Book of Abstracts

Thirty-Ninth Central Canadian Symposium On Water Quality Research

FEBRUARY 9 AND 10, 2004
Canada Centre for Inland Waters
Burlington, Ontario

Chaired by

Dr. John H. Carey
National Water Research Institute
Environment Canada

Co – Sponsored by

Canadian Association on Water Quality
National Water Research Institute

Monday, 16:00 – Main Mall:	Poster Reception/ Pre-meeting Break
Monday, 16:30 – Auditorium:	CAWQ Annual General Meeting
Tuesday, 15:25 – Auditorium:	Philip H. Jones Award
	Concluding remarks

Symposium Committee

ORGANIZING COMMITTEE
Chair: Michael Forbes

PROGRAM COMMITTEE
Chair: Dr. Nathalie Ross

DRINKING WATER: TASTE & ODOUR, TREATMENT
Chair: Dr. Susan B. Watson

DRINKING WATER: WATERBORNE PATHOGENS
Chair: Dr. Tom Edge

GROUNDWATER: REMEDIATION
Chair: Dr. Nathalie Ross

GROUNDWATER: QUALITY AND QUANTITY
Chair: Dr. Nathalie Ross

SEDIMENTS
Chair: Dr. Michael Zarull

STORMWATER AND CSOs
Chair: Dr. Sandra Kok

SURFACE WATER
Chairs: Dr. Patricia Chambers
Dr. Joanne Parrott

WASTEWATER
Chairs: Dr. Jim A. Nicell
Dr. Yves Comeau

SYMPOSIUM COORDINATOR
Karen Balkwill

AUDIO VISUAL/VENUE SETUP
NWRI Technical Operations Support

GRAPHICS LAYOUT
Grazyna Modzynski

PROGRAM SUMMARY

Monday, February 9, 2004

Main Mall				
07:45	• **Registration** • **Poster Installation**			
Plenary Session: Auditorium				
08:30	**Welcome to the National Water Research Institute:** **Dr. John H. Carey, Director General, National Water Research Institute**			
08:35	**Opening Remarks: Dr. Yves Comeau, President, Canadian Association on Water Quality**			
08:45	**Plenary: Dr. Jim A. Nicell, Associate Professor,** **Department of Civil Engineering and Applied Mechanics, McGill University** **"Environmental Applications of Enzymes: Opportunities and Obstacles"**			
Room	**Session 1 – Auditorium**		**Session 2 - North/South Seminar Room**	
	Session Theme	**Number of Oral Presentations (25 Minutes Each)**	**Session Theme**	**Number of Oral Presentations (25 Minutes Each)**
09:30	**WASTEWATER**	3	**DRINKING WATER: TASTE& ODOUR, TREATMENT**	3
10:45	**Health Break – Main Mall**			
11:00	**WASTEWATER**	3	**DRINKING WATER: TASTE& ODOUR, TREATMENT**	2
12:15	**Lunch – Main Mall**			
Room			**Session 3 - North/South Seminar Room**	
13:15	**WASTEWATER**	3	**SEDIMENTS**	3
14:30	**Health Break - Main Mall**			
14:45	**DRINKING WATER: WATERBORNE PATHOGENS**	3	**SEDIMENTS**	2
16:00	**Poster Reception/Pre-meeting Break – Main Mall**			
16:30	**CAWQ Annual General Meeting – Auditorium**			

PROGRAM SUMMARY

Tuesday, February 10, 2004

Main Mall				
07:30	• **Registration**			
Room	**Session 1 – Auditorium**		**Session 2 - North/South Seminar Room**	
	Session Theme	**Number of Oral Presentations (25 Minutes Each)**	**Session Theme**	**Number of Oral Presentations (25 Minutes Each)**
08:00	**GROUNDWATER: QUALITY AND QUANTITY**	4	**STORM WATER AND CSOS**	4
09:40	**Health Break – Main Mall**			
10:00	**GROUNDWATER: REMEDIATION**	4	**STORM WATER AND CSOS**	2
11:40	**Lunch – Main Mall**			
Room	**Session 3 – Auditorium**			
12:40	**SURFACE WATER**	3		
13:55	**Health Break - Main Mall**			
14:10	**SURFACE WATER**	3		
15:25	**Auditorium: Philip H. Jones Award and concluding remarks by John H. Carey**			

Note: There are 46 oral presentations, 9 poster displays and a number of commercial exhibits

ORAL PRESENTATIONS

Monday, February 9, 2004

Main Mall		
07:45	• **Registration** • **Poster Installation**	
Plenary Session: Auditorium		
08:30	**Welcome to the National Water Research Institute:** **Dr. John H. Carey, Director General, National Water Research Institute**	
08:35	**Opening Remarks: Dr. Yves Comeau, President, Canadian Association on Water Quality**	
08:45	**Plenary: Dr. Jim A. Nicell, Associate Professor,** **Department of Civil Engineering and Applied Mechanics, McGill University** **"Environmental Applications of Enzymes: Opportunities and Obstacles"**	
Room	**Session 1 – Auditorium**	**Session 2 – North/South Seminar Room**
Theme	**Wastewater** Chair: DR. JIM A. NICELL Associate Professor McGill University	**Drinking Water** Chair: DR. SUSAN B. WATSON Research Scientist National Water Research Institute
09:30	Development of Bioreactors for the Treatment of Colored Industrial Effluents D. K. SHARMA *, M. SINGH, H. S. SAINI, B. S. CHADHA, AND S. S. CHIMMNI	Dhaka's Waterways: "Save the Buriganga River Program" P.A. GRAY, T.A. BONIN, AND M.F. AHMED
09:55	Releases of Pharmaceuticals and Personal Care Products by Selected Ontario Sewage Treatment Plants L. LISHMAN, K. SARAFIN, S. A. SMYTH, J. TOITO, T. PEART, B. LEE, M. SERVOS, AND P. SETO	Probing the Ramsey Lake Watershed G.A. SPIERS, A. LOCK, F. PREVOST, D. PEARSON, B. HOSTETLER, AND J. RAY
10:20	Performance of an Anaerobic Baffeld Reactor for Olive Mill Oil Wastewater Treatment M. S. KHABBAZ *, M. VOSSOUGHI, AND M. SHAKERI	Taste and Odour Outbreaks in N.W. Lake Ontario: Physical, Chemical and Biological Drivers S. WATSON, T. HOWELL, M. CHARLTON, M. SKAFEL, R. YERUBANDI, C. MARVIN, B. BROWNLEE, L. HEINTSCH, J. MILNE, AND G. MACINNIS
10:45	**Health Break – Main Mall**	
11:00	Combined Peracetic Acid-UV Disinfection Process for a Physicochemical Effluent X. DONG AND R. GEHR	Pilot Scale Investigation of the Removal of Geosmin and MIB by Granular Activated Carbon Filtration S. NDIONGUE, W.B. ANDERSON, A. TADWALKAR, J. RUDNICKAS, S. PILLAI, AND P. HUCK
11:25	Unified Theory for Endogenous Decay in Aerobic Digestion C. ESKICIOGLU *, R. L. DROSTE, AND A. TAEBI	TerraQSAR™ — LOGP — A PNN-Based Octanol/Water Partition Coefficient Computation Program for PCs K.L.E. KAISER

11:50	Biosorption of Pentachlorophenol by Fungal Biomass T. MATHIALAGAN *, AND T. VIRARAGHAVAN	
12:15	**Lunch – Main Mall**	
Room		**Session 3 – North/South Seminar Room**
Theme	**Wastewater** Chair: DR. YVES COMEAU Professor École Polytechnique de Montréal	**Sediments** Chair: DR. MICHAEL ZARULL Project Chief National Water Research Institute
13:15	Impact of Redox Potential and Protozoan Predation on Nitrification in Activated Sludge Y. LEE AND J. A. OLESZKIEWICZ	Opportunities, Needs and Strategic Direction for Research on Flocculation in Natural and Engineered Systems I. G. DROPPO, G.G. LEPPARD, S.N. LISS, AND T.G. MILLIGAN
13:40	Model Optimisation for BAF Systems X. LE TALLEC, K. HELLESHØJ SØRENSEN, AND P. GILLES	Unique Tools for Determining the Geometry of Contaminated Sediments J. (HANS) BIBERHOFER
14:05	Two-Stage Low Sludge Production Process for the Treatment of Municipal Wastewater L. BOURQUE*, L. KHAROUNE, AND Y.COMEAU	Comparison of Mercury and Lead Sediment Concentrations in Lake Ontario (1968-1998) and Lake Erie (1971-1997/98) Using a GIS-Based Kriging Approach M. DENNIS* AND K.W. FORSYTHE
14:30	**Health Break**	
Room	**Session 4 – Auditorium**	
	Drinking Water: Waterborne Pathogens Chair: DR. TOM EDGE Research Scientist National Water Research Institute	
14:45	Coliforms Give Me Gas M. H. BRODSKY	Assessing the Biological Impact of Contaminated Sediments: Peninsula Harbour, Lake Superior: Case Study D. MILANI AND L. GRAPENTINE
15:10	Changes in Drinking Water Treatment: What Are the Effects on Microbial Water Quality in the Distribution System? S. SPRINGTHORPE, S. A. SATTAR, AND M. PRYOR	Reductions in Detroit River Area Sediment PCB Levels M. ZARULL J. HARTIG, AND T.M. HEIDTKE
15:35	DNA Microarray Fingerprinting of Microbial Communities in Commercial Microbial Biotechnology Products for Water Treatment. T. EDGE, J. DUBOIS, S. HILL, L.S. ENGLAND, L. MASSON, J.T. TREVORS, AND R. BROUSSEAU	
16:00	**Poster Reception/Pre-meeting Break – Main Mall**	
16:30	**CAWQ Annual General Meeting – Auditorium**	

* Competing for the Philip H. Jones Award

Tuesday, February 10, 2004

Main Mall		
07:30	• **Registration**	
Room	**Session 1 – Auditorium**	**Session 2 – North/South Seminar Room**
Theme	**Groundwater: Quality and Quantity** Chair: DR. NATHALIE ROSS Research Scientist National Water Research Institute	**Storm Water and CSOs** Chair: DR. SANDRA KOK Senior Program Engineer Great Lake Sustainability Fund
08:00	Use of Stable Isotopes to Assess Groundwater Discharge within the Grand River Watershed S. DAY , A. PIGGOTT, J. GIBSON, P. LAPCEVIC , AND F. LONGSTAFFE	Water Pollution Analysis for the City of Sarnia J. LI
08:25	The Current Understanding of Microbial Transport in Saturated Subsurface Environments, and Directions for Future Research Q. ZHENG *, S.E. DICKSON, AND Y. GUO	Investigations of Sediment Quality at a Stormwater Management Facility in Toronto using Benthic Techniques Q. ROCHFORT, L. GRAPENTINE, AND J. MARSALEK
08:50	Geochemical Mechanisms Controlling Acid Generation, Acid Neutralization and Metal Attenuation at the East Tailings Management Area, Lynn Lake, Manitoba. M.R. GUNSINGER*, C.J. PTACEK, D.W. BLOWES, AND J.L. JAMBOR	Feasibility of Stormwater Treatment by Conventional and Lamellar Settling with and without Polymeric Flocculant Addition J. WOOD, M. YANG, Q. ROCHFORT, P. CHESSIE, J. MARSALEK, P. SETO, AND S. KOK
09:15	The Qanat Discharge and Ground Water Table Changes under Water Spreading Impact in Part of the Zanjan Plain, Iran F. B. MOVAHHED	Simulation of Flow and Sediment Transport in a Combined Sewer Overflow (CSO) Storage and Treatment Facility C. HE, J. MARSALEK, Q. ROCHFORT, AND K. KRISHNAPPAN
09:40	**Health Break – Main Mall**	
Theme	**Groundwater Remediation** Chair: DR. NATHALIE ROSS Research Scientist National Water Research Institute	
10:00	The Effect of Biofilm Development on Solute Diffusion in Low Permeability Rock A.M.CHARBONNEAU *, K.S.NOVAKOWSKI, AND N.ROSS	The Use of Ballasted Flocculation (ACTIFLO® process) for Combined Sewer Overflow (CSO) Treatment S. LAJOIE, C. DESJARDINS, J. BEAUDET, C. SCOTT, AND B. GAGNÉ
10:25	Characterizing Biofilm Development in Fractured Bedrock Using Hydraulic Testing and Point Dilution G. BICKERTON, N. ROSS, AND J. VORALEK	Benefits and Application of Real Time Control for Sewer Systems H. COLAS, M. PLEAU, AND A. CHARRON

10:50	Laboratory Evaluation of Zero-Valent Iron Mixtures for Use in Permeable Reactive Barriers for Treatment of Acid Mine Drainage M.B.J. LINDSAY*, C.J. PTACEK, AND D.W. BLOWES	
11:15	Containments' Formation and their Impact on Groundwater Quality M. ELEKTOROWICZ, R. CHIFRINA, AND R. HASNAWI	
11:40	**Lunch – Main Mall**	
	Session 3 – Auditorium	
Theme	**Surface Water** CoChairs: DR. PATRICIA CHAMBERS DR. JOANNE PARROTT Research Scientists National Water Research Institute	
12:40	Thermal Bar Evolution and Attached Algae, Western Lake Ontario M .G SKAFEL, R R YERUBANDI, AND M. N CHARLTON	
13:05	Cyanobacterial Toxins in the Lake Winnipeg Watershed and their Implications Regarding Eutrophication C.R. HERBERT*, H.J. KLING, J. DAHLMAN, AND M.P. STAINTON	
13:30	Iron-Stimulated Growth and Toxin Production of Microcystis Novacekii UAM 250 H. LI, T. MURPHY , J. GUO, T. PARR, AND L. MILLER	
13:55	**Health Break – Main Mall**	
14:10	**A**n ELISA for Cutthroat Trout (*Oncorhynchus Clarki)* Vitellogenin (Vg) and its Use to Assess the Estrogenic Impacts of Agricultural Runoff in a B.C. Watershed J. SHERRY, T. HOOEY, S. SYLVESTRE, M. SEKELA, T. TUOMINEN, P. HANSEN, AND B. HOCK	
14:35	Using an Airborne Laser Remote Sensing System (Lidar) for Pollution Detection and Point Source Location an the Great Lakes and Associated Watersheds – A 2003 Case Study S. BABICHENKO AND M. FRIZZELL	
15:00	Sensitivity of HSPF Model to Land Use Data of Different Scale I. ISKRA* AND R. L. DROSTE	
15:25	**Auditorium: Philip H. Jones Award and concluding remarks by Dr. John H. Carey**	

* Competing for the Philip H. Jones Award

POSTER DISPLAYS
(MAIN MALL)

Poster displays are available in the Main Mall on both Monday, February 9, and Tuesday, February 10. The authors will be in attendance at their posters during the Poster Reception on Monday, February 9, at 16:00.

Session Theme – GROUNDWATER: QUALITY, QUANTITY AND REMEDIATION
Remediation of a Cold-Climate Petroleum Spill in Moose Factory, Ontario G. BICKERTON, D.R. VAN STEMPVOORT, J. VORALEK, AND S. LESAGE
Stability of a Nutrient-Starved Biofilm in a Limestone Fracture F.CASTEGNIER, N. ROSS, R.P. CHAPUIS, L. DESCHÊNES, AND R. SAMSON
Biofilm Development in a Planar Fracture: Effects of a BTEX/Ethanol-Contaminated Groundwater P. GRANDE, N. ROSS, H. STEER, AND J.F. BARKER
Peculiarities of Arsenic Removal by Ion Exchange A.K. M SAIDUZ ZAMAN

Session Theme – SURFACE WATER
Laboratory and Field Validation of Elimination Kinetics and Accumulation of Organochlorines in *Elliptio complanata* and Semi-Permeable Membrane Devices (SPMDS) S. O'ROURKE, G.D. HAFFNER, AND K.G. DROUILLARD

Session Theme – SEDIMENTS
In Situ Sediment Treatment in Hong Kong J. GUO, T. MURPHY, AND L. CHAN
Small-Scale In Situ Sediment Treatments T. MURPHY

Session Theme – WASTEWATER
Innovative Leachate Treatment Technology D. GAGNON, H. HANEY, H.C. LAVALLÉE, AND C. DANEAULT
Precipitation of Hexavalent Chromium from an Electroplating Wastewater by Electrocoagulation S. KULAC AND I.A. SENGIL

NOTE: There will be a number of commercial exhibits in the Main Mall, including:

- AssayNet Canada Inc.
- Brightwell Technologies
- Hanson Pipe & Products Canada, Inc
- IDEXX Laboratories

PLENARY SESSION

Environmental Applications of Enzymes: Opportunities and Obstacles

JIM A. NICELL

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

Recent research has focused on developing environmental applications of enzymes that have been isolated from their parent organisms. When accomplishing the transformation of chemical species, cell-free enzymes are often preferred over intact organisms containing the enzyme because they act with greater specificity, their activity can be better standardized, they are easier to handle and store, and enzyme concentration is not dependent on bacterial growth rates. This can lead to some important advantages of enzymatic processes over biological systems. For example, enzymes can be applied to transform targeted contaminants including many of those that may resist biodegradation. In addition, this catalytic action can be carried out on, or in the presence of, many substances that are toxic to microbes. Also, some enzymes can operate over relatively wide temperature, pH and salinity ranges compared to cultures of microorganisms. They can also be used to treat contaminants at high and low concentrations and are not susceptible to shock loading effects associated with changes in contaminant concentrations that can often irreversibly damage or metabolically inactivate microbial cells. Importantly, the catalytic action of enzymes enables the development of smaller systems of lower capital cost due to the high reaction rates associated with enzymatic reactions. Also, since bacterial growth is not required to accomplish waste transformations, sludge production is reduced since no biomass is generated.

Enzymes can also offer a number of advantages over conventional chemical processes. In particular, the significance of enzymes lies in their ability to carry out processes that are impractical or impossible through non-biological chemistry. Their high degree of specificity allows enzymes to remove target pollutants selectively, which precludes undesirable or unnecessary reactions that would otherwise increase reactant consumption and, correspondingly, increase the cost of treatment. They also make efficient use of chemical reagents and typically are characterized by a high reaction velocity. Their selectivity and high reaction rates make them ideal for the treatment of compounds that are present in trace quantities or that cannot be removed by traditional physico-chemical processes. Additionally, they operate at low temperature conditions, thereby reducing energy requirements for processes normally conducted at elevated temperatures. They also operate under mild pH conditions, thereby reducing the impact of corrosion on reaction vessels and avoiding the need for waste neutralization. Finally, an inherent advantage of enzymes is their compatibility with the environment and their non-hazardous nature. Thus, enzyme residues that may be present following waste treatment are of low pollution potential.

This concept of using enzymes in waste treatment applications is not new. In fact, applications were suggested as long ago as the 1930s. However, recent interest in the development of enzymatic waste treatment systems has grown for a number of reasons. Firstly, the rate of introduction of recalcitrant organic pollutants into the environment is on the rise, and it is becoming increasingly difficult to achieve an acceptable degree of removal of these pollutants using conventional chemical and biological processes. Secondly, there is a need for the development of alternative treatment methods that are faster, cheaper, more reliable, and simpler to implement than current processes. Thirdly, there is a growing recognition that enzymes can be used to target specific pollutants for treatment. And, finally, recent biotechnological advances foreshadow the production of cheaper and more readily available enzymes through genetic manipulation of microbial and plant cells and through improved efficiency of isolation and purification procedures. Much of this work remains very new and substantial hurdles must be overcome before full-scale industrial application of enzymes can become a reality. This presentation will focus on identifying opportunities and obstacles that must be overcome in bringing enzymatic systems to fruition.

Wastewater

Chairs: DR. JIM A. NICELL
DR. YVES COMEAU

COMPETING FOR THE PHILIP H. JONES AWARD

Development of Bioreactors for the Treatment of Colored Industrial Effluents

D. K. SHARMA[1*], M. SINGH[1], H. SINGH SAINI[1], B. SINGH CHADHA[1] AND S. SINGH CHIMMNI[2]

[1] *Department of Microbiology, Guru Nanak Dev University, Amritsar-143005, Punjab (India)*
[2] *Department of Chemistry, Guru Nanak Dev University, Amritsar-143005, Punjab (India)*

The waste water discharged from textile dyeing units, dyestuff processing and paper industries contains a considerable amount of intensely colored complex aromatic compounds. Their color and xenobiotic nature makes them environmental nuisances as they contaminate the fresh and ground water system and act as potential pollutants. Due to an increasing awareness of the need for protection and conservation of ecosystems, a sincere effort is required for devising efficient biological treatment system capable of decolorizing/ detoxifying the pollutants. The conventional systems based on physical and chemical treatment of these effluents do nothing but generate hazardous solid-sludge more toxic than the effluents, which need proper disposal as per existing laws.

In our laboratory, we developed different kinds of up flow immobilized cell bioreactors using bacterial strains isolated by selective enrichment on various triphenylmethane dyes viz. Acid violet-17, Acid violet-49, Acid blue-15, Crystal violet, Malachite green etc. Different kinds of support materials like refractory brick pieces, seashell pieces, pieces of polyurethane foam, cubes of nylon webs etc. are being used for developing biofilms for the continuous treatment of colored industrial effluents. The formation of different biofilms was studied by scanning electron microscopy.

More than 90% decolorization of these effluents accompanied with higher BOD and COD removal efficiencies have been achieved at laboratory scale. The UV-VIS spectrophotometeric and thin layer chromatographic analysis of treated samples has shown biotransformation of these dyes into non-aromatic intermediates/ products as evidenced further by ^{1}H-NMR spectra, thus reducing the toxicity level of the effluents considerably for the possible release into the environment.

[*] Presenting author; Sharma_dee@yahoo.com

Releases of Pharmaceuticals and Personal Care Products by Selected Ontario Sewage Treatment Plants

L. LISHMAN[1], K. SARAFIN[1], S. A. SMYTH[1*], T. PEART[1], B. LEE[1], M. SERVOS[2], AND P.SETO[1]

[1]*National Water Research Institute, Environment Canada, Burlington, Ontario*
[2]*University of Waterloo, Department of Biology, Waterloo, Ontario*

Many factors influence the distribution of pharmaceuticals, hormones and personal care products (PPCPs) in the sewage treatment plants (STP). Releases of these chemicals to the receiving waters will depend on their fate within the STP. Currently, there exists a very limited Canadian database to draw on to quantify the loadings of PPCPs from STPs to the receiving waters.

To broaden the Canadian database, this study surveyed twelve STP discharging into the Thames River. This study examined the influent concentration, and plant effluent levels of: ten acidic pharmaceuticals; triclosan; the hormones, 17β-estradiol and estrone; and five polycyclic musks. The twelve plants encompassed three different treatment configurations: lagoons, conventional activated sludge and conventional activated sludge followed by media filtration. The sampling campaign was carried out in the mid to late fall when the operating temperatures generally approached 15 ºC. Treatment plants surveyed did not practice disinfection at this time of year. The effect of treatment configuration and operating parameters (e.g. sludge age, hydraulic residence time) and plant performance (e.g. carbon removal, degree of nitrification) on individual compound removal was investigated. The goal was to identify treatment conditions that generally favoured target compound removal, if they exist.

This presentation will provide an overview of the survey data and compare the influent and effluent concentrations of target compounds. These values will be compared to values from the literature which is predominantly European. Treatment conditions benefiting target compound removal also will be identified.

* Presenting author; ShirleyAnne.Smyth@cciw.ca

COMPETING FOR THE PHILIP H. JONES AWARD

Performance of an Anaerobic Baffeld Reactor for Olive Mill Oil Wastewater Treatment

M. S. KHABBAZ*, M. VOSSOUGHI AND M. SHAKERI

Biological and Bioenvironmental Research Center (BBRC), Department of Chemical Engineering, Sharif University of Technology, Tehran, Iran

The anaerobic baffled reactor (ABR) contains a mixed anaerobic culture segregated into compartments and a novel process with a series of vertical baffles, which form a number of upflow and downflow compartment. OMW contains major amounts of organic matter, the average concentration of volatile solids and inorganic matter being 15% and 2%, the organic fraction includes sugars, tannins, polyphenols, polyalchols, pectins and lipids. The maximum BOD and chemical oxygen demand (COD) concentrations reach 100 and 220g/lit, respectively. In this experiment, the influent COD concentration of olive oil wastewater was increased from 1000 mg/l to 15000 mg/l but range 1000 mg/l to 5000 mg/l at a hydraulic retention time of 48hr was studied in this paper. Maximum COD removal was created in influent COD 3000 mg/l. In low influent COD was seen two minimum of pH in first and 3rd compartment but it was negligible in pH diagram in huge influent COD so diagram of volatile fatty acid (VFA) could response two maximum production of VFA in those two compartments. Hydrocarbons caused the first increase in pH and oil caused the second increase of pH.

The hydraulic retention time (HRT) was 48hr and the temperature was kept constant at 36°c. The substrate loading removal rate was compared with predictions made from the Kincannon-Stover model and the Monod model. Analysis of data indicated that the Kincannon-Stover model could produce the best fit with the experimental results.

* Presenting author; saeed@totalsurf.com

Combined Peracetic Acid-UV Disinfection Process for a Physicochemical Effluent

X. DONG AND R. GEHR*

Department of Civil Engineering, McGill University, Montreal, Quebec

Ultraviolet radiation (UV) is well known as an effective disinfection process for wastewater treatment. One of the drawbacks is the long tailing which occurs on many response-dose diagrams [i.e. plot of log (N/N_0) vs. UV-fluence, where N is the number of surviving microorganisms and N_0 is the original count]. Such tailing implies that there will always be a significant number of surviving bacteria, no matter the value of the UV fluence. This is especially acute with physicochemical effluents with relatively high concentrations of particles. In some cases, then, UV alone may not be able to satisfy target effluent microbial levels. Peracetic acid (PAA) has also been found to be an effective chemical disinfectant for wastewaters, but doses (especially for physicochemical effluents) have been found to be uneconomical.

Recent studies in Italy have determined that the combination of PAA and UV could yield synergistic effects, with very low levels of indicator organisms being reached at disinfectant levels far lower than if they were to be used independently. This synergism was attributed to the production of hydroxyl radicals (OH•), a well-known effect which occurs with UV and hydrogen peroxide (H_2O_2), which itself is a component of any PAA solution. Hence experiments in the present study were designed to assess whether the combined PAA-UV process could be used to achieve target fecal coliform (FC) levels below 900 CFU/100 mL, at realistic doses, for the physicochemical effluent from the Montreal Wastewater Treatment Plant.

Effluent samples from the primary settling basins (following coagulation with ferric chloride) were tested in batch experiments with PAA alone, UV alone, and a combination of PAA plus UV. PAA doses were 1 mg/L, 2 mg/L, and 4 mg/L at a contact time of 30 minutes. Sodium thiosulfate followed by catalase were used for PAA quenching. The UV fluences were 10 mJ/cm^2, 20 mJ/cm^2, and 40 mJ/cm^2. In the combination experiments, UV radiation was applied immediately following the addition of PAA in order to facilitate the formation of OH•.

The combined PAA and UV tests showed at least an additive effect, which was encouraging considering that neither process alone could achieve the target. Although PAA alone could attain up to 4-log reductions at the highest dose of 4 mg/L, and UV alone could achieve close to this value at 40 mJ/cm^2. In most cases these levels of disinfection could not be attained, and the combination always performed better, in one case reaching over 5-log removals. Furthermore, the target fecal coliform level could in some tests be reached at PAA&UV levels of 2 mg/L&10 mJ/cm^2, and almost always at 2 mg/L&20 mJ/cm^2, and these may indeed be economically feasible levels. Hence this combined process shows great promise for disinfecting "recalcitrant" wastewaters.

* Presenting author; Ronald.Gehr@Mcgill.ca

COMPETING FOR THE PHILIP H. JONES AWARD

Unified Theory for Endogenous Decay in Aerobic Digestion

C. ESKICIOGLU[1*], R. L. DROSTE[1] AND A. TAEBI[2]

[1]*Department of Civil Engineering, University of Ottawa, Ottawa, Ontario*
[2]*Department of Civil Engineering, Isfahan University of Technology, Isfahan, Iran*

Endogenous decay results in a decrease of biomass and an accumulation of relatively nonbiodegradable particulates with a net reduction of volatile suspended solids (VSS). Activated sludge models incorporate these two phenomena separately to more accurately describe the process. The standard simple model for aerobic digestion addresses nondegradable solids as a fixed component. Although this model will correctly describe overall disappearance of VSS in batch digestion it does not describe dynamic variation of inert and degradable VSS. Furthermore batch kinetic constants do not translate to continuous flow situations when this model is applied.

In this project, aerobic digestion was monitored. Conditions in the activated sludge process from which the mixed liquor was taken were also known. Batch and semi-continuous flow digesters were operated under varying conditions. Endogenous decay in the activated sludge units and all digesters was modeled for degradation of particulates and accumulation of nondegradable particulates. Three levels of models were used ranging through simple (developed by Adams *et al*., 1974), intermediate (developed by Droste, 1998), and International Water Association (IWA) complex activated sludge models. A commercial solver called AQUASIM was utilized for parameter estimation and International Water Association (IWA) complex activated sludge models. A commercial solver called AQUASIM was utilized for parameter estimation and sensitivity analysis.

All models provided good prediction of solid destruction in aerobic digestion process. Although complex models have more parameters to fit the measured data, the improvement was not too significant. Sensitivity analysis of digester VSS revealed significant correlations among the sensitive parameters of complex activated sludge models.

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Biosorption of Pentachlorophenol by Fungal Biomass

T. MATHIALAGAN* AND T. VIRARAGHAVAN

Faculty of Engineering, University of Regina, Regina, Saskatchewan

Pentachlorophenol (PCP) is a priority pollutant in which five chlorine atoms have been added to the phenol molecule. PCP and its sodium salt have been widely used in the past as a biocide, particularly in the treatment and preservation of wood and in the textile industry. Because of its widespread use in the past, pentachlorophenol contamination of water, soil and air is not uncommon. PCP is acutely toxic to a variety of living organisms, including humans.

Biological treatment and adsorption are the widely used techniques to treat wastewaters and soils contaminated with chlorophenols. Biosorption of chlorophenols by microbial biomass is considered to be an important removal mechanism during the biological treatment of chlorophenolic wastewaters. But researchers around the world have shown the feasibility of treating chlorophenolic wastewaters using low-cost biosorbents such as bacterial and fungal biomass, chitin and chitosan derivatives, sludge and anaerobic granules.

Research at the University of Regina is being conducted to study the adsorption of trace quantities (1 mg/L and less) of select chlorophenols such as 2,4-dichlorophenol, 2,4,6-trichlorophenol and pentachlorophenol from aqueous solutions using the fungal biomass of *Aspergillus niger*. Studies were conducted with PCP and *A. niger* biomass in the pH range of 3 to 8, the pH range in which the PCP exists as mostly molecules to completely ionic species. The results showed that PCP adsorption decreased from 90% to less than 35% with an increase in pH suggesting that molecular species are better adsorbed than the ionic species. The equilibrium time of biosorption was within one hour. Experiments are in progress to evaluate the effect of various pretreatment techniques on biosorption.

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Impact of Redox Potential and Protozoan Predation on Nitrification in Activated Sludge

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Biological nutrient removal plants (BNR) incorporate nitrification as one phase of a multi-phase reactor, most typically operated in a sequence of anoxic-anaerobic-anoxic-aerobic conditions (aerobic means high oxidation-reduction potential - redox or ORP). Autotrophic nitrifiers, as obligate aerobes, are stressed when exposed to low ORP (typically un-aerated) conditions which must affect their growth and substrate utilization rate. Many plants, e.g. the older UCT modifications, will have well over 50% of the solids residence time (SRT) under un-aerated conditions – particularly if final clarifier conditions are taken into account. The real impact of stress of the non-aerobic cycles on these autotrophs has not been determined well. Based on observed increased rates of substrate utilization by heterotrophs undergoing variable ORP cycles, imposing stress on the autotrophic aerobic population may actually be beneficial to the overall rate of nitrification.

Predatory microorganisms in the activated sludge, such as protozoa and metazoa, are considered to be aerobes as well, and there are conflicting opinions on the effect of predation on nitrification, with some suggesting decreased nitrification (preferential grazing on the nitrifiers) and other pointing to lack of impact, explained by assumed tendencies of nitrifiers to agglomerate and thus fend off predators. The study was initiated to test the impact of ORP and predators on nitrifiers. Using sequencing batch reactors operated in fully aerated; alternating aerated/anoxic, and fully anoxic modes several runs were with and without inhibitors of predatory microorganisms.

Predation was shown not to have a significant impact on maximum nitrification rates. On the other hand, ORP conditions were found to impact maximum nitrification rates with the rate being greater under alternating conditions. Specifically, nitrification rates were found to be 42% greater in alternating SBRs as compared to aerobic reactors. For protozoa inhibited reactors, alternating anoxic/aerobic nitrification rates were 57% greater than those of aerobic conditions. A possible explanation for these observations is that the feast/famine process in alternating reactors may induce increased energy requirements during the aerobic phase. Current research is testing this hypothesis using molecular techniques to identify the dynamics of stress protein appearance in the variable oxidation reduction potential SBR cycle.

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Model Optimisation for BAF Systems

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Over the last 20 years, Biological Aerated Filter technology has been widely used for wastewater plants where conventional biological processes were not suitable. The evolution of the standards requirements, and the latest BAF applications forced the utilization of sophisticated tools to design such plants. The calculations with some black box models, based only on statistical analysis of data, cannot be used to predict the operation of plants complaining such requirements.

Compared to the modeling of an activated sludge system the modeling of an attached biofilm system is much more complex. The heterogeneity of the system, and the role of detachment of biofilm demand for more sophisticated tools. Several models have been presented simulating biofilm growth from 1D to 3-D. Those models can simulate the growth and structure of biofilms in lab scale, but the scale up and verification for full-scale application are not available. A more simple approach based on a modification of the ASIM1 model has been presented. This model, developed for soluble degradable COD and Ammonia removal, did not take into account the hydrolysis and the influence of filtration. Since these processes have a crucial influence on the performance of a BAF another approach was necessary.

A new modeling approach has been developed to fit both the process (quality, oxygen…) and operational (headloss, backwash…), which is based on a global description of the BAF where the activity of the autotrophic and heterotrophic biomass is introduced from real pilot experiments data. The relations used allow a complete description of all the processes involved in the treatment application from the biomass growth, the sludge production, headloss build-up and oxygen demand. The model, calibrated and tested on several full-scale plants, is now widely integrated in our design tools for plant upgrade. An example of the design of a facility achieving nitrification with cold-water influent will be presented.

As a conclusion, this deterministic modeling approach has been developed to better analyze the experimental results and provide a tool for design of biofilters. The model can be easily calibrated to different types of biofilters provided experimental results are available

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COMPETING FOR THE PHILIP H. JONES AWARD

Two-Stage Low Sludge Production Process for the Treatment of Municipal Wastewater

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The treatment and disposal of sludge represent 25 to 65% of the operating cost of wastewater treatment (WWT) plant. A two-stage low sludge production process (LSP) based on predation of bacteria reduced between 50 and 80% the sludge production of pulp and paper effluent treatment processes. The first stage is a completely mixed aerated reactor without sludge recirculation operated at a low hydraulic retention time (HRT) to favour the growth of dispersed bacterial biomass. The second stage is an activated sludge system in which dispersed bacteria produced in the first stage are consumed by predatory microorganisms, resulting in an overall low sludge yield.

The aim of this study was to evaluate the feasibility of the LSP process for the treatment of municipal wastewaters at bench scale.

Two primary effluent batches of 1000 litres each from a municipal WWT plant in St-Hyacinthe (Quebec) were used. The first stage was operated with a 2-litre reactor at a temperature of 18^{o}C and an HRT (equal to sludge retention time [SRT]) of 2 h. The second stage was an activated sludge operated with a 10-litre sequential batch reactor at an HRT of 20 h and an SRT of 20 d.

Only 50% soluble chemical oxygen demand (sCOD) removal and 25% volatile suspended solids (VSS) production were observed in the first stage. No significant reduction in sludge yield was measured after this period with the LSP process compared to a control process operated in parallel with the same influent, but without the first stage reactor.

With pulp and paper industry effluents at 3 h of HRT and 30^{o}C, first stage sCOD removal and VSS production efficiencies were reported to attain 80 and 200%, respectively. Factors typical to municipal WWT in Quebec, are suggested to explain these results: 1) low influent readily biodegradable organic matter concentration; 2) lack of active heterotrophic bacteria in influent wastewater; 3) low reaction time in the first stage (2 h); and 4) low reaction kinetics in the first stage at a relatively low temperature (18^{o}C).

The application of the LSP process for the treatment of municipal wastewaters under similar conditions does not appear to be recommendable on the basis of the results obtained in this study.

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Drinking Water:
Taste and Odour, Treatment

Chair: DR. SUSAN B. WATSON

Dhaka's Waterways: "Save the Buriganga River Program"

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The Buriganga River and the interconnected system of waterways around Dhaka provide a means of transport, communication, and sustenance to millions of people each year. Yet, despite the vital role of Dhaka's waterways to life in Bangladesh, millions of cubic metres of untreated sewage and industrial waste enter the waterways each year.

In some cases in Dhaka, major pollutant discharges are located upstream of surface water bodies that are being developed as water supply sources in Dhaka.

Reducing the influx of pollutants into Dhaka's waterways will reduce the health risk to city inhabitants that are, or will be, drinking water from surface water sources. According to the United Nations, 80% of all illnesses in developing countries are water-related; over 1.1 billion people lack access to safe water and as a result 3 billion cases of illness and 2 million deaths occur annually. The urgency of the current water quality problems will continue to mount as increasing demands on groundwater resources accelerate the shift to the use of surface water resources. A more aggressive approach to waterways protection is needed to ensure that the incidences of illness and death associated with poor water quality decrease in Bangladesh.

Dhaka's waterways play a vital role not only in water supply, but also in transportation, fish production and support of various ecosystems, irrigation, recreation and other social and aesthetic purposes. Many of these roles of Dhaka's rivers and channels are not compatible with watercourse use as a waste repository or a site for urban and rural settlement through encroachment and infilling these latter uses must be firmly controlled.

This paper addresses the serious problem of surface water contamination in and around Dhaka, discusses major pollution sources, and provides an approach to combating the deterioration of the waterway system. More than two-thirds of the sewage generated by Dhaka City's population of over 8 million people remains untreated and is discharged into the interconnected system of rivers and canals around and within the city. Some of Dhaka's major industries, such as the Hazaribagh Tanneries on the Buriganga River, also release heavy metals and other contaminants to the rivers. These industrial contaminants complicate the treatment processes needed to clean the waterways and pose additional threats to human and environmental health. The situation is most critical in areas where surface water is used as the drinking water supply or where body contact with contaminated surface water is highest. A new wastewater treatment plant is recommended. Program management issues (i.e., means of prioritizing, integrating and implementing remedial solutions to the water quality problems) are discussed.

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Probing the Ramsey Lake Watershed

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The Ramsey Lake watershed, a "living laboratory" that has survived a century of extreme industrial acid and metal-laden emission insult, is at the centre of ongoing regional development, being a source for potable water, recreation and relaxation. With water sources being from groundwater, streams from conservation lands, and runoff from urban infrastructure, Ramsey Lake provides a unique challenge, responsibility and opportunity for environmental monitoring research to utilize both long-term and the real-time data from chemical and physical measurements of both inputs to, and exports from, the watershed.

This presentation will highlight data obtained from both towed sensors measuring bottom water physical and chemical parameters, and from continuous monitoring equipment designed to allow development of dynamic predictive models crucial for planning and effective resource management. Instrumented buoys, profiling units and inflow samplers provide sub-daily limnological measurements that can be accessed remotely, in real-time, a feature particularly important for the detection of episodic events that may play a critical role in determining lake characteristics throughout the season. Analytical units providing data for wind speed, radiation, temperature, humidity and trace gas concentrations will parallel the water quality monitoring initiatives as development progresses. Innovative communication methods to water managers for this plethora of data include website feeds displaying data as daily updated, finite, cumulative graphs and triggered alarm systems using control charts to identify water quality parameter exceedences. With the increasing realization that potable water will be the most valued resource of the twenty-first century and the real threat of terrorism in this post 9/11 era, advanced environmental monitoring sensors are being developed for integration with these innovative monitoring tools to test performance and obtain maximum effectiveness in harsh environments.

The towed sensor array has proven to be an excellent tool for identifying areas of upwelling groundwater, point sources of urban runoff, and in-lake mixing patterns. Typical "finger prints" for upwelling groundwater in surface water are evident near the sediment-water interface, identified by elevated chloride, conductivity, turbidity and reduced temperature, dissolved oxygen, and oxidation/reduction potential values. Common urban runoff contaminant sources are indicated by near shore zones that exude higher chloride, nitrate, and/or conductivity. In-lake mixing patterns can be elucidated from detailed gradient monitoring of plumes. The progressive monitoring techniques applied to this research show that there can be a vast diversity of chemical environments vertically and laterally in a water body, therefore a project design that incorporates high sampling and monitoring resolution provides greater insight to lake system health and drinking water resource sustainability.

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Taste and Odour Outbreaks in N.W. Lake Ontario: Physical, Chemical and Biological Drivers

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In the past decade, erratic outbreaks of the biological metabolite geosmin have caused extensive drinking water odour along the northwest shore of Lake Ontario. Effective treatment and remediation of such odour events require the prediction of their timing and intensity, based on the identification of their biological source(s) and environmental triggers. However, these are often difficult to identify, particularly in sizeable waterbodies such as Lake Ontario, with heterogeneous weather patterns, basin and watershed characteristics and large-scale hydrological events. These odour events have been the focus of research by a large multidisciplinary collaboration of scientists, government agencies, industry and universities. This paper will summarize the key findings of 5 years of laboratory and field research, and demonstrate how the synchrony of large- and small scale physical, chemical and biological processes plays a key role in determining the timing and severity of these geosmin outbreaks.

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Pilot Scale Investigation of the Removal of Geosmin and MIB by Granular Activated Carbon Filtration

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This paper reports on pilot studies conducted to investigate the removal of geosmin and 2-methylisoborneol (MIB) by new and semi-exhausted granular activated carbon (GAC) under experimental conditions similar to those employed in the full-scale GAC filters of the City of Toronto water treatment plants.
Four pilot filters constructed of 5 cm (2") internal diameter clear PVC pipe containing GAC, sand and gravel were designed to simulate flow conditions and media composition of the full-scale filters and run in parallel throughout the study. Except for the GAC media age, the design and operating conditions of Pilot Filters 1 and 2 were the same. Pilot Filters 1, 2, 3 and 4 contained 25 cm of used bituminous GAC, 25 cm of fresh bituminous GAC, 30 cm of used lignite GAC and 95 cm of used bituminous GAC, respectively. All used GAC was core sampled from full scale filters and had been in the filters for about 3 years.

The pilot filters were supplied with settled water from the R.C. Harris Filtration Plant. Geosmin and MIB solutions were pumped into the influent of each pilot filter and samples were collected from different locations to monitor the removals. Each column was equipped with at least 4 sample ports. Sample Port 1, which was located 15 cm above the surface of the GAC, was used to sample the influent. Sample Ports 2 and 3 were located half way into the GAC layer and at the GAC-sand interface, respectively. Sample Port 4 was located following the sand layer.

Experiment 1, the first of four sets of experiments, was designed to investigate potential losses of geosmin and MIB due to adsorption on surfaces such as tubing and column walls, and other factors. As such, this experiment was performed before the columns were filled with the media and utilized two columns supplied with settled water spiked with geosmin and MIB. Experiment 2 investigated the removal of geosmin and MIB at empty bed contact times (EBCTs) corresponding to the design capacity of the full scale filters being modeled. The experimental conditions included high (211 to 541 ng/L) and low (52 to 83 ng/L) levels of geosmin and MIB concentrations combined with a 2.8 minute EBCT for Pilot Filters 1 and 2, 3.4 minute EBCT for Pilot Filter 3 and a 3.8 minute EBCT for Pilot Filter 4. Experiment 3 investigated potential desorption of geosmin and MIB from the GAC following Experiment 2. The filters were run at the same EBCT as in experiment 2 with no geosmin or MIB being fed. Experiment 4 investigated the removal of geosmin and MIB when the EBCT was increased to 5 minutes in Pilot Filters 1, 2, and 3 and 7.5 minutes in Pilot Filter 4.

The system losses for geosmin and MIB appeared to be similar and dependent on the influent concentration, with increasing losses being observed when the influent concentration increased. Between Sample Port 1 and the column effluent, the total losses for geosmin ranged between 23 and 40% for the influent concentrations tested (215 to 328 ng/L) and the total losses for MIB were between 24 and 40% for influent concentrations of 184 to 282 ng/L. However, results obtained subsequently when investigating the removals by the GAC seemed to suggest that the losses may decrease with the time or become negligible for lower geosmin and MIB influent concentrations.

For both geosmin and MIB, the effluent concentration and the amount removed increased with an increase in the influent concentration, as was expected. Geosmin was better removed than MIB. None of the pilot filters appeared to be capable of reducing the geosmin and MIB below the commonly cited threshold odour limits of 4 ng/L for geosmin and 9 ng/L for MIB. When operated at a 5 minute EBCT with influent geosmin concentrations in the range of about 70 to 110 ng/L, the removal was 10% for Filter 1 (25 cm of used bituminous GAC), 83% for Filter 2 (25 cm of fresh bituminous GAC) and 38% for Filter 3 (30 cm of used lignite GAC). When operated at a 7.5 minute EBCT, Pilot Filter 4 with 95 cm of used bituminous GAC removed 78% of the geosmin present in the filter influent.

The results of this study suggest that in the event of a geosmin/MIB odour spike, the filters containing exhausted GAC would not be able to remove levels to less than the threshold values. The results of this study will assist in identifying short-term strategic options for taste and odour control in the City of Toronto.

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TerraQSAR™ — LOGP —A PNN-based Octanol/water Partition Coefficient Computation Program for PCs

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The octanol/water partition coefficient, commonly known as "logP" or "Kow", is one the most widely used physico-chemical bulk parameters in medicinal and environmental chemistry. The mobility and uptake of drug molecules, the bioconcentration of contaminants onto adsorbing materials, and their accumulation in the food chain are highly related to logP. Not surprisingly then, methods to calculate logP solely from a molecule's structure have long been sought after. Indeed, a variety of computer programs for personal computers (PCs) exist to do just that.

Neural network programs, particularly the probabilistic neural networks (PNNs) are rapidly "coming of age" for the *a priori* computation of important physico-chemical and biological properties of chemicals. TerraBase Inc. has now developed a novel program, available under the name TerraQSAR™ - LOGP for the Windows® platform on PCs, which computes logP using a proprietary PNN algorithm.

This presentation gives an overview of the program method, statistical descriptors of its training and cross-validation, and sample applications.

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Drinking Water:
Waterborne Pathogens

Chair: DR. TOM EDGE

COLIFORMS GIVE ME GAS

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While waterborne diseases are typically considered to be problems of underdeveloped countries with inadequate sanitary practices, there is increasing recognition that industrialized, developed countries also have significant public health problems caused by use of untreated, partially treated, or inadequately treated domestic water supplies. The incidence of major outbreaks of the classical waterborne bacterial diseases, such as typhoid fever and cholera, has become very low in developed countries since the initiation of chlorination of domestic water supplies. However, outbreaks of waterborne diseases still occur. The organisms/agents of concern are found in fecal material of infected/carrier individuals. Some are also present in the fecal material of healthy, asymptomatic individuals, and/or in fecal material of other animals. One of the fundamental problems with current regulatory approaches for addressing water supply-associated waterborne diseases is that the bacteriological standards that are used for evaluating the "sanitary quality" of treated water do not reliably assess the presence of cyst-forming protozoa or enteroviruses. In addition, due to analytical time requirements, reliance on microbiological criteria to determine water potability will not protect consumers from exposure to pathogenic organisms should there be a breech in the treatment or distribution system. There is obviously a need to redefine our definition of "potability". We must significantly improve our ability to determine the adequacy of municipal water treatment systems to prevent microbial pathogens from causing epidemic as well as endemic waterborne and foodborne illness.

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CHANGES IN DRINKING WATER TREATMENT: WHAT ARE THE EFFECTS ON MICROBIAL WATER QUALITY IN THE DISTRIBUTION SYSTEM?

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Historically, management of drinking water quality has focused on multiple barriers, including disinfection with chlorine, to prevent potentially pathogenic as well as taste- and odour-causing microorganisms entering the distribution system. More recently, recognition of risks from by-products of chlorination has led to optimization and diversification of disinfection strategies to minimize risks from both microbial and chemical contaminants. As a result, a number of municipalities are changing their chemical disinfection regimes or adding a UV unit to improve microbial inactivation in water entering the distribution system. Many, if not all, such changes follow engineering decisions without an understanding of whether there will be impacts on the microbiological quality of the water in the distribution system.

Biofilms on drinking water distribution pipes are typically complex communities of many species of microorganisms that may be, at least partially, interdependent. These biofilms are believed to develop through gradual acquisition and succession of species and to achieve a mature, quasi-steady state while upstream water conditions remain relatively constant. Changes made in the water treatment regime can have profound influences on the species composition of biofilms and hence on the microbial quality of water delivered to the consumer. It is even possible that tougher and more pathogenic microorganisms may proliferate better in such biofilms due to higher levels of reduction by disinfection in the more ubiquitous and less harmful bacteria. Of particular concern are the opportunistic pathogens, such as legionellae and mycobacteria, which thrive in biofilm communities because of their relative resistance to disinfectant residuals.

Changes in water treatment regimes are rarely accompanied by analysis of biofilm composition. Results reported here for one utility using unfiltered groundwater show marked changes in biofilm composition following installation of a sulphide removal plant and with a switch from chlorination to chloramination. This utility has also experienced a decrease in overall water quality as a consequence of these changes. Investigations are ongoing to try and understand these phenomena.

Increasing incentives to use a total quality management (TQM) approach to drinking water systems and to apply HACCP (hazard analysis critical control point) principles suggest the need to have a thorough knowledge and understanding of the system and of how any imposed changes can affect it. Such changes may be particularly important if their effects are progressively apparent along the distribution system. Thus, in considering an approach to drinking water that truly stretches 'from the source to the tap', it is important to take a holistic approach to issues by considering the physical, chemical and biological/microbiological effects and how they may be interrelated.

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DNA Microarray Fingerprinting of Microbial Communities in Commercial Microbial Biotechnology Products for Water Treatment

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A variety of microbial biotechnology products containing bacteria are marketed in Canada for water treatment applications ranging from cleaning drains, to removing ammonia in ponds, and enhancing septic tank and aquarium operations. Some of these products consist of a complex consortium of unidentified microorganisms. These consortia products pose a challenge for assessing product safety and efficacy since existing culture-based methods are insufficient for characterizing microbial diversity in complex microbial communities. New methods are needed to better characterize microbial community composition and stability in biotechnology products and processes and identify potential pathogen contaminants. Environment Canada's New Substances Branch provided funding under the Canadian Regulatory System for Biotechnology Program for the present study to investigate advances in genomics and DNA fingerprinting techniques for characterizing microbial biotechnology products. A prototype DNA microarray composed of oligonucleotide probes for functional genes, virulence factors, and taxonomic genes for a number of bacterial species was developed to examine the potential of microarray technology for characterizing consortia. The genomic DNA from four different commercial consortia products was extracted by two methods and examined with the prototype microarray and by denaturing gradient gel electrophoresis (DGGE). Although the identity of the microbial species in the consortia remains unknown, the microarray assay provided unique and reproducible hybridization patterns for all four products. The results also agreed with the DNA fingerprints generated by DGGE. The ability to differentiate between a variety of consortia products demonstrates that DNA microarrays have the potential to be a powerful tool in monitoring complex microbial communities.

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Sediments

Chair: Dr. Michael Zarull

Opportunities, Needs and Strategic Direction for Research on Flocculation in Natural and Engineered Systems

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An international workshop on flocculation was held at the National Water Research Institute (NWRI) in September of 2003. This workshop provided credence for a paradigm shift from the traditional view of sediments as single grain entities to that of dynamic flocculated material with an active biological component. Flocculation is a common process which promotes the removal of sediments and contaminants from the water column to the bed sediments via aggregation and settling, and is ubiquitous within freshwater, marine and engineered (e.g. wastewater) systems. Flocculation has a significant impact on environmental and water resource management with significant sums of money spent to rectify issues such as dysfunctional treatment systems, remediation of contaminated bed sediments, dredging harbours and navigation channels and assessing fish habitat destruction resulting from sedimentation. The workshop brought together 26 academics and government scientists from around the globe to address this critical issue of sediment flocculation and its unifying principles between freshwater, marine and engineered systems. This paper will summarize the research needs and strategic directions for flocculation research derived from this authoritative workshop.

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Unique Tools for Determining the Geometry of Contaminated Sediments

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Sediment geometry is requisite for the management of contaminated sediments sites. Site managers have to know the inventory of contaminated sediment as related to the capacity of the remedial option(s) under consideration. Any improvement in the resolution of sediment volume estimates translates to more effective planning and utilization of resources. NWRI has employed a unique set of tools to acquire the information for the volume calculations. High-resolution multibeam sonar data mapped the elevation of the upper layer of the deposit for the study area. The thickness of the overlying contemporary sediments was measured with two different probes. A tripod equipped with an acoustic transducer was used in shallow sediments and sediment thickness was estimated from the sounder output. A Seabed Terminal Newton Impact Gradiometer (STING) was deployed throughout the balance of the study area. The STING is a self-contained, tethered probe which can be outfitted with a steel shaft up to three meters protruding from the nose cone. The cone of the probe contains electronics to record pressure and acceleration as it contacts and penetrates into the sediment. The point data from these two instruments is combined and interpolated using geospatial techniques to model the lower level of the deposit. The volume of the deposit can then be calculated for the total extent of the study area under as well as unique polygons for each data point. Individual polygons can then be selected based on existing sediment chemistry and toxicology information. The area and volume can be summed as a group to estimate the volume of sediment for priority zones within the study area.

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COMPETING FOR THE PHILIP H. JONES AWARD

Comparison of Mercury and Lead Sediment Concentrations in Lake Ontario (1968-1998) and Lake Erie (1971-1997/98) using a GIS-based Kriging Approach

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This research analyzes sediment contamination concentrations for mercury and lead in Lake Ontario and Lake Erie using a GIS-based kriging approach. The data were obtained from Environment Canada sediment surveys of Lake Ontario (1968 and 1998) and Lake Erie (1971 and 1997/98). The use of point measurement data without the application of interpolation methods does not allow for spatial data trends to be fully analyzed. The kriging technique enables the creation of interpolated prediction surfaces, with the advantage that the results can be statistically validated. For both lakes, the more recent data reveal reduced concentrations of mercury and lead, and there has been an overall reduction in contamination levels. There are however still areas in both lakes that exceed Canadian Sediment Quality Guidelines in terms of the Threshold Effect Level (TEL) and Probable Effect Level (PEL). In both cases however, the extent of the affected areas has been reduced. Areas of major concern in Lake Ontario are found mostly within deep lake basins, in proximity to the mouth of the Niagara River, and in the area of Hamilton Harbour (Ontario). For Lake Erie, the problem areas continue to be located in the western and south central portions of the lake.

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Assessing the Biological Impact of Contaminated Sediments: Peninsula Harbour, Lake Superior: Case Study

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The assessment of the biological impacts of contaminated sediment involves the integration of four lines of evidence: surficial sediment chemistry, benthic community structure, laboratory toxicity and the potential for biomagnification where persistent bioaccumulative substances exist. Changes in benthic invertebrate assemblages and toxicity to laboratory organisms are assessed by comparing biological response to those in uncontaminated reference sediments (previously established for the Great Lakes region) using multivariate techniques. The potential for biomagnification is assessed by measuring contaminant concentrations in benthic invertebrates, examining relationships between invertebrate and sediment contaminant concentrations (regression analysis) and estimating contaminant concentrations in tissues of consumers of benthic invertebrates and their predators (receptors of concern) using a screening-level trophic transfer model.

Peninsula Harbour, Lake Superior, is designated as an "Area of Concern" due to residual mercury contamination. On two previous occasions (fall 2000 and May 2002) sediment, overlying water and two benthic invertebrate taxa (chironomids and amphipods) were sampled from 13 reference locations and up to 25 locations in Jellicoe Cove, an area in Peninsula Harbour that received historical discharges of mercury. Samples were analyzed for total and methyl mercury concentrations and a series of physico-chemical variables (sediment and overlying water). From the initial survey, the benthic invertebrate community shows enrichment compared to reference and there is no laboratory toxicity due to Hg. From the second survey, total Hg in surficial sediments range from 0.1 to 32 μg/g, and concentrations in sediment as well as in chironomids and amphipods at most sites in Jellicoe Cove are significantly elevated above concentrations at reference sites. Sediment methyl mercury range from <0.001 to 0.024 μg/g, and concentrations in sediment and amphipods from most Jellicoe Cove sites are also significantly higher than concentrations at reference sites. For chironomids, methyl mercury levels exceed the maximum for reference sites only at a few sites. Total and methyl mercury concentrations in chironomids and amphipods from test and reference sites are significantly influenced by mercury in sediment (r^2 = 0.11 to 0.85), with the strongest relationship for total mercury and amphipods. Trophic transfer models indicate that predicted receptor mercury levels in a third of the sites in Jellicoe Cove are greater than predicted receptor mercury levels for reference area sites. Among all predictions, methyl Hg concentration in receptors for a group of seven sites in the southeastern section of Jellicoe Cove is consistently indicated to exceed both reference site conditions as well as tissue residue guidelines for mercury.

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Reductions in Detroit River Area Sediment PCB Levels

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Between 1993 and 2001 there was approximately $130 million spent for sediment remediation within the western Lake Erie/Detroit River basin. This includes 10 sediment remediation projects and at least two containment projects in the Detroit River/Western Lake Erie basin (BASF Riverview Site, Riverview, Michigan; Dura Landfill, Toledo, Ohio). Total estimated volume removed in the 10 sediment remediation projects was 843,500 m^3 (1,103,290 yd^3). Total estimated mass of PCBs removed in the 10 projects was 197,623 kg or 198 tonnes.

It is difficult to accurately estimate the mass of PCBs removed as a result of navigational dredging, however, the U.S. Army Corps of Engineers-Detroit District has been able to provide some rough estimates. Approximately one tonne of PCBs was removed as a result of navigational dredging (608 kg removed by dredging 150,358 m^3 (196,668 yd^3) of material during 1993-2001 from the Rouge River and 317 kg removed by dredging 507,225 m^3 (663,450 yd^3) of material during 1993-2001 from the Detroit River).

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Groundwater:
Quality and Quantity

Chair: DR. NATHALIE ROSS

Use of Stable Isotopes to Assess Groundwater Discharge within the Grand River Watershed

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Groundwater is important, not only to humans as a source of drinking water, but also to ecosystems in maintaining water levels and flows and thereby water quality and aquatic habitat within streams during dry conditions. As there is a vast supply of surface water within the Great Lakes region, the function and importance of groundwater within the Great Lakes basin have frequently been underestimated. Stressors of groundwater resources such as drought, large scale withdrawals, contamination and land use have recently caused both public and political interest in groundwater issues and the need to quantify this resource has become apparent.

Direct determination of the quantity of groundwater discharging to surface water features is difficult and time consuming at a regional scale, and therefore is often estimated using base flow separation techniques. These techniques are aimed at determining quantitative indices related to the long-term base flow response of a watershed and can not differentiate the sources of this base flow. Certain features within a watershed (e.g., wastewater treatment facilities, dams used for flow regulation, and lakes and wetlands) create a stream flow signature that is similar to that of groundwater discharge, resulting in an overestimation of discharge if not factored into the interpretation of base flow.

The use of stable isotopes of water (^{2}H and ^{18}O) in hydrograph separation studies has increased in recent years and has proven to be a successful strategy for partitioning stream flow components such as base flow and event water. Although relatively few studies have applied stable isotopes directly to study baseflow sustainability, the potential exists for the technique to improve understanding of local and regional variability in base flow sources. Various approaches including isotope mass balance are being developed and tested for the Grand River watershed.

Isotope, water quality and discharge data are currently being collected for a network of 27 sub-watersheds located within the Grand River watershed in west-central Ontario. Isotope sampling sites are located at surface water and groundwater quality monitoring sites so that water quality and discharge data are also available. Precipitation samples are being collected from five stations located at meteorological towers within the watershed. A combination of physical and base flow indices and isotope-based indicators will be used to highlight and discuss key patterns in base flow sustainability regimes across the Grand River basin.

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COMPETING FOR THE PHILIP H. JONES AWARD

The Current Understanding of Microbial Transport in Saturated Subsurface Environments and Directions for Future Research

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Interest in the fate and transport of microorganisms in groundwater is motivated by concerns over (1) microbes as pollutants or disseminators of pollutants in groundwater; (2) the role of microorganisms in the biorestoration of contaminated aquifers; and (3) the use of microbial tracers in developing a better understanding of groundwater movement in various types of aquifers. This presentation will present an overview of the current understanding of the processes controlling microbial transport in saturated subsurface environments, discuss the factors affecting these processes, establish directions for future research, and provide an overview of the authors' planned research program regarding microbial transport in single variable-aperture fractures.

The recent literature indicates that subsurface microbial transport involves a host of complex and interacting processes, which for convenience are often classified as physicochemical and biological processes. The physicochemical processes include convective-dispersive transport, passive attachment/detachment, and pore size and anion exclusion. The biological processes include growth and decay, active attachment/detachment, motility, competition, predation, and co-metabolism. Both the physicochemical and biological processes are, in turn, influenced by other factors including the substratum characteristics, the geochemical properties of the groundwater, hydrodynamics, temperature, cell size and shape, cell surface characteristics, and growth cycle. Although the physicochemical processes have been studied extensively in saturated unconsolidated porous medium environments, and are reasonably well understood, much work remains to be done regarding the understanding of biological processes. Studies examining both the physicochemical and biological processes in fractured media are much more sparse than those in porous media.

The objective of the authors' research program is to evaluate the effect of aperture field variability, flow rate, and ionic strength on microbial transport in fractured environments. This will be achieved through both physical model experiments and numerical simulations. The physical model experiments involve both natural and transparent fractures, and are designed to develop a relationship between dispersivity and aperture field variability. Aperture field characterization will be achieved through both light transmission and tracer techniques. Flow cytometry will be employed to quantify the microbial concentration in both the influent and effluent flow streams. A mathematical model will be developed to describe the attachment/detachment process with respect to fracture surfaces. A stochastic transport equation for single fractures incorporating the dispersivity and attachment/detachment model will be solved using numerical techniques. The simulation results will be compared with experimental data to verify the dispersivity and attachment/detachment models.

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COMPETING FOR THE PHILIP H. JONES AWARD

Geochemical Mechanisms Controlling Acid Generation, Acid Neutralization and Metal Attenuation at the East Tailings Management Area, Lynn Lake, Manitoba

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Field investigations were carried out on the East Tailings Management Area (ETMA) in Lynn Lake, Manitoba during summer 2002, to evaluate mechanisms controlling metal release and mobility in the tailings. Extraction of ore from the Farley Ni/Cu Mine began in 1952 and was terminated in 1976. Since then, the tailings have oxidized depleting the near-surface sulfide mineral content and resulting in the generation of acidic, metal-rich pore waters. Mineralogical study indicates that the principal sulfide mineral is pyrrhotite, with smaller amounts of pentlandite and chalcopyrite, and trace amounts of pyrite. The oxidation of sulfide minerals has created high concentrations of SO4 (max. 9760 mg/L), Fe (max. 4220 mg/L), Ni (3870 mg/L), Al (max. 2390 mg/L), Cu (max. 270 mg/L), Zn (max. 226 mg/L), Co (max. 156 mg/L), Pb (max. 4.75), Cr (max. 0.85 mg/L) and Cd (max. 0.54 mg/L) in the pore waters of the ETMA. Pore-gas measurements indicate that O2(g) has ingressed deep into the cycloned tailings of the ETMA. The extensive vadose zone in the cycloned tailings has allowed for the depletion of sulfide minerals and the generation of low pH conditions. The tailings slimes show less extensive O2(g) ingress. The relatively high moisture content of the tailings slimes probably limits the depth of oxygen ingress. Distinct pH plateaus occur at most locations throughout the ETMA. These plateaus are attributed to pH buffering reactions involving minerals such as carbonates ($pH \geq 5.7$), aluminium hydroxides ($pH \geq 4.0$), ferric hydroxides ($pH \geq 3.5$) and aluminosilicate minerals ($pH \geq 1.3$). The relative mobility of the metals in the ETMA generally follows the order $Zn \geq Fe \geq Ni = Co = Cd > Cr > Pb > Cu$. The mobility of the metals is primarily controlled by the pore-water pH. Geochemical equilibrium calculations made using the geochemical speciation/mass transfer model MINTEQA2 indicates that the pore water is supersaturated with respect to various ferric oxyhydroxide and hydroxysulfate solids. The calculations indicate that the pore water is undersaturated with respect to discrete Ni, Co, Cd and Cr phases. The primary mechanisms of attenuation of these trace metals are likely adsorption or coeprecipitation onto secondary ferric oxyhydroxide and hydroxysulfate minerals, most likely goethite, ferrihydrite and jarosite. In some areas the pore water is at equilibrium with respect to anglesite. The precipitation of anglesite probably controls Pb concentrations in the tailings pore water. Over time, an expanded zone of low pH pore waters is expected to develop, leading to increased concentrations of heavy metals into the tailings pore waters.

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The Qanat Discharge and Ground Water Table Changes under Water Spreading Impact in Part of the Zanjan Plain, Iran

F. B. MOVAHHED*

Today's, decreasing of ground water level and lack of enough existing water for agricultural activities is the most important factors which limit the development. Having knowledge of the function of water spreading systems and their effects on the ground water resources as a new vector along with other natural factors influencing the recharge of aquifers is one of the most important activities that could be assessed in managing water spreading and aquifers recharge projects. The study area is located in the part of the Zanjan plain, in north-west of Zanjan city that has been occupied by quaternary deposition. This plain has an aquifer with depth of 80-120 m that flood water by applicating of artificial recharge projects can be recharged and stored on it.

In this study, the impact of amount of spreaded floodwater on the changes of water quantity of a qanat located in the spreading area has been investigated and compared with a qanat as control. Also the changes of ground water table of the plain and some pizometric wells during 7 years from 1995 – 2002 has been surveyed. For this purpose, the amount of rainfall and diverted floodwater to the station were monitored and measured during all flooding time. Although during most of the study years, the amount of rainfall was about 30 % less than mean annual precipitation of a period 32 years, floodwater was harvested and spread 7 times. The comparing of two qanats showed that one located in spreading area was completely affected from water spreading and had extreme changes on spreading times. Whereas the control one with having larger basin had not more changes. Also this study showed that not only the decreasing of ground water table in this part of Zanjan plain was stopped, but also some increasing on wells around the spreading area was observed. Due to the occurrence of drought during these years, such changes were important.

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Groundwater: Remediation

Chair: DR. NATHALIE ROSS

COMPETING FOR THE PHILIP H. JONES AWARD

The Effect of Biofilm Development on Solute Diffusion in Low Permeability Rock

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In fractured rock environments, the process of matrix diffusion strongly influences the persistence of groundwater contamination. Biofilm growth in the matrix - a natural process in groundwater systems - can have a significant effect on the solute transport properties of that medium. If the properties of a biofilm can be understood and accurately modeled, then this knowledge can be used to support the design of biostimulation and/or natural attenuation programs for groundwater remediation. In this study, preliminary conservative tracer experiments were undertaken to investigate mass transport into an intact rock sample in the presence of a biofilm. Radial diffusion cells were constructed by boring out a central reservoir from saturated dolostone core samples, encasing the samples in heat shrink plastic between UHMW polyethylene endcaps, and then filling the reservoirs with groundwater. This configuration is analogous to a cylindrical fracture in any rock matrix. In half of the diffusion cells, biofilm growth from indigeneous bacteria was stimulated by adding invertose to the groundwater used to fill the reservoir. Each of these biofilm cells had a corresponding cell constructed from the same rock sample in which biofilm growth was not stimulated. The decay in the concentrations of bromide and lissamine FF introduced into the reservoir was monitored over a 45 day period in 18 diffusion cells. The presence of the biofilm could not be visually confirmed on the surface of the reservoirs when the diffusion cells were disassembled at the end of the test, but there was a measurable difference in the diffusion curves between biofilm and non-biofilm cells. In general, stimulating biofilm growth acts to impede diffusion from the reservoir to the matrix. A semi-analytical model was developed from a solution of the diffusion equation for solute transport in radial coordinates which accounts for the presence of a biofilm. The results from the biofilm experiments have been used to validate this model and to assign average mass transport parameters to the biofilm.

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Characterizing biofilm development in fractured bedrock using hydraulic testing and point dilution

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Biological barriers have recently been explored as a possible containment technology for contaminated groundwater. This approach involves developing a biofilm *in-situ* to reduce the permeability of the geological formations through which contaminated groundwater flows. Recent field results from this study suggest that this concept may be successfully applied to fractured bedrock environments. This field experiment involved developing a biofilm within a horizontal bedrock fracture located approximately 10 m below ground surface. The fracture was previously identified and shown to be laterally extensive and associated with the contact between limestone and shale units. The current site configuration includes 29 vertical boreholes that provide access to the fracture in approximately a 25 m x 25 m area. One of the difficulties in demonstrating the efficacy of this technology was determining the nature and extent of biofilm development. Constant-head injection, pulse interference and point dilution testing were used to infer the distribution of biofilm and to quantify the impact of its development on permeability and groundwater velocity at the study site. The hydraulic approaches to estimating fracture permeability appear to provide reliable measurements with no detectable disruptions on the developing biofilm, despite their reliance on injecting pressurized water. Comparisons to pre-biofilm measurements indicated a reduction of 70% to 90% in groundwater velocity and typical permeability reductions between 33% and 93% in the study area. Future work will include testing the longevity of this biofilm.

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COMPETING FOR THE PHILIP H. JONES AWARD

Laboratory Evaluation of Zero-Valent Iron Mixtures for use in Permeable Reactive Barriers for Treatment of Acid Mine Drainage

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Permeable reactive barriers for treating acid mine drainage are comprised of materials which promote sulfate-reduction, acid neutralization, and metal-sulfide precipitation reactions. Organic-carbon and zero-valent iron may be utilized to support biotic and abiotic sulfate-reduction. Abiotic sulfate-reduction by zero-valent iron generally occurs at a greater rate than with sulfate-reducing bacteria due to more rapid reaction kinetics. However, the presence of organic materials and sulfate-reducing bacteria generally results in greater increases in dissolved organic carbon and alkalinity. Laboratory batch experiments were conducted using simulated mine-drainage water to evaluate sulfate reduction and metal removal rates associated with mixtures of organic-carbon materials and zero-valent iron. Each reactive mixture had constant total proportions of reactive materials (58 dry wt. %), porous support (25 dry wt. %), and neutralizing agent (15 dry wt. %). The reactive portion was comprised of a decreasing proportion of organic-carbon materials (58-0 dry wt. %) amended by a corresponding increase in the proportion of zero-valent iron (0-58 dry wt. %). A bacterial source (2 dry wt. %) was added to all mixtures containing organic-carbon materials. The simulated mine drainage water had a pH of 4.5-5.0, and contained approximately 6000 mg/L SO_4, 1500 mg/L Fe, 200 mg/L Ni, 200 mg/L Zn, 40 mg/L Co, 10 mg/L Cd, and 3 mg/L Pb. Conditions favorable for sulfate-reduction, indicated by observed redox potentials of <-200 mV, developed within days to weeks. Observed declines in redox potential occurred at a greater rate with mixtures containing greater fractions of zero-valent iron. Increases in pH from <5.0 to >6.0 were observed over the same period. Higher pH values were generally associated with reactive mixtures containing greater percentages of zero-valent iron. Alkalinity increased from <60 mg/L (as $CaCO_3$) to >1000 mg/L (as $CaCO_3$) for all mixtures containing organic materials. Results obtained from this study will be utilized in determining optimum mixtures of zero-valent iron and organic carbon for treatment of acid mine drainage.

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Containments' Formation and their Impact on Groundwater Quality

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Groundwater quality is affected by human activities and environmental conditions: eg. leaching, spills of contaminants and saltwater intrusion. In these cases, containments may be used to protect aquifers; among them various curtains including silica gel might be applied. However, the formation of this curtains *in-situ* can present certain danger for water quality if it is situated close to water uptake facilities. Therefore, the impact of these curtains has to be tested in order to design an accurate method of their formation. Subsequently, research was performed on silicate grout combined with two different reagents: ethyl acetate-formamide (SA) and calcium chloride (SC) in order to evaluate their impact on groundwater quality where aquifer strata contained natural clayey soil (with some organic matter) and silica sand.

The setting process which occurred during the chemical grouting in the soil media was studied using IR and UV spectroscopy. IR analyses showed that in the presence of organic reagents, the complexation reactions between organic compounds and the silicate took place as a preliminary stage of the setting process. The impact of natural organic matter was examined by UV spectrometry. The UV was also used to assess the processes of curing in the presence the salt water intrusion into aquifer. The spectral results were completed with other lab tests such as permeability tests and the durability of grouted curtains when various conditions were applied.

The results demonstrated the relationship between curing time, temperature and pore water composition for both type of reagents applied to form silica gel curtains. The grouting of natural soil and sand with SA (organic reagent) caused a transfer to the environment of sodium formate, sodium acetates, ammonia and part of the ethyl acetate and formamide. This process has tendency to decrease for approximately 4 months. The stability of this curtain was low. The grouting of soil and sand with SC (calcium chloride) did not cause a significant impact on environment. The increase of pH of environmental water was much less than for curtains with SA grouting. Also the stability of curtains was higher in comparison to SA grout. It was found that curtains might be very successful in costal areas where the intrusion of salt water to the aquifer is a common situation. In fact, the composition of salt water protected the specimens grouted with both SA and SC from disintegration with time and prevented release of contaminants into aquifer.

The experiment results can have a significant impact on the development of adequate materials and technologies for soil grouting in order to form protective curtains for the groundwater quality.

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Storm Water

Chair: DR. SANDRA KOK

Water Pollution Analysis for the City of Sarnia

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The St. Clair River is an important international waterway, with heavy demands put on it as a shipping channel and as a source of water for power generation, municipal water supply, recreational uses including boating and fishing, and industrial cooling and process water. Discharges of chlorinated organic compounds, heavy metals, oils and greases, phenols, and suspended solids from petroleum and chemical industries, combined sewer overflows, sewage treatment plants, spills, as well as historically contaminated sediments, are the major concerns. Implementation priorities have been developed and are actively being pursued to allow the St. Clair River to be delisted as an Area of Concern (AOC).

The City of Sarnia, located at the St. Clair River AOC, developed a pollution control plan (PCP) in 1993. The primary municipal pollution sources were identified to be the sewage treatment plant effluent, combined sewer overflows, and stormwater discharge. The recommended solution includes sewage plant upgrade, storage-treatment systems for combined sewer overflows, and a new stormwater quality pond at the waterfront area. Upgrade of the sewage treatment plant and construction of combined sewer overflow control measures have been undertaken. The only remaining municipal pollution source is stormwater discharge.

In 1994, the Ontario Ministry of the Environment (MOE) published the Stormwater Management Practices Planning and Design Guidelines (herein called Stormwater Guidelines) which advocate a holistic approach to stormwater management. A treatment train concept, which incorporates stormwater practices at the source, along drainage systems, and at outfalls, is recommended for stormwater management. A recent update of the MOE's Stormwater Guidelines (2003) also advocates the holistic approach for stormwater management. As the Sarnia's PCP was developed ten years ago and stormwater management has evolved significantly since then, it is imperative that the plan be revisited and effective stormwater management options be considered.

This presentation will address stormwater pollution in the City of Sarnia by:

- Development of a master stormwater retrofit plan using the holistic approach of stormwater management;
- Re-evaluation of stormwater pollution loadings in relation to other municipal sources of water pollution such as combined sewer overflows and wastewater treatment plant effluent;
- Demonstration of an effective stormwater treatment technology.

By addressing the last remaining municipal source of water pollution, the proposed project will contribute to the delisting of the St. Clair AOC.

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Investigations of Sediment Quality at a Stormwater Management Facility in Toronto using Benthic Techniques

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The performance of a stormwater management treatment train in the protection of downstream benthic habitat quality was studied at the Terraview-Willowfield stormwater management facility in Toronto. This facility comprises a number of control measures installed in parallel or in series, including an oil & grit separator, a sand filter, two extended detention ponds (in series), and finally a downstream vegetated drainage ditch. The facility receives highly contaminated runoff from a multi-lane divided highway (401) and much less polluted residential area runoff.

Over the field year (January – November, 2003), bottom sediments in the facility were sampled and analyzed for such constituents as trace metals, PAHs (polycyclic aromatic hydrocarbons) and selected nutrients. The sediment chemistry reflects the fact that the Terraview pond receives highly contaminated highway runoff with contaminated sediments, which accumulate in the pond. Coarse sediments (75-90% sand) accumulate in the forebay and towards the outlet of the Terraview pond, with finer, clay-like sediments accumulating in deeper parts of the upstream half of the pond. The clay-like sediments appeared to contain the highest observed levels of contaminants for both metals and PAHs. Metal contamination was highest at the Terraview sediment forebay, with Cr, Cu, Fe and Mn levels exceeding the severe effect levels (SEL) in MOE guidelines, but the contaminant burden generally decreased towards the pond outlet with coarser sediment deposits. Elevated levels of Fe persisted downstream in the Willowfield pond, but both Fe and Zn were below the lowest effect levels (LEL) at the outfall. Lower contaminant levels were generally found in the Willowfield pond, where sediments consisted of 65-95% sand. PAH contamination was the greatest near the inlet of both ponds, with some reduction in concentrations towards the outlets. Although several sites exceeded the LEL and probable effect level (PEL), no site was contaminated by PAHs above the SEL.

Surficial sediment for toxicity testing was collected in July 2003 from 14 locations, extending from the sediment forebay at the inflow to Terraview Pond to approximately 250 m downstream of Willowfield Pond in a drainage ditch representing the receiving stream. Toxicity of the sediments was assessed based on 10 acute and chronic endpoints from 10 to 28-day laboratory tests with four benthic organisms (*Hyalella azteca, Chironomus riparius, Hexagenia* spp. and *Tubifex tubifex*). Greatest overall toxicity was observed in sediment from sites near the inflow to Terraview Pond, where mortality to amphipods and mayflies ranged up to 100%. As a group, Willowfield Pond sediment was less toxic than sediment from Terraview Pond, but not from the outflow stream. Water column toxicity was also assessed at the inflow and outflow of Terraview and Willowfield ponds. *In situ* survivorship of *Hyalella azteca* held in plastic cages suspended from floats was measured weekly for 4 weeks in October 2003. Mean mortality declined with distance from the inflow to Terraview Pond, but remained below 50%. Amphipod growth did not significantly differ among sites. Among-site patterns of sediment and water toxicity are being compared to distributions of contaminants, nutrients concentrations and physical habitat attributes to identify potential causal relationships.

Study results indicate the need to re-examine the design of the Terraview-Willowfield facility with respect to the sources of contaminated sediment (particularly highway runoff) and localized control of such sources preventing spreading of such sediments through large stormwater detention ponds. Future research will focus on confirmation of contaminated sediment sources and development of suitable control measures.

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. Feasibility of Stormwater Treatment by Conventional and Lamellar Settling with and without Polymeric Flocculant Addition

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Stormwater treatment by lamellar and conventional clarification, with and without flocculant addition, was investigated in Toronto, Ontario, Canada using a pilot-scale rectangular clarifier vessel with removable lamellar plates. During the 2001, 02 and 03 field seasons, over 100 stormwater runoff events were characterized with respect to flow and quality, and further investigated for stormwater treatment. The stormwater at this site was significantly polluted, with most constituent concentrations exceeding those for the US NURP median urban site. A polymeric flocculant dosage of 4 mg/L with lamellar clarification provided the best results with total suspended solids (TSS) removal of 70-84% range at a total vessel surface load of 15-35 m/h. The clarifier sludge was strongly polluted by heavy metals and would require special disposal procedures.

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Simulation of Flow and Sediment Transport in a Combined Sewer Overflow (CSO) Storage and Treatment Facility

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One of the most common methods of combined sewer overflow treatment is by settling, whose efficiency depends on properties of solid particles and characteristics of the flow transporting such solids. Since geometry and hydraulics of CSO facilities are often very complex, traditional design methods based on many simplifying assumptions may not predict well the actual operational performance. Therefore, there is a growing need for new tools assisting engineers in design or management of CSO storage and treatment structures.

In a study of a CSO facility, a commercial CFD model (FLUENT) was used to investigate flow and sediment behaviour, and to explore the ways of optimizing the facility performance through improved particle settling rates. A two-stage approach was adopted in this study, by simulating first flow patterns by means of a volume of fluid (VOF) model and, then, using such patterns as a basis for simulation of particle transport by the discrete phase (DP) model. The simulation results for water surface, flow fields in different structure configurations, and particle transport are presented.

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The Use of Ballasted Flocculation (ACTIFLO® process) for Combined Sewer Overflow (CSO) Treatment

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The ACTIFLO® process is a high rate settling process that combines the advantages of microsand ballasted flocculation and lamella clarification. The ACTIFLO® process consists of the following treatment steps: 1) rapid mix coagulation in the first contact basin; 2) microsand and polymer injection in the second contact basin; 3) maturation of microsand ballasted flocs in the third basin and 4) high rate sedimentation in the lamella clarifier. Microsand at the bottom of the clarifier is separated from the sludge or reuse by means of a recirculation/extraction pump and a hydrocyclone using the centrifugal vortex principle with a tangential inlet. Key advantages of the ACTIFLO® process are short contact times (retention time from 5 to 7 min), high rise rates (80-200 m/h) and reduced space requirements. The ACTIFLO® process has proven is efficiency in various applications: production of drinking and service water, municipal and industrial wastewater treatment, filter backwash water treatment and combined sewage overflow (CSO) treatment.

Stormwater often upsets wastewater treatment plants (WWTP) as it creates peak flows, causing plants to bypass most of the incoming hydraulic surge. The latter is most commonly called CSO. With the ACTIFLO® process, WWTPs can treat storm flows as they occur. Its compactness and quick start-up make the ACTIFLO® process particularly well suited for this application. In dry weather, the ACTIFLO® process may be reverted to tertiary treatment for the polishing of secondary effluent.

Since 1997, the process has been used for CSO water treatment in North America and Europe. Several CSO ACTIFLO® installations can be found around the world such as: Colombier, Switzerland (1998, 55 767 m³/d); Achere (Paris), France (2000, 1 647 000 m³/d); Geneva, Switzerland (2001, 518 000 m³/d); Bremerton, WA, USA (2002, 37 854 m³/d) and Lawrence, KS and USA (2002, 151 416 m³/d).

Typical ACTIFLO® performances for CSO treatment are as follows: 80-95 % removal of Total Suspended Solids (TSS), 50-70 % removal of Chemical Oxygen Demand (COD), 50-80 % removal of 5-day Biological Oxygen Demand (BOD_5), 80-95 % removal of Total Phosphorus (TP), 15-20 % removal of Total Kjeldahl Nitrogen (TKN), 50-80 % removal of Oil & Grease and 85-100 % removal of Heavy Metals.

Full-scale and pilot test results, which will be presented during the conference, show that the ACTIFLO® process is capable of producing a clarified water exceeding provincial and federal guidelines that specify TSS and BOD_5 removal requirements.

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Benefits and Application of Real Time Control for Sewer Systems

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Real time control (RTC) is a technology that is gaining more and more attention in the field of wet weather control. The technology has evolved with the development of information technology, telecommunications, instrumentation, control and automation. Some communities have considered real time control evaluation as part of their CSO control plan and have concluded in its benefits. Some have even gone further in implementation real time control systems.

Many organizations disregard RTC as a viable option for CSO, SSO or flood control, for very diverse reasons, one of the being the basic understanding of the concept of RTC.

BPR CSO has been involved in many RTC evaluations and implementation in Canada, in the United States, and in Europe (France, United Kingdom). Although each sewer system and community have different set-ups, considerations, and constraints; there are a few factors guiding the evaluation and implementation of RTC which are common to many applications.

In the paper and presentation, we will present three applications, namely Quebec City, Montreal, and Louisville, KY, where BPR CSO has been involved in the evaluation and implementation of RTC, and we will illustrate the benefits of RTC, the pitfalls of RTC applications, and the main element that make a RTC project successful. Each application being at different stages of their CSO control program, these three examples will better illustrate various settings for RTC applications. The paper will address technical aspects and issues of RTC evaluation and implementation, as well as softer, but important issues, such as integration of RTC within organizational structures, operation of an RTC system and training.

By presenting examples and case studies of activities, results of RTC evaluations, and design elements present in operating RTC systems, we want to address some of the more pressing issues that presently restricts the spreading of RTC as a viable and proven cost effective solution to wet weather control.

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Surface Water

Chairs: DR. PATRICIA CHAMBERS
DR. JOANNE PARROTT

Thermal Bar Evolution and Attached Algae, Western Lake Ontario

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A multi-disciplinary team has been formed to address the renewed issue of abundant *Cladophora* fouling beaches each summer in Lake Ontario. One aspect that is being studied is the development of the algae early in the spring. It is postulated that there may be a significant opportunity for vigorous growth during the spring thermal bar evolution. The thermal bar is a shore parallel front which separates descending waters at or near the freshwater temperature of maximum density (4°C) during spring and fall seasons. The thermal bar is important because of its influence on mixing, cross-shore exchanges and variability of biotic factors in the coastal zone. An intensive field study was undertaken in 2003 to document the thermal bar evolution at the west end of Lake Ontario. On a profile running from the 10 m contour to the 80 m contour off Oakville, ON, seven stations were established to monitor temperature and currents during the thermal bar evolution. Weekly profiles and water samples were also taken. By 24 April the thermal bar was well established at about the 20 m contour and persisted there until 14 May. By 26 May the 4°C isotherm had moved offshore. The nearshore waters appeared to maintain their integrity well into the early summer providing opportunity for significant nutrient input into this zone from surface runoff and WWTP discharges.

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COMPETING FOR THE PHILIP H. JONES AWARD

Cyanobacterial Toxins in the Lake Winnipeg Watershed and their Implications Regarding Eutrophication

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Lake Winnipeg, the 10th largest freshwater body in the world, has the highest watershed/surface are ratio, 39.1, of any large, non-saline lake. Agricultural soils and human activities, mainly to the south and west of the lake, are contributing phosphorus and nitrogen that are promoting the eutrophication of the lake. Concentrations of phosphorus and chlorophyll-a have increased significantly in Lake Winnipeg sediments since 1969. The increased dominance and frequency of cyanophytes is indicative of phosphorus excess and declining phytoplankton community diversity.

Since 2000, opportunistic horizontal plankton hauls, surface water and fish tissue samples have been collected and analyzed for various congeners of Microcystin and Anatoxin. With the implementation in 2002 of a better defined sampling program utilizing the CCGS Namao, a more complete set of data has been collected and begun to be analyzed. The presence of Microcystin in more than one congener form has been detected throughout the July to September season, as well as in some fish livers.

Lake of the Woods, a large international lake, also experiences frequent occurrences of algal blooms during the summer months. Surface water and clam tissue samples from areas around Lake of the Woods have also exhibited the presence of algal toxins, including the uncommon presence of Microcystins in the cyanophyte A*phanizomenon* sp.

The presence of algal toxins in two key freshwater sources in central Canada leads to the questions of what kind of impacts this will have on the delicate ecosystem balance in these systems in the near future.

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Iron-Stimulated Growth and Toxin Production of Microcystis Novacekii UAM 250

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The impact of iron on the growth rate of algae and the generation of micro-cystin algal toxins was studied using Microcystis Novacekii UAM 250. Four different iron concentrations, ranging from 0 to 0.28 μmol/L, were applied while other nutrients remained constant. The algae cells were harvested with GF/F filters and ruptured with liquid nitrogen. The microcystins were extracted with a 75% methanol solution and subsequently analyzed with HPLC. Microcystins in the water phase were captured with a C18 cartridge and re-dissolved in 75% methanol for analysis. It was found that the growth rate of the algae and the production of microcystins were critically limited at iron concentrations below 0.28 μmol/L. Three types of microcystins were identified from the Microsystis Novacekii UAM 250 culture: MCYST-LR, -YR and –RR. The concentrations of microcystins in the water phase were found to be lowest at the initial growing phase of the algae. The concentrations increased subsequently as the algae cells began to decay, releasing their microcystin content to the water phase.

The relevance of this research is associated with the potential effects of excess iron discharge from sewage treatment plants. It is prudent to optimize the amount of iron that is used for phosphorus removal and to avoid excessive discharges of iron. In the past few years, Hamilton Harbour has experienced toxic blooms of *Microcystis*. More iron is used that is likely required for optimal phosphorus removal.

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An ELISA for Cutthroat Trout (*Oncorhynchus clarki)* Vitellogenin (Vg) and its use to Assess the Estrogenic Impacts of Agricultural Runoff in a B.C. Watershed

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We developed an enzyme linked immunosorbent assay (ELISA) for the measurement of Vg in the plasma of cutthroat trout (*Oncorhynchus clarki).* The ELISA is based on a monoclonal antibody that was previously produced against rainbow trout (*Oncorhynchus mykiss*) Vg. A triple precipitation procedure which was followed by column chromatography on DEAE Sepharose was used to purify Vg from the plasma of female cutthroat trout that had been induced with 17ß-estradiol. The purity of the Vg was assessed by gel electrophoresis and Western Blots. The ELISA was calibrated, optimized, and characterized. The ELISA was used to measure Vg in the plasma of juvenile cutthroat trout that were exposed to surface water at a series of sites along an intensively farmed BC watershed. We used a flow-through regime to expose the fish to surface water. The exposures were long term (60 d) and the study was repeated over several seasons.

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Using an Airborne Laser Remote Sensing System (LiDAR) for Pollution Detection and Point Source Location in the Great Lakes and Associated Watersheds – a 2003 Case Study

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In December 2003, Laser Diagnostic Instruments (LDI^3) flew its Fluorescent Lidar Spectrometer (FLS-AU) over parts of three Great Lakes and three of the watersheds. The flight path included Lake Simcoe, the Toronto port area, Hamilton Harbour, then to Lake Erie, up the Grand River, the Maitland River to the near-shore waters of Huron county and the Saugeen River near Walkerton. The project's goals were twofold: to provide a comparative study using three different water analysis methodologies, and to demonstrate the value of the LiDAR temporal and spatial information for surface water quality monitoring, watershed modeling and pollution source location. In conjunction with the LiDAR data, simultaneous ground based samples were taken from the Hamilton Harbour and the Grand, Upper Thames, and Maitland rivers. One set of samples was analysed using standard MOE lab procedures, while another set was returned to LDI^3 for analysis using its real time, flow through instrument - the Skalar Fluo-Imager. The Fluo-Imager, also based on fluorescent technology, provides a broadband excitation of the untreated sample, permitting a detailed analysis including organic compound identification in just a few minutes. A special thanks to the Grand, Thames and Maitland conservation authorities and the Ontario MOE and CCIW for participating in this study.

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COMPETING FOR THE PHILIP H. JONES AWARD

Sensitivity of HSPF Model to Land Use Data of Different Scale

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The Hydrologic Simulation Program Fortran (HSPF) is a U.S. EPA model for simulation of watershed hydrology and water quality for both conventional and toxic pollutants. HSPF is the core program of Better Assessment Science Integrating Point and Nonpoint Sources (BASINS), the most commonly used integrated model to support watershed analysis and TMDL development in the U.S.

HSPF is a comprehensive watershed model with a large data requirement. It uses time series of precipitation, temperature, solar radiation, cloud cover, wind speed; land use patterns and land management practices to simulate the processes that occur in a watershed. The result of this simulation is a time series of the quantity and quality of runoff from an urban or agricultural watershed.

This paper presents results of study the sensitivity of HSPF hydrograph to land use data of different scales. Low and high resolution land use data were used for various South Nation subwatersheds. Five types of land use data were specified for current study: forest, agriculture, water, urban or build-up land and barren land. Hydrologic pathways in four surface layers are modeled in HSPF: interflow, upper zone (e.g. unsaturated), lower zone and active ground flow. Losses to deep percolation are also considered. Digital elevation model (DEM) data with 10 meters resolution were used to determine land slopes and all parameters of stream cross-sections.

HSPF hydrograph was calibrated and validated using hourly precipitation and daily discharge data together with high spatial resolution land cover data of impervious and pervious areas. Uncertainty of hydrological parameters in HSPF model was studied using the Monte Carlo method.

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Posters

Remediation of a Cold-Climate Petroleum Spill in Moose Factory, Ontario

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A spill of fuel oil from a tank farm in Moose Factory, Ontario has contaminated the underlying sand units and the local groundwater. The spill is believed to have occurred primarily in the late 1970's. Environment Canada, Health Canada and Moose Cree First Nation partnered in 2002 to find an environmentally sound, cost effective approach to remediating groundwater and soils contaminated with diesel fuel. Soil sampling indicated that residual LNAPL is distributed in a "smear zone" which coincides approximately with the range of the seasonally fluctuating water table. Automated water levels collected during the previous year have shown the local water table to vary between 0.3 and 2.3 meters below ground surface. The corresponding groundwater temperatures for the same period were observed to range between 0.9 and 8.7 ^{o}C. Analyses for a variety of geochemical parameters were obtained from the 50 monitoring wells installed around the site. TPH and BTEX concentrations in groundwater indicate the extent of the dissolved-phase plume and show that the leading edge is currently within 80 m of the Moose River. Other geochemical indicators suggest that both aerobic and anaerobic intrinsic bioremediation of the fuel oil has been occurring both within and down-gradient of the source zone. The physical and geochemical evidence collected at the site suggests that the plume is likely at pseudo steady-state; continued monitoring is planned to verify the plume's status. The plume definition was the initial phase of an effort to identify viable and economical clean-up alternatives for the Weeneebayko Hospital property. Using humic acids to treat contaminated soils and groundwater is a new technology that has proved effective under controlled conditions. The approach allows soils to be treated in place by increasing the removal of fuel bound to the soil and enhancing the natural processes of degrading the fuel components found in groundwater. Humic acids are naturally occurring compounds that act as a flushing agent for diesel. Compared to conventional flushing agents, they are inexpensive, nontoxic and stable. The test site at the hospital's above-ground storage-tank farm (ASTF) area represents the first trial of this technology at a contaminated site. Injection and monitoring of the humic-acid treatment effectively began in September 2003 and successful weatherproofing/winterization permitted the extension of this pilot test through December 2003. To date, the evaluation of the performance of this technology has focused on the hydraulics of the system.

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Stability of a Nutrient-Starved Biofilm in a Limestone Fracture

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The remediation of contaminated groundwater in fractured media is technically and financially challenging. The biobarrier concept, which involves the use of biofilms to fill voids in geological media, is a promising remedial approach for the control of polluted groundwater in fractured aquifers. The aims of the present study were first to monitor the effects of biofilm growth on the hydraulic conductivity (K) of a 49.8-cm long and 11.4-cm^3 volume single fracture in limestone and second to investigate the biofilm stability over a six-month of starvation. The horizontal limestone apparatus was equipped with four piezometers installed upstream, downstream and along the fracture to detect small changes in K. This apparatus was maintained at 10°C and continuously fed with synthetic groundwater. After a 43-day biostimulation of the groundwater indigenous microorganisms using molasses (initial loading rate = 1.04 x 10^{-3} mgC mL^{-1} min^{-1}) to initiate the biofilm growth (phase I), the effects of a 179-day starvation (phase II) on the stability of the developed biofilm were investigated. After this two-phase experiment (day 222), the fractured-apparatus was dismantled at 20°C in sterile conditions. Physicochemical (pH, ORP, DO, TOC, TKN, P_{tot}, carbohydrates, EPS), geochemical (Ca^{2+}, Fe^{2+}, Fe^{3+}, Mg^{2+}), and microbiological analyses (bacterial counts) were carried out on the effluent groundwater throughout the two-phase experiment while the Ca^{2+} content and bacterial densities were determined on the biofilm once the apparatus was dismantled. The K in the central section of the fracture (K_f) (K_{f0} = 2225.3 cm min^{-1}) was reduced by 3.2 logs during phase I and by a further 0.2 log during phase II, leading to an overall 3.4-log reduction for the 222-day experiment. Accumulation of short and filamentous rod-shaped bacteria as well as precipitated calcite was thought to account for the decrease in K_f. Sporadic hydraulic instabilities, more frequent after 100 days of operation, were presumably related to biofilm sloughing events, which were attributed to a combination of processes including physicochemical changes, biofilm ageing, and decreasing fluid shear. This study suggests that biofilms developed in fractures can persist for extended periods at reduced and stable K when exposed to starvation despite an increasing risk of loss in stability with time. These results will help define a maintenance strategy for the biobarrier concept.

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Biofilm Development in a Planar Fracture: Effects of a BTEX/Ethanol-Contaminated Groundwater

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Ethanol fuel is a renewable energy source that has been ignored until recently as an exploitable future fuel resource in Canada. Provided that environmental releases are inevitable, there are legitimate concerns for ethanol's presence in gasoline and its chemical interaction with other gasoline components, BTEX especially. Micro-organisms have been successful in forming biobarriers that reduce hydraulic conductivity of fractures in rock, thus making it a potential approach for ethanol-gasoline remediation. A biobarrier developed via biostimulation was tested at laboratory-scale to measure the effects of a BTEX/ethanol-contaminated groundwater plume on a mature biofilm and to assess the biodegradation/containment of these chemicals by the biofilm.

A clean groundwater supply was collected from a field site in Mississauga (Ontario, Canada). The groundwater was pumped at a rate of 1.06 ml/min into a glass-fracture plane of 50 cm by 30 cm and an aperture of 0.15 cm. This fracture plane was equipped with a Teflon port for nutrient injection of invertose and $NaNO_3$ at a rate of 0.19 ml/min to stimulate bacterial growth and biofilm development. The biofilm growth was monitored using a light transmittance probe that converted light into millivolt readings and by enumerating the change in suspended bacteria using a Baclight® Viability kit. Once a mature biofilm was established, it was then exposed continuously to a 10:1 groundwater to ethanol-gasoline formulation. Biodegradation was assessed in the groundwater by quantifying nitrate, BTEX, ethanol, and organic acids concentrations. The influence of the biofilm on the flow system within the fracture was evaluated by conducting visual tracer tests. The groundwater had an initial bacterial density of 2.0×10^4 bact. mL^{-1}, and the dominant species were identified, after profiling the community with denaturing gel gradient electrophoresis (DGGE), as *Caulobacter/Sphingomonas*, bacteria known to participate in the production of biofilm.

A visible biofilm developed around the nutrient injection port after 32 days of biostimulation then reached maturity after 60 days. The visible biofilm correlated to a reduction in light transmittance of 10 millivolts. Fracture inflow and outflow samples revealed that ethanol and BTEX losses were low and could possibly be explained by adsorption to the biofilm. Minor consumption of NO_3 corresponded with the low contaminant removal. Visual tracer experiments show groundwater flow diversion around the biofilm region limiting contact time with the biofilm and NO_3 amendments. Permeability of the biofilm will be estimated by modeling the groundwater flow system in the fracture plane.

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Peculiarities of Arsenic Removal by Ion Exchange

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The use of groundwater as a source of potable water supply presents serious problems in many countries including Canada, US, Bangladesh, India, Thailand, Japan, and China, amongst others. It is the variety of specific arsenic impurities in groundwater and their toxicity, which demands serious attention and changes to the conventional technology of water treatment and conditioning, and the development of new variations on the conventional processes of ion exchange, coagulation, filtration, and adsorption. Therefore, this research is focused on the problems associated with the aboveground treatment of arsenic-contaminated groundwater by ion exchange. Accordingly, this study was conducted in order to determine the dynamics of sorption of arsenic onto a commercially available ion-exchange medium. The investigation was carried out in the laboratory on a fixed unit incorporating dynamic columns with a MnO2 based material and the anionic-exchange media Purolite A-300 (chloride ion form) serving as oxidizing and ion-exchanging filters respectively. Simulated water served as the input water. Standard stock solution for As(III) was prepared by dissolving As2O3 in distilled water. Raw water was pumped and flowed through the oxidizing filter which was used to oxidize As(III) to As(V). Water then flowed into the anion-exchange filter where arsenate ions in water were sorbed onto the resin. After each run, the exhausted resin was regenerated with salt in combination with a small amount of caustic. This addition gave a higher operating capacity. The experiment was designed to investigate the effects of input arsenate concentration, pH values of water being treated, and linear velocity of filtration. Arsenate-exchange capacity and residual arsenate concentration were chosen to be the target functions. Preliminary tests determined the levels and intervals of the factors. The results of the full factorial experiment served to obtain polynomial dependences of arsenate-exchange capacity of gel-type resins on the various concentration and hydrodynamic factors. Statistical analysis of the regression equations obtained in this study revealed that pH values have the largest impact on arsenate-exchange capacity while input arsenate concentration impacts the most on the residual concentration of arsenate. Larger values of arsenate-exchange capacity are achieved on the lower border of pH range, i.e. in weakly acidic and weakly basic media. Particularly pH has a strong impact in the area of lower arsenate concentration. Sorption mechanism was observed to be anionic, since arsenate, at increased pH values, is dissociated and soluble in water. In the area of higher pH values (pH – 8.5) arsenate-exchange capacity was decreased and residual arsenate concentration was increased, which obviously, can be explained as the presence of a counter-ion effect. The study showed among others the viability, from a technical standpoint, to remove high levels of arsenic concentration by ion-exchange while meeting the present-day maximum contaminant level of 10 ppb. Also despite large-scale research in the field of arsenic removal, polynomial dependences have not previously been studied.

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Laboratory and Field Validation of Elimination Kinetics and Accumulation of Organochlorines in *Elliptio complanata* and Semi-Permeable Membrane Devices (SPMDs)

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Water Quality is an elusive input parameter that is essential for environmental fate modeling. Many techniques are used to derive these parameters but their estimates have been questioned with regards to the accuracy with which they predict the bioavailable fraction of chemical in water. Both semi-permeable membrane devices (SPMDs) and transplanted bivalves have been used to estimate water concentrations of organic contaminants. A number of studies have qualitatively compared mussels and SPMDs with respect to chemical accumulation patterns but few studies have examined how these two techniques differ with respect to chemical exchange rates. In this study both a lab depuration study and field elimination study were performed in order to investigate the elimination (k_2) kinetics of synoptically deployed time integrated samplers. Prior to deployment, both SPMDs and freshwater mussels were spiked with the same Performance Reference Compounds (PRCs) to determine how local abiotic conditions influenced elimination rates of each method. The elimination rates of lab depurated mussels and SPMDs were compared with previously published elimination relationships. Lab depurated mussels showed good agreement with the previously established k_2 values. SPMDs from the laboratory study suggest a departure from the predicted elimination rate. For the field portion of this study SPMDs and freshwater mussel biomonitors were placed at three locations in the Detroit River and compared with regards to their relative accumulation patterns. Accumulated PCB congener patterns and elimination kinetics of performance compounds differed between SPMDs and freshwater mussels.

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In Situ Sediment Treatment in Hong Kong

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The Shing Mun River of Hong Kong had been severely contaminated primarily by the discharge of sewage, resulting in bad odor and algae blooms. As part of an environmental improvement project, *in-situ* sediment bioremediation was carried out on 20 hectares of riverbed, using Environment Canada's Limnofix technology. Over 3,000 tonnes of calcium nitrate were injected into the sediments using a barge controlled by four winches under the guidance of a GPS (global positioning system) navigation system. To monitor the injection process, sediment cores were collected after injection and analyzed on-site. The AVS (acid volatile sulphide) contents in the sediment decreased from 2,300 μg/g (dry weight) to <5 μg /g. Redox increased from –330 mV to +125 mV. Fish, birds and people have returned to the area.

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Small-scale *In Situ* Sediment Treatments

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Prior to full-scale sediment treatment it is necessary to conduct small-scale treatment evaluations. *In situ* assessments have some advantages over laboratory treatments with respect to control over temperature, redox, and light. Pilot-scale treatments allow for evaluations of equipment but have less control over the treatment process than laboratory assays. Direct injection with divers allows for in situ incubations but the lack of control over the treatment produced variance that makes optimization of the treatment difficult. To have the advantages of both *in situ* and laboratory approaches, we collected box cores via a diver, mixed in the reagents at the surface and put the samples back into the hole in the sediments where they came from. Evaluations of full-scale equipment are also required to optimize the treatment process.

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Innovative Leachate Treatment Technology

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A full size industrial pilot scale trial is now underway at a pulp and paper mill site on leachate treatment using an innovative technology. The new technology has already been successfully experimented on various surface waters, groundwaters and industrial and municipal wastewaters. This chemical-free technology is essentially based on concurrent physical mechanisms occurring simultaneously or in sequence in multiple reactor vessels. Mechanisms included: mechanical sieving, static settling, cavitation, flotation, sheer stress, oxidation, degassing, sonoluminescence, air supersaturation effects and pressure, salinity, temperature and velocity variations. The use of thin-film is sometimes necessary for the treatment of some kinds of various types of wastewaters, as it is in the actual case for the leachate coming from a landfill site.

The main objective of this ongoing experimental research work is to evaluate the global efficiency of this technology under real industrial conditions in order to determine its capability to produce an effluent in compliance with very stringent pollution standards set for this particular stream. Actual treatment of this leachate requires its transportation from landfill site to the mill's wastewater plant. This represents an important treatment cost, particularly in the spring. This on-site treatment project is foreseen to be a very attractive, economical alternative. The preliminary results obtained are very encouraging and promising beyond the expectations.

To date, the best performances obtained with this technology installed *in situ* were reductions superior or equal to 99,9 % for BOD_5, COD, RFA, suspended solids, total sulphides and metal ions (below D.L.), 99 % for conductivity, 98 % for phenolic compounds, 86 % for Kjeldahl total nitrogen and 84 % for ammonia nitrogen . Generally speaking, the treated leachate is in full compliance with the environment standards set by the legal authorities. The study follow-up and process optimisation will further increase treatment performances.

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Precipitation of Hexavalent Chromium from an Electroplating Wastewater by Electrocoagulation

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Chromium reduction is the most common application for electrochemical reduction-precipitation. This process utilizes consumable iron electrodes and electricity to generate ferrous ion which react with the hexavalent chromium to produce trivalent chromium. The electrochemical method has been employed in the present study to precipitation of chromium from an electroplating wastewater. An electrochemical reactor was designed and operated to treat the solution containing chromium ions. There were four electrodes connected in a bipolar mode in the electrochemical reactor, each with a dimension of 7x5, 5x3 mm. The effective area of each electrode is 24 cm² and the spacing between electrodes is 1.5 cm. The same samples volume (200 mL) was used in all the batch tests. The investigated parameters were; reaction time, concentration, applied voltage, pH of solution and conductivity. Optimum operating ranges each of these operating variables are experimentally determined. After the batch experiments were completed, a continuous electrolytic reactor system was designed based on the experiences gained in the batch studies. The electroplating wastewater used in the experiments contained Cr concentrations in the range of 454-968 mg/L. The chromium removal efficiencies in the bipolar electrocoagulation (EC) units were higher than 99.9 % and the Cr concentrations in the treated effluent were less than 0.5 mg/L. The initial pH values were varied in the range of 1.0 – 7.0. The optimum pH was found to be in the range of 3.0 – 4.0. The affects of applied voltage and initial chromium concentration on the removal efficiency has been investigated, and the consumptions have been determined. Increasing applied voltage has resulted in an increase in removal efficiency and energy consumption. Energy consumption of the EC unit was found to be in the range of 18 – 48 kWh/m³. The removal efficiency increases up to approximately 99.9 % after 10 minutes of electrolysis time at 24 V. Conductivity had big effect on treatment efficiencies in the investigated range 5 to 20 mS/cm. The greater ionic strength causes an increase in current density at the same cell voltage. The amounts of wet sludge and dried sludge were 83.5 and 37.6 kg/m³ wastewater, respectively. The sludge volume was 20% of the volume of the wastewater.

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