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Canadian Association on Water Quality
Environment Canada

Science Meets Policy

Book of Abstracts

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MESSAGE FROM THE PROGRAM CHAIR

It is my pleasure to welcome you to the 43rd Central Canadian Symposium on Water Quality Research. This year’s theme is “Science Meets Policy”, and we have assembled a strong technical programme encompassing a variety of disciplines. Our goal is to convene a symposium to benefit delegates interested in a broad range of water quality issues. We are also pleased to offer an interactive sessions on Harmful Algal Blooms (HABs) and open a workshop on the subject to the general public. In addition, we are pleased to welcome Dr. Pierre Payment as our plenary speaker, who will open the Symposium with a presentation on public health and drinking water standards. On behalf of the organizing committee, welcome to Burlington, and I wish you a successful and informative Symposium.

C.H. Marvin
Programme Chair
SESSION CHAIRS

**Advances in Wastewater Treatment Technologies and Approaches**
Wayne Parker (University of Waterloo)
Hongde Zhou (Environment Canada)

**Environmental Modeling**
Ferdous Ahmed (Rideau Valley Conservation Authority)
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**Harmful Algal Blooms**
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**Advances in Water Treatment Technologies and Approaches**
Rajesh Seth (University of Windsor)
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**Applications of Remote Sensing and GIS to the Assessment of Watershed Health**
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**Biotechnology-Environmental Applications and Potential Risks**
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**Science, Policy, and Legislation**
Hugh Simpson (OMAFRA)
Neil Hutchinson (Gartner Lee Limited)

**Stormwater and Urban Lake Management**
Sandra Kok (Environment Canada)
Deborah Sinclair (Gartner Lee Limited)

**Policies and Technologies for Small Communities**
Jim Higgins (Jacques Whitford Limited)
A Word on Environmental Economics and Social Marketing - Dan Christopher

Why connect environmental policy to economics?

A healthy environment provides a self-replenishing supply of resources, such as fresh air to breathe, clean water to drink, and ample land on which to live. As with any resource, once demand outpaces supply, resource scarcity becomes an issue. Since economics is defined as the science that studies the production, distribution, and consumption of resources (particularly when scarce), it seems only natural to connect the two together. Economics not only deals with assets, but also with analyzing tradeoffs; examining all associated costs of a particular outcome. There are explicit costs that can easily be measured, and there are costs called externalities - costs that exist but are not payable by anyone, as is often the case with pollution. For example, an individual or nation who pollutes does not often pay to do so, but many suffer for it over various lengths of time. The process by which an externality is corrected is called internalizing - discouraging air pollution by selling clean air shares to the highest bidder, for example. The polluter will then be required to pay the full social cost if they wish to continue polluting, and must form their decisions accordingly. Economics is about correctly estimating the cost of options available to an individual or a nation; consequently, economic analysis is an appropriate way to deal with environmental problems.

It is a common misconception that the health of the environment and that of the economy are mutually exclusive - if one flourishes the other weakens. This is not the case. According to a study performed by the German Institute for Economic Research, if average global temperatures rise in excess of two degrees Celsius above pre-industrial levels (which current trends indicate will happen), it is estimated that global economic damages could reach $20 trillion annually by 2100. Yet even this staggering price still does not take into account the trickle-down cost of biodiversity loss and other externalities.

<table>
<thead>
<tr>
<th>Approach to climate protection</th>
<th>Average global temperature increase by 2100</th>
<th>Annual cost by 2100 for climate-related maintenance</th>
<th>Annual cost by 2100 due to climate-related damages</th>
<th>Net annual cost by 2100</th>
<th>Loss of Biodiversity</th>
</tr>
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<tbody>
<tr>
<td>Rigorous and immediate climate protection policies implemented</td>
<td>&lt; 2° Celsius</td>
<td>3 Trillion</td>
<td>$8 Trillion</td>
<td>$11 Trillion</td>
<td>Serious</td>
</tr>
<tr>
<td>Inactive approach to climate protection policy</td>
<td>&gt; 2° Celsius</td>
<td>(presumably) $0</td>
<td>$20+ Trillion</td>
<td>$20+ Trillion</td>
<td>Catastrophic</td>
</tr>
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The report also estimates that a comparatively small investment could be enough to curb rising temperatures, and benefit from the resulting savings. One of the first steps required in building a sustainable future - both environmentally and economically, is to forgo the trend of instant gratification spending and begin investing IN such a future. In this respect, cradle-to-grave analysis demonstrates that environmental policy and economics support each other and exist in symbiosis. Stakeholder interest in one automatically qualifies interest in the other.

Cradle-to-Grave analysis

From the moment a resource becomes annexed for use (cradle), straight through to final disposal (grave), many significant phases occur, possibly including but not limited to: extraction, processing, manufacturing, transportation and actual use. Cradle-to-grave analysis considers the environmental impact for all phases of the life cycle, allowing for a much clearer understanding of possible ramifications present day decisions may have on future generations.
Social Marketing: The change agent

We are bombarded by marketing on a daily basis. Be it billboards along highways or catchy jingles on the radio, the goal of any advertisement is the attention of the consumer. While the majority of marketing is commercial in nature – namely, promoting a product or service which turns a direct financial profit (instant gratification), there also exists a very important niche for social marketing.

The anti-tobacco movement boasts one of the more popular and successful social marketing campaigns in recent years. In 2002 Canadian tobacco-related illnesses resulted in over 37,000 deaths and almost 2.25 million days of acute care hospital stay, so the social benefit of a large scale reduction in smoking is obvious. Do the benefits end there however? For the same year, the economic cost of health care for tobacco-related illnesses totaled $17 billion. Consider an anti-tobacco marketing campaign with a modest budget of $100,000. If one in every 100 smokers were made more aware of the adverse effects smoking had on human health and thus decided to break the habit, theoretically the total annual savings would amount to 370 lives, 22,500 days of acute care hospital stay and $17 million in health care costs. A very handsome return on investment by any account.

Bridging the gap between ideas

A similar, yet much larger scaled return could be gained by educating the public in matters of environmental responsibility. When faced with a situation where the lives at risk rank in the millions (possibly billions) and dollar figures rank in the trillions, the potential for benefits resulting from merging environmental economics and social marketing becomes enormous.

5 considerations when applying social marketing to environmental economics:

5) Avoid scare tactics.
People generally don’t enjoy being told the sky is falling; many will react by tuning out completely. Present information at face value, with as little spin and personal bias as possible.

4) Focus on positives rather than negatives.
Success (even in small doses) is inspiring and highly motivational. Focusing entirely on negatives may illicit a “what’s the use?” response. See above.

3) Research ideas thoroughly.
Are there any successful templates to model your design after? What has worked in the past for others?

2) Adapt to your audience.
Some people don’t respond to lectures on scientific facts and figures as readily as others. Establish a common ground and convey your message in a language your audience can understand and identify with.

1) Lead by example.
Effective leaders not only communicate, they follow through with action and ‘walk the talk’.

References


Advances in Wastewater Treatment Technologies and Approaches

Chairs: Hongde Zhou and Wayne Parker
Regional Variations in Constructed Wetland Designs for Optimal Protection of Receiving Waters

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Constructed wetlands are used to treat wastewater streams from industrial sources, such as landfills or photo processing facilities, as well as agricultural, and residential sources. The advantage of constructed wetlands is that they are passive treatment systems, where low maintenance and setup costs, make them ideal systems for agricultural facilities and landfills whose effluents, whether from runoff or seepage, require treatment prior to discharge to drinking water sources. Constructed wetland treatment systems rely on physical treatment mechanisms, such as sedimentation and sorption, chemical mechanisms, including chelation, precipitation, and complexation and biological mechanisms, from bacterial conversions to vegetative uptake, for removal of constituents from the wastewater stream.

The flow within the constructed wetland affects all aspects of the treatment efficiency, mainly though contact time of the wastewater stream within the wetland. Wetlands are designed for specific flows with safety factors to account for added water to the system from groundwater surges or precipitation events. These safety factors maintain minimum contact times within the constructed wetland and treatment efficiencies for biological and chemical treatment mechanisms.

Physical constituent removal mechanisms, such as sedimentation and precipitation don’t rely as heavily on contact time and therefore the safety factor put in place to ensure adequate contact don’t have as much of an effect on these processes. Settling of particles within a water system is based on flow velocities and quiescent conditions, and is more sensitive to changes in these parameters as the settling particle size decreases. Precipitation and snow melt create high flow volumes, which increase velocities and can retard sedimentation and disturb and resuspend sediment particles, lowering the efficiency of the system while under these stresses.

Increased water volumes form precipitation and groundwater has the greatest affect on sorption of wastewater constituents. Sorption rates are driven by concentration gradients between the wastewater and the media. Precipitation events and snowmelt not only introduce high volumes of water into the system, but there is also dilution of constituents within the wastewater stream. This diluted wastewater stream can result in desorption of wastewater constituents from the media back into solution. The highest risk of desorption is present in constructed wetland which experience seiching, when low constituent concentration waters from the receiving bodies can enter the constructed wetland which can result in desorption from the media and eventual entry of the constituents into the receiving water that the system is designed to protect.
Constructed wetlands are an excellent, low cost option for sources water protection, but the design of such systems must go beyond the sizing models and safety factors. Design must include allowances for the high flows associated with snowmelt and precipitation and in areas where seiching can become a problem; this affect needs to be addressed as well. With a good understanding of the hydrology of the area, and not just the design methods for constructed wetlands, there can be assurances that the treatment system will act as a sink for wastewater constituents, and will not eventually become a source.

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Electrokinetic Flotation of Paint Sludge Water in a Kinetic Model Tank

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The treatment of sludge water from paint booths in automotive assembly plants typically involves applications of large quantity of coagulants and other chemicals, which bring suspended paint solids to the surface of sludge pits. The paint sludge is then collected from the top of the sludge pit for dewatering and disposal. Disadvantages of the chemical flotation technology include:

1) High and ever increasing costs of chemicals;
2) Effective dosage (feed rate) and type of chemicals change with paint type, production volume and water properties, which need to be closely monitored and routinely tested to ensure the system performance. This increases operation costs.
3) Unsatisfactory performance of sludge flotation may not be discovered and corrected immediately. This causes sludge build-up in the sludge pit and water circulation channels, leading to additional maintenance costs;
4) Chemicals added to water cannot be recovered, which may have environmental impacts and impose higher disposal costs.
5) Chemicals added to water result in a significant increase in the volume of sludge. It is also well known that coagulants added sludge is more difficult to dewater. This leads to higher dewatering and disposal costs.

A study has been carried out to explore using electrokinetic flotation (EKF hereafter) for paint sludge water treatment. EKF utilizes two well-known scientific principles, i.e. (1) electrically charged particles move in a direct current (DC) electric field in the direction opposite to the charge carried by the particle (electrophoresis) and (2) gas bubbles are generated on electrodes when they deliver a DC electric current through water (electrolysis). As a result, when a DC current is passing through water with suspended paint solids, electrophoresis mobilizes charged paint particles, and electrolysis generates oxygen and hydrogen bubbles on submerged electrode surfaces, which carry paint solids to the water surface. It has been identified that the influencing parameters in EKF process include the electrode configuration, type of paints, paint solid loading, applied current per unit volume of water and current density on electrode surfaces. This paper presents the results on a bench scale kinetic model tank that simulates the sludge pit from an automotive assembly plant. The study demonstrated that the EKF process generated quick flotation of paint solids without using any coagulants. The suspended solid removal can be readily controlled by adjusting the applied DC current based on the paint type, solid loading and other water properties.

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Efficiency of Phosphorus Removal in Pond Based Trout Farms by Collecting Accumulated Sludge

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Freshwater fish farming in Quebec has reduced its production since the year 2000 due to environmental regulations imposed by the Ministry of Environment. An agreement was made to reduce the environmental release of phosphorus to 4.2 kg of phosphorus (P) per ton of fish produced by 2014. In Quebec, more than 60% of installations are small pond-based trout farms needing extensive and economically viable solutions. As solids removal (fish feces and uneaten food) was shown to be a good solution to remove P from intensive land-based fish farm (Cripps and Bergheim, 2000), the aim of our study was to measure the efficiency of this method in small pond based fish farm. In many pond based trout farms, sludge is typically removed once a year. We selected two identical concrete ponds (#1 and #2) in a trout-farm and analysed P accumulation in sludge and the efficiency of annual P removal done in August (Phase 1, Sep 2006-Aug 2007). During phase 2 (Sep 2007-Aug 2008), P accumulation will be estimated each two months in a concrete bottom pond (#2) and in a soil bottom pond (#3) by pumping sludge according to a pattern of 10 subsections. An annual estimation of P removal will be conducted in parallel in concrete bottom ponds #1 and #2, and in soil pond #3.

Results obtained during Phase 1 were compiled and a P mass balance was prepared. Calculations were done according to equation 1 by measuring P in sludge and estimating P accumulated in fishes and provided in the fish food.

\[ P_{\text{effluent}} = (P_{\text{influent}} + P_{\text{food}}) - (P_{\text{fish}} + P_{\text{sludge}}) \] (1)

The P mass balance in the concrete bottom ponds # 1 & #2, showed that the P released of 6.3 and 6.0 kg P/t respectively was greater than the limit of 4.2 kg P released/t fish produced. An annual P balance will be done in an additional soil pond #3 to establish its P retention efficiency.

Phase 2: the first results enabled us to draw a sludge accumulation pattern in pond #2. The pumped sludge from the 10 subsections gave a P content average of 12.7 g P/kg total solids (TS). The sludge was mainly accumulated under the middle pond surface aerator.

Finally, by emptying accumulated sludge only once a year, the concrete based ponds studied were not able to trap enough P to meet the upcoming P legislation. Phase 2 analyses will enable us to determine the effect of a higher sludge collection frequency on the P removal efficiency.

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Assessing the Ability of Treatment Wetlands to Mitigate Contaminants from Wood Waste Leachate

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There is a growing concern and awareness about the negative effects of leaching residuals from wood waste at saw mill sites in Ontario. The proposed demonstration research project is located in Whitney, Ontario, which is 3km east of Algonquin Provincial Park, will be one of the first of its kind in the province. Implementing a surface flow and subsurface flow treatment wetland at the study site to remove metals and other organic compounds will promote source solution practices and will help in maintaining watershed health. Experimental wetland designs will be tested for performance and efficiency.

The objectives of the project are to: 1) examine the sources of contaminants in leachate runoff through column testing of the most abundant varieties, species, and forms of wood waste; and 2) test the effectiveness of wetland designs for sequestering or transforming selected contaminants of interest. The treatment wetland will need to function efficiently for a prolonged period of time and throughout annual environmental and seasonal weather variations.

Parameters of primary interest include the metals copper, zinc, and iron, and organic compounds such as tannins, lignins, and phenols. Test variables for the treatment wetland will include species of vegetation, substrate media, and abundance of dissolved oxygen through passive and forced aeration. Operation and maintenance, as well as management and monitoring guidelines for the treatment wetlands will be developed concurrently throughout the research program.

Previously tested effluent samples from the study site reveal levels of copper, iron, zinc, and phenols which are periodically above Provincial Water Quality Objectives during the last five years. Prior to construction of full scale treatment wetlands, column test experiments will be conducted to determine the most effective vegetation types and substrate media that will reduce concentrations of metals, and tannins, lignins and phenols to below PWQOs. A variety of native and non-native plant species will be used under controlled conditions in column tests at Fleming College’s Centre for Alternative Wastewater Treatment facility.

Starting May 2008, a thorough inventory and assessment will be carried out at the study site to determine an optimal design for the treatment wetland. Historical water quality data, and local hydrology, topography, and geology of the study area will also be examined and considered.
The wood waste leachates can be toxic in the environment, unless treated at the source. Contamination of surface water and groundwater are a significant risk from these discharges. The Ministry of the Environment has encouraged saw mill owners to develop wood waste management plans which mitigate harmful impacts and protect the environment. This research has the potential to promote sustainable and effective saw mill practices through optimization of treatment wetland design and through the development of best management practices and guidelines for use throughout this important resource industry.

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Electrochemical Remediation of Sulfide Ions Using Coke Electrodes

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Sulfide ion is a significant contaminant in the geothermal brines that are by-products of oil and gas extraction. Hydrogen sulfide or, at alkaline pH, sulfide ion, is well known for its toxicity and corrosivity leading to “sour brine” that produces sulfidic scale. Past removal techniques involved a combination of chemical precipitation and oxidation followed by disposal of a toxic sludge. In the gas fields of Alberta sour brines are usually disposed by reinjection at a geologically suitable site, often requiring costly transportation to the reinjection site in pressurized containers.

Previous work in our laboratory focused on the remediation of sulfide sour brines by electrochemical oxidation using boron-doped diamond electrodes in the presence or absence of chloride ions (J. Applied Electrochem., 2007, 37, 367). Near-quantitative conversion of sulfide to sulfate was achieved, with current efficiency > 90%. Kinetically, the reaction was current controlled: first order in current density and zero-order in sulfide concentration.

The goal of the present research is the remediation of sulfide solutions by electrochemical oxidation using industrial coke electrodes in batch electrochemical reactors. Coke was donated by both Dofasco and Stelco, Hamilton, ON. Electrolyses of the synthetic solutions were conducted in both the presence and absence of chloride, using sodium hydroxide as the supporting electrolyte.

Batch cell electrolyses appeared to follow partial order kinetics with respect to sulfide concentration, but were better explained in terms of two successive zero order reactions. For example, at 200 mA in both the presence and absence of chloride ion, an initial rate of ~24 mM/min was followed by a reaction rate of ~10 mM/min. It was hypothesized that the most highly reactive sites of the coke surface became blocked by precipitation of sulfur, which was determined qualitatively by XPS.

In order to favor the 2-electron oxidation of sulfide to sulfur over the 8-electron oxidation to sulfate, electrolyses were carried out in the presence of the surfactant sodium dodecyl sulfate (SDS). Oxidation of sulfide at 200 mA then proceeded with a single current-controlled rate of reaction of ~23 mM/min. SDS can be considered to be a model for naphthenate salts, which constitute a natural polycyclic carboxylate surfactant present in authentic sour brines. In the presence of 3% naphthenic acid the electrochemical oxidation at 200 mA followed an initial current controlled rate of ~24 mM/min for the first 60% conversion, followed by 5 mM/min rate for the remainder of the reaction. Ongoing work is directed towards method development for quantitative analysis of elemental sulfur by HPLC, and analysis of byproduct sulfate ion by ion chromatography, as well as optimization of reaction parameters such as current and naphthenic acid concentration, and the need to avoid Kolbe oxidation of the naphthenic acids.

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Polycyclic Synthetic Musk Partitioning in a Suspended Growth Aerobic Activated Sludge System

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Polycyclic synthetic musks (PSMs) are fragrance compounds used in personal care products (e.g. perfumes, lotions and deodorants) and thus they belong to an emerging class of micro-contaminants known as pharmaceuticals and personal care products (PPCPs). Within this class, there are six different musks commonly reported with two musk compounds (i.e. Galaxolide and Tonalide) typically accounting for 95% of the total PSM (tPSM) concentration. PSM have a low water solubility and a demonstrated ability to bio-accumulate. Sorption to biological solids increases the retention time of the musks within the wastewater treatment system where ultimately it may be degraded. The purpose of this study was to define PSM reduction and develop an understanding of the reduction mechanisms occurring in the aeration basin of a conventional activated sludge treatment plant. The study made use of laboratory scale sequencing batch reactors (SBR) fed primary effluent from a municipal wastewater treatment plant to carry out a two level factorial design (temperature(T) (11°C and 19 °C), sludge age (SRT) (3.5 and 11 days)).

It was determined that tPSM reduction was substantial (e.g. 60-80%), based on concentrations in the influent (e.g. primary effluent) and the effluent. As PSM are non-ionic lipophilic compounds, and reasonably reduction values would reflect to a large degree the tendency of the musks to become associated with the biological floc (BF). BF concentrations reflect the combined effects of enmeshment of musk containing suspended and colloidal particles into the floc; sorption/desorption of soluble musks; and biodegradation. Previous investigators have shown SRT affects floc properties. An a priori assumption was that floc properties would strongly influence the degree of BF associated PSM.

The total concentration of PSMs in the solids was in the range of 17-24 µg/g d.m and averaged 10 µg/L in the influents. This suggests that BFs are a significant sink for PSMs. Significant higher concentrations (24 µg/g d.m) were found for reactors operating at 11°C when compared to 19 °C (17 µg/g d.m). BF generated under conditions supporting nitrification were also shown to have lower amounts of tPSM. It is unlikely that nitrifiers are responsible for reduced values; however, presence of nitrification can be considered a marker indicating a diverse culture containing slow growing organisms.

Floc properties (i.e. size and porosity; surface charge (SC); and relative hydrophobicity (RH)) were assessed. Reactors operating at 11 C generated a larger and more diffuse floc than those operating at 19 C; thereby, providing more surface area for sorption and other partitioning processes. RH and SC are dominant surface properties that
were suspected to play a role in sorption processes. RH was found to be influenced by all operating variables with the most hydrophobic sludge being produced at SRT of 11 d and T of 19 °C. SC did not significantly change with operating conditions. Both SC and RH were determined as being negatively correlated with tPSM partitioning. This finding seems counterintuitive as SC was not significantly influenced by T and underscores that both enmeshment and biodegradation are occurring concurrently.

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Pulp Mill Treatment Technologies Have Differential Endocrine Disrupting Effects on Rainbow Trout

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Endocrine disruption effects due to pulp and paper mill effluents involving different industrial procedures and effluent treatments (SPE specific extracts obtained from non-treated, primary and secondary treated pulp and paper mill effluents) were evaluated using a fish (hatchery-reared immature triploid rainbow trout Oncorhynchus mykiss) pulse-exposure toxicity experiment. The protocol involved the use of intra-peritoneal injection, corrected for individual fish weight and utilizing previously determined dose information, and also included several laboratory standards (steroidal hormones and phytosterols). Multiple biomarkers at different levels of biological organization (molecular, cellular, tissue and individual organism level) were analyzed. Previous results indicated that non significant changes were observed in the individual physiological indices represented by condition factor and liver somatic index during different sampling times. Significant induction of the cytochrome P4501A1 was observed between different effluent treatments and experimental controls. Significant endocrine disrupting effects (reproductive level) were observed in all effluent treatments involving significant increments in gonadal somatic index and plasma vitellogenin (Vtg) levels. Untreated effluent exposed fish had significantly higher Vtg levels compared to fish exposed to primary and secondary treatment effluents, indicating a decrease of the endocrine effect due to the effluent treatment. These results will be confirmed by immunohistochemical analysis of Vtg in the fish gonads.

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Limit of Treatment (LOT) Nutrient Removal from Wastewater: the Move From BNR Through ENR to UNR

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The removal of nutrients from wastewater is now an accepted standard treatment around the world, with developing countries and Canada catching up by imposing emission-based effluent permits, typically 1 to 1.5 mg TP/L and 10 to 15 mg TN/L. In the most fragile ecological regions in the United States and a few other locations regulators impose immission-based “limit of treatment” permits typically TP < 0.1 mg/L and TN < 3 mg/L. The latter limits require going beyond the standard biological nutrient removal (BNR) and employment of, what the industry calls, “enhanced nutrient removal’ (ENR), typically involving a multi-biomass process and a combination of chemical treatment and external carbon addition. In extremely fragile areas (for example Florida Everglades) and in case of water reuse, the “ultimate nutrient removal” (UNR) is necessary to satisfy the permits which may ask for effluent concentrations in the range of 0.01 mg TP/L and 1 mg TN/L, regardless of the nature of species removed. The latter means that non-reactive and refractory fractions of TN and TP are counted as if they were degradable.

With already skewed ratio of the magnitude of point sources to non-point discharges one may ask if these limits are imposed because we think we can remove to such low levels. The cost of these technologies – particularly the operating costs are significant. At the present time the largest dischargers, located in the Chesapeake Bay area and Pacific Northwest are struggling and seldom meeting the ENR effluent standards. The paper will present the challenges facing the industry wanting to implement these effluent standards and the need to modify our designs to meet those limits in conditions of having to treat both dry flows and most, if not all, of the wet weather flows. Case studies will be presented including water reuse plants and plants discharging to water supply reservoirs and aquifers. The highlighted design changes will include the beneficial use of internal and external carbon sources, impact of biosolids management and concepts for optimizing the processes to minimize the operating costs.

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Trash and Grit Removal From Activated Sludge by Microscreening and Hydrocycloning

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The treatment and disposal of sludge is a major operating cost at biological wastewater treatment plants (WWTP). Removing inert particulate matter which accumulates in the sludge can enable WWTP to increase the sludge retention time (SRT), thereby decreasing the amount of sludge to treat and dispose of. An innovative process consisting of a microscreen to remove the inert organic particulate matter (trash) and a hydrocyclone to remove the inert inorganic particulate matter (grit) has been tested at lab scale and yielded promising results.

The experimental setup consisted of a 13 mm Krebs hydrocyclone and a 10 cm diameter microscreen equipped with a mechanical agitator 1 mm above its surface to prevent the formation of a dynamic filtration layer. Three different sizes of microscreens were tested: 200, 300 and 500 µm. Samples came from nine WWTPs located in the greater Montreal area. This enabled the determination of the effect of SRT, industrial organic loadings and the pre/primary treatments at the plants on the removal of trash and grit. Total suspended solids (TSS), volatile suspended solids (VSS) and fixed suspended solids (FSS) as well as particle size distributions were measured.

The microscreen primarily retained organic matter (VSS/TSS of screenings = 78-92%, average 87%) regardless of the raw sludge volatile fraction (VSS/TSS=57-85%, average = 71%). The reduced efficiencies ($E_{T'}$) of the hydrocyclone on the FSS varied between 8 and 33%. The SRT and the pre/primary treatments at the WWTP did not show a clear effect on the results, but the $E_{T'}$ of the hydrocyclone on the FSS appeared to increase with a decreasing industrial loading.

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Visualization of Pollutant Transport Using Transparent Soil

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This paper presents a feasibility study of visualizing and modelling pollutant transport using transparent soil. Transparent materials including glass beads or quartz powder have been used to help in understanding flow processes through the soil. However, glass and quartz surrogates are limited by both their poor transparency and their inability to represent the geotechnical properties of soils. Transparent soils used in this research are made of amorphous silica gels or powders with liquids having the same refractive index. Geotechnical laboratory tests show that transparent soil exhibits similar stress-strain relationships to natural soils. The permeability values are also similar to those of natural soils. It can be customized to meet the model requirements in terms of strength, deformation, or permeability. Its transparency is also superior to crushed glass. Another advantage of this material is that it is the only system that is capable of resembling soils with a wide range of grain sizes. Movement of a contaminant through soil was modeled. A red dye was mixed in a mineral oil solution to represent contamination. The concentration of the oil-soluble dye solutions with known concentrations was simulated. These tests demonstrate that transparent synthetic soil can be used to visualize and non-intrusively measure pollutant transport in natural soils.

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Application of Humic Substances to Enhance Leachate Treatment

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Stringent limits for nutrients in the effluents from wastewater treatment plants have been established to reduce nutrient load on receiving water bodies and prevent their deterioration. Meeting these limits necessitate wastewater treatment plants to apply new, more efficient technologies for nitrogen and phosphorus removal. Nitrogen removal can be achieved by nitrification and denitrification. Traditionally, phosphorus removal has been implemented by an addition of salts of multivalent metals: calcium, aluminum and iron. This method generates additional solids and increases effluent salinity. Biological nutrient removal (BNR), which has been becoming more popular recently, allows removal of nutrients without chemical addition. Application of this technology, however, requires substantial modifications in the existing treatment plants and well-trained operators to run it. In addition, BNR as any biological process is sensitive to the presence of inhibitory substances.

This paper describes respirometric studies on the effect of humic substances on removal of ammonia and phosphorus during biological treatment of landfill leachate with municipal sewage. Returned activated sludge (RAS) from a municipal treatment plant was the source of biomass. Initial respirometric tests indicated that the biological system complied with the Haldane model for inhibitory wastes. Consecutive tests with various doses of humate demonstrated that addition of humate mitigated the inhibitory effect of the leachate on RAS. It resulted in an increase in biological oxygen demand and better removal of ammonia and phosphorus. Non-linear regression analysis indicated that in the presence of 2000 mg/L of humate the biological system complied with the Monod model for non-inhibitory wastes.

Parallel abiotic and biological tests conducted under the same conditions indicated that humate stimulates biological processes, particularly nitrification. Humate was also able to remove both ammonia and phosphorus by abiotic mechanisms. It has been found that biological nutrient removal predominates but at higher doses of humate (>2000 mg/l) abiotic removal becomes significant. It is suggested that humate application would be beneficial for wastewater treatment plants receiving landfill leachate or industrial wastewater streams with inhibitory substances. It would allow improving their efficiency, particularly for ammonia and phosphorus removal without major modifications to their existing treatment process.

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Evaluation of Reactive Materials for the Removal of Phosphate in a Hypolimnetic Withdrawal Treatment System

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Pilot-scale experiments were conducted over three consecutive years to develop effective treatment media to remove phosphorus in a Hypolimnetic Withdrawal Treatment system. Phosphorus was removed by the Phosphex™ treatment technology. This technology utilizes basic oxygen furnace (BOF) slag to adsorb and precipitate phosphorus. The experiments included three large columns, in series, with a combined volume of approximately 3 m³. The columns removed 89% to more than 99% of dissolved PO₄ depending on the influent concentrations and residence times for treatment. Influent PO₄-P concentrations ranged from 0.256 to 0.37 mg/L. Residence times over the period of operation ranged between 0.5 to 2 days. The effluent from the columns was directed through two secondary chambers prior to discharge to the municipal sanitary sewer system. As the final pH of Phosphex™ column effluent is on the order of pH 12 it was adjusted through the addition of CO₂ gas with a gas diffuser, followed by settling to remove precipitates. Aluminum and vanadium in the effluent water were the most significant water quality issues. These constituents were removed by passing the Phosphex™ chamber effluent through an additional treatment chamber containing 5 wt. % zero valent iron filings. Calcium carbonate precipitation was minimised and aluminum removal optimized in the effluent chamber by buffering the pH to between 6.5 and 7.0 and passing the effluent through a graded sand filter. Decreasing hydraulic performance was observed in the second year of the study. This change in performance was attributed to precipitation of calcium carbonate in the bottom and top parts of the initial column. This problem was overcome in the third year by sealing the columns to restrict entrainment of atmospheric CO₂. The pilot testing has shown that removal of phosphorus in the Hypolimnetic Withdrawal Treatment system is feasible using the Phosphex™ treatment technology.

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Model-Based Evaluation of Aerated Facultative Lagoon Upgrades

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SIGNIFICANCE
Many small wastewater treatment plants across North America are being faced with the need to upgrade lagoon installations to keep up with increasing plant loading or to meet increasingly stringent effluent permits (e.g. Johnstown, CO; Trois-Rivières, QC). Relatively few tools exist that allow an accurate evaluation of the capacity of existing lagoon installations as well as their potential for upgrading. This paper presents approaches to processing modeling of lagoon installations that can be applied by engineers to address current design problems arising from upgrade requirements.

METHODOLOGY
This presentation will present process modeling solutions to typical problems faced by engineers in the form of case studies. Each case study will state a) the engineering problem b) data requirements and a protocol to calibrate the model and c) how the calibrated model was used to address the engineering problem. The general process model as configured in the BioWin simulation software is presented in Fig. 1.

CASE STUDY 1: BIOAUGMENTATION FOR IMPROVED NITRIFICATION

Problem:
Bioaugmentation with nitrifying biomass has been suggested as a way to extend the period of seasonal nitrification in a lagoon system operated in Trois-Rivières, QC. What is the best dosing strategy and by how much can the nitrification period be extended?

Solution:
A process model is calibrated by adjusting a single parameter to account for the effects of dissolved oxygen limitations on the growth rate of nitrifying biomass. The calibrated model is then used to predict the effects of bioaugmenting with nitrifying bacteria on accelerating the beginning and prolonging the duration of the seasonal nitrification period. Simulation results indicate that bioaugmentation could yield good results in Spring but have little effect in Fall.

CASE STUDY 2: AMMONIA RELEASE FROM LAGOON SLUDGE LAYER

Problem:
Installation of fixed-film reactors has been proposed upstream of a lagoon installation in Sainte-Julie, QC to achieve low temperature nitrification. Downstream lagoons would essentially be limited to the role of polishing ponds. In this scenario, do
*downstream lagoons need to be desludged to avoid excessive release of ammonia into the effluent?*

**Solution:**

A process model is calibrated based on sludge accumulation data for a lagoon over a five-year period. The calibrated model will be used to predict the effluent ammonia concentration and relative sources of ammonia load (i.e. influent ammonia *versus* ammonia released from the sludge phase) for the scenario in which the lagoon was located downstream from a fixed-film process with BOD₅ and NH₃-N concentrations of 20 and 2 mg/L, respectively.

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Photoreactivation is a repair mechanism occurring in many bacterial species; it allows for the restoration of damaged DNA following exposure to ultraviolet (UV) irradiation. The damage consists of dimerization of adjacent thymine bases. This defence mechanism involves the photostimulation of photolyase enzymes by wavelengths in the visible light range (peak at 368 nm). Photolyase is able to restore the dimers back to their initial configuration. The magnitude of photoreactivation is inversely proportional to the initial applied UV-C dose (200-290 nm): the more irradiation a cell receives, the less it is able to reactivate using this mechanism.

Little is known about the response of photolyase to various photoreactivating intensities. As the use of ultraviolet technology increases in North America, determining the conditions inhibiting photoreactivation can minimize the contact time associated with disinfection, and/or decrease the UV intensity required to reach standard disinfection levels. Currently, the Quebec Ministère du Développement durable, de l’Environnement et des Parcs assumes a 1 log photoreactivation for assessing required UV doses for wastewater treatment. However, a deeper understanding of photoreactivation combined with the effluent discharge conditions following treatment could eventually change this number.

A recent report suggested that photoreactivation takes place above a certain threshold of visible light intensity, hence behaving like an on-off mechanism. The threshold was approximately 700 lux. The focus of this research is to 1) confirm a threshold intensity value for photoreactivation of indicator organisms found in wastewater and 2) evaluate the sensitivity of the threshold to the applied UV-C dose as well as to delayed exposure to photoreactivating light. An additional objective is to quantify photoreactivation levels when microorganisms are subjected to simultaneous exposure of UV-C and visible (photoreactivating) light, thus mimicking medium-pressure UV lamps which have outputs in both ranges.

Wastewater samples were collected from the Montreal Wastewater Treatment Plant which employs physicochemical treatment. A low-pressure UV-C lamp emitting at 254 nm was used to irradiate samples, and time of irradiation was determined by the desired dose and the average intensity of the UV lamp. Photoreactivation experiments were conducted in ventilated light chambers containing wide-spectrum GRO-Lux lights. Fecal coliform (FC) counts were assessed by standard membrane filtration methods.
Preliminary results suggest that the photoreactivation increase of FC counts at 50 mJ/cm² initial UV dose is half the increase at 10 mJ/cm² (0.68 log and 1.27 log, respectively). When exposure to visible light is delayed by 3 hours, at 50 mJ/cm² and 20 mJ/cm² the photoreactivation effects drop to 0.33 log and 0.65 log, respectively. Three hours represents the hydraulic residence time in the effluent discharge tunnel at the Montreal Wastewater Treatment Plant, hence 1-log photoreactivation in this case would be an overestimation. Preliminary results also suggest a gradual decrease in photoreactivation for visible light intensities ranging from 200 to 8 lux. These findings contradict previous studies which set the critical level at 700 lux. Additional work is underway to clarify this phenomenon.

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Ammonia Extraction using AmRHEX to Reduce Recycle Water Ammonia Load from an Anaerobic Sludge Digester

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Typical recycle flows from anaerobic digester sludge dewatering contain ammonia concentrations of 500 - 1000 mg N/L. Ammonia concentration often exceeds 2000 mg N/L in flows from organics digesters solids dewatering. High concentration ammonia flows are amenable to physical-chemical treatment, however operational and cost considerations have limited the employment of this approach to only a few applications in the wastewater field. Two technological advances permit the AmRHEX machine to exploit the well established relationships between pH and ammonia ion and gas phase fractions. SpiraFlow media is a proprietary, high specific surface area mass transfer media developed by 3XR. It features a coiled laminar structure instead of the random packing incorporated into conventional stripper and scrubber equipment. The specific benefits are low head loss and plug free operation. SpiraFlow media is coupled with horizontal rotating extractor (RHEX) technology to efficiently extract ammonia from wastewater and react it with an acidic reagent by way of a recirculating head space gas.

This offers the opportunity to remove a significant fraction of the ammonia loading prior to biological treatment at a substantial saving in operating and equipment costs.

A prototype AmRHEX machine was operated at both the Skyway Treatment Plant in Burlington Ontario (Halton Region) and at the Dufferin Organics Digester (City of Toronto). The demonstration operations confirmed that the machine worked as designed. The nature of the operation was demonstrated and the efficacy at reducing high ammonia concentrations to levels where biological processes are more economical was demonstrated. Opportunities for scale up to higher capacity were developed and tested. Data will be presented showing the effectiveness of the machine at reducing ammonia concentrations from 550 mg/L and 2200 mg/L to 100 mg/L without the addition of chemical to the wastewater. Recovered ammonia was removed both as a high concentration liquid and in solid form.

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Ammonia Removal during Canadian Winters: An Investigation of Nitrifying Biofilms at Low Temperatures

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Ammonia removal within wastewater treatment plants is often achieved by nitrification, which is the sequential, biologically mediated, oxidation of ammonia via nitrite to nitrate in the presence of oxygen. The well established temperature sensitivity of nitrifying bacteria, however, creates considerable difficulties for current wastewater treatment plants to achieve ammonia removal during winter months in northern climates. In fact, numerous laboratory studies using suspended nitrifiers demonstrate that little or no growth of nitrifying bacteria is expected below 4 degrees C.

Notwithstanding the overwhelming evidence pointing to a lack of nitrification at low temperatures, there is some published speculation and some field data confirmation that attached growth nitrifying bacteria in the form of biofilms have the potential to achieve ammonia removal at low temperatures. In this work, we investigate the ability of attached growth treatment systems to achieve nitrification at 4 degrees C for a span of 4 months, which corresponds to the lowest average temperature and the average span of winter conditions for treatment plants in Canada. The experimental work consists of an investigation of the kinetic nitrification rate of an attached biofilm and an investigation of the structural and ecological variance of the in-situ bacterial biofilm.

The kinetic rate experiments were conducted using a laboratory continuously-stirred-tank-reactor with recirculation. Ammonia, nitrite and nitrate concentrations were monitored along with dissolved oxygen and pH concentrations. The design of the reactor incorporates a substratum sampling method that enables sampling with minimum disturbance of the in-situ biomass. A novel protocol to characterize the biofilm, as it remains attached to the substratum onto which it was grown, in terms of its structure and ecology was developed and used in this study. Thus, loss of mass and distortion of in-situ perspective that is prevalent during detachment procedures is minimized.

The combined microscopic techniques of environmental scanning electron microscopy (ESEM) and confocal laser scanning microscopy (CLSM) form the biofilm characterization protocol used in this study to investigate attached biofilms. ESEM was used to produce surface images of the attached biofilm to quantify the structure of the biofilm in terms of percent coverage and thickness. CLSM in combination with fluorescent staining of the bacterial cells and Fluorescent In-Situ Hybridization (FISH) of specific genera of bacteria was used to characterize the ecology of the biofilm. The 3D CLSM images were analyzed to quantify the ecology of the biofilm in terms of the strains of bacteria, the distribution of bacteria and the number of bacteria that exist within the biofilm.
This work provides kinetic and microbial evidence of attached growth nitrification at 4 degrees C for a period of 4 months. The experimental data shows decreasing rates of nitrification after prolonged exposure to 4 degrees C conditions. Although the kinetic rate of nitrification drops with increased exposure to low temperatures, the rates after a 4 month exposure to 4 degrees C conditions remain promising for biological nitrification in cold climate countries. The microbial analysis of the biofilm demonstrates promising results for the maintenance of an active nitrifying community even after 4 months of exposure to 4 degrees C.

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Membrane Fouling by Anaerobically Digested Sludge

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The use of AnMBRs for sludge digestion has received little attention, however, if feasible they could be employed to concurrently thicken and digest sludges with reduced footprints and capital costs as compared to current practice. Membrane fouling is considered to be the most significant issue limiting membrane bioreactor application. An understanding of the parameters that control membrane fouling is critical for successful AnMBR application. While there has been considerable study of fouling of membranes under aerobic conditions, there is limited information on these phenomena under anaerobic conditions. The objective of this study was to quantify the impact of common design and operating parameters on the rate of fouling of membranes when processing anaerobically digested WAS.

APPROACH

Short term filtration tests were conducted using a bench scale membrane setup. The testing conducted in this study was completed in two phases (preliminary and detailed). In the preliminary phase the critical permeate flux was determined for two different membranes (negative and neutral surfaces) using a relatively dilute feed (approximately 6 g TSS/L) that was obtained from a pilot anaerobic digester treating thickened WAS at a 15 day HRT. The detailed testing phase involved an evaluation of the impact of feed concentration, permeate flux, membrane type and filtration test duration on the membrane fouling rate.

RESULTS

TMP versus flux profiles were determined for tests that were conducted with clean water and digested sludge. The clean water data showed a linear relationship between the TMP and flux for all membranes. For the digested sludge, the relationship between the TMP and flux was linear between 6 to 20 LMH and a sharp increase in TMP was observed beyond 30 LMH. From these results it was concluded that the critical flux was in the range of 30 LMH and operation beyond this range would cause irreversible fouling. In comparison to the negatively charged membrane, the neutral membrane required larger TMPs to obtain the same permeate flux.

In the detailed testing it was observed that at a flux of 8 LMH the TMP response was similar for the dilute and concentrated feeds despite a three fold increase in solids concentration. However at the higher permeate flux of 30 LMH the TMP increased significantly faster for the concentrated feed as compared to the dilute feed. The difference in response between the low and high fluxes could be due to increased rate of mass transfer of material towards the membrane surface for the latter resulting in increases of deposits at the membrane surface there by increasing the fouling rate. For operation of AnMBRs at a high flux options such as intermittent filtration that could
allow deposits to relax or decreasing the colloidal concentration by feed treatment might be considered. The results obtained in this study provide clear indications of the feasible operating conditions for AnMBR membrane operation. The full paper will present all of the results that have been obtained and will provide in-depth analysis and discussion.

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Nanoparticles in Wastewater Sludge – Future Concern

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Nanotechnology involves production and use of extremely small particles (1 – 100 nm size scale), wherein the particle synthesis is controlled or manipulated at the molecular level. Moreover, the market size for nanotechnology products is predicted to grow exponentially to $1 trillion by year 2015. The major industries currently using nanomaterials include personal care products, pharmaceutical, automobile, electronics, paints and coating industries. Sun screens, cosmetic products, drug delivery systems, batteries, spill resistant fabrics, wear resistant protective coatings, heat transfer fluids, durable tennis balls and point of use filters are some of the products that contain nanoparticles. Metal oxide nanoparticles (e.g. ZnO, TiO2, SiO2, CeO2, LiCoO2) are primarily used in personal care products, semiconductor polishing, batteries and fuel cells. Likewise, nanostructured polymers and surfactants used in drug delivery and environmental remediation. Although the use of nanomaterials is rapidly increasing, very little is currently known about their fate, transport and toxicity effects of nanoparticles in the environment. EPA and other organizations have recently initiated studies to evaluate some of these issues, but every aspect has not been still explored.

The increasing use of nanoparticles in everyday products increases the potential for their release in water sources and wastewater streams. The release of nanoparticles into the wastewater streams may have the following implications: a) when present in trace levels (µg/l), based on toxicity study data, some nanoparticles may potentially be added to the list of constituents to be removed prior to water recharge/reuse applications and; b) when present in higher concentration (mg/l), the nanoparticles may impact the performance of waste treatment processes by various mechanisms, including inhibition of microorganisms in activated sludge, increasing the turbidity, fouling of membranes or affecting the efficiency of disinfection processes. No methodical studies have been performed till date to evaluate the removal of nanoparticles during various wastewater treatment processes and consequent presence in wastewater sludge which is the ultimate sink. There is a possibility that these nanoparticles agglomerate or even get adsorbed to the extracellular polymers during primary and secondary treatment eventually ending up in wastewater sludge. This presentation will discuss the gaps in research and challenges that we face on the fate of nanoparticles in the environment, in general and wastewater and wastewater sludge, in specific. Moreover, does the presence of nanoparticles in wastewater sludge really raise an alarm when we are still tackling with the macro-quantities of heavy metals and polycyclic aromatic hydrocarbons?

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Evaluation of a Pilot Scale Membrane Supported Biofilm Reactor Treating High Strength Industrial Sewage

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Background
The membrane supported biofilm reactor process has been developed and studied at lab and pilot scale in several universities since the 1980's (Casey et al., 1999). The membrane is submerged in the liquid waste and a gas (oxygen or air) is circulated inside the lumen. The membrane serves as a media for biofilm growth and to transfer oxygen directly to the biomass without bubble formation. The substrates diffuse from the liquid phase on the opposite side of the biofilm.

The process looked promising with high rates of carbon and nitrogen removal, the ability to absorb shock loads, a reduced footprint, and unprecedented oxygen transfer performance. However it has never been commercialized due to difficulties appearing with long term operation. After several months, the membranes may wet or clog and the biofilm may grow too thick, leading to anaerobic system failure (Semmens et al., 2003).

Objective
Zenon has developed a new gas permeable hollow fiber membrane combining a high surface area with resistance to wetting. After lab scale testing, two pilot scale units were designed and operated in parallel for 16 months with a high strength synthetic feed mimicking the biodegradable effluent of a chemical factory. The objectives included:

- assessing the treatment performance for this specific sewage and effluent compliance with common sewer discharge bylaws (TSS < 350 mg/L, BODs < 300 mg/L, TKN < 100 mg/L),
- verifying the durability of the membrane,
- devising the best method to control biofilm growth,
- collecting information for the design, start up and operation of a demonstration scale unit treating the actual effluent of the factory.

Description of the pilot plants
Each pilot plant consisted of 3 vertical cylindrical tanks in series, totaling 12 L. Each tank contained 2 modules of hollow fiber membranes in a tow configuration, totaling 10 m² (840 m²/m³ tank). The fibers were fed with compressed air. The methods to control biofilm growth in the first 2 stages included step feed and intermittent mixing. Unit A was mixed with air while unit B was mixed with inflating/deflating bellows. The last stage was not mixed to act as a settler.
Results
Detailed monitoring of the liquid streams, the air streams, and the biomass (biofilm + suspended solids) allowed to:

- verify mass balances,
- calculate carbon and nitrogen removal yields and rates for the whole system,
- calculate the contribution of each stage,
- monitor the biofilm growth,
- determine the oxygen transfer and sludge production.

After 16 months the biofilm was still slowly growing in both units, but there was no sign of system failure. The effluent concentrations were usually well below the sewer discharge limits, but both systems experienced transient performance drops. Their results will be presented in detail for two periods with increasing influent concentration (1300 and 4600 mg COD/L). To evaluate the benefits of the new process, its footprint, energy requirements and sludge production will be compared with more traditional processes when treating a similar sewage.

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Environmental Modeling

Chairs: Fedous Ahmed and Hugh Monteith
Dispersion and Hydrodynamic Connectivity of Near-Surface Waters: Applications of a 3D Ocean Circulation Model

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This presentation discusses the applications of a hydrodynamic model in Lake Huron and a coastal embayment, Lunenburg Bay on the south coast of Nova Scotia, Canada. The modeling system is based on the three-dimensional, primitive-equation z-level ocean circulation model known as CANDIE, and forced by wind forcing and climatological surface heat flux in the Lake Huron, and forced with the local wind, tides and remotely generated coastal waves in Lunenburg Bay. The 3D model currents are used to examine the dispersion and connectivity of passive particles at near-surface waters in the study region. Hydrodynamic connectivity of near-surface waters is studied using the transition probability matrix (Thompson et al., 2002), which quantifies the probabilities of passive particles that make a transition from one area to other areas during a fixed time interval.

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The Structural Harmony Chart of Hydrosphere as the Controlling Tool in Environmental Modeling

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The main feature of the Structural Harmony Chart of Hydrosphere (SHC), as it was found by Fletcher’s Creek project and presented at the 23rd East Canadian Symposium of CAWQ at Sherbrooke University in October 26, 2007, is the complete agreement between the structures of quantitative and qualitative parameters’ fluctuations (www.hydrology.ca/hydenvir.pdf). The correctness of this feature was investigated for different watersheds using the Separated Flow Approach (www.hydrology.ca/hm_web.pdf) enhanced by the SHC involvement.

Two watersheds were chosen for this purpose: the previously used watershed of Etobicoke Creek in its mouse (204 km²) characterized by the heavy anthropogenic impact, and the pristine Estonian peat bog stream Linnussaare (1.8 km²).

In order to estimate the structural divider Ki for the separated flow, the initial SHC was created using the available meteorological and hydrometrical data. The obtained separated flow was used to estimate the base, moderate and extreme components of the sought total daily concentrations of chlorides and heavy metals, which were verified by highest possible correlation coefficients between calculated and sampled concentrations. After the loads assessment, both concentration’s and load’s series were processed using the SimpleBase Delineation Model to estimate their fluctuation structures and to place them on the initial SHCs (see figures below: squares indicate base, triangles – moderate, and rhombuses extreme components; concentrations are located higher than loads on the base curve).

The qualitative and quantitative structures of parameters’ fluctuations are strongly agreed with each other proofing the entirety of hydrosphere and its structural singularity at any point. The huge extreme or storm component in case of Etobicoke watershed indicates destabilisation of hydrosphere at this location. For pristine watershed with low concentrations the Separated Flow Approach gives more rough result than for highly impacted one.

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Land-use Management and Watershed Health

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The soil conservation strategic plan with six projects was initiated by the Iranian Soil Conservation and Watershed Management Research Institute a year ago. The plan aims to reduce adverse environmental and economical impacts of soil erosion caused by improper management of land-use activities and will be carried out as pilot cases in a number of watersheds. One of the projects is entitled "optimizing land management for soil conservation". It is known that land-use optimization is one of the appropriate strategies for soil conservation. It can empower the decision makers and watershed managers to choose from different land-use scenarios to reach the best decision between the different combinations of variables.

The main objective of this research project is to study the optimized combination of land uses for minimized soil erosion and maximized people's net income. A linear programming model was applied in three different land-use scenarios including traditional land uses plus land management, traditional land uses with some degree of land management and standardized land uses plus land management. The study watershed was Kharestan watershed located in the northwest of Eghlid, Fars province, Iran. The results showed that current land uses are not optimized for minimum soil erosion and maximum net income. In the optimized condition, the area of orchards should be increased from 561 to 2115 ha (by 377%), rangelands with no changes, irrigated lands should be reduced from 871 to 237 ha (by 73%) and drylands should be decreased from 1050 to 207 ha (by 80%). Also, the results demonstrated that by traditional land management, land-use optimization, decreases soil erosion by 3.7% and increases net income by 163%. In traditional land uses implementation, some land management decreases soil erosion by 37% and increases net income by 206%, while in standardized land uses and management scenario, soil erosion decreases by 53% and net income increases by 208%. Sensitivity analysis showed that the area of orchards and rangelands are the most sensitive parameters and their changes have the most effects on the amount of net income and soil erosion.

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Modeling Biotransformation of Estrogenic Hormones in Municipal Wastewater Treatment

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Constituents in treated municipal wastewater effluents, such as synthetic hormones, pesticides and industrial chemicals in commercial products, can exert endocrine disrupting properties in receiving waters. One group of constituents that has been scrutinized intensively for their endocrine-disrupting potential is human hormones, chiefly the natural hormones 17β-estradiol and estrone, and the synthetic hormones 17α-ethinylestradiol and mestranol used in human birth control.

Mechanisms for the biotransformation of natural and synthetic estrogenic hormones in secondary wastewater treatment have been postulated in the literature. Biotransformation rate constants have been proposed, but there has been no testing and calibration of these rates with actual plant concentration data. In addition, while the knowledge base of hormone concentrations in treatment plant influents and effluents is substantial, the ability to evaluate the factors governing the extent of secondary biodegradation of metabolites under different operating conditions could not be attempted due to a lack of adequate modeling tools.

This paper will discuss the application of a dynamic model for predicting the fate of hormones during municipal wastewater treatment, with calibrations using published concentration data. Applications of the dynamic model will include:

• How would a shorter hydraulic retention time (HRT) affect the primary and ultimate degradation of the hormones?
• What effect might a higher solids retention time (SRT) have on the fate of the hormones?
• If the dissolved oxygen level in wastewater treatment falls below a critical concentration (e.g., 0.5 mg/L) how will the biodegradation of hormones be affected?
• Are there optimizing procedures which can be used to promote the ultimate biodegradation of the hormones?

The wastewater treatment simulator will also provide the distribution of effluent concentrations of the hormone metabolites for use in fate models which represent the receiving environment, including water sediments and biota.

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An optimization modeling for water quality management under uncertainty

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In river water quality management systems, there are many factors that should be considered by the decision makers, such as climate change, population growth, and river flow conditions. Moreover, many system parameters, impact factors and their interactions are associated with uncertainties. The spatial and temporal variations in many system components may further multiply these complexities and uncertainties. Therefore, to deal with these complexities and uncertainties, inexact system analysis techniques are desired to assist in developing long-term water quality management plans. Consequently, a number of stochastic, fuzzy, interval programming models were proposed to deal with these complexities. Inexact approach of water quality management system is vital under changing climate and economic development. This research proposes an interval-parameter optimization model (IPOM) for water quality management under uncertainty. Compare with other optimization techniques, the proposed modeling approach has two advantages. Firstly, it reflects uncertainties expressed as discrete intervals. Secondly, it provides a simulation for river water quality. The proposed IPOM method is applied to a hypothetical case study of river water quality management.

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A Survey of Some Physico-Chemical and Polyaromatic Hydrocarbon (PAH,s) Contents of Sediments at the International Zone, Northwest of the Persian Gulf

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The inertial zone of Persian Gulf area is generally subjected to several sources of pollutions from both seaside and inland area. The harsh natural environment of these shores with very saline and hot environment already has made the ecosystems of the shores very sensitive for fauna and flora. So, adding pollutions from both inlands and offshore have made the situation even worse. Therefore, a general survey of polyaromatic hydrocarbons (PAH,s) at the inertial zone of northwest area of this highly polluted Gulf was taken to evaluate the type and extent of these persistent and carcinogenic compounds within a section of about 300 km.

Over hundred sediment samples were taken from the inertial zone using perpendicular transects to the shores at three depths of 0-10, 10-20, and 20-30 cm. In each transect a total of 9 samples were taken. The samples were analyzed for some physical, chemical such ECe, pH, OC, ON, C/N ratio, clay content and the 16-PAH of US-EPA select for the analyses. The results showed the clay content of the sediments increased from east to west at the section of Persian Gulf coast. The organic carbon content had a similar pattern. However, salinity (ECe) of the sediments was increasing from east to west along the shore lines. The alkalinity of the sediments showed a small increase toward west. These sediment information in addition to the PAH’s will help us to develop vulnerability model for the shore lines, adsorption-desorption and decay model of PAH,s.

Following the sediment sample preparation and extraction of PAH,s from the collected samples using extraction method of US-EPA protocol 30358. The PAH contents of the samples were determined using a HPLC. The results showed a significant accumulation of PAH's at lower depths (20-30 cm) at the transects. From east coast to west coast, generally the content of PAH's increased. However, few transects did follow this trend. In nine of these transects, the total PAH's were above 50 ppb. Therefore at these sites, we should more carefully monitor the sediment quality for these compounds in the future.

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A numerical investigation on flow, transport, and biotransformation of a suite of chemicals in porous media

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In order to simulate the advection, dispersion, and reaction of a suite of chemicals in a stylized network of pores, an integrated groundwater flow and contaminant remediation model is presented in this study. For description of the groundwater flow in the pore-scale network, a novel set of periodic boundary conditions associated with the Stokes model are proposed that help efficiently reduce the computational domain without sacrificing the physical reality. Meanwhile, a system of coupled highly nonlinear equations are formulated that examines the transport and transformation of an electron donor, an electron acceptor, and active biomass. Advanced numerical methods involving adaptive-gridding techniques are employed in solving both flow and transport problems. The numerical simulation results demonstrate the fate of pore-scale transport of the acceptor and donor, as well as the growth of biofilm, providing guidelines for optimization of the process of groundwater pollution remediation.

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Analyzing Lake Erie Sediment Contamination Trends

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Aquatic ecosystems in the Great Lakes Basin have experienced widespread pollution due to the development of manufacturing, industry, mining, and agriculture. Large quantities of harmful contaminants (including arsenic, cadmium, chromium, copper, dieldrin, lead, mercury, nickel, DDE, DDT, and zinc which are analyzed in this research) from these sources can be found in lake sediments. In the 1960’s and 1970’s, and again beginning in the 1990’s, Environment Canada conducted wide-ranging sediment contamination surveys in the Great Lakes. Sediment core samples were obtained using a much denser grid in the historical surveys as compared to the contemporary sampling locations. For Lake Erie, 274 sediment cores were obtained in 1971, with 62 being resampled in 1997/98. Advances in geovisualization software, in particular, tools available within Geographic Information Systems (GIS) enable the generation of interpolated surfaces that are much more interpretable than i.e. conventional dot maps. The interpretation and mapping of point-based sediment contamination measurements without the application of spatial interpolation methods does not allow for data trends to be fully analyzed. The ordinary kriging geospatial analysis technique was used to produce concentration estimates. The results show recent improvements in some contaminant concentrations, however large areas within the lake still exceed sediment quality guidelines in terms of the Threshold Effect Level (TEL) and the Probable Effect Level (PEL). The estimation surfaces provide valuable information that can be used to analyze the spatial distribution of contamination. Where necessary, the data were log transformed in order to provide statistically valid results. For Lake Erie, the problem areas continue to be located in the western and south central portions of the lake. Kriging analysis provides an additional communication tool and means of influencing management options and decisions.

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Calibrating Watershed Models with Limited Data

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Limited data can make calibration of watershed models difficult. A Mike11 model of the Tay River Basin has been used here to illustrate such difficulties and how to work around them. Various measures of model performance and how they can be used when measured data is limited or incomplete have been discussed.

A numerical model for the Tay River Watershed has been developed using Mike11 model of the Danish Hydraulic Institute. The whole watershed has been sub-divided into 19 sub-basins, which were modeled using the rainfall-runoff (RR) module of Mike11. The Tay River, its tributaries and associated lakes were modeled using the hydrodynamic (HD) module.

Measured stream flow data at two locations (Perth and Port Elmsley) was available for a few years, but with significant data gaps. One set of data was used for calibration and other for validation. Due to data gaps, performance statistics could be measured only for the calibration period, but not the validation period.

Model performance has been appraised using various methods. Satisfactory results have been obtained for the higher end of the flow spectrum. Addition data and fine tuning are needed for the low flow simulation.

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Geostatistical Analysis of Lake Ontario Sediment Contamination

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This research examined sediment contaminant concentrations in Lake Ontario. The data were collected as part of the Environment Canada Great Lakes Sediment Assessment Program. Arsenic, cadmium, chromium, copper, dieldrin, lead, mercury, nickel, DDE, DDT, and zinc concentrations for 277 historical (1968) and 69 contemporary (1998) sediment cores were analyzed using GIS-based ordinary kriging spatial interpolation techniques. Geospatial analysis has become increasingly important when examining spatial trends as it provides a means of interpolating contamination estimates between sampling locations. In addition to analyzing the full datasets, two further analyses were undertaken. The first removed approximately 50% of the historical data points while the second reduced the historical datasets to approximate the locations that were sampled in the 1998 survey. The results indicate that contamination levels have generally improved, especially when they are evaluated in terms of the Threshold Effect Level (TEL) and Probable Effect Level (PEL) guidelines used by the Canadian Council of Ministers of the Environment. The reduced sample analyses show that the similar patterns of spatial contamination can be observed in comparison to the full historical datasets although in some cases the results are more generalized. Areas of major concern in Lake Ontario are found mostly within the deep lake basins, in proximity to the mouth of the Niagara River, and in the area of Hamilton Harbour.

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Towards Mathematical Models of Activated Sludge with Intrinsic Parameters

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The publication of the International Water Association (IWA) activated sludge models (ASM1, ASM2, ASM2d, ASM3) standardized the mathematical description of microbial activities in activated sludge wastewater treatment systems treating municipal wastewater. This standardization led to a better understanding of the behaviour of these mathematical models. As they are simplified abstractions of reality, the models’ formulation lumps together in a few processes all the complex bio-physico-chemical interactions taking place in the activated sludge. One consequence of this is that the calibrated values of the model parameters are dependent on the reactor conditions from which the sludge is harvested. In other words, the calibrated parameter values cannot be deduced directly from laboratory experiments on pure cultures. They are said to be extant values. This limits our ability to use biochemical properties of pure culture isolates to predict population dynamics such as the temporal variation in the abundance of filamentous bacteria causing foaming and bulking. In turn, this reduced predictive ability limits our capacity at engineering reactor conditions controlling the growth of these organisms. In order to circumvent these limitations, there is a need to develop a next generation of mathematical models capable of using true pure culture parameters, also called intrinsic parameter values. This is the objective of this work.

In order to develop mathematical models of microbial activities in activated sludge using intrinsic parameters, it is necessary to expand the current models to include the main ecological interactions and the main metabolic reactions occurring within the sludge environment. We performed this exercise in the context of studying the accumulation of biological foam on the surfaces of activated sludge systems caused by Gordonia sp. Data collected at a full-scale activated sludge plant suggested that these microorganisms were specialists of lipid degradation. On this basis, we hypothesized that all the bacterial populations present in the sludge are specialized in consuming their preferred compounds, which, according to the IWA-ASM models, classifies the populations as either consuming slowly-degradable or consuming readily-degradable substrates. We also developed a metabolic model keeping track of the level of ribosome (the protein synthesis unit) in the cell. Once calibrated with intrinsic parameters, we showed that this metabolic model was able to adapt the metabolic reaction rates to various reactor conditions and various metabolic configurations.

In this paper, we will present the data that led to the formulation of our ecological and metabolic models. We will also report on the results of diurnal population dynamics experiments conducted on full-scale activated sludge wastewater treatment plants to support our model hypotheses. Finally, we will discuss the implications of these new modelling developments for activated sludge engineering practices.

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Policies and Technologies for Small Communities

Chair: Jim Higgins
Full-Scale Process Evaluation of Recirculating Biofilters --- A Case Study for Residential Wastewater Treatment

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This study aims to evaluate four recirculating biofilters to develop a more improved understanding of the process mechanisms based on a long-term RBF operation (∼2 years) at the Municipality of Lunenburg (NS, Canada). To achieve this goal, this study evaluated each individual component of a RBF system, including septic tank, recirculation tank, filter bed, and UV disinfection (Figure 1).

Due to the shortage of water supply in this community and wastewater mainly coming from bathroom and kitchen, the average septic tank BOD 5 measured in samples (381±64 mg/L) was higher than BOD 5 concentrations reported in other septic tank studies.

To investigate the aerobic BOD 5 biodegradation within the filter beds, this study compared the actual recorded BOD 5 concentrations entering the filter bed (recirculation tank effluents) to the actual recorded BOD 5 concentrations leaving the filter beds. Figure 2 shows that the average BOD 5 removal rates in the sand, crushed glass, peat, and geotextile filter beds were 58 %, 64 %, 35%, and 39%, respectively. The average reduction rates for NH 4 + -N were 96%, 93%, 0%, and 73% for sand, crushed glass, peat, and geotextile filter beds, respectively, which resulted in an average NH 4 + -N concentrations of 0.7±0.4 mg/L, 1.1±0.6 mg/L, 17.4±2.9 mg/L, and 4.5±1.1 mg/L from these four filter effluents.

Using the average septic tank effluent fecal coliform count (1.6×10 8 ±7.9×10 7 CFU/100mL), the log reductions of fecal coliform in this study were calculated to be 1.3, 3.1, 3.9 and 2.2 for sand, crushed glass, peat, and geotextile RBFs, respectively.

This study investigated the function of the recirculation tank based on three of the measured parameters in the field-scale RBF systems, including BOD 5, NH 4 + -N, and TN. The projected TN and other water quality parameters were determined by the combined filter effluent and the septic tank effluent. The average projected and measured TN concentrations in the recirculation tank were 53.2±2.6 mg/L and 41.9±7.3 mg/L, respectively (Figure 3). Figure 4 also demonstrates that there was a difference between projected and actual measured NH 4 + -N concentrations in the recirculation tank. Figure 5 also shows that there was a reduction between the projected (90 ± 23 mg/ L) and the actual measured (36 ± 25 mg/ L) BOD 5 concentrations in the recirculation tank, which resulted in an approximately 60% BOD 5 reduction in the recirculation tank.

It was observed that the UV reactor did not provide sufficient removal to meet the local regulation in this field study, with an average 1.5 log-reduction for fecal coliform removal.

This study evaluated the process performance by investigating each individual component of a RBF system. It was found that the recirculation tank functioned as a bioreactor chamber for biodegradation, dilution, and mixing of water quality. The filtration beds provide aerobic BOD removal and nitrification processes, which could produce effluent with NH 4 + -N concentrations less than 1.0 mg/L. However, the UV reactor was not able to inactivate fecal coliform effectively.
Figure 1: Field-Scale RBF Design
Figure 2  Comparison between BOD₅ entering and leaving the filter bed: (A) sand; (B) crushed glass; (C) peat; and (D) geotextile.
Figure 3  Comparison of projected TN in the recirculation tank and measured TN in the filter effluent

Figure 4  Comparison of projected and actual NH₄⁺-N concentrations in the recirculation tank and measured filter effluent NH₄⁺-N concentrations

Figure 5  Comparison of projected and actual BOD₅ concentrations in the recirculation tank and measured BOD₅ concentrations in the combined filter effluent

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Treatment Wetlands for Wastewater Treatment in Small Communities in Northern Canada

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This paper will evaluate the use of treatment wetlands to manage municipal sewage and other wastewaters at northern Canadian locations, including those in the Arctic. It will provide background on natural wetlands, and on artificial wetlands such as created and constructed wetlands (CWs). The paper will overview the ecology, biology, pollution removals, costs, strengths & weaknesses, and designs of treatment wetlands in temperate areas and in more northerly ones. It also will review an advanced engineered wetland technology, the research that has occurred to develop this technology, and discuss how it may be used to upgrade existing lagoon-based wastewater treatment systems now used in many northern communities. (Engineered wetlands are advanced, semi-passive kinds of constructed wetlands that are much more efficient than ordinary CWs and can operate with superior pollutant removals, year-round, even under extreme weather conditions.) The impact of northern locations on the design and construction of treatment wetlands will also be addressed.

The proposal also will address the development and subsequent implementation of a new kind of natural treatment wetland for the Arctic now known as a Tundra Wetland. With Tundra wetlands, sewage is treated seasonally in natural bog areas by passing it through large areas of tundra vegetation and small ponds. The proposed paper will present data on the implementation of two new Tundra wetland systems in Nunavut: one at the hamlet of Coral Harbour on Southampton Island in the north part of Hudson Bay, and one at the Town of Baker Lake.

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Nitrogen Removal Through Recirculation and the Use of Carbon Media in the AQUA Wetland System

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The Aqua Wetland System (AWS) is a wetland design which uses intermittent pressure dosing and vertical sub-surface flow to maintain aerobic conditions to provide reliable year-round performance. The wetland is four feet deep, with three or four cells, each with specific media, operated in series to achieve a high level of nitrogen removal. The first cell receives septic tank effluent and recirculates the wastewater through gravel media. The second to last cell contains organic media such as wood shavings which provide a slow-release carbon source for denitrification under saturated conditions. The final cell contains a medium grained sand to provide a final polishing and may also incorporate recirculation within the cell. The surface layers of all cells consist of a sand and peat mixture around the dosing pipes with a mulch and plant litter layer on the surface. Cells are generally planted with nursery grown cattails (Typha sp.) but may be planted with aesthetically desireable plant species, such as wildflowers from seed.

The AWS provides tertiary treatment for a wide variety of wastewater types, including septic tank effluent, landfill leachate, high strength winery process water, bakery process water, abattoir wastewater, compost leachate from mushroom farms, and greenhouse irrigation leachate. Over fifty wetland systems have been installed since 1998, over thirty operating under Ontario MOE Certificates of Approval, two approved by Health Canada for sanitary sewage on First Nations Reserves, several approved under the Ontario Building Code and two permitted by NDPES for landfill leachate in the United States. A Certificate of Approval is not required for the remaining systems because they are closed loop systems with no discharge to the environment. The smallest AWS treats 1,850 L/day of sanitary sewage at a cottage in northern Ontario and the largest treats 400,000 L/day of greenhouse irrigation leachate at a greenhouse in southern Ontario.

The initial once-through flow pattern of the AWS provided excellent removal of BOD and TSS. Recirculation of cell 1 effluent was introduced partly to reduce the BOD in high strength industrial wastewater which could overload the sand media, but it was found that this resulted in greatly improved nitrification and denitrification. Subsequently, the addition of carbon media to a saturated penultimate cell was introduced as a means of further reducing nitrogen to levels as low as 3 mg/L total nitrogen.

Recirculation of cell 1 effluent enhances denitrification by lowering BOD to allow nitrifying bacteria to compete and then by bringing the nitrate back to a large pump chamber or septic tank where anaerobic conditions and carbon in the wastewater provide conditions for denitrifying bacteria to convert nitrate to nitrogen gas. Because the recirculation rate is low, approximately 1 Q (daily flow volume), some nitrogen will pass through to later wetland cells.
where the carbon source is provided by wood shavings or chips and the low oxygen conditions are maintained by saturating the bottom half of the cell.

Data is shown from a Niagara winery where the wetland cell 1 was modified for recirculation. Ammonia and nitrate levels were variable and elevated previous to the onset of recirculation, changing to uniformly low ammonia and nitrate concentrations after. An effluent with 8 mg/L total nitrogen and almost complete nitrification was achieved.

Data is presented from subsequent projects where carbon media was used, improving nitrogen removal to 3 mg/L total nitrogen.

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Sustainable Point-of-Use/Entry Drinking Water Treatment in Canada

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The provision of safe drinking water is an inherently challenging task. Instead of focusing on centralized treatment for contaminant removal, some studies favour the development of decentralized systems in certain situations for optimal utilization of resources. However, the question remains whether these systems are more sustainable than centralized water treatment systems in the more integrated sense. This paper focuses on point-of-use (POU) and point-of-entry (POE) water treatment as an increasingly sought decentralized alternative for ensuring the safety of drinking water. This increase in the adoption of POU/POE devices can be attributed to the emergence of new technologies with high removal efficiencies of water contaminants that can be implemented on a smaller scale to suit the needs of a small community. Membranes, adsorptive resins, and ultraviolet systems are some of the technologies considered promising for small water systems. With the commercialization of these devices, however, the task of selecting a suitable device for treatment has become cumbersome. In an extensive literature review an overview of the drivers for the adoption of POU and POE water treatment in Canada will be given. The various aspects pertaining to the selection of a certain treatment technology including regulatory, economical, social, and technical elements were carefully investigated. Finally, a conceptual framework for the proper selection of sustainable POU/POE devices needed to improve water quality, whether for health or aesthetic reasons, was developed. This framework encompasses indicators used to select and rank POU/POE treatment devices.

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Sustainable Wastewater Infrastructure for Small Communities

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Enabling development while protecting water resources and preserving natural open space is a challenge that small communities, developers and regulators must address to ensure the continued economic growth of their communities. Smart growth development, which preserves open space for recreation and wildlife habitat, is fast emerging as a top strategy for creating livable, neighborhood-friendly and environmentally sound communities. Open space development is characterized by homes clustered together within the development with the remaining area preserved as natural habitat. By preserving large areas as open space, wildlife habitat can be protected and hiking trails and other recreational amenities can be developed for the community at large.

Because the water and wastewater infrastructure is a major contributor to any development cost, alternative solutions for wastewater management are needed for the creation of the new wave of environmentally attractive open space developments. Decentralized, onsite wastewater management provides an alternative that breaks the economic binds that a centralized sewer system places on small communities and developers and allows sensible land use decisions within the economic realities of the development community. Community wastewater systems, many incorporating engineered wetlands are emerging as one of today’s “green” choices for onsite treatment and are providing efficient, cost effective wastewater infrastructure for smart growth development.

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Investigating the Performance of Constructed Wetlands in the Treatment of Municipal Wastewater in Northern Communities

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The Canada-Wide Strategy for the Management of Municipal Wastewater Effluent calls for implementation of significantly increased treatment of municipal sewage across Canada. However, as populations and their concomitant infrastructure needs grow in the Arctic, communities are faced with unique challenges in the treatment of municipal wastewater. Territorial Hamlets, with typically very small resident populations, cannot afford millions of dollars in capital investments required for modern sewage treatment facilities. The technologies suitable for northern applications need to be simple in operation, effective in performance and economical in use. Under these environmental, socio-political and economic conditions, constructed wetlands have been demonstrated as a viable wastewater treatment technology option.

Constructed wetlands are used in the treatment of point and non-point sources of pollution that take advantage of complex natural wetland processes involving microorganisms, plants, substrate (such as soil or aggregates), water, air, and the sun. They mimic natural wetlands in more or less controlled environment treating pathogens (such as E. coli and coliform bacteria), excess nutrients (nitrogen and phosphorus), organic matter (BOD5,) and other types of contaminants. While treatment wetlands are in use in many locations, there is a significant paucity of knowledge about their performance in northern communities. Research is needed that will assess treatment performance and that will examine design options most suitable to Arctic communities. Hence, this research will have the following components:

• Characterization of existing wetlands/ lagoons in six communities in Kivalliq region of Nunavut
• Experimental column tests under Arctic conditions in an environmental chamber at the Centre of Alternative Wastewater, Fleming College
• Pilot-scale implementation of engineered constructed wetlands (CW) in two communities in Kivalliq
• Calibration of an existing treatment wetland design model (SubWET Model).

It is expected that existing treatment wetlands in some communities will be found to be highly effective in the remediation of regulated parameters, while others may be found to be significantly ineffective at treating one or more parameters, at particular
times of the year, or under high loading conditions. This is anticipated because of the array of local conditions, differences in design and extent of treatment systems, and the ranges in strength of sewage effluent. Insights into the limitations and upper performance thresholds of various systems will provide greater understanding of treatment wetland bio-chemical processes unique to Arctic environmental conditions and allow for a validation of a pilot scale prototype design that can be scaled up. The modelling will provide a design tool for not only scientists but decision makers that can also be used in the identification of problems and for use in troubleshooting solutions through modified scenarios. Infrastructure and logistical limitations to implementation will also be examined and noted.

In summary, this research will provide important new knowledge concerning wastewater treatment challenges in the Canadian Arctic and will make significant contributions to the health and well-being of Northern peoples and their environment by improving our understanding of safe and appropriate wastewater treatment solutions.

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Drinking Water Source Protection

Chairs: Larry Moore and Simon Gautrey
Perfluoroacids in Canadian Rivers

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Perfluoroacids (PFAs), including perfluorooctanoic acid (PFOA) and perfluorooctane sulfonate (PFOS), belong to a family of chemicals that are persistent and deleterious to the environment. As such, they are under scrutiny by government agencies who must determine their risk to the general population and to the environment. Numerous studies have measured PFOS and PFOA in selected areas of the world, but no study has systematically measured these compounds throughout the freshwater environment of a country. This presentation reports on the concentrations of PFAs in 51 rivers across Canada (42° to 60° N and 62° to 94° W). Locations near populated areas were sampled upstream and downstream sites for that community. Samples were collected from 2005 to 2007. Values of PFOS ranged from <0.001 to 7.6 ng/L and PFOA ranged from 0.078 to 7.8 ng/L. Highest concentrations occurred in areas of high population densities, most notably in southern Ontario. Samples collected from glacier melt water contained the lowest levels of these compounds generally just above the MDL (<0.001 to <0.01 depending on the date of analysis). Of the 5 communities that were sampled upstream and downstream, there was a general increase in the PFOA and PFOS levels in the downstream sites. In the St. Lawrence River, concentrations were higher in samples collected near Bécancour than at sites near Quebec City and Lavaline.

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Mainstreaming Climate Change in Drinking Water Source Protection Planning in Ontario

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While some uncertainty remains, recent projections suggest that climate change effects in Ontario will include substantial temperature increases and changes in seasonal precipitation distributions, with more expected in the winter and less in the summer. Extremes, in the form of droughts and high-intensity rainfall events, are also expected to become more common. These anticipated changes are significant because they are outside of the historical or observed range of variability.

Due to the way it affects the hydrological cycle, global climate change is a local problem which specifically challenges source water protection measures being undertaken. Accordingly land use and infrastructure planning decisions being made today should account for the ways in which climate change will affect water resources. Thinking about the way in which climate change affects the hydrological cycle, and how these changes affect human societies and ecosystems, will permit earlier and more effective adaptation.

This presentation will provide information on how climate change will affect Ontario weather patterns and offer practical advice on how to incorporate the expected impacts of climate change on our surface and groundwater resources in watershed-based source protection plans. This will include discussion on how to develop appropriate adaptation strategies to deal with climate change as a component of source protection planning.

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An Investigation of Techniques for Hydraulic Intake Entrainment Envelope Delineation

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Hydraulic intakes represent the starting point of surface water delivery for industrial, commercial, and municipal consumption. Subsequently, it is vital to protect the hydraulic region from which the intake withdraws its water. The first step in developing guidelines for protection is the delineation of this critical region of withdrawal. The intake entrainment envelope defined herein represents the region where intake-bound velocities are sufficient to pull contaminants into the intake. A computational model was developed in an attempt to delineate this envelope for inviscid and viscous flow conditions. Inviscid results from the computational model were then checked against a potential flow theoretical model. Finally, experimental flow visualization was conducted to compare to the computational and theoretical results. The introduction of viscosity to the computational models revealed interesting limitations in the potential flow envelope prediction techniques. Also evident, was the computational model sensitivity to attempts to simulate the mathematical singularity present in the theoretical solutions. The laboratory flow visualization experiments provided some validation of the practical utility of these theoretical and computational prediction models.

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Collaborative Study to Protect Lake Ontario Drinking Water

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On October 19, 2006, the Clean Water Act, 2006 became law. In support of that legislation the Ontario Ministry of the Environment funds technical studies necessary to support the development of source protection plans.

Lake Ontario has 33 intakes (20 water systems) from the Niagara River to the Bay of Quinte. Together these water systems provide drinking water to critical businesses and institutions and approximately 6 million people.

The Collaborative Study to Protect Lake Ontario Drinking Water was established to identify and evaluate both local and lakewide hazards. This Collaborative includes the municipalities from Niagara Region to Prince Edward County as well as the conservation authorities and a wide range of scientists and consultants.

The Mission of the Collaborative is:
To ensure the long-term, proactive and strategic protection of Lake Ontario-based drinking water supplies.

In 2006, the Ontario Ministry of the Environment funded Phase 1 of the "Collaborative Study to Protect Lake Ontario Drinking Water". In 2007, the Collaborative was allocated additional funding for Phase 2 studies. Significant work has been completed and more is planned for 2008. This paper will speak to the structure of the Collaborative and the importance of good science as an input to sound decision making on protection of Lake Ontario as a critical source of drinking water.

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Polar Passive (POCIS) Samplers to Evaluate Nearshore Contamination in Lake Ontario and Lake Erie

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Pharmaceuticals and personal care products (PPCPs) and endocrine disruptor substances (EDS) are contaminants of emerging concern. Household chemicals, pharmaceuticals, hormones and personal care products are released directly to the environment after passing through wastewater treatment plants. Veterinary pharmaceuticals are released into the environment with animal wastes through leakage or land application. Though the concentrations of PPCPs and EDS in the environment are relatively low, continuous inputs of these compounds into the aquatic environment may induce adverse effects on aquatic organisms, or if taken up into drinking water distribution systems, may affect human health. Active grab sampling at specific sites only provides a snapshot of contamination, and is time-consuming and very costly. The recently developed POCIS (i.e. polar organic chemical integrative sampler) technology may provide an effective means of monitoring for contaminants of emerging concern in the aquatic environment. In this study, we deployed POCIS samplers in the nearshore zone in Lake Ontario and Lake Erie to monitor a range of PPCPs and EDS, including neutral drugs, beta-blocker drugs, sulfamamide antibiotics, acidic drugs, triclosan and triclocarban, selective serotonin reuptake inhibitor (SSRI) anti-depressants, natural and synthetic estrogens, alkylphenols and bisphenol A. The POCIS were deployed for 1 month at several stations in the near shore zone of western Lake Ontario in the summer of 2006, and in Lake Erie near Port Stanley in the summer of 2007. Samplers were suspended by a subsurface float at a depth 4 m to avoid damage and vandalism. Extracts were prepared and analyzed by liquid chromatography tandem mass spectrometry (LC-MS/MS) Most of the classes of PPCPs and EDS were detected in the POCIS extracts. To date, the neutral drugs (i.e. caffeine, carbamazepine) and the SSRI anti-depressant, venlafaxine are the compounds detected at the highest concentrations, ranging from 9.0 to 181.5 ng per POCIS. Among the POCIS deployed in Lake Ontario, the highest concentrations were detected in Hamilton Harbour, followed by Toronto Harbour and Humber Bay. The POCIS is an effective and reliable means for monitoring contaminant levels in the Great Lakes.

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Campylobacters: Occurrence at two Lake Ontario Beaches

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Thermophilic Campylobacter species in the environment can result from contamination by avian, animal and human feces as well as agricultural and urban run-off. C. jejuni, C. coli and C. lari are the species most commonly implicated in human waterborne gastrointestinal infections. These species commonly occur in the gastrointestinal tract of humans and certain species of birds and animals: C. jejuni harbors in birds and bovines, while C. coli is more prevalent in humans and pigs, whereas, C. lari is commonly present in ring-billed and herring gulls. Based on our 2006 preliminary results, a high prevalence of thermophilic Campylobacter sp. was observed in recreational waters at Pier4 and Bayfront beaches in Hamilton Harbour on Lake Ontario.

To investigate and understand the source of these thermophilic Campylobacter species, this year a more comprehensive study was conducted at these two fresh water beaches. A bi-weekly water sampling was carried out from three different depth zones (sand pore water, ankle depth water and chest depth water), as well as from the middle of the harbour. Samples were also collected from potential fecal pollution sources including a combined sewer overflow (CSO) tank at Bayfront Park, final effluents from four different municipal wastewater treatment plants surrounding the Hamilton Harbor, and surface water at a wastewater treatment plant outfall in the harbour. Moreover, samples from fresh fecal droppings of ring-billed gull and Canada geese were simultaneously collected for the isolation of Campylobacter species.

The results showed a high prevalence of Campylobacter in water (40%) and fecal (35%) samples. The putative culture isolates of Campylobacter spp. were confirmed to species by multiplex PCR assay using the 16S-23S rDNA internal transcribed spacer (ITS) region. C. coli was predominant in CSO and municipal wastewater effluent samples. On the other hand, C. jejuni and C. lari were frequently found in bird fecal droppings while C. coli was never present. All three species were detected in beach water samples, although C. coli was predominantly found later during the fall months. Consistent with previous E. coli microbial source tracking studies, the results suggest that birds are contributing to the occurrence of C. jejuni and C. lari at the beach.

It is possible that municipal wastewater may also be contributing to the occurrence of Campylobacter at the beach, particularly for C. coli later in the fall. The present study might help in preventing Campylobacter contamination at these beaches and in understanding the potential health risks to humans.

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The Clean Water Act and the Great Lakes: From Science to Policy

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The Clean Water Act received Royal Assent on October 19, 2006. It ensures communities are able to protect their municipal drinking water supplies through developing collaborative, locally driven, science-based protection plans. Communities will identify potential risks to local water sources through the development of an Assessment Report. Draft guidance materials have been prepared to guide the development of Assessment Reports. This guidance continues to be refined and will be incorporated into regulation and Director's Rules.

The Assessment Report provides the scientific basis and process to identify significant drinking water threats which will in turn contribute to the development of source protection plans. These plans will include policies that stipulate what tools will be used to address significant drinking water threats. Some of these policies may require that risk management plans be developed to address significant drinking water threats and will require that a combination of risk management measures be used to mitigate risks posed by significant drinking water threats.

This session will provide an overview and update of the source protection program under the Clean Water Act, 2006. The session will specifically focus on Great Lakes considerations of the Clean Water Act, including collaboration across multiple source protection areas and regions, the opportunities for local source protection committees to work together to identify and address common issues, and the consideration of Great Lakes Agreements.

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Multivariate Analyses on Ontario Pesticide Residue Data Gathered Through the National Water Quality Surveillance Program

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Surface water quality pesticide data collected in Ontario as part of Canada's first National Water Quality Surveillance Program focused on current-use pesticides in vulnerable aquatic systems and source waters. This program was funded by Environment Canada’s Pesticide Science Fund over a period of 4 years (2003-2006). In Ontario, approximately 800 samples were collected from over 90 sites and analyzed for 43 currently used pesticides. We present selected multivariate analyses conducted on a subset of the pesticides. In particular we examine the capability of discriminant analysis to provide insight on the association of specific land cover types and class of water body with distinctive pesticide signatures.

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Ethanol Fuels Potential Impacts on Source Water

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Gasoline spills and leaks at petrol stations and fuel distribution terminals are common sources of groundwater contamination in urban areas, where the use of groundwater for drinking is often high. Currently there is a good understanding that gasoline-derived hydrocarbon contaminants of concern, namely benzene and other monoaromatic hydrocarbon (BTEX as a group) do not pose a major threat to most source aquifers. This is because these compounds readily biodegrade in shallow aquifers. However, the addition of ethanol to gasoline has the potential to make benzene more recalcitrant and so more persistent. This enhances the risk posed by subsurface release/spills of ethanol-containing gasoline. Ethanol use in gasoline is increasing throughout the Americas. In Ontario, Regulation 535/05 establishes that gasoline should have an average of 5% ethanol. The replacement of some BTEX with ethanol brings a clear advantage by reducing the mass of toxic and carcinogenic compounds in the environment. However, research to date suggests that groundwater plumes from ethanol-gasoline might be more than twice as long as with normal gasoline. Current expectations and well head protection strategies need to consider the impact of longer benzene plumes.

In 2D visualization experiments simulating E10 (gasoline with 10% ethanol) spills ethanol partitioned and was retained in the water in the unsaturated zone while gasoline residuals retention in the unsaturated zone was decreased (McDowell et al., 2003). In other experiments, gasoline was injected in the top of the unsaturated zone and then ethanol was injected in the same position. It was verified that ethanol can mobilize the gasoline and alter its distribution, likely due to changes in interfacial properties and cosolvency. These two processes combined enhanced the mobility of gasoline compounds, which may increase the chances of having high contaminant concentrations reaching shallow supply wells. The visualization experiments also indicate that ethanol transport will happen mainly in the capillary fringe. Considering that monitoring techniques commonly used at fuel contaminated sites are not intended to sample the capillary fringe, high ethanol concentrations may pass undetected in our monitoring networks.

In the downgradient dissolved groundwater plume ethanol is expected to decrease the rate of BTEX biodegradation. Hubbard (1994), in a field test at CFB Borden, verified that alcohol increased the persistence of B, E and p-X, likely due to competition for electron acceptors. Degradation of ethanol and likely its metabolites (acetate, methane) are preferred substrates and so slow BTEX degradation. Lower biodegradation rates results in longer dissolved plumes when ethanol is present (Molson et al. 2002). In conclusion, ethanol may significantly alter the behaviour of gasoline fuel contamination and additional understanding and experience must be gained to adequately protect source aquifers. Monitoring techniques need to consider that the capillary fringe plays an important role in contaminant transport. Mathematical models should incorporate the ethanol effect on biodegradation. Remediation technologies, such as monitored natural attenuation and in situ bioremediation, may need modification in the presence of the high BOD presented by ethanol and its biotransformation products in groundwater.

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Automated Solid Phase Extraction of Sulfonyl ureas and Related Herbicides in Fortified Water and Natural Water Samples using LC-ESI/MS/MS

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The identification and determination of sulfonyl ureas and other related herbicides have presented a challenge, both in specificity and sensitivity, when using conventional analytical techniques. Recent advances in solid phase extraction (SPE) technology combined with liquid chromatography tandem mass spectrometry (LC/MS/MS) have greatly improved this process. Hence, we developed a sensitive and robust analytical technique with supporting method detection limits (MDLs) using fortified Type I water. The applicability of the analytical method was then investigated on approximately 100 natural water samples from urban and rural watersheds in Ontario and Quebec, Canada. Nine sulfonyl urea’s and six related herbicides (henceforth referred to collectively as SUs) in water were simultaneously extracted by an automated Autotrace SPE Workstation. The 800mL fortified or natural water samples were loaded onto an Oasis HLB cartridge at a flow rate of 5mL/min, dried with nitrogen for 10 minutes, eluted with 8 mL of methanol and concentrated to 1mL for analysis by LC-ESI/MS/MS. Recoveries in the spiked Type I water samples were 96% or higher for all compounds except rimsulfuron, which was recovered at 60% (n=12). Instrument and method detection limits ranged from 0.33 to 9.88 pg/μL and 0.7 to 22.0 ng/L, respectively. Maximum observed concentrations in natural water samples in 2007 were 858 ng/L for linuron and 873 ng/L for fomesafen.

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Compound degradation versus sample holding time was investigated for four herbicides; atrazine, glyphosate, 2,4-D (2,4-dichlorophenoxyacetic acid) and metolachlor using a magnetic-based, competitive direct, enzyme-linked immunosorbent assay (ELISA). The concentration of each pesticide in several surface water matrices from southern Ontario was determined and monitored for two identical sample batches, frozen and unfrozen. Subsamples were analyzed over the span of eight weeks in order to develop a stability value for each pesticide. Regression analysis showed that both frozen and unfrozen samples demonstrated a relatively insignificant difference in stability value for atrazine and metolachlor. For 2,4-D the frozen samples had an average stability value of 21 days; whereas, a majority of the unfrozen samples were indeterminate due to positive slope values. Glyphosate, however, demonstrated the most prominent decay rates with stored frozen and unfrozen samples having average stability values of 21 days and 13 days, respectively. The affects of temperature and matrix on the degradation of 2,4-D, atrazine, metolachlor, and glyphosate revealed that frozen samples tended to have higher stability values than unfrozen samples, and filtered surface water samples were observed to have the greatest precision. Consequently, in order to optimize the ELISA technique for surface waters and based on the sample matrices analysed in this study, filtered samples should be stored frozen for less than 21 days to minimize sample degradation.

The reliability of ELISA results for surface water samples was evaluated against gas chromatography/mass spectrometry (GC/MS) for 2,4-D, atrazine, and metolachlor and liquid chromatography/mass spectrometry (LC/MS) for glyphosate. Comparative analysis between wet chemistry methods and ELISA revealed a $R^2$ value of 0.35, 0.92, 0.32, and 0.88, for the above mentioned herbicides, respectively. The commercially available 2,4-D and metolachlor ELISA kits appeared to be unreliable alternatives to GC/MS analysis for the surface water matrices analysed in this study. However, glyphosate and atrazine ELISA test kits were determined to compare quantitatively with traditional analysis. As a result, they could be used in a complimentary approach with wet chemistry methods for the purpose of surface water quality monitoring in accordance with the Canadian Council of Ministers of the Environment Water Quality Index guideline for the protection of aquatic life. An application of ELISA as a cost effective alternative to traditional analysis with the benefit of increased spatial and temporal pesticide monitoring is described in the complimentary poster “Large Scale Field Utilization of the ELISA Method as a Water Quality Monitoring Tool for Surface Water Samples.”

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Large Scale Field Utilization of the ELISA Method as a Water Quality Monitoring Tool for Surface Water Samples in Ontario

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The surface water occurrence of atrazine and glyphosate was investigated in order to gain a better understanding of currently used pesticide concentrations in the environment. Atrazine and glyphosate were monitored because: 1) they are two of the most commonly used agricultural herbicides in Ontario, 2) they have been discovered to potentially cause environmental health effects associated with over exposure, and 3) atrazine and glyphosate have been shown to compare fairly reliably with wet chemistry analyses for surface water samples.

A total of 739 surface water samples from over 100 sampling locations throughout Ontario were monitored using enzyme-linked immunosorbent assay from April to October 2007, in order to obtain spatial and temporal trend information. Concentrations exceeded the method detection limit in 38% and 26% of the samples for atrazine and glyphosate, respectively. The highest concentrations for both pesticides were observed in samples collected during a precipitation event. Atrazine concentrations exceeded the Canadian Water Quality Guideline for the protection of freshwater aquatic life (1.8 µg/L) in less than 1% of the samples (6 of 739 samples). The highest concentrations of atrazine were observed in late spring/early summer in agricultural watersheds. Glyphosate concentrations showed a bimodal distribution with peak concentrations occurring in late spring/early summer and autumn. Glyphosate concentrations did not exceed the guideline for the protection of aquatic life (65 µg/L) in any of the samples. The highest concentration of glyphosate was 12.02 µg/L associated with a precipitation event in an urban watershed.

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Advances in Water Treatments Technologies and Approaches

Chairs: Rajesh Seth and Onita Basu
Influences of Dissolve Organic Matter on Aqueous Photolysis of PAHs

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Effects of fulvic acids (FA) from 5 different sources on the photolysis of 5 polycyclic aromatic hydrocarbons (PAHs) in air saturated pure water have been studied using xenon lamp as polychromatic light source. Results indicated that a similar effect happened among these 5 FAs from different sources. When with FA concentration of 1.25 mg·L⁻¹ in the systems, the photodegradation rates of acenaphthene, fluorine and phenanthrene were decreased while those of fluoranthene and pyrene were increased. However, with the increase of FA concentration in the systems, a decreasing trend of degradation rates was found for all the 5 PAHs. The production of singlet oxygen and hydroxy radical, which reacts with PAHs, was found to be enhanced in the presence of FA. However, FA would compete with PAHs for photons. Therefore, the presence of FA has two reversed effects on the photodegradation of PAHs. It resulted in the decrease of degradation rates of PAHs at some conditions and the increase of degradation rates at other conditions.

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Exploring Pre-treatment for the Solar Water Disinfection (SODIS) Process

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The World Health Organization estimates that 1.1 billion people do not have access to safe drinking water. The solar water disinfection (SODIS) process is helping to meet this need by providing potable water in developing countries. SODIS consists of exposing water in a clear glass or plastic (PET) container to direct sunlight. The UV-A component of sunlight works in conjunction with increased water temperature to destroy harmful microorganisms.

The current SODIS procedure begins with cleaning the containers, but the guidelines do not specify any particular cleaning agent. To determine whether this initial step is significant, we performed a single factor blocking experiment using three cleaning agents available in developing countries: alcohol, soap, and lime juice. The water was spiked with E.coli ATCC 11229 and colonies were enumerated using the pour plate method. Our results indicate that cleaning the containers daily is not necessary. In the case of alcohol, there was no significant effect, but soap and lime juice actually decreased the efficiency of SODIS.

The guidelines further state that the most favourable region for SODIS is between latitudes 35°N and 35°S. Our experiments were carried out between June and September in Waterloo, Ontario, which lies well beyond this zone (43°28' N). SODIS achieved four log-reduction, confirming that its utility extends to more northern and southern regions for at least part of the year.

For SODIS to be effective, the raw water must have low turbidity (i.e., less than 30 NTU) to allow sufficient penetration by the UV-A light. However, in many cases the source is extremely turbid surface water. Although various methods of turbidity removal exist, there appears to be no specific pre-treatment to compliment SODIS. Currently we are investigating the removal efficiency of simple roughing filters constructed from 2-L pop bottles, coarse sand, and gravel. We are also comparing the turbidity removal of an optimized filter to straining and settling, with the aim to augment the existing SODIS guidelines for the treatment of turbid water.

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Enzyme-Based Detection of E. coli and Total Coliforms in Drinking Water Using Fibre Optics and Fluorescence

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Substrates that have chromogens and fluorogens produce colour and fluorescence respectively, upon cleavage by a specific enzyme. These have been used for many years to detect and identify coliform bacteria, including the fecal pollution indicator *Escherichia coli*. *Escherichia coli* and total coliforms, indirectly detect based on the enzymatic activities of β-glucuronidase (β-glu) and β-galactosidase (β-gal). These enzymes utilize the substrates; *anthracene-β-d-glucuronide* and *pyrene d-galactopyranoside*. Substrate cleavage by the enzyme release the soluble fluorescent molecules 2-hydroxyanthracene and 1-hydroxypyrene, they are then selectively partitioned in a partitioning element within the sample holder. Fluorescence is coupled into the wave-guide and is selectively detected by a spectrometer. We are investigating the utility of this system in monitoring the microbial quality of drinking water and optimizing detection. This will be accomplished by varying drinking water quality parameters to detect a single cell faster than the traditional microbiological methods. These parameters include turbidity, pH, fluoride, and aluminum.

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Fractal Analyses of Flocs for Modelling of Solid/Liquid Separation in Water Treatment

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Many researchers have shown that the settling rates of flocs could not be predicted using a modified Stoke’s Law:

\[ v_{st} = \frac{4 \ g \ \rho_f - \rho_w \ D^{1/2}}{3 \ \Omega \ C_D \ \rho_w} \]  

Equation 1

Where \( v_{st} \) - terminal settling velocity, \( C_D \) - drag coefficient exerted on an impermeable sphere, \( g \) - gravitational acceleration, \( D \) - diameter of the settling floc, \( \rho_f - \rho_w \) - effective density of a floc, \( \Omega \) - correction factor for a drag force acting on a permeable floc. The experimentally measured settling velocities of flocs always show a non-linear relationship with the square root of the floc size, especially for flocs smaller than 60 microns. This is most likely due to the fact that the properties of flocs could not be adequately described in terms of Euclidian geometry on which the Stoke’s Law is based.

This paper proposes methods for analyses of flocs properties using concepts of Fractal geometry. A correction factor based on flocs’ fractal dimensions is proposed to be incorporated into the Stoke’s Law so it can be used more effectively for predicting the flocs settling rates.

Methods for determining full size distributions of coagulation flocs, including submicron particles, have been developed and tested at the University of Manitoba. The method requires concurrent analyses with optical microscopes, particle counters and photodispersion analyzers. Analyses of other properties of flocs are in progress. Surface area and internal volume of alum coagulation flocs will be analyzed on sections of the flocs obtained with confocal laser scanning microscope (CLSM). 3-D internal structure of alum flocs will be reconstructed using Image Pro-Plus image software and Matlab. Such reconstructions of structures of flocs formed in chemical coagulation have not been conducted before. Fractal dimensions of alum coagulation flocs will be determined directly and indirectly using the methods shown in the table below:
<table>
<thead>
<tr>
<th>Size Range</th>
<th>Measurement</th>
<th>Instrument</th>
<th>Equation of Fractal Dimension</th>
</tr>
</thead>
<tbody>
<tr>
<td>Indirect 20 μm – 2000 μm</td>
<td>Settling Velocity, v</td>
<td>Settling column and Image Pro-plus image analysis system</td>
<td>Mass Fractal Dimension $v \propto R^{D_n-1}$</td>
</tr>
<tr>
<td></td>
<td>0.01 μm – 20 μm</td>
<td>Light Intensity, I</td>
<td>DLS Photocor Tech</td>
</tr>
<tr>
<td>Direct 3 μm – 2000 μm</td>
<td>Floc Perimeter using box-counting method</td>
<td>Optical Microscopy</td>
<td>Boundary Fractal dimension $P \propto L^{D_{a}}$</td>
</tr>
<tr>
<td></td>
<td>Floc section Perimeter</td>
<td>CLSM Olympus IX-70</td>
<td>Surface Fractal Dimension $A \propto L^{D_{a}}$</td>
</tr>
<tr>
<td></td>
<td>Floc section area using box counting</td>
<td>CLSM Olympus IX-70</td>
<td>Volume fractal dimension $V \propto L^{D_{a}}$</td>
</tr>
<tr>
<td></td>
<td>1-Pore size distribution on floc sections</td>
<td>E400</td>
<td>Serpinski Fractal Dimension $D_s \propto \frac{\log a}{\log \frac{1}{r}}$</td>
</tr>
<tr>
<td></td>
<td>2-Solid fraction of the carpet</td>
<td>SMZ800</td>
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<tr>
<td></td>
<td></td>
<td>CLSM Olympus IX-70</td>
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<tr>
<td></td>
<td></td>
<td>Matlab 7.0</td>
<td></td>
</tr>
</tbody>
</table>

The general form of the correction factor to be introduced into the Stokes’ law is below:

$$v_{st} = \frac{4 \gamma (\rho_f - \rho_w)f(D_v, D_m)D^{1/2}}{3 f(D_B, D_A)C_D \rho_w}$$  \hspace{1cm} \text{Equation 2}
A Low Cost Method for Protozoan Enumeration from Large Water Volumes for Performance Demonstrations

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Protozoa, namely Cryptosporidium, are microbes that can be found in source waters and have the potential to cause life-threatening disease when ingested. For this reason, drinking water treatment plants must ensure that their water is adequately treated so as to avoid an outbreak. Performance investigations are routinely conducted to ensure that their full-scale units are working properly and that the protozoa have been adequately removed or inactivated prior to discharge to the distribution system.

Despite the improved mean Cryptosporidium recoveries (relative to previous methods) that have been obtained using U.S. EPA method 1623, methods for detecting and enumerating C. parvum oocysts in raw and treated drinking waters are still quite unreliable and fraught with uncertainty associated with the variability of recovery data. In U.S. EPA Method 1623 and many of the other methods currently available, processing large volumes of raw and treated water, such as those required in studies using indigenous or treatment process effluent concentrations of C. parvum oocysts or oocyst surrogates during performance demonstrations (seeding studies), has proven to be laborious, unreliable, costly and sometimes impossible due to the limited ability to obtain representative samples. One strategy substantially reducing uncertainty associated with the concentration and enumeration of C. parvum is to increase processed volume (with increased replication or improved analytical methods) so that at least several oocysts are observed.

This paper demonstrates a modified form of previously reported membrane filtration methods for Cryptosporidium and oocyst-sized surrogate enumeration. A critical feature of this modified method is that large volumes of water can be processed, concentrated, and enumerated. This procedure was further optimized to maximize recovery while also minimizing variability in recovery.

Preliminary investigations utilising deionized water, ground water, and treated surface water samples of up to 2000L (and all with turbidities <0.3 NTU) have demonstrated C. parvum recoveries of approximately 45-50% and oocyst-sized microsphere recoveries of 70-90%. The study demonstrated that the modified filtration protocol could yield oocyst and microsphere recoveries that are equivalent to or higher than, and equally variable than those obtained with U.S. EPA Method 1623. Additionally, the modified method represents a methodological alternative for processing large volumes of water that requires fewer consumable materials and is accordingly less expensive to use when conducting performance evaluations or seeding studies.
Full-scale performance demonstrations utilizing polystyrene microspheres as surrogates for *C. parvum* removal by filtration have been successfully conducted and utilizing the modified filtration approach makes them less time consuming and less costly. While not all treatment plants are capable of conducting full-scale experiments, studies conducted at a drinking water treatment plant in Ottawa resulted in an additional 1-log treatment credit for conventional filtration. Additionally, it demonstrated that methods other than U.S. EPA Method 1623 are certainly valid and recognized by governing bodies.

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Pd/MCM-41-Catalyzed Hexamethylphosphoramide Degradation

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The Mobile Corporation’s crystalline material #41 (MCM-41) is a silica-based compound consisting of a hexagonal arrangement of mesopores and possesses several unique characteristics. Perhaps most interesting is its exceptionally high surface area - in excess of 1 000 m²/g in well-formed samples. In general, the greater the surface area of a catalyst exposed to reagents in a reaction, the greater the reaction efficiency. Therefore, MCM-41 shows promise for applications in environmental catalysis as it would expose a large proportion of a catalyst adsorbed to its surface to target chemicals. Earlier batch experiments demonstrated the ability of a palladium catalyst loaded onto the surface and in the pores of MCM-41 (Pd/MCM-41) to rapidly degrade trichloroethylene in hydrogen-saturated deionized water. Current work addresses whether Pd/MCM-41 will degrade degradation-resistant chlorinated volatile organic compounds such as hexamethylyphosphoramide (HMPA). Complete degradation of HMPA produces ammonia, phosphorous, and methane as daughter products. Batch reactions were conducted in 60 ml sample bottles filled with 100 mg/l HMPA in hydrogen saturated deionized water. Reactive samples contained a Pd/MCM-41 to HMPA solution mass ratio of 1/120. Analysis of supernatant solution samples taken at 1, 3, 6, 24, and 48 h for aqueous HMPA, ammonia, and phosphate concentrations will indicate if degradation of initial HMPA occurred. Concurrent to the degradation work is an ongoing study to determine the uptake of moles of hydrogen gas per mole of Pd in a Pd/MCM-41 sample. Degradation reactions involving chlorinated volatile organic compounds such as trichloroethylene consume hydrogen. Therefore, knowledge of the degree of hydrogen uptake by Pd/MCM-41 will be useful in designing and interpreting future degradation experiments. Uptake experiments were conducted at constant temperature and data was collected using pressure transducers controlled by a computer and data logging board.

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Application of Multivariate Statistical Analysis for Factors of Trihalomethanes (THMs) Formation in Drinking Waters

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The presence of trihalomethanes (THMs) in drinking water is a critical issue because of their adverse health effects. Available THMs formation models considered as many as 22 explanatory factors, while individual models typically incorporated 3 to 8 factors. The previous studies characterized importance of some of the factors through controlled studies using synthetic or raw/treated waters, mostly by varying one factor at a time. Limited research have been performed to characterize individual factor’s behavior in the natural systems, where all factors vary simultaneously. This study presents multivariate statistical analysis on Drinking Water Surveillance Program (DWSP) data measured from 179 drinking water supply systems in Ontario between 2000 and 2004. The correlation coefficients and patterns for the possible factors affecting THMs formation were determined. Principal component analysis (PCA) was applied to the mean-centered and standard-deviation-scaled data to determine important factors and possible clusters. PCA identified dissolved organic carbon (DOC), chlorine dose, pH, temperature and reaction time as significant factors for THMs formation from a list of ten factors. This study identified separate clusters for DOC-color; chlorine dose-total chlorine-free residual chlorine; and hardness-alkalinity, indicating that the factors in a cluster are correlated. Temperature and pH were found significant and uncorrelated throughout the analysis. These factors can be simulated through factorial analysis for THMs formation modeling, which can be used to perform complex risk-cost balance studies for drinking water quality management.

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Rigorous Quantitative Analysis of Microbial and Particulate Data

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Many methods for quantifying microorganisms in water depend on counting discrete objects (e.g. colony/plaque forming units, Cryptosporidium oocysts, etc.). Applications may include monitoring of source or finished water, laboratory quality control, demonstration of performance tests for new technologies and treatment systems, and development of microbial detection methods. Similar methods and applications exist for other discrete particles such as polystyrene microspheres that are sometimes used as microbial surrogates.

Acquiring good data on the abundance of discrete (microbial) particles in water is complicated by their small size, their distribution in suspension, and their sometimes low abundance. Additionally, detection methods may be very laborious and may not recover all of the particles. Statistical analysis is complicated because the particles are discrete, errors may not be well known or quantified, and conventional statistical techniques may not be appropriate (e.g. techniques assuming normally distributed errors such as t-tests, regression, and ANOVA).

A simple statistical framework that addresses random sampling error, recovery (fraction of particles observed), and non-constant analytical recovery is discussed in the context of two common types of microbial enumeration methods: membrane filtration followed by microscopic enumeration and plating techniques. Concepts are also potentially applicable to other types of methods including most probable number techniques and quantitative PCR.

Through the use of Bayesian techniques, the statistical model is solved to generate distributions summarizing the uncertainty in concentration and removal of particles based on (replicate) enumeration data. These can be used to plot error bars on graphs and to evaluate the statistical significance of data and conclusions. General guidelines for the determination of model parameters through rigorous recovery studies are also discussed.

The research shows that there are numerous situations where it is either impossible or incorrect to use conventional statistical analysis techniques such as t-tests. The results also show that even when errors in replicate data are normally distributed, conventional statistical analysis techniques are incorrect without adjustment for recovery. In fact, this model has been shown to be a more robust and adaptable method of statistical analysis. It is therefore recommended that such models be used to analyze microbial enumeration data. The concepts used herein can also be more broadly applied to numerous applications including drinking water regulations, laboratory quality control, and detection method development.

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Science, Policy and Legislation

Chairs: Hugh Simpson and Neil Hutchinson
Linking Water Science to Policy: Observations From a Series of National Workshops

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In 2002, Environment Canada was approached by the Canadian Council of Ministers of the Environment (CCME) to lead a national, science-policy (S-P) workshop series on major water-related issues. The intent was to bring leading researchers together with policy and program managers to provide the recent science to practitioners/users, and allow them to inform the research agenda. The logic for these workshops and their products was that any new policy, regulatory or program initiatives would be stronger if informed by the latest aquatic science knowledge. With the help of lead researchers, a policy friendly report was then written that was subsequently posted online and more broadly disseminated to key science users. Five issue-specific, workshops were originally held under the CCME ‘banner’. The demand for this knowledge brokering tool continues and additional workshops and reports have since been held, under the EC banner. This presentation reviews the CCME experience and its effectiveness with respect to strengthening S-P linkages, based on a follow up survey.

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Effective Communication Tools to Build and Promote The City of Hamilton’s DWQMS

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The City of Hamilton’s (City) Water/Wastewater (WWW) Division is undertaking a unique approach to complying with MOE’s Drinking Water Quality Management System (DWQMS) Standard. The WWW Division is developing a DWQMS supported by a Division-wide “Beyond Compliance Operating System” (BCOS) Program. The paper describes the communication strategy used by the WWW Division to promote the City’s DWQMS Program to its stakeholders. An integrated strategy is used for both DWQMS and BCOS Programs; however, the subject of this paper is the DWQMS communications strategy.

The DWQMS Standard requires that a communications procedure be documented to describe how the DWQMS is communicated between the Drinking-Water System Owner, Top Management, Operating Authority staff, suppliers and the public. A first priority is to ensure that all organizational levels of the Division are aware of the DWQMS development. Members of WWW Division Senior Management lead DWQMS design through their attendance at Senior Management Team (SMT) Meetings. Ongoing development of DWQMS procedures and processes is driven by the BCOS Lead Team. Led by the Systems Management Representative (SMR), the Team is comprised of Intermediate QA/QC staff representing various Sections within the Division; these members work with their Section Managers to communicate system development to staff and to address any Section-specific issues during development. Owners (Mayor and Council) and Top Management are kept informed of DWQMS development through presentations and progress reports from the Division, and will attend Due Diligence Training to communicate their roles and responsibilities under the Safe Drinking Water Act.

The WWW Division has developed a Communications Strategy to support and promote the DWQMS. This strategy was built to complement the Division’s overall communications strategy and is linked to Divisional performance and employee feedback. Internal communication is executed through the use of software, videos, the City’s Intranet website, posters/brochures, meetings and staff information sessions; external communication is executed through the use of the City’s Internet website, distribution of information packages to the public, participation at public meetings, and correspondence with media outlets (television, radio, etc.). The WWW Division’s Customer Service/Community Outreach Section is an essential participant in developing all communication strategies for the DWQMS.

The WWW Division uses various IT tools and technologies to communicate the DWQMS to internal and external stakeholders. An integrated data approach ensures effective and lean communication lines. As an example, the CitySpills Program and the upgraded Laboratory Information Management System (LIMS) allow for examination of quality-related data. The WWW Division uses management system software to support internal communication requirements of the DWQMS. The BCOS Database provides a portal from which system
procedures, forms, visual aids and selected records can be accessed. The WWW Division is developing a comprehensive video training framework that will be viewable by all Division staff through the training portal. A critical component of this training is a DWQMS Awareness Training Video, which will be delivered to staff in early 2008; this video will be accessible to staff 24/7 and can be distributed to vendors and/or customers at the Division’s discretion.

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Marking the 35th anniversary of the Great Lakes Water Quality Agreement

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The year 2007 marks the 35th Anniversary of the Canada-US Great Lakes Water Quality Agreement (GLWQA). On April 15, 1972, Prime Minister Pierre Trudeau and President Richard Nixon signed the GLWQA. This Agreement expresses the commitment of Canada and the United States to restore and maintain the chemical, physical and biological integrity of the waters of the Great Lakes Basin Ecosystem. The GLWQA has had substantial influence on the cleanup and restoration of the region. The progress made since 1972 is evidenced by the documentation by scientists of the presence of spawning lake whitefish, the resurgence of cormorant population, the rediscovery of sturgeon populations, and the return of nesting and fledging bald eagles. Threats to the Great Lakes in the face of climate change, invasive species, habitat loss, and more, demand a renewal and revitalization of the GLWQA. The time is now to renovate the binational promises. Under current governance regime, the Great Lakes and St. Lawrence region is one where people, the environment and the economy are at increasing risk. The impediments to more integrated environmental regulation remain considerable and include the enduring single-medium approach to pollution control of federal programs and limitations of state, provincial, municipal or regional innovation. Nonetheless, regulatory integration need not be dismissed as a theoretical pleasantry that is politically unattainable. The inability to stem the re-emergence of threats to the integrity of the ecosystem is symptomatic of the accountability complex for the Great Lakes basin ecosystem. A move toward greater integration in the Basin can be generated if scientists, policy professionals and political leaders increasingly recognize the limitations of current approaches and are willing to devise binational alternatives.

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Linking Phosphorus Offsetting Strategies to Regulatory Mechanisms to Improve Water Quality.

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Development pressures introduce new sources of phosphorus to lakes and rivers that, in Southern Ontario, already exceed allowable phosphorus loadings. In addition, implementation of remedial strategies to reduce nutrient enrichment are frequently hampered by lack of remedial funds or uncertainty regarding who should pay. Two case studies are presented to show how a) a new sewage treatment plant discharging to the Humber River in Nobleton was permitted on the basis of a quantitative schedule for specific phosphorus reductions in the watershed and b) how phosphorus offsetting could be linked to development approvals to achieve meaningful reductions in phosphorus loading to Lake Simcoe. Phosphorus offsetting is a recent innovation in Ontario although it is established in the USA. Several key questions need to be resolved to lay the framework for implementing phosphorus offsetting in a manner that is fair to all, that results in real water quality improvements and that is cost effective. These include assessment of the bioavailability of phosphorus from different sources, determination of offsetting ratios, costing of offsets and a management framework to distribute offset credits, focus remedial measures where they are most needed and to assure fair allocation of credits to various Parties.
The Information Delivery Challenge

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Addressing Communication Gaps Between Science and Policy

The Task Force on the Canadian Information System for the Environment (CISE) has said that Canada ranked 25th in the world when it comes to availability of environmental information. In recent years, the Canadian Council of Ministers of the Environment (CCME) has repeatedly acknowledged the overall deficiency of reliable water information. If it can be taken for granted that water information is itself crucial to water management, it is should follow that effective access to and exchange of that information is equally essential.

With environmental issues coming to the forefront in policy debate - while at the same time cost saving measures are starving environmental agencies and political agendas are taking precedence over legitimate scientific prescriptions - a discrepancy in the decision making process becomes apparent. And, although such policy decisions are often complex and deliberate in their formulation and implementation, it is nevertheless critical that all relevant information be made available for consideration.

With this in mind, the Centre for Sustainable Watersheds (CSW) has been spearheading the national Water Connections initiative in an effort to address the issue of water information availability. The aim of this project is to build a comprehensive and universally inclusive Internet portal for the purpose of centralizing access to water information. The primary tools to be produced under the Water Connections initiative are: 1) a national directory of water resource actors and agents, 2) an online resource library of water management tools and best practices, 3) an archived news and events service and, 4) a central conduit to all digital water data libraries across the country. Ultimately, the goal of Water Connections is to facilitate data and information exchange among the broader water resource community.

The potential impact such a tool might have on the overall health of the water resource community’s body of knowledge is tremendous, and it is twofold. On the one hand, those “front line” water researchers, managers and practitioners will benefit from improved access to a wealth of otherwise inaccessible (or perhaps unknown) water data and resources. While on the other hand, as the body of information on the whole would be more complete, conclusions drawn from it would be naturally less susceptible to political neglect or irrelevance.
The tendency of policy makers to disregard legitimate scientific counsel in favor of other, more marketable, considerations is a habit with potentially catastrophic consequences. And so improving access to credible research becomes the first step towards transforming current decision-making processes.

In light of this, CSW is well into the process of developing the Water Connections project, its tools and resources and its centralized water information portal. In keeping with the session theme of Science, Policy and Legislation, we propose to highlight a number of challenges to the transfer of scientific knowledge across sectors using Water Connections as a working model for change.

**Coordinating Water Data Management and Informing Effective Policy**

Access to relevant data remains one of the biggest challenges to managing Canada's water resources. At the same time, it is evident from extensive national surveys among a range of stakeholders, that data management factors themselves are part of the problem: whether those of formatting, storage, retrieval, accessing or sharing, including schemas to unlock the data recesses of analysis and interpretation.

On top of this, the broad landscape of jurisdictional responsibilities whose mandates for water and information overlap – all levels of government, watershed agencies, industry, researchers, Aboriginal councils, and local community groups – makes sharing information and resources difficult.

Seamless sharing of information relies, in the first instance, on documentation of metadata and the development of common thematic data standards. It is, however, the prevailing lack of certainty about thematic data standards for water – showing the critical need to assess metadata protocols and develop best practices and data exchange guides for the most significant water data parameters – that drives this project, in response to the real user needs.

Well organized, comprehensive and carefully documented metadata is crucial to effective collaboration on even the smallest scale, let alone the demand to be able to understand and share data on life-threatening water issues at a national level. Therefore, a primary activity for this project is the rigorous examination among all collaborating groups of their metadata and all standards that pertain to each water parameter under review, to this end:

1) through consensus building, reach agreement on common schema, that can also accommodate deeper levels, appropriate for varying user capacities and sophistication

2) sufficiently comprehensive to provide pathways to related data through keyword searches

3) ensure that all standards are CGDI compatible, and thereby facilitate interoperability
Data exchange guides will analyze existing metadata among the collaborators and their end-users, capacity requirements for collection, administration and sharing, as well as appropriate formatting to accommodate interoperability, together with an evaluation of challenges. Best practices guides will encompass the wide array of current data protocols to be found in different communities of practice among varying capacities of user groups. This analysis will take into account the ‘lessons learned’ and evaluate the most effective way to develop common standards of largest credibility and usefulness for national dissemination, while adapting the protocols for interoperability.

The nuts and bolts of these kinds of activities may lack flash and glamour, but they are vital if this country, in any effective way, is to link the ongoing work of research communities and government bureaucracies on the one hand, with the broad potential power of a truly engaged citizenry, on the other. Regional, local and community groups are essential both to the exchange, as well as dissemination, of vital information. Without this, all the webs and portals of the world are but a shell. And if that engagement doesn’t take place – and the development of those common standards and data exchanges fail, despite all the facilities the web affords mass society – we will have to countenance those unthinkable costs born of the degradation of both environmental and human health.

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Assessing Canada’s Water Information Challenges

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Water quality and quantity are of undisputed importance to all Canadians. Sustainability of our water resources is affected by many issues, including: increasing demands and aging infrastructure; urban and rural stormwater runoff; domestic, industrial and agricultural wastewater; and impacts from climate change. Critical choices need to be made to safeguard our water resources now and for the future. The foundation of all these decisions is knowledge - based on credible, up-to-date data and information on the quantity, quality and availability of Canada’s water resources. Access to relevant data and information remains one of the biggest challenges to water resource management.

To this end, Centre for Sustainable Watersheds (CSW) created the Water Connections initiative, the purpose of which was to address the pressing need for improved access to water information by the different stakeholders in Canada's water community. The objective of the feasibility study conducted in the first Phase was to explore information requirements among stakeholders, as well as existing technological and human/social resources, and to develop an integrated and inclusive approach to facilitate information access.

Data collection for the feasibility study took place between September 2005 and March 2006. Primary data sets were gathered using a mix of qualitative and quantitative techniques including; individual consultations, telephone and online surveys, website research, an evaluation of existing web-based tools and services, and a literature review of documents related to information sharing, communities of practice, and the state of water management across Canada. These elements comprising the research methodology are further described below.

Surveys

Two surveys were developed to gather input on information needs and priorities from 1) local-level practitioners (non-governmental organizations, local governments, Aboriginal groups, researchers and watershed agencies) and 2) provincial/regional organizations (provincial governments, provincial/regional non-governmental organizations and networks).

Twenty-three surveys were conducted via phone and an online survey was developed and posted (in English) on the Water Connections website (www.waterconnect.ca). An invitation to participate was circulated to over 1,200 national
inventory contacts. 125 surveys representing 116 organizations/agencies were completed with good sectoral and regional representation.

Consultations

Consultations were carried out with 35 water information stakeholders and experts to augment information gathered from the surveys and to explore partnership opportunities and requirements.

Website Review

A strategy for reviewing websites was developed to inventory websites related to water, including those with national, provincial/territorial, local and international scope.

Literature Review

The team reviewed several pertinent documents related to information sharing, communities of practice, and the state of water management across Canada.

What emerged from the study was the endorsement of an innovative solution – a water information web portal - that builds on and connects existing organizations and expertise across jurisdictions and sectors. This will support information sharing and community engagement in water protection from coast-to-coast-to-coast.*

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Harmful Algal Blooms

Chairs: Sue Watson and Greg Boyer
Environmental Influences on Cyanobacterial Abundance and Microcystin Concentrations in Three Grand River Reservoirs in 2005

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Cyanobacterial blooms have been a concern in reservoirs within the Grand River catchment basin in recent years. With increased cyanobacterial biomass, the occurrence of microcystin, a hepatotoxin produced by certain strains of Cyanobacteria, becomes a possibility. In 2005, three reservoirs managed by the Grand River Conservation Authority (GRCA), Belwood Lake, Conestogo Lake, and Guelph Lake, were sampled biweekly from July to the end of September. Belwood Lake was again sampled in October when an unexpected cyanobacterial bloom occurred. Light, temperature, and major nutrients were measured along with the distribution of major algal groups using an *in situ* Fluoroprobe profiler. Total microcystin (both particulate and dissolved) was measured via the protein phosphatase inhibition assay.

Belwood Lake had the lowest mean epilimnetic irradiance, the greatest total P, the highest chlorophyll *a* levels and the greatest cyanobacterial biomass. Particulate C:N and C:P ratios suggest that there was no N limitation in any of the reservoirs but there was moderate and extreme P limitation throughout the 2005 season. Microcystin levels were highest in Belwood Lake but only once reached 1.0 ug/L, the maximum level of safe exposure according to the World Health Organization. Conestogo and Guelph lakes had microcystin levels below 0.2 ug/L and 0.6 ug/L, respectively. Perhaps surprisingly, the major cyanobacterial bloom in October, 2005 was accompanied by relatively low microcystin levels (<0.2 ug/L). Over all of the reservoirs, microcystin was positively associated with chlorophyll *a* and total phosphorus. These data suggest that the occurrence of a cyanobacterial surface bloom does not necessarily indicate worrisome levels of microcystin. However, Cyanobacteria with the potential to produce microcystin do occur in all three of these reservoirs.

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Cyanobacterial impairments in the Great Lakes-St. Lawrence River: benthic fingerprints of anthropogenic activity.

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Despite widespread remediation in the late 20th century, the Great Lakes and connecting rivers are experiencing a resurgence of algal-related impairment. Intense agricultural and urban watershed development, diffuse shoreline loading, and invasive biota have resulted in significant changes in water quality. Increased noxious algal/cyanobacterial metabolite outbreaks raise concern for the integrity of these surface waters, a source of drinking and recreational water to over 24 million people. Many of these impairments are occurring in the absence of visible blooms, derived instead from ‘hidden’ benthic and littoral sources.

This paper reports preliminary results from two case-studies where dense benthic/epiphytic populations of cyanobacteria (Lyngbya cf. wollei and Gloeotrichia pisum) have been ‘discovered’ recently, impacting regional shorelines and drinking water. Both sites are located downstream from tributaries draining dense agricultural regions, but they differ in local flow/circulation, resuspension and nutrient regimes. In one case, Lyngbya mats growing in the mouth of the Maumee River (W. Lake Erie) produce extensive shoreline fouling and beach closures from detached material, provoking considerable media and public concern for potential cyanotoxins. The second site is located in the plume of the Ottawa River at its confluence with the lower St Lawrence River near Montreal, where municipal drinking water intakes experience increases in late summer taste and odour problems. In this area both Lyngbya and Gloeotrichia develop in distinct patterns reflective of segregated plumes of differing P and N concentrations. We describe the physico-chemical regimes of the two sites, the taxa and associated noxious metabolites, and potential socioeconomic and ecological impacts.

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A Proposed Bluegreen Algal Bloom Indicator: Low-Nitrate-Days (LND)

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When nitrate is low in Fanshawe Lake, a hardwater reservoir of the North Thames River in London, Ontario, cyanobacteria proliferate into blooms. Based on this observation an index was developed that relates an easily measurable variable, the period of Low-Nitrate-Days (LND), to the period of cyanobacteria blooms. The bloom indicator LND (days/year) is defined as the period of time during summer and early fall, when nitrate concentration is below a certain threshold, which was 1-2 mg/L in hyper-eutrophic, nitrogen-rich Fanshawe Lake. The usefulness of this index is evident: Even though biomass data were scarce, relationships with water quality and climatic variables could be tested for many years. For example, significant correlations with 38 years of seasonal flow and climatic index (winter North Atlantic Oscillation) suggested that algal blooms were more frequent during low-flow rather than high-flow years.

Long-term information on cyanobacterial blooms (despite missing information on algae biomass) would be valuable in many systems, and LND may represent periods of such blooms in all lakes, where nutrient limitation switches from phosphorus to nitrogen during summer. Therefore, the concept of LND and the importance of the nitrate threshold will be examined for other man-made and natural lakes with different trophic states, nitrogen to phosphorus ratios, and surface temperature, by comparing seasonal algal biomass estimates with LND values.

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Limitation of Bloom Forming Cyanobacteria by Ferrous Iron

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Blooms of large cyanobacteria, many of which are toxic, remain a global problem in lakes and rivers receiving excessive amounts of nutrients. Major investments in phosphorus control strategies have greatly reduced their occurrence but blooms have reappeared in the lower Laurentian Great Lakes and are appearing for the first time in smaller inland lakes. While numerous hypotheses have been advanced, there is no clear understanding of why large cyanobacteria, which have higher iron requirements than eukaryotic algae, typically dominate eutrophic waters or why they are rare in oligotrophic waters where biological productivity is usually limited by low levels of phosphorus. An experiment in a eutrophic lake in the Experimental Lakes Area in northwestern Ontario showed that formation of a cyanobacterial bloom can be prevented and growth of eukaryotic algae promoted by reducing access to ferrous iron despite elevated concentrations of phosphorus and other forms of iron. Evidence to date indicates that iron-limitation explains the very low abundance of large cyanobacterial species in oligotrophic waters. These results have implications for improved control of cyanobacterial blooms in eutrophic waters.

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Chlorination of the Cyanotoxin Microcystin-LR: Reactant Consumption and By-Products Elucidation

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With climate change and anthropic pressure, the occurrence of algae crisis is drastically increasing in temperate countries. The main consequence is that cyanotoxins must be considered in water treatment. In order to preserve consumers’ health, their behaviour towards classical processes like disinfection should be examined.

This study aims to investigate the reaction between a widespread cyanotoxin and a frequently used disinfectant, respectively the microcystin-LR (MCLR) and the hypochlorous acid (HOCl). On the first hand, the reaction has been studied focusing on the reactant consumption. On the other hand, identification of by-products formed has been carried out, because few studies had explored this way.

Due to analytical reasons, experiments were performed in high purity water with an initial MCLR concentration of 20mg/L. In order to ensure an [HOCl]/[MCLR] molar ratio R=20, an aliquot of bleach solution was added. Disinfectant consumption has been monitored during 1 hour using the DPD method to dose free and total chlorine. Then, to examine toxin disappearance as well as products formation, the reaction has been stopped at different contact time with sodium nitrite 10% in excess. After that, samples were analysed by HPLC/MS to screen mass/charge Ratios (m/z) in the range 100-1500. For each by-product observed, a chemical formula has been proposed, based on the accurate mass resolution provided by the LTQ-Orbitrap technology. Afterwards, tandem mass spectrometry experiments and isotopic massifs examination have been undertaken in order to confirm those hypothesis.

On the first hand, the toxin degradation is observed with a rate of 95% in 2 minutes, and more than 99% of the initial microcystin quantity is degraded in 30 minutes. From the reaction study, a chlorine demand of 12.5 moles per mole of MCLR is deduced. On the second hand, thanks to Fourier transformed mass spectrometry 6 reaction by-products and their isomers are observed at m/z 1029.52; 1029.56; 1047.53; 1063.52; 1097.48 and 1115.45. According to isotopic massifs examination and tandem mass spectrometry experiments showing a loss of H₂O or HCl, proposed chemical formulas are based on hydroxylation of the initial microcystin or substitution of hydrogen by chlorine. On the third hand, when presenting by-products abundance as a function of chlorination time, different profiles can be observed showing that some products may be only intermediaries.

In conclusion, the hypochlorous acid efficiently and quickly reacts with the microcystin-LR to form at least 6 by-products, in our experimental conditions. 4 of them do not seem previously reported in the literature. The 2 other ones have been already studied but either a
different formula or new isomers are suggested here. Further investigations will be undertaken in the future to confirm that these disinfection by-products of MCLR are also formed in a human-scale treatment plant. We also plan to investigate in the same way ozonation or UV irradiation.

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Commercially-Available Immunoassays for Microcystin Analysis

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The seasonal occurrence of microcystins, or cyanobacterial toxins, in Ontario has become a growing concern. With the advance of immunoassays, simple portable versions of test kits for microcystins are now commercially available (Qualitube, Envirologix). The user-friendliness of these kits is comparable to home test kits for blood sugar or pregnancy. Despite the ease of use and the value of the results obtained, the kit results are not intended to replace test results of drinking water samples provided by licensed laboratories. The immunological principles of the portable microcystin kit are similar to the laboratory-based immunoassay; however, the test formats (tube versus microplate, respectively) are not interchangeable. Most importantly, the Safe Drinking Water Act, 2002, mandates that only licensed laboratories are permitted to test drinking-water samples. Thus, these portable microcystin test kits should only serve as a first line of defence for concerned community members for surface water evaluation. This first alert could serve as a trigger and warrant further investigations by licensed test methods.

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The Occurrence of Anatoxin-a and Other Cyanobacterial Toxins in Lake Erie and Lake Ontario: It is More Than Just Microcystins.

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Lake Erie and Lake Ontario both have well established populations of the toxic cyanobacteria. In the past decade, blooms of Microcystis have led to elevated levels of hepatotoxic microcystins in the water column. Toxic cyanobacteria can also produce other toxins. This includes the hepatotoxin cylindrospermopsin and the neurotoxins, anatoxin-a, anatoxin-a(S), saxitoxin and neosaxitoxin. To study the distribution of these other toxins in these two lakes, nearly 1000 water samples were collected between 2000 and 2006 from offshore and near shore environments. Particulate cyanobacteria toxins were determined after extraction in 50% methanol using HPLC and LCMS techniques. Anatoxin-a was the most common toxin found after the microcystins and occurred in ~10% of the samples. Maximum concentrations in Lake Erie were low (0.2–0.6 ug/L) but levels exceeded 1.4 ug/L in the embayments of Lake Ontario. Cylindrospermopsis has been identified in Lake Erie but the toxin, cylindrospermopsin has not been found. Despite the wide spread abundance of Aphanizomenon species in both lakes, the paralytic shellfish toxins saxitoxin and neosaxitoxin were extremely rare in planktonic samples, with no confirmable occurrences in the samples analyzed to date. The importance of these studies in developing a strategy for protection against harmful cyanobacterial blooms will be discussed.

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Cyanobacterial Hepatotoxin Variants in the Ontario Environment

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According to the Safe Drinking Water Act, 2002 (SDWA), Ontario Regulation 169/03, the standard for microcystin-LR, expressed as a maximum concentration in mg per litre is 0.0015 or 1.5 parts per billion (ppb). This regulatory standard is written specifically for the microcystin-LR variant. The ability of the current liquid chromatography-tandem mass spectrometric (LC-MS/MS) method to accurately detect and quantify toxin variants is limited by the availability of commercial reference materials. The five common commercial reference materials available are microcystin-LR, -RR, -YR, -LA, and nodularin. Yet, over 80 toxic variants of microcystins are known. Recently, our laboratory has been using a new immunoassay technology for microcystin detection. In this immunoassay, antibodies recognize the 3-amino-9-methoxy-2,6,8-trimethyl-10-phenyldeca-4,6-dienoic acid (ADDA) moiety common to all toxic variants. In at least 11 instances among 82 samples tested (13%) in 2007, immunoassay results were positive for hepatotoxins, while LC-MS/MS results were at or below method detection limit (MDL) of 0.05 ppb. Furthermore, immunoassay results did not correlate with LC-MS/MS results for microcystin-LR ($R^2 = 0.21; N = 40$). Our observation strongly implies that more toxic variants exist in the Ontario environment than the mere five variants detectable by LC-MS/MS, and this hypothesis deserves further investigation.

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Applications of Remote Sensing and GIS to the Assessment of Watershed Health

Chairs: Raul Ponce-Hernandez and Bill Pain
Atmospheric Deposition of Phosphorous Over Lake Simcoe

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Pollutants such as nutrients are emitted to the atmosphere by numerous processes in agriculture, industry, and urban non-point and point sources. Once entrained or dissolved in the air stream, contaminants are transported to various locations depending on many factors such as precipitation, wind patterns, topography, land use, and regional contaminant sources. Pollutants, either entrained or dissolved, can be returned to the ground or water sources by wet (episodic) and dry (continual) atmospheric deposition. Gases or particles removed by wet deposition are deposited by rain, sleet, snow or fog. Dry deposition deposits particles and gases in the absence of precipitation, namely by adsorption, impaction and settling (USGS-1 2005).

High levels of phosphorus in Lake Simcoe have been attributed to the decline in lake water quality since 1970. Out of the estimated 53 to 67 tonne/annum (1998 to 2004 water years) of phosphorus entering the lake, atmospheric deposition is believed to be responsible for 16 to 38 tonne/annum. Historical estimates for atmospheric deposition involved averaging rain gauge (rainfall depth) and rain quality (phosphorus concentration) station data. Thus, through use of this procedure, any spatial variability in the data (quality and quantity) is lost as each gauge is given an equal weighting.

This study investigates the use of Next Generation Radar (NEXRAD) to spatially represent rainfall data, as well as a method to correct radar-rainfall estimates to rainfall recorded by local rain gauges. Along with radar-estimates, rain quality data was spatially interpolated and radar and interpolated rain quality data were both used in atmospheric deposition calculations. From this analysis it was found that the radar generally represented localized rainfall well, with the majority of correlation coefficients (R²) being over 0.90. For large bulk TP deposition events the dominant parameter in calculating TP loads is rainfall depth and the revised method provides a significant improvement in rainfall depth calculation. Results from this analysis demonstrated a large (-147% to +46%) difference between historical and revised estimates of bulk atmospheric deposition of phosphorus over Lake Simcoe.

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A Bayesian Approach to Causal Discovery of Resource Degradation and its Application to Land Degradation Assessment and Conservation for Water Protection at Source

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Bayesian networks have been used effectively as a tool for causal discovery in environmental degradation of some aquatic and terrestrial ecosystems. Combined with GIS analytical functions, resource databases, and information obtained on the ground from formal surveys and interviews with land users, land owners and local agency representatives about indicators of drivers, pressures and states (DPS) of degradation of land resources, they can provide an effective model for elucidating the most probable causes of such states of resource degradation so that policies for addressing the root causes of the problem can be formulated and implemented. This paper introduces a Bayesian Network (BN) modeling approach for use in causal discovery of the most likely drivers and pressures exerted on land resources causing degradation, from a range of social, economic, demographic and land use variables relevant to a specific geographic context of a watershed, thus enabling the possibility of effective conservation and protection of water at source in the watershed. Results of the application of the Bayesian Network model to a particular geographic context are used to illustrate the model development and its practical application.

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A Paradigm of Integration of Remote Sensing, GIS and Modeling Tools for Assessment and Monitoring of Watershed Ecosystem Health and Water Protection at Source

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The advent of a new range of earth-observing remote platforms and sensor technologies (RS), combined with the enhanced functionality of Geographical Information Systems (GIS), the advances in watershed processes modeling and the availability of large natural resource and demographic databases, together with archival satellite imagery now in the public-domain, provide for seemingly limitless possible modes of their integration in applications to the assessment, evaluation and modeling of natural resources and the multiple aspects and indicators of ecosystems health and water protection at source. This paper introduces a paradigm of integration of procedures, models, technology and tools for effectively assessing the state of indicators of watershed ecosystem health and the protection of water at source in the watershed context. The pattern of integration suggested in this paper utilizes the Driver-Pressure-State-Impact-Response (DPSIR) approach to determine the assessment and monitoring methods and procedures. Useful indicators of drivers, pressures and particularly states of watershed ecosystem health are identified and those whose spatial distribution is amenable to mapping are mapped through a suitable combination of remote sensing change detection techniques and GIS analytical functions. The states of other indicators (e.g. soil erosion and land degradation), their pressures and drivers are identified and determined through process modeling techniques aided by GIS spatial analysis. The paradigm of integration of GIS, Remote Sensing and modeling technologies introduced and applied to watershed health and protection is found useful in facilitating the assessment and monitoring of the ecosystem health and water protection at source, and as an important tool for resource management and protection.

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Tracking Saturated Areas in the Landscape: A Topographic Approach

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Topographically driven soil saturation has been a key area of scientific inquiry in geographical and hydrological analysis and modelling. Current approaches in computing the secondary DEM attribute, the topographic wetness index (TWI), as an indicator of surface saturation, tend to rely on digital elevations models (DEMs) computed with inverse distance weighted (IDW) algorithms and without hydrological correction or stream enforcement such as that available in the Australian National University Digital Elevations Models (ANUDEM) algorithm. With these approaches, it is common for the TWI to be calculated using the Direction Eight (D8) flow direction model of O’Callaghan and Mark (1984), which has two main restrictions: (i) flow originating over a two-dimensional pixel is treated as a point source (non-dimensional) and is projected downslope by a line (one dimensional) (Moore et al., 1991), and (ii) the flow direction in each pixel is restricted to eight possibilities (Costa-Cabral and Burges, 1994; Tarboton, 1997).

This research presents a cumulative approach to wetness index modelling emphasizing the interpolation of a hydrologically correct DEM and the use of a distributed flow direction algorithm to improve the overall distribution of the TWI. It was found that the TWI provided a good predictive classification of surface water distribution including aerial features such as wetlands and open aquatic areas (i.e., lakes and ponds) as well as linear features including ephemeral and permanent streams. With this cumulative approach, the secondary DEM attribute, $W = \ln \left( \frac{AS}{\tan \beta} \right)$ can be used as an automated means of mapping the distribution of surface water and what is described as a surface’s topographical hydrologic connectivity index (THCI). The index is proposed as a tool for landscape management, environmental assessments, site selection and restoration planning, hydrological modelling, source water protection planning, non-point source surface water flow paths, and watershed characterization and conservation management planning.

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Mapping Wetland Vegetation in the Coastal Wetlands of Georgian Bay: Can We Track Changes in Water Quality Using Remote Sensing Techniques?

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The coastal wetlands of eastern Georgian Bay represent some of the most pristine wetlands in all of the Great Lakes. They also represent an area which is undergoing increased human development. To be properly protected these wetlands must be mapped. The large area covered by wetlands and their remote location make them too costly and labour-intensive to map with traditional aerial photographs and field surveys. In this study we present an approach currently under development, which can classify coastal wetland vegetation using IKONOS satellite imagery. Here we use Definiens Cognition Network Technology® (Definiens AG; München, Germany) to classify separate coastal wetland regions into distinct vegetation classes, rocks and water for both aquatic and terrestrial portions of wetlands. Our goals are to develop a process to assess and quantify fish habitat and to identify areas of high conservation value and priority. This can be completed by tracking human density using docks as an indicator as well as changes in water quality through changes in the composition of wetland vegetation. Increases in emergent vegetation and the loss of floating or submerged vegetation are often associated with either lower water quality or quickly dropping water levels. Here we show a new methodology for identifying and grouping vegetation based upon their functional morphology.

During the summer of 2007 new sites were sampled throughout Eastern Georgian Bay. At each location ground truth data was collected for a variety of coverage types including: floating vegetation, emergent vegetation, open water, meadow, shrubs, sphagnum mats and open water, and rock. The dominant vegetation along with the GPS coordinate was noted at each point. The field information was used to develop a classification scheme and to assess the accuracy of the classification. Coastal wetlands represent the land-water interface of the watershed. Since all water including urban runoff is filtered by these wetlands a loss of vegetation can impair wetland function. Changes in watershed health will be expressed in the coastal vegetation. By tracking changes in vegetation composition in regions which are undergoing increasing levels of development, such as Georgian Bay, we may be able to identify new areas of concern without the need for expensive and time consuming field studies.

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Trends in Water Clarity of the Lower Great Lakes from Remotely Sensed Aquatic Colour.

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Satellite observations of aquatic colour enable environmental monitoring of the Great Lakes at spatial and temporal scales not obtainable through ground-based monitoring. By merging data from the Coastal Zone Color Scanner (CZCS) and the Sea-viewing Wide Field-of-view Sensor (SeaWiFS), monthly binned images of water-leaving radiance over the Great Lakes have been produced for the periods 1979-1985 and 1998-2006. This time-series can be interpreted in terms of changes in water clarity, showing seasonal and inter-annual variability of bright-water episodes such as phytoplankton blooms, re-suspension of bottom sediments, and whiting events. Variations in Secchi disk depth over Lakes Erie and Ontario are predicted using empirical relationships from coincident measurements of water transparency and remotely-sensed water-leaving radiance. Satellite observations document the extent to which the water clarity of the lower Great Lakes has changed over the last three decades. Results confirm dramatic reductions in Lake Ontario turbidity, and present evidence of a reduction in the frequency/intensity of whiting events in agreement with suggestions that calcium uptake by mussels has influenced lake water clarity. Increased spring-time water clarity in the eastern basin of Lake Erie also corroborates previous observations in the region. Despite historical reports of localised increases in transparency in the western basin immediately following the mussel invasion, image analysis shows a significant increase in turbidity between the two study periods, in agreement with more recent reports of longer term trends in water clarity. Through its capacity to provide regular and readily interpretable synoptic views of regions undergoing significant environmental change, this work illustrates the value of remotely sensing water colour to water clarity monitoring in the lower Great Lakes.

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Utilization of Remotely Sensed Data for Mapping Impervious Surfaces

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AMEC Earth & Environmental

AMEC Earth & Environmental is utilizing remote sensing to delineate and update areas of pervious and impervious surfaces for many municipalities to comply with regulations of the National Pollutant Discharge Elimination System (NPDES). This information allows for effective stormwater management, improved hydrological runoff models and the determination of appropriate stormwater user fees for residential and commercial properties.

AMEC Earth & Environmental used QuickBird multispectral satellite imagery acquired in July 2005 to map impervious surfaces within a pilot area encompassing approximately 125 sq km for the County of Arapahoe, Colorado. This imagery is available from DigitalGlobe and is particularly well-suited for mapping impervious surfaces. It has 2.4 meter spatial resolution for its 4-band multispectral data and 0.60 meter spatial resolution for its panchromatic data.

Using ERDAS Imagine, A Normalized Difference Vegetation Index (NDVI) was applied to the imagery to identify those pixels containing vegetation. An iterative approach was then used to evaluate a whole pixel unsupervised classification method versus a pan-sharpened unsupervised classification procedure. Upon completion of the image classification, results from both methods for 272 selected single family residence (SFR) parcels were compared to results from traditional hand-digitization of natural color aerial imagery acquired between April and June in 2004. Results from this project guided the methodology for mapping impervious surfaces within a larger area for the North East Ohio Regional Sewer District. This study area includes the city of Cleveland and encompasses approximately 913 sq km. Results from both remote sensing exercises will be presented and the utility of this application will be demonstrated.

Advantages of remotely sensed data include synoptic views that allow for simultaneous regional-scale assessments as well as frequent and repeated coverage that allows for easy updating. For large areas, use of satellite imagery and digital image processing techniques is less expensive and less time consuming than hand digitization.

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Soil Map Upgrade Challenges in Ontario: 1. Modeling Approaches for Valley Complex Improvements

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Presently, the best available detailed Ontario soil maps are digitized versions of the county-level paper maps developed from surveys conducted over a six decade period. One of these maps, the one for the former Durham County (Webber et al., 1946) along the Lake Ontario shoreline, was presented at a scale of 1 inch to 2 miles (1:126,720). The best available, high resolution (sub-metre accuracy) digital elevation model (DEM) that covers this area was created in 2002. An overlay of this Durham County soil map over this DEM revealed many problems with soil unit boundary locations within this terrain. One of the most obvious issues was the lack of correspondence of valley complex soils with the actual valley bottoms. In many cases, these soil unit boundaries were observed to be “shifted” from where they should be located in the landscape. This digitized 1946 vintage source had them extend well onto or entirely located on valley hillsides. Consequently, adjacent hillside soil units were shown to be in the actual stream and riparian area locations in other cases. This situation must be rectified in order for accurate and adequate soil information to be input into environmental models and planning decisions. Valley complex soil boundaries are important hydrological parameters with riparian zone, wetlands and flooding management implications.

A modeling approach was developed that uses the high-resolution DEM and the digital version of “heritage soil survey” mapping work – for Durham County in this case – as inputs to assign valley complex soil unit boundaries to locations that more accurately reflect their true landscape positions. SoLIM (Soil Land Inference Model; Zhu, 2007) was the model inference engine used for this work. Based on the landscape rendered from the DEM, the focus was to isolate its main components – the valley complex (mainly bottomlands) being one of those features. Three basic input layers for this fuzzy logic model were: the “Gradient Operator” (from the grid package in the Surfer™ software product (Golden Software, Inc. 2002)); and two “relative position indices”- the “% Z to streams” parameter from LandMapper™ Software Toolkit - C++ Version (MacMillan, 2003) and the ArcMap-Spatial Analyst™ software product “Distance to” parameter. The “Gradient Operator” (set at > 0.08 for valley sides) was used to produce terrain inflection points. The “% Z to streams” parameter (set at < 20%) further identified bottomlands. The “Distance to” parameter (< 100m) effectively tied the bottomland and adjacent valley side designations to the stream valleys. This approach produced a SoLIM soil polygon product with an “edge” that was used to correct valley complex soil unit locations from their “heritage map” positions (a product of both coarse-scale original mapping and shifts during rubber-sheet digitizing) to much more accurate landscape positions. On-going applications of this mapping approach, using SoLIM, will permit Ontario’s “heritage” soil survey information to be portrayed more accurately. This will add considerable value to future environmental modeling efforts where detailed spatial soils information is a required input.

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Grand Lake Watershed Assessment for Nutrient BMP Implementation Targeting

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AMEC Earth & Environmental

Grand Lake watershed is 10,300 square miles and experiences excess nutrient and sediment loadings associated with agricultural production, including cattle and poultry operations, residential development, and other activities. As a result, extensive portions of the stream network are listed as water quality impaired and the receiving reservoir, Grand Lake, is eutrophic.

AMEC coordinated with the Conservation Commission to design and conduct a state-of-the-science watershed investigation focused on accurately characterizing non-point source nutrient and sediments loading sources. This investigation included a detailed assessment and prioritization of sites to support targeting BMP implementation.

The Grand Lake investigation:

- Applied remote sensing techniques (Landsat TM) and extensive field data to characterize land cover and land management practices;
- Developed a watershed modeling application (using SWAT) to predict nutrient and sediment loadings to receiving waters;
- Applied the model to support prioritization of sub-watershed and specific sites in terms of nutrient loading; and
- Focus limited resources (e.g., 319 & state funding) on the areas that will achieve the greatest load reductions.

As a result of the project, Grand Lake Watershed stakeholders are able to use limited grant funds to select BMPs that will achieve optimal success in removing water quality impairment.

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Stormwater and Urban Lake Management

Chairs: Deborah Sinclair and Sandra Kok
Weeping Tile Disconnection as an Effective Method of Extraneous Flow Reduction

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The issue of the efficacy and feasibility of private property extraneous flow reduction via systematic weeping tile or foundation drain disconnection programs has been examined and evaluated over the past twenty years. Typically weeping tile disconnection programs are aimed primarily at the prevention of sewer surcharge related basement flooding with little no regard paid to the quantification of the net extraneous flow reduction resulting from these programs.

The City of Niagara Falls in conjunction with the Town of Fort Erie, Great Lakes Sustainability Fund and the Niagara Water Quality Protection Strategy retained Associated Engineering, AE, in June of 2006 to conduct a monitoring program in order to quantify the amount of extraneous flow contributed by residential weeping tiles to local sanitary sewers.

The City and Town have both experienced high inflow and infiltration rates in areas considered to be partially separated with storm sewer servicing. These areas, primarily constructed in the mid 60’s to late 80’s, prior to the introduction of applicable bylaws governing foundation drain connections, have direct connections between weeping tiles or foundation drains to the sanitary sewer network.

Niagara Falls is currently considering the introduction of a mandatory and retroactive bylaw for the removal of sources of extraneous flow from the City of Niagara Falls sanitary sewer network on a global, proactive and staged basis. The Town of Fort Erie has already introduced a local sewer use bylaw which prevents the connection of sources of extraneous flow to the local sanitary system and allows for the retroactive removal of existing sources.

This study supplemented previously anecdotal evidence concerning the efficacy and financial impact of weeping tile disconnection as part of an overall extraneous flow removal program via detailed site specific monitoring of approximately 20 residences over a period of 6 months.

This presentation will present the data collection methods, results and the impact of the study on municipal policy in both locations.

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Sediment Removal Efficiency of Compost Biofilters

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Construction activities near water bodies such as streams, rivers and lakes have a great potential to cause water pollution and stream degradation if erosion and sediment control measures are not implemented properly. Use of compost for erosion control has been limited to mulch covers and compost blankets so far, but a green sustainable technology is introduced recently which suggests the use of compost as a filter media within a mesh photodegradable tubular sock.

Field experiments were conducted in the summer of 2006 at the Guelph Turf Grass Institute, University of Guelph to verify the sediment removal efficiency of the so called compost biofilter, as well as the effect of compost type, sock diameter and number of socks on sediment removal efficiency. Lab experiments were also conducted in School of Engineering, University of Guelph to determine flow-through properties of the biofilter. In order to increase the settlement of high volumes of very fine suspended solids in stormwater runoff, polymer tests were conducted by adding different concentrations of Polyacrylamide polymer (PAM) products as a flocculent in agent.

The utilized compost was made up of various yard waste including twigs, bark and wood chips and was provided from three different sources (Alltreat farms, Region of Peel and Region of Waterloo). Maximum flow through rate for the 8 inch sock for three compost materials was determined to be 1.5 L/s per unit width. Flow through capacity of 12, 18 and 24 inch socks were approximately 50%, 200% and 300% higher than the flow through rate of the 8 inch sock respectively. For all four diameters, the flow through rate reduced to almost half, as sediment started to cumulate in the biofilter over time.

The average sediment removal efficiency of the 8 inch socks for 5, 10 and 15 rolls were 34%, 48%, and 60% respectively. The average sediment removal efficiency for 18 inch socks for 5, 10 and 15 rolls were 69%, 84% and 95 % respectively. The decrease in sediment removal efficiency of the biofilter over time was significant. The average sediment removal efficiency of 5 rolls of the 18 inch sock started to decrease gradually from 70 % to 62%, 58%, 56% and then 54 % after 1, 5, 10, 15 and 20 consecutive runs. Sediment removal efficiency of sediment particles in the size range of clay was found to be 30%, while coarser particles such as fine silt and coarse silt had 50% and 80% of removal efficiency respectively. The results from the Polyacrylamide polymer (PAM) tests show significantly higher sediment removal efficiencies (more than 90%) and the optimum application rate for liquid PAM was around 5 mg/L.

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Particle Size Characteristics and Trace Metal Content of Particulate Matter in an Urban Sewershed

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This study examines the particle size characteristics (particle morphology, grain size distribution) and metal (Cu, Pb, Zn) content of particulate matter in a small southern Ontario urban sewershed. Surface sediment was collected from two connected parking lots, sewer infrastructure and Stormwater detention pond. Total metal content and non-residual (acid extractable) metal content of sediment samples were evaluated. The median grain size diameter (D$_{50}$) decreased along the gradient from the upper parking lot to the pond. Large, angular grains with little aggregation were predominant in both parking lots and the D$_{50}$ of these surface materials was ~ 19µm. The D$_{50}$ of particles in surface runoff from the parking lots decreased to ~ 5 µm and a small degree of flocculation was apparent. Using digital images of the sediment, particle morphology changed from coarse angular surface materials in the upper parking lot to finer, more complex and highly flocculated materials in the pond. Concentrations of Pb (31 mg/kg) in the upper parking lot sediments exceeded the Provincial Sediment Quality Guidelines (PSQG). Levels of Cu (16mg/kg) and Zn (120 mg/kg) exceeded the PSQG in the lower parking lot (Cu only) and detention pond. Fine grained sediments in the pond had the highest levels of acid extractable Cu, Zn and Pb. The study shows that sewer infrastructure, including a Stormceptor® Model STC 1000 Oil and Sediment Separator, is not effective at removing sediment < 60µm which has important implications for the transport and fate of sediment-associated metals.

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Wet Weather Performance of a Green Roof in Waterloo, Ontario

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Green roof technologies are increasingly being adopted as treatment measures to mitigate the effects of urban stormwater. A mass balance approach was used to assess the treatment performance of an extensive vegetated roof located on the City Hall in Waterloo, Ontario. Vegetated and control sections of the roof were instrumented to measure precipitation inputs, storage and outflow for 12 storm events from June to October, 2006. Concentrations of suspended solids (SS), total phosphorus (TP), soluble reactive phosphorus (SRP), copper (Cu), zinc (Zn), chromium (Cr) and cadmium (Cd) in precipitation and roof (vegetated and control) runoff were measured. A total of 155.6 mm of rain fell during the study period. The vegetated roof retained 72.6 mm (46\%) of the total rainfall while the control roof retained ~ 5.1 mm (3.3 \%). For individual rain events, the vegetated roof retained an average of 4.2 mm (56.5 \%) while the control roof retained ~ 0.3 mm (5.5 \%). Water retention varied with storm size, season and frequency of storm event. The green roof retained 93.4 \% of precipitation for light storm events (\leq 2.5 mm), 45.4 \% for moderate storm events (2.5 mm – 6.0 mm) and 53.8\% for large storm events (\geq 6.0 mm). Water quality varied as a function of storm size, duration, antecedent days and time of year. The green roof effectively decreased runoff (decreased peak, extended lag time) but losses of TP and SRP were significantly higher than either the precipitation or runoff from the control roof.

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There are 14 lake/pond systems in the City of Brampton. These lakes and ponds are either “esker type” lakes – former pits or quarries that are groundwater fed with limited or no direct surface outlet, or are surface water dominated and associated with creek systems. One rare meromictic lake is also located within the City. There have only been limited attempts to document lake status and, aside from Heart Lake that is managed by the TRCA, any management activities have been in response to specific “crisis” issues. In 2004, The City of Brampton implemented the Citywide Lake Assessment and Management Study in response to the need to develop sound management plans for the lakes and improve designs for any future lakes. A field program was implemented to identify key physical, water, sediment, aquatic, and terrestrial characteristics for each lake. The information was used to complete an evaluation of each lake that identified and established the fundamental roles and functions of each lake system and identified any current or anticipated problems. The evaluation was used to compare and contrast the current state of each lake studied and to assign management recommendations and priorities for groups of lakes and individual lakes. The evaluation found that the surface water lakes all had a similar level of poorer water quality, while the water quality in groundwater fed lakes fell into three categories: very good, transitional, and poor. The management objectives for the surface water lakes and the poor quality groundwater lakes focused on mitigating causes of nutrient enrichment, improving water clarity, and naturalizing shorelines. Both the transitional and good quality lakes management objectives focused on naturalization of shorelines and littoral areas. The management strategy also recommended promoting the lakes as valuable urban amenities and natural “oases” that are frequently ignored or overlooked in a rapidly urbanizing center.

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A stakeholder consultation workshop, “Working Towards Developing a Test Protocol for Performance Verification of Hydrodynamic (Oil/Grit) Separators in Stormwater Management Applications”, took place in Toronto in May 2007 (http://www.etvcanada.ca/etvworkshops.asp). The workshop recommended the development of a full-scale laboratory testing and verification protocol to provide the means to obtain credible support data for verifying technology performance. It was suggested that the proposed undertaking be done in collaboration with experts, vendors and key institutions to encourage co-operation among Ontario municipalities in support of a Province-wide approach.

The proposed undertaking directly supports the City of Toronto’s “Wet Weather Flow Management Policy” which provides direction on how to manage wet weather flows on a watershed basis and assigns first priority to the management of wet weather flows “at source”. The following next steps are proposed:
- Develop a draft of the full-scale laboratory testing and verification protocol and survey appropriate hydraulic testing facilities capable of conducting full scale laboratory testing.
- Present the draft protocol to stakeholders for discussion.
- Undertake a demonstration project relevant to City of Toronto and incorporate final revisions to the protocol.

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Suitability of urban pond ecosystems for zooplankton growth

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Stormwater management ponds (SWMPs) are typically built into urban developments to slow the movement of water and to sequester sediments and anthropogenic contaminants coming out of residential areas. These ponds also provide a potentially-rich wetland-like habitat for aquatic fauna and flora. We examined the capability of urban ponds to support healthy zooplankton populations by measuring growth rates of laboratory *Daphnia* reared in whole-water samples taken from 38 SWMPs located across southern Ontario, Canada. To assess the potential drivers of variable *Daphnia* growth rate, we also measured an array of food parameters and water chemistry variables including total suspended C, chlorophyll *a*, elemental composition (C:N:P ratios) of suspended materials, the quantity of suspended sediments, temperature, pH, dissolved oxygen, and conductivity. *Daphnia* growth rates varied considerably depending upon the SWMPs providing the whole water. As we found no relationship between *Daphnia* growth rate and any aspect of food or water chemistry, we are unable to determine the detrimental agent(s) slowing *Daphnia* growth. Nevertheless, it does appear that SWMPs should be capable of supporting zooplankton populations as *Daphnia* grew 50% or greater of their maximum in approximately two thirds of the sampled SWMPs.

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Determinants of Water Quality in Urban Ponds: A Limnological Approach

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Stormwater management ponds (SWMPs) are designed to retain urban runoff, which reduces sediment and pollutant load to receiving waters. However, by acting as a sink, contaminants accumulate in ponds in concentrations that exceed Canadian Water Quality Guidelines. Although these ponds are not intended as habitats, they "self seed" into wetlands and are colonized by aquatic flora and fauna. It is currently unknown what algae and zooplankton communities are typical of SWMPs and if pond characteristics cause variation in these communities. We sampled 56 SWMPs varying in size, age and location in Southern Ontario to: (1) characterize algae and zooplankton communities (2) determine whether nutrient levels affect plankton community structure, and (3) determine the role of pond characteristics, management protocols and landscape characteristics in structuring zooplankton and algae communities and predicting limnological parameters. Preliminary physico-chemical data show that SWMPs vary widely, and are unique and very different from surrounding waterways. SWMPs typically have high total phosphorus and total suspended solids (24-563 µg L-1 and 0-97 mg L-1 respectively), extremely high bottom conductivity and surface temperature (207-4505 S/cm and 16-32°C respectively) and can be depleted in oxygen levels (as low as 0.09 mg L-1), especially in ponds that stratify, which occurred in 47 of the 56 ponds sampled. Pond age, which ranged from 2 to 32 years, was found to be an important factor in influencing many of these parameters. Forebays had higher total suspended solids and nutrient levels than their corresponding main ponds, indicating that they may play an important role in stormwater pond systems. This research will provide developers and municipalities with science-based guidelines to use in designing stormwater management systems that provide higher quality aquatic habitat in addition to improving understanding of aquatic ecosystems within urban landscapes.

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Radial Sedimentation Pond

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Rectangular sedimentation ponds have traditionally been used by designers and design equations are only available for this shape. However, constraints are often encountered in real world which dictate pond shapes other than rectangular. Here, the case radial (or pie-shaped) pond is considered.

Since standard design equations are not available for sedimentation ponds of this shape, they have been derived from first principles. The detailed derivation of equations for radial ponds and associated assumptions are presented. The corresponding equations for rectangular ponds are also given for easy comparison.

The radial ponds can be used for efficient sedimentation and water quality enhancement where land availability is limited.

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Development of an Inexact Urban Stormwater Management Model

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Urban storm water management is a serious problem facing the local authorities and stakeholders. Every year, more than half of the pollutants entering the rivers and lakes come from storm water runoff. At the same time, a number of impact factors exist in the urban storm water management systems which interact with each other. Uncertainties also exist associated with system objectives, parameters, and their interactions. Thus, effective storm water management is desired for the decision makers for supporting the decision making. Mathematical models and uncertainty analysis approaches are very useful tools for facilitating the planning and management of urban storm water management. Therefore, an inexact urban storm water modeling system will be developed and applied to a real world case for demonstrating its applicability.

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Biotechnology – Environmental Application and Potential Risks

Chairs: Bin Zhu and Réal Roy
Characterization of WAS Pretreatment by Ultrasound

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Pre-treatment of waste activated sludges (WAS) prior to digestion processes is of increasing interest to wastewater treatment utilities. While there has been considerable study of pre-treatment processes, a common approach to describing the impact of pretreatments on sludge biodegradability has not been developed. In addition there has been little evaluation of the interaction between WAS characteristics and pre-treatment efficiency. In this study, a range of physical, chemical and biological responses are being evaluated to assess the impact of sonication on WAS properties as well as sludge digestibility. WAS that was generated at differing SRTs on municipal wastewater was employed to facilitate an assessment of the interaction between pre-treatment and WAS properties on digestibility. The overall objective was to develop protocols that can be employed to characterize the impact of pre-treatment processes on WAS digestion.

Approach:

Three SBRs were operated on screened municipal wastewater at SRT’s of 1.95, 3.9 and 15 days to provide a source of WAS for this study. WAS samples from the SBRs were treated by sonication and the raw and treated samples were characterized with respect to solids and COD concentrations, particle size distribution and oxygen uptake rate. Batch anaerobic digestion tests of the raw and pre-treated samples were conducted to assess the Biochemical Methane Potential (BMP) as well as the Biochemical Acid Potential (BAP).

Results:

Mean particle diameter was used as an indicator of the physical properties of the raw and pre-treated sludges. All of the pretreated particles had similar mean diameters and there was significant reduction in particle size for virtually all levels of treatment intensity and for all 3 sludge ages.

The incremental change in the filtered COD was compared to the incremental change in volatile dissolved solids as ultrasound intensity increased. The results indicate that the solids which were solubilized from the 15 d SRT sludge were different in composition than those solubilized from the 7 and 15 day SRT. The impact of pretreatment on methane production was evaluated in BMP tests. Pre-treatment appeared to increase the ultimate methane yield only marginally despite the significant impact on the sludge properties as indicated by the physical, chemical and biological indicators.
Pre-treatment did not appear to be successful in converting materials from a non-biodegradable to a biodegradable form. Pre-treatment did appear to significantly impact upon the rate of methane generation in the first 20 days of the test.

The effect of pre-treatment on the anaerobic biodegradation process was further investigated by examining the generation of NH4-N in the BMP tests. Pre-treatment substantially reduced the time required convert a fixed fraction of the TKN to NH4-N during anaerobic digestion suggesting that the rate of hydrolysis was substantially enhanced. These results confirm the CH4 data in that the rate of conversion which is commonly believed to be limited by hydrolysis was increased by pre-treatment. A lag was not observed for the 25 minute pre-treatment as was observed in the CH4 data thereby supporting the conclusion that inhibition of methanogens was responsible for the lag in CH4 production.

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Many controversies remain with respect to the key constituents responsible for fouling in membrane bioreactors (MBR). Most studies investigate fouling under steady-state conditions and little information is available during the stabilization period after the MBR is seeded. As well, no information is available about the dynamics of mixed liquor characteristics in MBRs and their effect on fouling during the stabilization period. The general goal of this research was to provide a better understanding of the fundamental mechanisms in membrane fouling. Specifically, the objectives included:

1. to establish the dynamics of mixed liquor characteristics during stabilization,
2. to assess the effects of mixed liquor characteristics on membrane fouling, and
3. to confirm the existence of an empirical relationship between critical flux and colloidal total organic carbon (cTOC).

Three submerged MBR pilot plants (6, 10 and 15 day SRTs) fed with municipal wastewater were operated in parallel during the stabilization period. Each pilot plant was equipped with a ZeeWeed® 10 (GE/Zenon Membrane Solutions, Canada) module. Fouling potential was measured using critical flux and fouling rate. Mixed liquor characteristics including mixed liquor suspended solids (MLSS), mixed liquor volatile suspended solids (MLVSS), diluted sludge volume index (DSVI), time to filter (TTF), particle size, zeta potential, soluble and bound extracellular polymeric substances (protein, humic substance and carbohydrate concentrations), temperature and colloidal TOC were measured.

For all three pilots, the fouling potential increased and then decreased to an almost constant value. This is consistent with previous observations that stabilization is not only a function of time but also of raw wastewater composition. A decreased fouling potential with increased SRT was observed after quasi steady-state was achieved. There was an initial decrease in bound carbohydrate concentration followed by an increase to a constant concentration and an increase in soluble carbohydrate concentration followed by a decrease to a constant concentration. This inverse relationship indicated that soluble carbohydrate increases and decreases during stabilization are largely due to biomass associated products (BAP) and, to a lesser extent utilization associated products (UAP). No other general trends were observed for any of the other monitored mixed liquor characteristics.

To assess the effect of mixed liquor characteristics on fouling rate, all data collected from the pilot tests was pooled together. A low negative correlation between soluble EPS and fouling rate was observed but soluble carbohydrates were found to be the most important EPS constituent. A high positive correlation between cTOC and fouling rate was also observed and a correlation between soluble carbohydrates and cTOC was established. This correlation indicated the concentration of soluble carbohydrates in MBR systems could be reported in cTOC.
equivalents. cTOC measurements are much easier and more rapid compared to soluble carbohydrate concentration measurement. No other correlations were observed for any of the other characteristics.

* Presenting author; aportela@uoguelph.ca
Effect of Athermal Microwave Exposure and Digestion Temperature in the Anaerobic Degradation of Wastewater Sludge

N. COELHO,1∗ K. KENNEDY,1 R. DROSTE,1 AND M. BERROUET 2

1University of Ottawa, Department of Civil Engineering
2Université de Limoges, Faculté de Génie

Two different types of sludge, Thickened Waste Activated (TWAS) and biofilm, were subject to different microwave athermal pre-treatment. Two concentrations were tested for each type of sludge (1% and 3% total solids). The athermal exposure allowed irradiation with microwaves while keeping sludge at room temperature. Different exposure times were tested (0, 6 and 25 minutes), in order to test the influence of exposure time in several sludge parameters. Changes were compared to sludge not subject to any pre-treatment.

Results show that the exposure to athermal microwave pre-treatment increases the solubilization of COD, proteins and sugars, and that for TWAS, greater exposure periods increase solubilization, confirming previous studies that showed that athermal effect does exist. This effect is more noticeable in sludge with higher solids concentration, both for TWAS and for biofilm sludge. The results also show that the degree of solubilisation depends on the power absorbed, since increases in exposure time were coupled with increases in the amount of soluble COD; proteins and sugars. The particle size distribution of the sludges also shows a change when exposed to athermal microwave pre-treatment. The percentage of smaller particles increases compared to sludge non pretreated, and the higher exposure times cause a higher generation of smaller size particles. This is most likely caused by the disruption of floc structure, and release of the particles and cells comprised in the polymeric matrix that form the floc.

Pretreated sludge was then subject to anaerobic biodegradation at two different conditions, thermophilically (55 ºC) and mesophilically (35º C). Results show that thermophilic anaerobic digestion produced more methane than mesophilic digestion for the same type of sludge and pre-treatment. The effect on subsequent biodegradability showed that irradiation of sludge with microwaves increased the yield of methane attainable in anaerobic digestion. The production of methane was faster in the mesophilic tests, but reached higher values in the thermophilic ones, showing that some inhibition phenomena was more prevalent in the test made at higher temperatures.

∗ Presenting author; nuno.coelho@uottawa.ca
Survival and Persistence of Introduced Bacteria in Freshwater Microcosms

B. ZHU,1* J. R. LAWRENCE,1 Y. WEI,2 J. ROY,1 AND T. HE1

1AEPRD, Water Science & Technology Directorate, Environment Canada, Saskatoon, Saskatchewan
2Department of Biology, University of Saskatchewan, Saskatoon, Saskatchewan

Microbial biotechnology products (wild-type strains or genetically modified) can be used for industrial production, bioremediation, bio-control, etc. After their commercial release, live cells may persist in the environment. Regulatory agencies are becoming increasingly concerned over the persistence and spread of microorganisms used in biotechnology. One component required by regulatory agencies is the development of methods for detecting the survival of live cells and generation of persistence trend data in relevant environments. The fate of some Bacillus strains on the Domestic Substances List (DSL) was monitored after introduction into laboratory microcosms. The cells were detected by polymerase chain reaction (PCR) with functionally specific amplified fragment length polymorphism (AFLP) primers, and were quantified by quantitative real time PCR. During incubation, some cells may lose viability but still carry DNA; DNA-based detection methods cannot differentiate whether positive amplification of PCR products originated from live or dead bacterial cells. Therefore, the distinction between viable and dead cells is a major issue in terms of monitoring their long-term persistence in relevant environments. It has been reported that propidium monoazide (PMA) is highly selective in penetrating only into dead bacterial cells with damaged membranes but not to live cells with intact cell membranes and walls. We have attempted to use PMA to treat Bacillus cells sampled from microcosms to inhibit PCR amplification of DNA derived from dead cells. Cell survival of the Bacillus strains was tested in river water microcosms at 3 different temperatures (23°C, 16°C and 4°C). The results showed that live Bacillus cells can be detected after >100 days of incubation when inoculated at 107 cells/ml.

* Presenting author: bin.zhu@ec.gc.ca
Bioplastics Production by the Isolated Polyhydroxyalkanoate (PHA) Accumulating Bacterial Strains from Pulp and Paper Industry Wastewater Activated Sludge

S. YAN,1* S. BALA SUBRAMANIAN,1 R.D. TYAGI,1 AND R.Y. SURAMPALLI2

1Institut national de la recherche scientifique, Centre Eau, Terre & Environnement, Université du Québec, 490 de la Couronne, Québec, G1K 9A9, CANADA.
2US Environmental Protection Agency, P.O. Box 17-2141, Kansas City, USA, KS 66117.

In a previous study, pulp and paper activated sludge showed a potential of producing PHA in fermentor employing acetate as well as different types of wastewater as the carbon sources, the maximum PHA content reached up to 60% (w/w). In this study, bacterial isolates from the pulp and paper activated sludge were screened for polyhydroxyalkanoates (PHAs) accumulation. Initially Nile Blue A staining was performed to detect lipid cellular inclusions. Lipid-positive isolates were then grown in a synthetic medium containing acetate as sole carbon source to promote accumulation of PHA. The PHA was analyzed by Gas Chromatography Linked to Mass Spectroscopy (GCMS) to further confirm the presence and the concentration of PHA. It was found that six bacterial strains isolated from pulp and paper activated sludge can produce PHA (PHA content obtained from 5.22 to 35.5%), The maximum PHA content of 35.5% was obtained by strain PHA-P5. These sludge microorganisms were identified based on their 16S rDNA sequences and these six bacterial strains were identified as Microbacterium, Stenotrophomonas sp., Acinetobacter sp., Wautersiella sp., and Comamonas sp. respectively. The maximum PHA producing strain PHA-P5 was identified as Comamonas sp. The bacterial strains isolated from pulp and paper activated sludge were also compared with isolates from municipal activated sludge and were identified based on their 16S rDNA sequences.

* Presenting author; song.yan@ete.inrs.ca
Differential Gene Expression in a Lab and Environmental Strain of *Escherichia coli* Using Microarrays and its Potential Use in Bacterial Source Tracking.

C. MARTENS,¹ AND R. ROY ¹*

¹University of Victoria

The intent of bacterial source tracking (BST) is to develop methods to identify the host source of fecal contamination in the environment. Most molecular methods in BST use only a single gene region to differentiate and classify fecal bacterial species. Recent developments in genomics, such as microarrays, may provide methods allowing for coverage of whole genome or several gene markers improving the reliability in source identification. In this study, we intended 1) to evaluate, with an environmental isolate, the use of a commercial microarray (Affymetrix) based on the genome of *Escherichia coli*, an indicator of fecal contamination and 2) identify new genetic markers in *E. coli* to be possibly included in a BST microarray. Specifically we looked for genes that are differentially regulated in response to environmental stress. We compared transcriptional profiles of *E. coli* K12 and an environmental isolate (*E. coli* 43(C)-4A) grown in two different stress conditions, 21°C and 1/10th strength Luria-Bertani (LB) broth, to the control grown in LB at 37°C. Both strains differentially regulated only 0.9% to 3.2% of the genes in response to the environmental stresses. By contrast, 8.4-15.1% of genes were differentially expressed between the two strains of bacteria. We found that there were more genes differentially expressed between the bacteria regardless of the environmental conditions. These genes may also be potential genes markers that could be used to differentiate between strains of *E. coli*. Although microarray technology provide a powerful method as demonstrated in our study, further investigation of more environmental isolates should be pursued in connection with BST.

* Presenting author, realroy@uvic.ca
Differential Gene Expression In Rainbow Trout (*Oncorhynchus mykiss*) Exposed to Carbamazepine

T. NEHELI,¹* K. BURNISON,¹ J. SHERRY,¹ B. LEE,¹ D. CRUMP,² AND S. KENNEDY²

¹Environment Canada, Water Science and Technology Directorate, Burlington
²Environment Canada, National Wildlife Research Centre, Ottawa

The antiepileptic drug Carbamazepine (CBZ) is difficult to remove during waste water treatment and as a consequence is present and persists in the aquatic environment. We used the Fluorescent RNA Arbitrarily Primed Polymerase Chain Reaction technique (FRAP-PCR) to identify rainbow trout genes that were differentially expressed after exposure to CBZ. FRAP revealed several gene transcripts from the livers and brains of rainbow trout that were up or down regulated by CBZ. The parent genes of those transcripts were identified by BLAST analysis of the cloned and sequenced cDNA. The FRAP data indicated that CBZ altered the expression of genes associated with apoptosis, transcription regulation, ion regulation, and a lipoprotein receptor. The CBZ exposures were repeated using different carrier solvents (water, ethanol, and PEG 200) after which real-time or quantitative-PCR was used to validate the differential expression of the FRAP identified genes.

* Presenting Author; Tannis.Neheli@ec.gc.ca
Microbial source tracking of fecal pollution at a beach on the Ottawa River

S. HILL,¹* F. SUEN,¹ AND T.A. EDGE¹

¹National Water Research Institute, Water Science & Technology Directorate, Environment Canada, 867 Lakeshore Road, Burlington, ON, Canada L7R 4A6

A library independent microbial source tracking (MST) study was conducted with the City of Ottawa in 2007 to assess the potential impact of municipal wastewater at a beach on the Ottawa River. Petrie Island Beach occurs downstream of municipal wastewater treatment plant (WWTP) and CSO outfalls on both the Ontario and Quebec sides of the Ottawa River. At times, high numbers of *E. coli* have resulted in beach postings at the beach. Weekly water samples were collected at four sites along Petrie Beach (ankle and chest depth). Weekly water samples were also collected across four upstream transects traversing the Ottawa River, from three small upstream tributaries of the Ottawa River, and from untreated municipal wastewater from the City of Ottawa's WWTP (positive reference sample). *E. coli* was enumerated and the water samples were screened for DNA markers for human-specific (HF183) and generic (BAC32) *Bacteroides* strains. *E. coli* numbers were lowest across the Ottawa River transect upstream of WWTP outfalls, and highest along the Quebec shoreline downstream of a WWTP outfall. The human-specific *Bacteroides* DNA marker was detected in 25% of the Ottawa River samples, 19% of tributary samples and 26% of beach water samples. Occurrence of the human-specific *Bacteroides* DNA marker at Petrie beach was often associated with periods of rainfall, and was most highly correlated (Spearman correlation coefficient) with detection of the human-specific DNA marker at the Ottawa River site immediately downstream of the City of Ottawa WWTP offshore outfall. Analysis of *E. coli* numbers at Petrie Beach did not indicate such a strong association with an upstream WWTP outfall.

* Presenting author: stephen.hill@ec.gc.ca
Membrane Pervaporation to Reuse Contaminated Blackish Water for Agricultural Microirrigation

E.E. QUIÑONES-BOLAÑOS AND H. ZHOU*

1School of Engineering, University of Guelph, Guelph, Ontario N1G 2W1

A novel wastewater microirrigation technology for plants to extract reclaimed water directly from hydrophilic, homogeneous dense membrane modules embedded in the soil was studied. The experiments were first conducted by using a sweeping air pervaporation unit to characterize hollow fiber (HF) and corrugated sheet (CS) membrane modules in terms of water permeate flux and enrichment factor, using borate, selenate, sodium chloride and glucose as model contaminants. As well, a bench soil pervaporation unit was designed and constructed to quantify the irrigation water in loamy sand and loam soils by varying feed temperature, pressure, solute concentration, soil water content and membrane configuration. The results showed that the maximum water permeate fluxes from CS and HF modules buried in saturated and unsaturated soils with less than 15% moisture content ranged from 0.2 to 1.0 L/m²/d and 0.1 to 1.0 L/m²/d, respectively. The average enrichment factors for glucose, selenate, borate and sodium chloride were 0.18, 0.08, 0.19 and 0.23, respectively, indicating that the new microirrigation technology can efficiently deliver high quality water to the crops as needed, eliminating clogging problems and potential ground and surface water contamination commonly associated with conventional irrigation systems.

From the collected data, a mathematical model was also developed by combining the solution diffusion model for mass transport through the pervaporation membrane, the Richard’s equation for soil water movement and the root-activity function for plant water uptake to predict the water permeate flux for different soil and process operating conditions. A good agreement was observed between the model predictions and the experimental measurements. Further analysis concluded that the plants will self-extract water from the membrane, as needed, depending on their evapotranspiration potential and the water potential of the soil. Thus, it can be concluded that the proposed membrane pervaporation microirrigation system holds great promise as an efficient, environmentally friendly alternative to reuse brackish or contaminated waters for plant growth.

* Presenting author, hzhou@uoguelph.ca
## 43rd Central Canadian Symposium on Water Quality Research
### Program Schedule and Presentations

**Sunday, February 10, 2008**

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<th>Time</th>
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<td>CAWQ Board Meeting</td>
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**Monday, February 11, 2008**

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<td>7:45</td>
<td>Main Mall</td>
<td>Registration, Poster Installation</td>
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<tr>
<td>8:30</td>
<td>Auditorium</td>
<td>Opening Remarks: Dr Ron Droste (President: CAWQ)</td>
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<td>8:35</td>
<td>Auditorium</td>
<td>Welcome to the Canada Centre for Inland Waters: Chris Marvin (Program Chair)</td>
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<td>8:40</td>
<td>Auditorium</td>
<td>Introduction of NWRI Distinguished Speaker: Dr. Tom Edge</td>
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<td>8:45</td>
<td>Auditorium</td>
<td>Third Annual NWRI Distinguished Speaker Series and CAWQ Plenary Lecture: Dr. Pierre Payment “Public Health and Drinking Water Standards: Are We Doing More Harm Than Good?”</td>
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<tr>
<td>9:20</td>
<td>Auditorium</td>
<td>NWRI Distinguished Speaker Award: Presented by Jacinthe Leclerc; A/Director General, Water Science &amp; Technology Directorate, Science &amp; Technology Branch, Environment Canada</td>
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<td>9:45</td>
<td>South Seminar</td>
<td>Calibrating Watershed Models with Limited Data. F. AHMED</td>
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<tr>
<td>10:00</td>
<td>Auditorium</td>
<td>Ammonia Extraction using AmRHEX to Reduce Recycle Water Ammonia Load from an Anaerobic Sludge Digester. K. HAGGERTY</td>
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<tr>
<td>10:00</td>
<td>South Seminar</td>
<td>Dispersion and Hydrodynamic Connectivity of Near-Surface Waters: Applications of a 3D Ocean Circulation Model. J. ZHAO, R. YERUBANDI, and J. SHENG</td>
</tr>
<tr>
<td>10:00</td>
<td>North Seminar</td>
<td>Differential Gene Expression in a Lab and Environmental Strain of <em>Escherichia coli</em> using Microarrays and its Potential Use in Bacterial Source Tracking. C. MARTENS and R. ROY</td>
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**Note:** Names appearing in bold are presenters competing for the Philip H. Jones Award.
<table>
<thead>
<tr>
<th>Time</th>
<th>Session</th>
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<td>10:40</td>
<td>Health Break - Main Mall</td>
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<td>T.G. ADAMS, K.W. FORSYTHE, and M.-C. ARCHAMBAULT</td>
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<td>D. FRIGON</td>
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<td>12:15</td>
<td>Lunch - Main Mall</td>
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<td>13:00</td>
<td>CAWQ Annual General Meeting - South Seminar Room</td>
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<td>13:00</td>
<td>Poster Session “Meet and Greet” - Main Mall</td>
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<td>P. GUO, G.H. HUANG, and H. ZHU</td>
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<td>14:05</td>
<td>Membrane Fouling by Anaerobically Digested Sludge.</td>
<td>M. DAGNEW, W. PARKER, and J. CHALLENG-URBANIC</td>
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<td>The Structural Harmony Chart of Hydrosphere as the Controlling Tool in Environmental Modeling.</td>
<td>R. VEDOM</td>
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<td><strong>Drinking Water Source Protection</strong></td>
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<td>Mainstreaming Climate Change in Drinking Water Source Protection Planning in Ontario.</td>
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<td>R. de LO, A. BERG, and M. RETALLACK</td>
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<td>Nitrogen Removal through Recirculation and the use of Carbon Media in the AQUA Wetland System.</td>
<td>A. HELLEBUST and L. ROZEMA</td>
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<td><strong>P and T for Small Communities</strong></td>
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<td>Collaborative Study to Protect Lake Ontario Drinking Water.</td>
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<td>S. WATSON and L. F. MOORE</td>
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<td>14:45</td>
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<td><strong>Health Break - Main Mall</strong></td>
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<tr>
<td>15:00</td>
<td>Advances in Wastewater Treatment Technologies and Approaches</td>
<td>Chairs: Hongde Zhou and Wayne Parker</td>
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<td>Electrokinetic Flotation of Paint Sludge Water in a Kinetic Model Tank.</td>
<td>J. SHANG and Y. XU</td>
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<td>Treatment Wetlands for Wastewater Treatment in Small Communities in Northern Canada.</td>
<td>J. HIGGINS and M. LINER</td>
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<td><strong>Drinking Water Source Protection</strong></td>
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<td>North Seminar Chairs</td>
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<td>Larry Moore and Simon Gautrey</td>
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<td><strong>Corrections</strong></td>
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<td><strong>Polices and Technologies for Small Communities</strong></td>
<td>Jim Higgins</td>
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<td>**Sustainable Point-of-Use/Entry Drinking Water Treatment in Canada.</td>
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<td>M. A. HAMOUDA, W. B. ANDERSON, and P. M. HUCK</td>
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<td>Campylobacters: Occurrence at two Lake Ontario Beaches.</td>
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<td>I.U.H. KHAN, A. LOUGHBOROUGH, and T.A. Edge</td>
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<td>15:40</td>
<td>Application of Humic Substances to Enhance Leachate Treatment.</td>
<td>J. KOCHANY and E. LIPCZYNSKA-KOCHANY</td>
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<td>Full-Scale Process Evaluation of Recirculating Biofilters: A Case Study for Residential Wastewater Treatment.</td>
<td>Z. HU and G. GAGNON</td>
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<td>An Investigation of Techniques for Hydraulic Intake Entrainment Envelope Delineation.</td>
<td><strong>T. OLATUNJI</strong>, R. CARRIVEAU, D. TING</td>
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<td><strong>Perfluoroacids in Canadian Rivers.</strong></td>
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<td>B. SCOTT, C. SPENCER, E. LOPEZ, and D. MUIR</td>
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<td>16:00</td>
<td>Visualization of Pollutant Transport Using Transparent Soil.</td>
<td>J. LIU</td>
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<td>Investigating the Performance of Constructed Wetlands in the Treatment of Municipal Wastewater in Northern Communities.</td>
<td>D. SHRESTHA, B. WOOTTON, and C. METCALFE</td>
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<td>Perfluoroacids in Canadian Rivers.</td>
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<td><strong>Ethanol Fuels Potential Impacts on Source Water.</strong></td>
<td>J. DE FREITAS, and J. BARKER</td>
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<td>16:20</td>
<td>Sustainable Wastewater Infrastructure for Small Communities.</td>
<td>T. BIRKELAND</td>
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<td><strong>Sustainable Wastewater Infrastructure for Small Communities.</strong></td>
<td>J. DE FREITAS, and J. BARKER</td>
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<td><strong>Ethanol Fuels Potential Impacts on Source Water.</strong></td>
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<td>16:45</td>
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<td><strong>Poster Session “Meet and Greet” - Main Mall</strong></td>
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<td>17:30</td>
<td>AGILENT TECHNOLOGIES RECEPTION</td>
<td>at Emma’s Back Porch Pub</td>
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<td>2084 Old Lakeshore Rd. (5 minute walk from Travelodge Hotel)</td>
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Note: Names appearing in bold are presenters competing for the Philip H. Jones Award.
**Tuesday, February 12, 2008**

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<td>07:30</td>
<td>Registration</td>
<td>A Tribute to Jim Maguire</td>
<td>Science, Policy, and Legislation</td>
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<td>• Auditorium</td>
<td>Chairs Mehran Alaee and Adrienne Bartlett</td>
<td>Chairs Hugh Simpson and Neil Hutchinson</td>
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<td>08:00</td>
<td>Introductory Remarks</td>
<td>Fractal Analyses of Flocs for Modelling of Solid/Liquid Separation in Water Treatment.</td>
<td>Marking the 35th anniversary of the Great Lakes Water Quality Agreement.</td>
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<td>John Carey</td>
<td>B. GORCZYCA and A. VAHEDI</td>
<td>G. KRANTZBERG</td>
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<td></td>
<td>Screening Chemicals in Commerce to Identify New Persistent and Bioaccumulative Chemicals: New Results</td>
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<td>Derek Muir</td>
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<td>Brian Brownlee</td>
<td>S. CHOWDHURY, P. CHAMPAGNE, and J. MCLELLAN</td>
<td>K. SCHAFFER and A. BIELAK</td>
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<tr>
<td>08:40</td>
<td>Jim, TBT and Me.</td>
<td>Rigorous Quantitative Analysis of Microbial and Particulate Data.</td>
<td>The Information Delivery Challenge: Addressing Communication Gaps Between Science and Policy.</td>
</tr>
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<td></td>
<td>Uwe Borgmann</td>
<td>P. SCHMIDT, and M. EMELKO</td>
<td>B. SNEYD</td>
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<tr>
<td>09:00</td>
<td>Toxicity and Bioaccumulation of Tributyltin in Freshwater Invertebrates.</td>
<td>Enzyme-Based Detection of E coli and Total Coliforms in Drinking Water Using Fibre Optics and Fluorescence.</td>
<td>Linking Phosphorus Offsetting Strategies to Regulatory Mechanisms to Improve Water Quality.</td>
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<td>Adrienne Bartlett</td>
<td>N. HEWAGE, M. SALEH, and E. GARDNER</td>
<td>N. HUTCHINSON</td>
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<td>09:20</td>
<td>Health Break - Main Mall</td>
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<td>09:40</td>
<td>Environmental Influences on Cyanobacterial Abundance and Microcystin Concentrations in Three Grand River Reservoirs.</td>
<td>A Low Cost Method for Protozoan Enumeration from Large Water Volumes for Performance Demonstrations.</td>
<td>Effective Communication Tools to Build and Promote The City of Hamilton's DWQMS.</td>
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<tr>
<td>10:00</td>
<td>Chlorination of the Cyanotoxin microcystin-LR: Reactant Consumption and By-Products Elucidation.</td>
<td>Exploring Pre-treatment for the Solar Water Disinfection (SODIS) Process.</td>
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<td>S. MEREL, F. MONTEAU, B. LEBOT, O. THOMAS, and M. CLEMENT</td>
<td>L. HIRTLE and S. ANDREWS</td>
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*Note: Names appearing in bold are presented competing for the Philip H. Jones Award*
<table>
<thead>
<tr>
<th>Time</th>
<th>Auditorium</th>
<th>South Seminar</th>
<th>North Seminar</th>
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<tbody>
<tr>
<td>10:20</td>
<td>Harmful Algal Blooms</td>
<td>Advances in Water Treatment Technologies and Approaches</td>
<td>Applications of Remote Sensing and GIS to the Assessment of Watershed Health</td>
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<tr>
<td></td>
<td>Chairs Sue Watson and Greg Boyer</td>
<td>Chairs Rajesh Seth and Onita Basu</td>
<td>Chairs Raul Ponce-Hernandez and Bill Pain</td>
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<td>12:20</td>
<td>Lunch - Main Mall</td>
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<table>
<thead>
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<tr>
<td>15:10</td>
<td>Urban Lake Assessment and Management: City of Brampton Example.</td>
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<td>D. SINCLAIR and N. HUTCHINSON</td>
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<td>15:30</td>
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<td><strong>Auditorium</strong></td>
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<tr>
<td>16:30</td>
<td>Presentation of Philip H. Jones Award</td>
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<td>16:35</td>
<td>Concluding Remarks</td>
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<tbody>
<tr>
<td><strong>AWT</strong> C. GUTHRIE, E. REARDON, AND J. VOGAN</td>
<td>Pd/MCM-41-Catalyzed Hexamethylphosphoramide Degradation.</td>
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<td><strong>BEA</strong> S. HILL, F. SUEN, AND T.A. EDGE</td>
<td>Microbial source tracking of fecal pollution at a beach on the Ottawa River.</td>
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<td><strong>SPL</strong> B. SNEYD</td>
<td>Assessing Canada’s Water Information Challenges.</td>
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<td><strong>DWSP</strong> S.J. CAGAMPAN, J.M. GRABUSKI, J. STRUGER, AND B. RONDEAU</td>
<td>Automated Solid Phase Extraction of Sulfonyl ureas and Related Herbicides in Fortified Water and Natural Water Samples using LC-ESI/MS/MS.</td>
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<td><strong>DWSP</strong> J. BYER, J. STRUGER, P.KLAWUNN, AND E.SVERKO</td>
<td>Large Scale Field Utilization of the ELISA Method as a Water Quality Monitoring Tool for Surface Water Samples.</td>
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<td><strong>DWSP</strong> L. D. HESLIP, J. STRUGER, P. J. KLAWUNN, O. B. ALLEN, AND G. J. UMPHREY</td>
<td>Multivariate Analyses on Ontario Pesticide Residue Data Gathered through the National Water Quality Surveillance Program.</td>
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<tr>
<td><strong>SUL</strong> M.A. MARCUS AND P.C. FROST</td>
<td>Suitability of Urban Pond Ecosystems for Zooplankton Growth.</td>
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Advances in Wastewater Treatment and Technologies
Chairs: Hongde Zhou and Wayne Parker

Environmental Modeling
Chairs: Ferdous Ahmed and Hugh Monteith

Biotechnology-Environmental Applications and Potential Risks
Chairs: Bin Zhu and Réal Roy

Policies and Technologies for Small Communities
Chair: Jim Higgins

Drinking Water Source Protection
Chairs: Larry Moore and Simon Gautrey

Advances in Water Treatment Technologies and Approaches
Chairs: Rajesh Seth and Onita Basu

Science, Policy, and Legislation
Chairs: Hugh Simpson and Neil Hutchinson

Harmful Algal Blooms
Chairs: Sue Watson and Greg Boyer

Applications of Remote Sensing and GIS to the Assessment of Watershed Health
Chairs: Raul Ponce-Hernandez and Bill Pain

Stormwater and Urban Lake Management
Chairs: Deborah Sinclair and Sandra Kok

Symposium Coordinator
Denis Carr

Graphic Design
Grazyna Modzynski

Special Thanks To:
Jim Maguire, Ron Droste, Janet McAvella, Alex Bielak, Karl Schaefer, and Dan Christopher