, rivers and streams have moderate loads of phosphate, nitrate, and ammonium, therefore oxygen levels and some other chemical characteristics are self-regulated. Once it receives waste water effluents, nutrients load rise and oxygen becomes low, in addition to the regular oscillations within the river through daily and seasonally. Accurate approaches based on real data are necessary in order to understand the impact on nitrogen and O2 cycles and find solutions to enhance welfare for populations and the biological community. This work is being conducted in the Central area of the Grand River (Southwestern Ontario, Kitchener-Waterloo region) in order to describe the impact of wastewater effluents on the main course of the River, analysing physical-chemical properties of the water (concentrations and nitrogen isotopes) in several locations downstream from the Waste Water Treatment Plant (WWTP). Concentration and 15N data showed that ammonium concentrations is controlled by nitrification, volatilization and plant uptake, while nitrate tend to increase in the in the five kilometres plume downstream of the WWTP effluent. To date, laboratory experiments are being conducted, in order to better describe the isotope fractionation phenomena due to ammonia volatilization.

[*]Presenting author; ecejudo@uwaterloo.ca

Spatial and Temporal Dynamics of Carbamazepine Plumes at Two Septic System Sites

M. J. SABOURIN[1*], C. J. PTACEK[1], L. G. GROZA[1], K. L. MCLAGAN[1], K. HEBIG[2], S. SEIBERT[2], T. SCHEYTT[2], W. D. ROBERTSON[1], D. W. BLOWES[1]

1 Department of Earth and Environmental Sciences, University of Waterloo, Waterloo, Ontario, Canada N2L 3G1
2 Technische Universität Berlin, Department of Applied Geosciences, Ackerstraße 76, 13355 Berlin, Germany

Onsite wastewater treatment systems represent a significant source for the release of pharmaceutical compounds, such as carbamazepine, to soil-aquifer systems. Two septic system tile beds which receive seasonal discharge of wastewater were investigated in this study to evaluate the transport of carbamazepine through the subsurface. At each site, wastewater is released from the tile beds, passes vertically through 1-2 m of unsaturated soil before entering the groundwater zone and developing into a plume. At the first site in southern Ontario, Canada, five separate groundwater sampling events were conducted. Carbamazepine was detected in the groundwater at concentrations that exceeded 3050 ng L^{1}. In two of the temporal snapshots at this site, elevated concentrations of over 850 ng L^{-1} and 1100 ng L^{-1} were observed at a distance 30 m beyond the end of the tile beds. The observed concentrations of carbamazepine and the size of the septic system plume were lower in the spring after the tile beds had been non-operational for several months. However, carbamazepine concentrations exceeding 2000 ng L^{-1} did persist over the winter. Two additional groundwater sampling events were carried out at a second site in central Ontario, Canada, which also demonstrated persistence of high concentrations of carbamazepine (>3300 ng L^{-1}) even though the dosing of wastewater effluent to the tile bed at this site was much lower than at the first site.

*Presenting author; msabouri@uwaterloo.ca

The Effect of Carbon Nanotubes on the Ability of the Ciliated Protozoan, *Tetrahymena thermophila*, to Consume Bacteria

M. PINHEIRO[1*], Y. ZHAO[1], S. CHOWDHRY[1], X. YU[1], X. TANG[2], N. BOLS[1]

[1]*Department of Biology, University of Waterloo, Waterloo, ON N2L 3G1*
[2]*Department of Chemistry, University of Waterloo, Waterloo, ON N2L 3G1*

Carbon nanotubes (CNT) are a new type of environmental contaminant but also a platform for developing new technologies for environmental monitoring and water treatment. CNT are incorporated into products, such as sports gear, to provide strength, and are used in electronics because of their unique electrical properties. Environmental applications include improved filtration and sorption processes. CNTs come in multiple forms, depending on how the carbons are organized and functionalized. The main organizations are single walled (SWNT) and multiwalled (MWNT) nanotubes. Some functionalizations are COOH, NH2 and polyethyleneimine (PEI).

Numerous ciliate species, including *Tetrahymena thermophila*, are found in sewage treatment plants where ciliate numbers correlate with improved sewage effluent. Better effluent is brought about by the ciliates regulating bacterial populations through bacterivory, which is the eating of bacteria.

We have studied the effects of COOH, NH2 and PEI SWNT and of NH2 MWNT on *E. coli* and *T. thermophila* and on interactions between the two. Over 4 h at concentrations of up to 14.6 μg/ml these CNTs had no effect on *E. coli* viability. The same treatments also had little effect on *Tetrahymena* except at the highest PEI SWNT concentrations, which slowed the ciliates and caused many of them to swell and become vacuolated. When the two were examined together in a bacterivory assay with an *E. coli* strain expressing green fluorescent protein (GFP), the consumption of bacteria was impaired only by PEI SWNT. Inhibition was observed at the lowest concentration tested, 0.9 μg/ml. At 0.9 μg/ml ciliates swam normally, maintained their usual morphology, and had vacuoles with fluorescent *E.coli* inside. This suggests that PEI-SWNT do not interfere with internalization but with the digestion of bacteria. Therefore, this type of CNT has the potential to interfere with the role of ciliates in waste water treatment and impact sewage effluent.

[*]Presenting author; mpinheir@uwaterloo.ca

Parameter Estimation in Groundwater Models using Surrogate Optimization

M. KAMALI*, K. PONNAMBALAM

University of Waterloo

Ground water models are employed for different purposes such as solute and flow transport modeling, heat transfer and etc. These models are usually finite element or partial differential equations based and hence are computationally intensive. The other issue that makes using such model more challenging is the choice of proper parameters set. This process is very demanding as the input parameters are high dimensional. Thus, an optimization technique that conducts parameters estimation task in a reasonable time and can work well with such models is of very importance. The literature suggests variety of techniques for parameter estimation of ground water models but still there are other options that have not investigated yet. This research aims at conducting parameter estimation for a groundwater model such as MODFLOW using Surrogate Model Optimization (SMO) technique using grid computing. In this approach, the space of the error is modeled using a rather fast soft/mathematical model which eventually can present the real model with good precision. The best parameter set is chosen based on the soft model and will be examined using the real model. Once the selected parameter set works well on the real model the parameter estimation process is terminated.

*Presenting author; mkamali@engmail.uwaterloo.ca

Pomace Waste Management Scenarios In Québec – Impact On Greenhouse Gas Emissions

F. GASSARA[1], S. K. BRAR[1], F. PELLETIER[2], M. VERMA[2], S. GODBOUT[2], R.D. TYAGI[1*]

[1]*INRS-ETE, Université du Québec, 490, Rue de la Couronne, Québec, Canada G1K 9A9*
[2]*Institut de recherche et de développement en agroenvironnement inc. (IRDA), 2700 rue Einstein, Québec (Québec), Canada G1P 3W8*

Fruit processing industries generate tremendous amount of solid wastes which is almost 35-40% dry weight of the total production during juice manufacture. These solid wastes, referred to as, "pomace" contain high moisture content (70-75%) and biodegradable organic load (high BOD and COD) so that their management is an important issue. Moreover, these pomace wastes, if not managed properly at the source end up in the wastewater treatment plants straining the system and enhancing release of more GHG gases. During the pomace wastes management, there is production of greenhouse gases (GHG) which must be taken into account. In this perspective, this study compares GHG emissions from five waste management options, incineration, landfill, composting, solid-state fermentation to produce high-value enzymes and animal feed using life cycle assessment (LCA) model. Environmental assessment of a product (apple pomace waste) over its entire life cycle can indicate the extent of the manufacturer's environmental responsibilities beyond the boundaries of its own facilities, and it can help to identify appropriate management options.

The results indicated that of all the pomace waste management sub-models for a functional unit, solid-state fermentation to produce enzymes was the most effective method for reducing GHG emissions (906.81 tons CO_2 eq. per year), while apple pomace landfilling resulted in higher GHG emissions (1841 tons CO2 eq. per year). It has been demonstrated that incineration is environmentally sustainable mode of waste management (1122.1 tons CO_2 eq. per year). This was due to the recovery of energy (CO_2) produced during incineration and its using within the framework of the urban heating, unlike others waste management options. Thus, solid-state fermentation was a green and low GHG producing alternative which can be sustainable in terms of value-addition and environmental protection to manage different kinds of agro-industrial solid and liquid wastes in Quebec, such as apple pomace.

Key words: pomace; incineration; composting; landfill; fermentation; enzymes

[*]Presenting author; tyagi@ete.inrs.ca

Mineral Aqueous Carbonation using Chrysotile Tailings

L.C. PASQUIER*, G. MERCIER, E. CECCHI

INRS-ETE, 490 rue de la Couronne, Québec, QC, G1K 9A9.

The Province of Québec has engaged itself to reduce its CO_2 emission by 2012. Many avenues are investigated to reach this target, including the sequestration of CO_2 from industrial emitters. Today's solutions face similar obstacles, notably the cost of the sequestration (capture, transport, energy used by the processes…). The ideal approach would be integrated within industrial processes without negative economic impacts. Mineral carbonation is a natural phenomenon, which has been observed and studied. This phenomenon uses CO_2 to create carbonate compounds, a stable way to capture CO_2.

The Province of Québec has large quantities (2Gt, Huot et al., 2003) of ultramafic tailings from chrysotile exploitation in Thetford Mines and Asbestos regions. The Mg content (around 30%MgO) of the residues offers interesting opportunities for mineral carbonation. Also, due to their, proximity to CO_2 emitters, transportation costs are reduced. Moreover, the presence of iron, nickel, chromium and cobalt may offer the possibility to commercialize by-products and offset the operating cost. Therefore, the objectives of this research project are to understand the reaction mechanisms in aqueous conditions, to determine the best experimental conditions and to valorize the by-products (metallic concentrate and carbonate compounds) . In the end, the objective is to offer to industries a valuable and economical process that offers good CO_2 emissions reductions using chrysotile tailings. The target is to reduce 90% of the CO_2 emissions directly from industrial gases without a CO_2 concentration step. Though aqueous carbonation hasn't offered good results previously, this project will examine original approaches, by working with a new material and conditions mimicking raw industrial gases while keeping in mind that changes in industrial gas emissions are directly linked to the reduction of green house gases.

*Presenting author; louiscesar.pasquier@ete.inrs.ca

Algal Blooms in Ontario: Incidences and Response

A. MORLEY[1*], J. WINTER[2]

[1] *Ontario Ministry of the Environment, Eastern Region, Operations Division*
[2] *Ontario Ministry of the Environment, Environmental Monitoring and Reporting Branch, Environmental Sciences and Standards Division*

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.

[*]Presenting author; Andrew.Morley@ontario.ca

Cyanobacteria in North America: Developing Regional and Continental Predictive Models

M. BEAULIEU[1*], F. PICK[2], S.B. WATSON[3], I. GREGORY-EAVES[1]

[1] *Department of Biology, McGill University, Montreal*
[2] *Department of Biology, University of Ottawa, Ottawa*
[3] *Environment Canada, Canadian Centre for Inland Waters, Burlington*

Cyanobacteria blooms can negatively impact water quality and recreational use of water bodies. Most research in the field has focused on drivers of total cyanobacteria dominance and abundance at regional or global scales, with little detail on how scale and sampling differences might affect these models. While nutrients, mainly total phosphorus, have been shown to explain ~50% of the variation, we hope to improve upon the predictive power of these models through the use of several large sets of unpublished data from North American regions as well as published data. We will develop empirical models for cyanobacteria dominance and abundance using nutrient, temperature, hydrology and lake morphology data as predictors and identify whether these differ at regional and continental scales. We will also identify predictors of important cyanobacterial genera and functional groups (e.g. nitrogen-fixers, potentially toxic-producing species) at these scales. With our work, one of our goals is determine whether a regional model from Ontario (for example) could be applied with reasonable confidence to a lake in a different region. As there has been a recent increase in the reports of cyanobacteria blooms in many Canadian lakes, there is a growing need to better understand cyanobacteria blooms and provide scientifically-sound information to lake managers.

[*]Presenting author; marieke.beaulieu@mail.mcgill.ca

Microcystin Concentrations in Freshwater Lakes in Relation to Nitrogen-to-Phosphorus Ratios

D. ORIHEL[1], S. WATSON[2*], B. KOTAK[3], R. ZURAWELL[4]

[1]*Department of Biological Sciences, University of Alberta, Edmonton, Alberta*
[2] *Environment Canada National Water Research Institute, Burlington, Ontario*
[3]*AlgalTox International, Pine Falls, Manitoba;*
[4]*Alberta Environment, Edmonton, Alberta.*

The production of hepato-toxic microcystins by freshwater cyanobacteria has emerged as a major public health concern. Because cyanobacteria tend to dominate in lakes when the ratio of nitrogen-to-phosphorus (N:P) in the water column is low, we tested the hypothesis that high concentrations of microcystins only occur at low N:P ratios. In our multi-year survey of Canadian lakes, we observed an inverse threshold relationship between N:P ratios and microcystin concentrations. Furthermore, the probability of microcystin exceeding 1, 2, 5, or 10 µg/L in the lakes decreased with increasing N:P ratio. When we manipulated N:P ratios in an in-lake mesocosm experiment, we observed the same inverse threshold relationship between N:P ratios and microcystin concentrations. Consistent with our field studies, microcystin concentrations in laboratory cultures of *Microcystis* were highest in the lowest N:P treatment . The results of our comprehensive study demonstrate that high microcystin concentrations only occur at low N:P ratios. Consequently, we recommend that remediation strategies for eutrophic lakes focus on limiting phosphorus inputs in order to increase N:P ratios and reduce the occurrence of high microcystin levels.

[*]Presenting author; Sue.Watson@ec.gc.ca

The challenges of Implementing a Sediment Remediation Strategy in an Active Industrial Port

R. JOYNER*, M. GRAHAM, R. SANTIAGO

Environment Canada

Randle Reef is an area of highly contaminated sediment that exists in close proximity to active industrial and port lands integral to the local community. The sediment at the Randle Reef site is contaminated with polycyclic aromatic hydrocarbons and metals with very strong evidence of sediment toxicity. The overall strategy for the Project is the construction of a 7.5 hectare engineered containment facility (ECF) which isolates most of the contaminated material in-situ within the facility. Other contaminated sediment from the area is then dredged and placed into the facility.

The presence of industrial facilities such as US Steel in close proximity to the remediation area creates several challenges when attempting to design a remediation plan for contaminated sediments.

1) The presence of industrial slag used to stabilize industrial dock walls present challenges in terms of determining their precise limits for dredging plan development, determining off-set areas so as not to undermine stability and determining management actions. These slag areas can still contain thin layers of contaminants on their surface or between the larger rock size particles as well as accumulate thin layers of contaminants from the residuals generated during environmental dredging.

2) Environmental dredging utilized for the site is not possible in the channel area created between the ECF and the US Steel dock wall because of the requirements of the adjacent USS facility. In order to reduce the toxicity of the sediment in the channel an isolation cap will be placed atop the channel's contaminated sediment to eliminate the exposure of aquatic biota. Specific challenges include protecting and maintaining the flow rates and water quality entering the USS intakes and ensuring the integrity of the isolation cap is not compromised by the scouring action from either the flow into the intakes or the propellers of large commercial vessels docking along the USS dock wall. The presence of the USS intakes and the need to avoid impacting flow rates into intakes restricts the possible thickness of the isolation cap in the area adjacent to the intake pipes. A portion of the cap at the mouth of the channel will also be armoured with stone and a geo-textile atop the cap to protect against potential scouring action from the propellers of large commercial vessels.

3) There are a number of dock walls in the vicinity of the area requiring remediation. Stability of these dock walls prevents dredging directly to the walls and the maintenance of required navigational depths presents a constraint on the use of thin layer caps.

*Presenting author; rupert.joyner@ec.gc.ca

Urban Runoff Quantity and Quality Control – Malaysian Perspective

A. MAMUN[1], W.M. NAWANG[2], A. IDRIS[3]

[1]*Bioenvironmental Engineering Research Unit (BERU), Faculty of Engineering, International Islamic University Malaysia (IIUM), Jalan Gombak, 53100 Kuala Lumpur, Malaysia.*
[2] *Pwm Associates Sdn. Bhd., No. 37-4 Jalan SP 2/1, Taman Serdang Perdana, 43300 Sri Kembangan, Selangor, Malaysia.*
[3]*Department of Chemical & Environmental Engineering, Faculty of Engineering, Universiti Putra Malaysia (UPM), 43400 UPM Serdang, Selangor, Malaysia.*

Despite significant efforts made by the government, owes due to flash flood and water pollution continued to increase at the urban areas in Malaysia. Such deteriorating trend was linked to increased land conversion activities, rapid disposal concept of drainage systems, main target on the control of point pollution sources (municipal and industrial wastewater) only, illicit connections and discharge of untreated sullage (grey-water) to the drainage systems. Realizing the limitations of the past efforts, various initiatives are taken in the recent pasts to improve the flood mitigation measures and river water quality throughout the country. Quantity and quality control of urban runoff is one of the most significant initiatives taken by the government of Malaysia. The significance of urban runoff quantity and quality control is gaining recognition throughout the country since the endorsement of Urban Stormwater Management Manual for Malaysia (USMMM), which was mandated in June 2000 by the Ministry Cabinet. It is now being applied for urban land development approval. The Manual consists of detailed engineering procedures and guidelines for runoff quantity control and treatment of non-point (diffuse) source pollutants. Receiving response from various stake-holders during the last 10 years, the government has taken another initiative to further improve the USMMM and prepare Standard Books for the legal enforcement of the runoff quantity and quality control. Such initiative by the government is highly expected to assist regulatory authorities and practitioners to reduce urban runoff related problems (flash flood and diffuse pollution) from the municipalities and help achieve the target of improved in river water quality nationwide. Various types of structural and non-structural best management practices (BMPs) are proposed in the manual. All stakeholders are working together to adopt the BMPs recommended in the USMMM. Lack of nationwide data on runoff quality from various landuses and local performance data of the structural best management practices (BMPs), are the main constraints the authorities are focusing on. The initiatives taken by the government of Malaysia can be a model for other developing nations in controlling runoff quantity and quality from urban areas. This paper briefly overviews the background of the urban runoff (both quantity and quality) management practices highlighting the issues regarding its implementation and improvements.

*Presenting author; mamun@iium.edu.my

Hydrological Consequences of Urban Development in Lake Simcoe Watershed

S. ONI[1*], M. FUTTER[2], P. DILLON[1]

[1]*Trent University*
[2]*Swedish University of Agricultural Sciences*

Lake Simcoe watershed is an important socioeconomic region in the province of Ontario, Canada. The watershed is under the increasing pressure of developments due to sprawling urbanization from Greater Toronto Area (GTA) and city of Barrie. For example, the extent of impervious areas have from city of Barrie has grown into Lovers Creek; a subcatchment within Lake Simcoe watershed. Impervious areas modify runoff generation and distribution processes by preferential discharge of waters to run off land surfaces very quickly as quickflow (QF) over subsurface and baseflow. The resultant effect of this is an abrupt peak in hydrographs resulting from altered pristine hydrologic processes (e.g. infiltration and percolation), thereby leading to generation of urban stormwater that are difficult to model using rainfall-runoff model. Urbanization of Lake Simcoe watershed has been predicted to increase in future and thus a need to develop new techniques. Coupled with remote sensing analytical techniques that was used to estimate the extent and change in impervious covers, this study presents a new approach that can be used to model urbanized runoff using a rainfall-runoff models such as HBV that was designed to simulate pristine hydrological processes. Understanding how urbanization impacts runoff and successful modelling of such will help watershed authorities in managing urban stormwater in future.

[*]Presenting author; stephenoni@trentu.ca

A Novel Method to Monitor Wastewater Treatment Process

B. RAZBAN[1*], D. MCMARTIN[1], R. CULLIMORE[1], D. WANG[2]

[1]*Droycon Bioconcepts Inc.*
[2]*Center for Sustainable Infrastructure Research (NRC)*

In monitoring aerated wastewater treatment systems, biochemical oxygen demand (BOD) is one key test which is being performed in almost all wastewater treatment plants. Critical challenges exist for municipalities to discharge safe, treated municipal sanitary wastewater effluent to the environment addressing both health and environmental risks including the possible impacts on aquatic life (as indicated by discharged BOD5 concentration).

An investigation of the identification of the bacterial communities using the MIDI identification technology began on 25th March, 2008 with the establishment of the protocols for the reliable enhancement of the FAME from the different communities within the wastewater treatment process. This enhancement process was developed from the primary influent (PI), primary effluent (PE), secondary effluent (SE) and the final effluent (FE) using samples from the City of Regina waste water treatment plant (WWTP).

For the total evaluation of the RASI-MIDI protocol (rapid agitation followed by static incubation) a total of 481 samples were analyzed. The distinct and replicable fatty acid profile results indicated that the RASI-MIDI protocol defined herein is a potential method for monitoring changes and functions in bacterial communities in aerated wastewater treatment plants. The measurable shift within fatty acid content of each stage provides a finger print to evaluate the quality of treatment in any given stage. In the application of the RASI methodologies with the rapid FAME analysis, the speed with which a test can be completed (26 hours) from receipt of sample would be a favorable adjunct to the operation of any wastewater treatment plant.

[*]Presenting author; BehroozRazban@gmail.com