24th Eastern Canada Symposium of the Canadian Association for Water Quality

and

8th Annual Symposium of the McGill Brace Centre for Water Resource Management

Abstract Book

November 7, 2008

McGill University, Montréal

Climate Change: Impact on Water Quality and Adaptation *and* Research on Water Quality and Treatment Technologie

PROGRAM

8:00-8:45 **Registration**

8:45-9:00 **Welcome address**

9:00-9:40 **Brace Symposium and CAWQ Keynote Speaker (plenary session)**

Dr. Linda Mortsch
Environment Canada
Climate Change: Implications for Water Quality

9:40-10:00 ***Coffee Break***

10:00-11:40 **CAWQ Research Symposium (parallel sessions A to D)**

11:40-13:00 ***Lunch***

13:00-14:40 **CAWQ Research Symposium (parallel sessions E to H)**

14:40-15:10 ***Coffee Break***

15:10-17:10 **Brace Symposium (plenary session)**

Dr. Jiri Marsalek
National Water Research Institute of Canada
Urban Storm Drainage in Changing Climate: Fundamentals of Adaptation

Dr. David Pearson
Laurentian University
Mainstreaming Climate Change into Source Water Protection: Policies and Practices

Dr. Chandra Madramootoo
Brace Centre and McGill University
Climate Change Impact in Agriculture and Water Quality

Panel discussion on theme

17:10- 18:00 ***Reception Cocktail***

MCGILL BRACE CENTRE ANNUAL SYMPOSIUM

Climate Change: Impact on Water Quality and Water and Wastewater Industry Adaptation

Morning Plenary Session

Climate Change: Implications for Water Quality

Dr. Linda Mortsch, senior researcher with the Adaptation and Impacts Research Division of Environment Canada Coordinating Lead Author for the North America Chapter for the 2007 IPCC Fourth Assessment Report.

Afternoon Plenary Session

Urban Storm Drainage in Changing Climate: Fundamentals of Adaptation

Dr. Jiri Marsalek, research scientist and chief of the Urban Water Management Section with the Canada Centre for Inland Waters.

Mainstreaming Climate Change into Source Water Protection: Policies and Practices

Dr. David Pearson, professor in the Department of Earth Sciences at Laurentian University and Co-Chair of the Ontario Government Expert Panel on Climate Change Adaptation.

Climate Change Impact in Agriculture and Water Quality

Dr. Chandra Madramootoo, professor with the McGill Brace Centre and Dean of the Faculty of Environmental and Agricultural Sciences at McGill University.

Panel discussion on climate change and water quality issues.

CAWQ RESEARCH SYMPOSIUM

Morning Parallel Sessions of Oral Presentations

(A) Water Quality - Monitoring and Climate Change (Ballroom A)

10:00-10:20	Impacts des changements climatiques sur l'évolution du carbone organique dissous et d'autres paramètres de qualité des eaux **O. Thomas**, E. Baures
10:20-10:40	DRAIN-WARMF: A watershed scale coupled surface and subsurface flow/water quality model **S. Dayyani**, S. Prasher, C. Madramootoo, A. Madani
10:40-11:00	Detection of trend and variability of precipitation in Southern Quebec and Ontario regions of Canada **R. Doria**, C.A. Madramootoo, A. Sarangi
11:00- 11:20	Use of Bayesian Blief networks to improve real time sensor information **S. Murray**, M. Ghazali
11:20-11:40	Reducing pollutant discharge into urban rivers by real-time control of the stormwater retention time in a stormwater pond **J.F. Carpenter**, M. Paré-Bourque, G. Pelletier, P. Van Rolleghem

(B) Waste Treatment in Agriculture (Ballroom B)

10:00-10:20	Removing poultry pharmaceuticals in agricultural runoff with a constructed wetland **S. Hussain**, S. Prasher, R. Patel
10:20-10:40	In-storage psychrophilic anaerobic digestion: a wastewater treatment strategy adapted to the needs of Canada's pork producers **S. King**, S. Barrington, S. Guiot
10:40-11:00	Caractérisation et réduction des émissions de N_2O et de CH_4 dans un biofiltre à milieu organique traitant du lisier de porc C. Dufour-L'Arrivée, **C. Bourgault**, P. Lessard, Y. Le Bihan, N. Turgeon, G. Buelna
11:00- 11:20	Sédimentation, coagulation et séparation solide-liquide d'un lisier de porc A. Beaulavon, **R. Leduc**
11:20-11:40	Conception et performance d'un système novateur pour la gestion des rejets piscicoles **P.Y. LeFrançois**, J. Puigagut, F. Chazarenc, Y. Comeau

(C) Water Quality - Monitoring (Room C14-A)

10:00-10:20	Water quality risk assessment in rapidly growing municipalities in sub Saharan Africa: case of Buea-Cameroon **F. Folifac**, S. Gaskin, L. Lifongo
10:20-10:40	Investigation of water quality improvement option in Jajrood river **S. Isazadeh**, N. Saborimanesh, M. Pourabdollah, A. Karaji
10:40-11:00	Risk assessment of using domestic greywater for the irrigation of food crops **S. Finley**, S. Barrington, D. Lyew
11:00- 11:20	Non-invasive visualization of bacteria in porous media using X-ray Computed Tomography **A. Bhakta**, G. McKenna, N. Tufenkji, S. Ghoshal
11:20-11:40	The use of fluorometric probes for monitoring of cyanobacteria blooms in two sources of potable water **N. McQuaid**, A. Zamyadi, M. Prévost, D.F. Bird, S. Dorner

(D) Wastewater Treatment - Physicochemical Technologies (Room C14-B)

10:00-10:20	Analyse granulométrique des débris inorganiques (grit) des boues activées séparés par hydrocyclonage **M. Mansour-Geoffrion**, D. Lamarre, P. Dold, I. Takacs, Y. Comeau
10:20-10:40	Génération in situ d'acide hypochloreux pour le traitement électrolytique d'effluents contaminés par des colorants synthétiques **F. Zaviska**, P. Drogui, J.-F. Blais, G. Mercier
10:40-11:00	Improvement of the activated sludge mixed liquor properties by electrocoagulation process **W. Hirzallah**, K. Bani-Melhem, M. Elektorowicz, J. Oleszkiewicz
11:00- 11:20	Rheological changes during Fenton oxidation and ultrasonication of wastewater sludge **T. Pham**, S. Brar, R. Tyagi
11:20-11:40	Effect of particles and bioflocculation on ultraviolet desinfection **K. Kollu**, B. Ormeci

Afternoon Parallel Sessions of Oral Presentations

(E) Water Quality – Issues with Phosphorus and Pathogens (Ballroom A)

13:00-13:20	Karaj river water quality assessment with TMDL approach **N. Saborimanesh**, A. Torkian
13:20-13:40	Examining the influence of cell concentration on bacterial migration in granular porous media **C. Chornewich**, M.B. Emelko, N. Tufenkji
13:40-14:00	Treatment of surface water by nonwoven geotextile filtration for removal of suspended and dissolved solids **T. Inoue**, C. N. Mulligan, M. Fukue, and D.Zaghtiti
14:00- 14:20	Hydrologic, seasonal and management controls on water quality response in Fourchette twin watersheds experiment, Beauce region, Québec **A.R. Michaud**, J. Desjardins, D. Lemelin, J. Deslandes, V. Samson, E. van Bochove
14:20-14:40	Influence des microorganismes aquatiques sur les flux de phosphore au sein d'élevages piscicoles en étangs **M.-L. Boutray**, J. Puigagut, Y. Comeau

(F) Wastewater Treatment – New Technologies and Modeling (Ballroom B)

13:00-13:20	Production de laccase à l'aide de boues d'épuration pour la biorémédiation des polluants récalcitrants dans les eaux usées **J.-A. Majeau**, R.D. Tyagi
13:20-13:40	Simulation du comportement d'une station par biofiltration P. Lessard, **G. Samie**, V. Rocher
13:40-14:00	Caractérisation du résidu endogène de boues activées produites dans un bioréacteur à membranes aérobie **A. Ramdani**, P.L. Dold, A. Gadbois, Y. Comeau
14:00- 14:20	Novel aspects in mathematical modeling of activated sludge wastewater treatment systems **M. Tajparast**, D. Frigon
14:20-14:40	Multi-variable model of pre-treatment processes for anaerobic digestion of primary and secondary sludge R.L. Droste, **É.L. Bordeleau**

(G) Groundwater Quality and Bioremediation (Room C14-A)

13:00-13:20	Aggregation of titanium dioxide nanoparticles: role of a fulvic acid, pH and ionic strength **R. Domingos**, K.J. Wilkinson
13:20-13:40	Bare and modified nanoiron characterization and transport in sand packed column G. Naja, **T. Raychoudhury**, S. Ghoshal
13:40-14:00	A laboratory study of bacterial pathogen transport in Quebec agricultural soil **T. Schinner**, A. Letzner, S. Liedtke, F.D. Castro, I. Eydelnant, N. Tufenkji
14:00- 14:20	Petroleum hydrocarbon biodegradation in extreme environment: Effect of cold temperature fluctuation and seasonal freezing **W. Chang**, L. Spagnuolo, P. Simon, L. Whyte, S. Ghoshal
14:20-14:40	Faisabilité de l'utilisation des déchets pour la production de la diète d'insecte (Cydia pomonella) **J.-R. Gnepe**, S. K. Brar, R.D. Tyagi, J.R. Valero, R.Y. Surampalli

(H) Drinking Water Treatment (Room C14-B)

13:00-13:20	Recycling membrane backwash water: effects on recovery, coagulant demand and organic removal in UF membrane filtration **S.L. Gora**, M. Chaulk, M.E. Walsh
13:20-13:40	Control of Manitoba's potable water with chlorine dioxide **J.M. Rak-Banville**, B. Gorczyca
13:40-14:00	Preparation of an alum water treatment residual solid as an adsorbent for arsenate **M. Gibbons**, G. Gagnon
14:00- 14:20	The detection of water quality aberrations after the injection of *Escherichia coli* into tap water **K. Journal**, M. Ghazali, E. McBean
14:20-14:40	Multi-stage response and probability metric selection in data mining for identifying contaminant source ingress to a water distribution system **H. Shen**, E. McBean, M. Ghazali

Poster Session

Climate Change and Water Quality

1. Réponse du bassin versant de la rivière aux Brochets en termes d'érosion et de perte de nutriments, sous deux scénarios de changement climatique, modélisés à l'aide de SWAT : le calibrage. **C. Gombault**, I. Beaudin, A. Michaud, M. Chikhaoui, C. Madramootoo
2. Stochastic and deterministic approaches of climate data to evaluate the potential climate change impacts. **M. Khalili**, V. T. van Nguyen, P. Gachon

Wastewater Treatment

3. Effects of unsaturated long chain fatty acids (LCFAs) and volatile fatty acids (VFAs) on hydrogen consumption. **S.J. Reaume**, J.M. Roy, J.A. Lalman.
4. Effects of lauric acid (C12) on hydrogen production from glucose by an anaerobic mixed culture. **N. Saady**, J. Lalman
5. Traitement physicochimique des biofilms adhérant sur des installations agroalimentaires afin d'éviter la contamination des eaux usées industrielles. **F. Gassara**, T. Benezech, N. Rossi, J. Diaz, S. K. Brar, R.D. Tyagi.
6. Etude de la biodégradabilité des effluents de l'industrie papetière à base de pâte d'alfa. **T. Rouissi**, D. Schieder, M. Faulstich, R. Beichekh, S.K. Brar, R.D. Tyagi.
7. Kinetic formulations for growth and substrate uptake in biological wastewater treatment. R.L. Droste, **Q. Zhang**.
8. Municipal and industrial wastewater treatment by adsorption onto inert solid biomaterial derived from Launea arborescens plant. M. Chiban, A. Soudani, F. Sinan, M. Persin.
9. Développement d'un lit filtrant réactif constitué de scories pour la rétention du phosphore des rejets piscicoles. **Z. ANJAB**.

Groundwater Quality and Bioremediation

10. Transport and retention of engineered nanomaterials in model groundwater systems. **A.R. Petosa**, N. Tufenkji.
11. Role of water chemistry on the groundwater contamination potential of quantum dots. **I.R. Quevedo**, M. Joos, N. Tufenkji.
12. Biopile bioremediation of petroleum hydrocarbons in soils from a northern site. **J. Snelgrove**, W. Chang, S. Ghoshal

ABSTRACTS of
ORAL PRESENTATION

Session A
Water Quality :
Monitoring and Climate Change

Impacts des changements climatiques sur l'évolution du Carbone organique dissous et d'autres paramètres de qualité des eaux

O. Thomas, E. Baures

Ecole des Hautes études en Santé publique

Les impacts des changements climatiques sur la qualité des eaux n'ont été que relativement peu étudiés par rapport aux aspects quantitatifs (ruissellement, inondation, sécheresse) et aux impacts sur l'énergie (barrages). Si les facteurs affectants la qualité de l'eau (température et régime hydrologique) sont bien connus, les effets sur les paramètres de qualité sont moins connus car très variables selon la nature des paramètres (matière organique ou nutrients, …), les situations (fortes pluies ou sécheresse), et le contexte hydrogéologique (substrat perméable ou non). L'objet de cette présentation est de faire une synthèse des données de la littérature concernant les effets des changements climatiques sur l'évolution des concentrations de matière organique (carbone organique dissous, COD), des nutrients (composés azotés et phosphorés), et de certains micropolluants (pesticides, pharmaceutiques, …). Pour chauqe famille de paramètre, les impacts de leur évolution sur l'environnement et la santé seront étudiés. En particulier, l'accroissement du COD des eaux destinées à la prodution d'eau potable entrainera une difficulté de traitement et un accroissement des concentrations sous-produits de traitements tels que les THM (tri-halométhanes). Ces derniers induisent des risques sur la santé humaine, par ingestion ou inhalation. Pour les nutrients, les conséquences sur l'accroissement de la biomasse aquatique et la fréquence d'apparition des crises de cyanophycées sont importantes. Comme pour le COD, l'accroissement des concentrations en micropolluants implique une modification des procédés de traitement. Les résultats présentés permettront de faire un état des connaissances et des manques dans le domaine et ainsi dégager des pistes de recherche et d'actions prioritaires.

DRAIN-WARMF: A Watershed Scale Coupled Surface and Subsurface Flow/Water Quality Model

S. Dayyani[1], S. Prasher[1], C. Madramootoo[2], A. Madani[3]

[1]*PhD Candidate, Department of Bioresource Engineering, McGill University, Canada*
[2]*Faculty of Agricultural and Environmental Sciences, McGill University, Canada*
[3]*Department of Engineering, Nova Scotia Agricultural College*

Agricultural non-point source (NPS) pollution is one of the major threats to water quality in many countries of the world, including Canada. Although non-point source pollution originates at the field scale, usually water quality problems become more noticeable at the watershed scale. In Canada, several rivers, draining agricultural land, have elevated nitrate, phosphorous and pesticide concentrations. The Ministry of Agriculture of Quebec (MAPAQ) has stated that 85% of agricultural pollution is resulted from non-point sources. This research project is designed to improve our understanding of the processes contributing to NPS pollution from agricultural activities on a watershed scale in colder climates. An integrated approach is taken to model surface and subsurface flow and nitrogen transport by linking DRAINMOD 5.1 and WARMF models. In this modeling approach, surface flow/nitrogen is simulated using watershed-scale WARMF model, and subsurface flow/nitrogen is monitored using field-scale DRAINMOD model. The coupling results in a distributed parameter model based on the water balance of both models that calculates the total flow and nitrogen losses at the outlet of watershed. The linked model will be evaluated for the St. Esprit Watershed, located approximately 50 km northeast of Montreal. Once the model is validated, different alternatives and BMPs will be evaluated to reduce the risk of water contamination on the watershed.

Detection of trend and variability of precipitation in Southern Quebec and Ontario regions of Canada

R. Doria, C.A. Madramootoo, A. Sarangi

Brace Centre for Water Resources Management, McGill University, Canada

Assessment of spatio-temporal variability of precipitation due to climate change has posed a serious challenge to the hydrologists, water resource engineers and managers. Efforts have been made by the researchers to use different data analysis methods and tools to accomplish these tasks. IPCC reports indicate completely contrasting results of precipitation change around the globe and as an example; the report portrays conclusive evidence of decreased precipitation over southern Africa region and increased precipitation over southern Quebec region. In this study, an attempt have been made to detect the trend and generate spatio-temporal variability maps using long term historical point rainfall data of 11 meteorological stations spanning over Southern Quebec and Ontario regions of Canada. First of all, the statistical downscaling techniques were employed to generate the long term local precipitation data from the General Circulation Models (GCMs'). The rainfall data for the period from 1961 to 2005 were used for calibration and validation of the regression based downscaling model. Further, both the observed and generated data up to the year 2050 were subjected to a non parametric statistical test viz. Mann-Kendall test to identify the trend in the daily, monthly and annual data under different seasonal and decadal settings. Subsequently, the generated precipitation amounts were subjected to geostatistical analysis using semivariogram models to generate the variability maps and estimate the precipitation amount at different locations within the study region. This will assist in quantification of the available water resources on field scales for agricultural water management activities leading to sustainable production. Over all, analysis of precipitation trends and its spatial extent on different temporal scales plays a significant role in studying the impacts of climate change on water resource availability and variability leading to judicious management and chalking out suitable adaptation measures pertaining to integrated water use for agricultural production.

Reducing Pollutant Discharge into Urban Rivers by Real-time Control of the Stormwater Retention Time in a Stormwater Pond

J.F. Carpenter[1], M. Paré-Bourque[1], G. Pelletier[1], P. Van Rolleghem[2]

[1] *Department of Civil Engineering, Université Laval, Québec, Canada*
[2] *ModelEAU, Université Laval, Québec, Canada*

Preserving urban river ecosystems while providing access to riverbank parks is a goal shared by many Canadian municipalities for improving the quality of life of their citizens. It is easy to forget that they constitute a major part of the municipal drainage system. While vegetation on riverbanks plays an important role in decreasing velocities at which runoff reaches the river, the storm sewer network is the greatest accelerator, discharging stormwater more rapidly compared to natural runoff. This has a direct impact on river hydraulics through point discharges at relatively high velocities during rainstorms, which tend to disturb river ecosystems in the vicinity, as well as downstream, of the storm outlets. Stormwater also carries potential contaminants from runoff on the urban landscape that can negatively impact the local ecosystems.

The objective of this contribution is to integrate real-time control (RTC) in stormwater management to reduce the impact on local aquatic ecosystems. This is achieved by managing stormwater from a typical urban catchment by equipping existing stormwater ponds with a dynamic sluice gate. The goal is to increase water retention time in the pond to increase sedimentation and thus removal of suspended solids and the pollutants attached to them. Based on modeling water quality and quantity and implementing dedicated control algorithms for the sluice gate, real-time control proved to be an effective solution for reducing the suspended solids discharge in the urban river. The challenge resides in adjusting the ponds' sluice gates to retain stormwater as long as possible without causing overflow of the ponds and damages to neighbouring structures when the next rainfall comes in. In all studied cases, the controlled ponds offered a sedimentation efficiency higher than a traditional pond controlled solely by a static device, as in an orifice.

Extending the retention time makes for increased sedimentation of fine particles, on which the majority of contaminants are agglomerated [1]. The modeling of suspended solids at the stormwater pond inlet and outlet helped demonstrate the efficiency of this solution by quantifying the pollutant load at these two points. The quantity of particles removed by sedimentation for the three studied summer periods was at least twice as large as in an uncontrolled pond. In the best of scenarios, the removal of particles reached 10 to 25 times that of a traditional pond. For the three summer periods, of 3000 kg of suspended solids entering the pond, only 16.59 kg were released into the receiving waters. Evidently, the amount of suspended solids reaching the ponds depends on the surface area of the catchment, its imperviousness and general slope. These aspects were modelled in SWMM for a storm sewer located in a typically urban, 75.7 ha catchment in Quebec City. Typical values (available in SWMM) were used for suspended solids build-up and wash-off during storm events depending on their particle sizes and settling velocities.

This simulation study showed that the proposed solution to integrate real-time control in stormwater ponds has the potential to considerably reduce the load of contaminants released into the receiving waters, improving water quality in urban rivers and lakes and improving aquatic ecosystems in typical residential catchments. The next step in this research project is to test the simulation results by conducting measuring campaigns for analysis of different water quality variables at both the inlet and outlet of an urban stormwater pond, improve the stormwater pond's

model with these data, and further develop the control algorithms to deal with the multiple objectives of a stormwater pond.

[1] - Characklis G.W. ,Wiesner M.R. 1997. Particles, metals, and water quality in runoff from large urban watershed. Journal of Env. Eng., ASCE, august 1997, p.753-759

Use of Bayesian Belief Networks to Improve Real Time Sensor Information

S. Murray, M. Ghazali

School of Engineering, University of Guelph, Ontario, Canada

The advent of inexpensive computing resources alongside increasingly small sensing devices is ushering in a new era of water quality monitoring opportunities. In response, the design and implementation of such monitoring systems is being assessed for application to a water distribution system. The situation is fundamentally beneficial to public welfare as variations within the distribution system can be investigated and addressed far more rapidly and thoroughly than conventional monitoring through 'grab' sampling techniques. However, there are only a small number of water quality parameters which may be accurately measured in real time by sensors and they are almost all indirect indicators of water quality, or 'surrogate parameters'. The sensors include, but are not limited to, pH, residual chlorine, UV 254 nm, turbidity, conductivity and dissolved oxygen.

A significant barrier to wide scale implementation of such systems is the generation of false positive signals in sensing equipment, greatly reducing the utility of the approach. This paper describes a methodology and its application which can integrate both similar and disparate information sources to reduce false positive generation for real time water quality sensing. Bayesian belief networks (BBN) are being employed as they are causal networks wherein events and variables are linked based on their independence and dependence. Events and variables each possess a finite set of states. If the state of an event or variable is not known then a conditional probability for that event or variable exists based on prior probabilities. The conditional probability of an event is contingent upon the state or prior probability distribution of the events and variables it is causally dependent upon. BBNs are powerful as they provide a formalised method for reasoning under uncertainty. The evidence provided by a sensor network can be weighed against prior knowledge of sensor error rates, observed natural variation in parameters and evidence established by human operators. The operation of a BBN in real time is untenable outside of computerised implementations and thus software must be employed.

As part of the application of BBN to water distribution quality assessment, the natural variation of pH, free and total residual chlorine and turbidity have been characterised over roughly three months for a local water source. Shorter studies on TOC and conductivity have also been completed. A pilot distribution network has been constructed to examine possible inter-correlation of these parameters. A case study application is employed to demonstrate the utility of the BBN.

Session B
Waste Treatment in Agriculture

Removing Poultry Pharmaceuticals in Agricultural runoff with a Constructed Wetland

S. Hussain, S. Prasher, R. Patel

McGill University, Canada

Concern on pollution by pharmaceuticals is growing after confirmation of their presence in our environmental waters. The widespread administration of antibiotics to livestock and poultry has significantly increased the probability of veterinary drugs to reach freshwater resources, particularly from manure-applied fields. This study evaluates the efficiency of a surface flow wetland in removing veterinary pharmaceuticals from agricultural wastewaters. Two type of soils (sand and sandy clay loam) were filled in triplicate in 6 HDPE half pipes (6.1m x 1.5m x 0.75m). Two aquatic plant species, cattails (typha lotifolia) and reed canary grass (Phalaris arundinaceae L.) were planted in bands perpendicular to the flow direction. Monensin, Salinomycin and Narasin ionophore antibiotics, commonly used in poultry, were applied in simulated runoff water in three concentration, 100 μg L-1, 500 μg L-1 and 1000 μg L-1. The results obtained indicated a low removal, particularly in clay loam soil treatment, for the first level. This observation could be attributed to low environmental temperature and a potentially corresponding low microbial population in start of growing season. The sand treatment depicted higher removal (33%-53%) for the selected antibiotics as compared to soil (16% - 29%) indicating an active role of physicochemical processes. In the second level the percent removal was found to be the highest (40% to 50%) in both soils, however, with increase in concentration level although total removal increased, the removal percentage went down again (21% to 34%). This decline could partly be attributed to the lowering of environmental temperature in September-October period in Montreal which could have in turn affected the microbial induced removal efficiency. It appears that the enhanced microbial activity associated with the high seasonal temperatures prevalent during the level 2 run (July-August) substantially offset the abiotic factor effect predominant in sand treatment. This also underscores that in pharmaceutical removal by the wetland, biotic and abiotic (adsorption and precipitation) processes are probably working together, with abiotic factor dominating in sand treatment and the biotic factor dominating in field soil treatment. The antibiotic removal was also found to be correlated well with the flow rate that fluctuated on an average for different treatment replications from 0.7 to 1.6 L/min over the course of the study. Average residence time for both soils was determined experimentally to be 2 days. For the lower concentration used, Monensin was observed to have higher comparative mobility in the wetland, averaging around 79% - 91% for field soil and 63%-73% for sandy soil treatment. Narasin depicted the lowest relative average mobility in both sandy and field soil treatments. In the second and third level no appreciable difference was recorded in between the mobility of the three antibiotics used in the wetland. However, third concentration level did depict a higher mobility rate for sand treatment. The study showed that wetlands have a substantial removal potential for veterinary pharmaceuticals evaluated.

In-Storage Psychrophilic Anaerobic Digestion: a wastewater treatment strategy adapted to the needs of Canada's pork producers

S. King[1], S. Barrington[1], S. Guiot[2]

[1]*McGill University, Bioresource Engineering, Ste. Anne de Bellevue, Canada*
[2]*National Research Council of Canada, Biotechnology Research Institute, Montreal, Canada*

Anaerobic digestion (AD) is often recommended as a treatment option for manures with high moisture contents, such as swine and dairy. Unlike aerobic treatment systems, AD produces methane-rich biogas, which can be used to offset the costs of owning and operating a treatment system. However, there are several important factors that discourage widespread agricultural usage of AD, the most significant of which are: the high initial cost and long payback period, high maintenance, operator time and expertise requirements and unreliable biogas production rates. "In-Storage Psychrophilic Anaerobic Digestion (ISPAD)" was conceived as a low-cost, low-maintenance, un-heated, stable system requiring minimal operator intervention, in response to the above-mentioned concerns. ISPAD is expected to occur when an existing in-ground concrete manure storage basin is covered with a floating, insulated, airtight, polymeric membrane cover. While review of the literature suggests that such a system could be successful, no similar installation has yet been tested. This study is part of a larger on-going project evaluating the performance of several pilot ISPAD installations in Quebec.

The objective of the study reported here was to confirm that the facultative enteric mesophilic microbial population introduced to the ISPAD basin with the feed material is acclimated over time to the ISPAD conditions, resulting in effective anaerobic treatment of manure in the basin. Acclimation was quantified in the laboratory, using biochemical methane potential assays, which indicate the time lags, maximum methane production rates of the microbial biomass, and the ultimate methane release potential of the substrate used. The experiments in this study evaluated the performance of the microbial consortium from an ISPAD basin at three temperatures: 8, 18 and 35^{o}C. The microbial population from a similar, but uncovered, storage basin was also evaluated, as was the facultative population in fresh manure, to assess the methanogenic advantage of the ISPAD biomass. The extent of digestion occurring in the pilot installation was evaluated by extensive laboratory analysis of the basin contents, in comparison with material from the uncovered control basin as well as fresh manure.

The results of this laboratory study confirm that an acclimated microbial population is present in a pilot ISPAD installation, after 3 years of operation, and that material in the basin has undergone extensive digestion. Further laboratory studies are investigating the trophic interactions occurring in the acclimated population, using specific activity assays, as well as the degradation of protein compounds as it relates to ammonia production in the system. Field studies are evaluating temperature profiles, methane production patterns and the development of the system over time.

Caractérisation et réduction des émissions de N_2O et de CH_4 dans un biofiltre à milieu organique traitant du lisier de porc

C. Dufour-L'Arrivée[1,2], C. Bourgault[1,2], P. Lessard[1], Y. Le Bihan[2], N. Turgeon[2], G. Buelna[2]

[1]*Département de génie civil, Université Laval, Québec, Canada*
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Depuis une trentaine d'années au Québec, la production porcine a connu un essor considérable. Si cette industrie engendre des retombés économiques importantes (3,1 milliards $ en 2003 [1]), elle entraîne aussi certains problèmes dont la gestion du lisier généré. Les lisiers en surplus ne peuvent être épandus sur les sols déjà chargés en azote et en phosphore au risque de contaminer les eaux de surface et souterraine. Une solution consiste donc à installer une technologie de traitement du lisier à la ferme. Une de ces technologies est la biofiltration sur support organique permettant de traiter et de désodoriser le lisier de porc ainsi qu'une partie de l'air vicié des bâtiments porcins. Or ce procédé de traitement peut entraîner la production de gaz à effet de serre (GES) dont le protoxyde d'azote (N_2O) et le méthane (CH_4). En effet, il a été démontré que la production de N_2O au sein du biofiltre est causée majoritairement par une dénitrification incomplète et peut représenter jusqu'à 12 % de l'azote introduit [2]. Quant à la production de CH_4, elle a aussi été mise en évidence. Un biofilm trop dense au sein du biofiltre jumelé à de fortes charges appliquées en carbone, favorise la création de zones anaérobies propices à la méthanisation. Dans un contexte où la lutte aux changements climatiques représente un enjeux majeur pour le développement durable, le traitement globale du lisier doit donc viser à limiter les émissions de N_2O et de CH_4 en plus de la réduction de la charge azotée et carbonée de la phase liquide.

Des travaux sont donc en cours pour mieux caractériser la production de ces gaz et pour proposer des stratégies de gestion du procédé afin de minimiser la génération de GES. L'objectif de la présentation est de montrer les premiers résultats issus de ces travaux.

Trois biofiltres pilotes de 1,1 m de hauteur par 0,4 m de diamètre ont été construits et mis en fonction depuis le mois de juin 2008. Les charges appliquées en carbone (DCO) et en azote ($N\text{-}NH_4^+$) sur chaque prototype sont respectivement de : 0,04 et 0,008 $kg.m^{-2}.j^{-1}$. Un débit d'air de 4,5 $m^3.m^{-2}.h^{-1}$ est appliqué en continu par le bas sur les trois biofiltres. Les suivis gazeux se font bi-hebdomadairement (N_2O, NH_3, CO_2, CH_4 et débits gazeux) tandis que les affluent et effluents liquides sont analysés 2 fois par mois (pH, alcalinité, DCO, MeS, NTK, NH_4^+, NO_2^- et NO_3^-).

Les premiers résultats d'opération montrent une bonne efficacité des biofiltres pour l'enlèvement du carbone (75 %) et de l'azote (99,8 %). Toutefois, la production de CH_4 et de N_2O a été observée jusqu'à maintenant à des taux respectifs de 100 mg et 450 mg par litre de lisier traité. Cependant, cette production semble variable dans le temps et très influencée par la composition du biofilm. Des stratégies d'opération, fondée sur la gestion de l'aération (intermittente ou continue) sont présentement en cours d'expérimentation.

[1] AGÉCO (2008). Impact économique de la croissance de l'industrie porcine au Québec. [En ligne].http://www.leporcduquebec.qc.ca/fppq/prod-4.html. Page consultée le 3 septembre 2008.
[2] Aubry G. (2008). Étude du comportement de l'azote dans un biofiltre à lit ruisselant traitant du lisier de porc. *Thèse de doctorat* en cours. Université Laval. Québec.

Sédimentation, coagulation et séparation solide-liquide d'un lisier de porc

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Le lisier agricole est principalement constitué des excréments d'animaux et d'eau mais il peut contenir des corps granulaires comme des graines de plantes. Le lisier est employé pour l'épandage sur les champs agricoles car il s'avère être un excellent fertilisant. Cependant, utilisé en trop grande quantité, il concentre sur de trop petites surfaces agricoles de trop grandes quantités de matières fertilisantes. De nos jours les exploitations porcines tendent à produire trop de lisier et vient le problème de son recyclage et de son traitement.

En effet, si le lisier est utilisé en trop grande quantité pour fertiliser les champs et les cultures, il y a un risque de contamination des nappes souterraines par infiltration et de contamination des cours d'eau par ruissellement. Les agents fertilisants tels que les phosphates et nitrates peuvent mener à la prolifération des cyanobactéries (algues bleues) dans les plans d'eau récepteurs.

Le but de la recherche est d'examiner s'il y a possibilité d'adapter aux lisiers de porcs les techniques développées pour le traitement de l'eau comme par exemple la sédimentation, la coagulation et la floculation. Ces techniques sont reconnues et couramment utilisées pour leur efficacité.

Des essais de décantation avec le cône Imhoff et des jar tests avec l'alun comme coagulant ont été menés sur du lisier de porc.

Le lisier brut, contenant de 4 à 5% de matières sèches, ne sédimente pas dans le cône Imhoff. Une dilution à l'eau 10 :1 a permis de décanter une couche granulaire de 14 ml et une floconneuse qui atteint 13 ml après 24 h et ainsi séparer du lisier ces deux types de matières solides. La vitesse de sédimentation des flocs a varié de 0.04 à 0.15 mm/s pour des diamètres allant de 1 à 4 mm.

Un jar test à l'alun montre une chute importante de turbidité à partir de 3 mol/L d'alun et une chute correspondante de pH de plus de 2 unités. Des essais de coagulation avec éprouvettes pour des concentrations d'alun variant de 10 à 25 g/L, suivis d'une filtration sous pression, permettent de soutirer entre 58 et 73% de l'eau du mélange lisier-alun.

Conception et performance d'un système novateur pour la gestion des rejets piscicoles

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La production piscicole est une source significative de polluants organiques et de phosphore. Pour réduire les problèmes d'eutrophisation, l'industrie aquacole québécoise s'est donnée pour but de réduire les rejets à 4,2 kg de phosphore rejeté par tonne de poisson produit d'ici 2010. Le phosphore des rejets piscicoles se retrouve à plus de 70% sous forme particulaire (Ouellet, 1999; Cripps & Bergheim, 2000). Une proportion importante de ce phosphore peut néanmoins être solubilisée par hydrolyse (Garcia-Ruiz & Hall, 1996). Des résultats préliminaires de notre équipe de recherche ont démontrés que plus de 75% des boues s'accumulent sous les aérateurs. L'objectif du projet était de concevoir et d'étudier les performances d'un dispositif de récupération des boues positionné sous un aérateur d'un étang de production piscicole et opéré selon un mode de vidanges séquentielles.

L'entreprise sélectionnée était une pisciculture de salmonidés avec un mode de production en étangs. Le dispositif de captage des boues était constitué d'un réceptacle pyramidal tronqué inversé de 1,5 mètre de côté et d'une profondeur de 1,2 mètre. Au printemps 2008, le dispositif a été positionné au fond d'un étang de production en terre, sous une profondeur d'eau de 1,8 mètre sous l'emplacement de l'aérateur. Les boues ont été extraites de façon hebdomadaire à l'aide d'une pompe à diaphragme.

Le système a permis d'extraire plus de 17% du phosphore total apporté par la moulée, correspondant à un enlèvement de 24% du phosphore particulaire total des rejets. Le taux d'accumulation des boues était relativement constant autour de 28 kg MT par semaine pour une masse de poissons estimée à 500 kg. Les valeurs de MVT et de DCO des boues se situent en moyenne à 18 g/L et 34 g/L respectivement.

Les résultats démontrent le réel potentiel d'un tel dispositif de captage des boues pour la gestion des rejets piscicoles des étangs de production en terre. Le projet a par ailleurs permis d'établir les critères de conception pour la mise en application d'un tel système.

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Session C
Water Quality : Monitoring

Water quality risk assessment in rapidly growing municipalities in sub Saharan Africa: case of Buea-Cameroon

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Water quality awareness can be an indicator in determining exposure to water quality risk and can inform the design of water quality protection strategies. This is particularly important for rapidly growing municipalities in sub Saharan Africa, where the emphasis is on providing adequate access to potable water supply and ensuring water quality through source water protection is neglected. Water source protection involves the regulation of human activities and depends on factors such as the geology and topography of the area. Adequate protection at the water source leads to protection of human health, the ecosystem, the local economy as well as ensuring a sustainable water sources for the future.

A typical example of rapid urbanisation (3-4% population increase/yr) with little attention given to water quality protection is Buea municipality in Cameroon. Buea, the capital of the South West Province of Cameroon, is located at the foot of Mount Cameroon (4010m) at an elevation of 1000m above sea level with a population of about 200.000 in an area of 870 km². It has favourable climatic conditions for agriculture with high annual rainfall (3000 to 5000mm), temperature (20 to 28 °C), high humidity and fertile volcanic soils. It is characterised by a hilly topography and a dense network of springs and rivers.

The aspect of water quality has emerged as an area that requires immediate action from an initial field survey to provide an overview of the current state of the potable water supply service conducted in early 2008 as part of a larger project on water resources management. Data was collected using questionnaires, semi-structured interviews, focus group meetings, a round table water policy dialogue workshop and field appraisals. Users' perception of water quality and awareness thereof were investigated using proxy questions during the data collection exercise. 90% of users drink their water without additional treatment indicating that they perceive that water quality to be high. However field appraisals indicate that water quality must be considered as the potential for significant degradation is present and increasing. Currently there is no solid waste management, sewage treatment is minimal, zoning of activities is not implemented and there is no control of pollutants. This is evident in indiscriminate dumping of waste into water courses, no regulated sanitation measures, occurrence of construction in water courses and close to water sources, application of agricultural inputs (pesticides and fertilizers) without control in source water areas.... In spite of these water quality risks for the population of Buea, interviews with key informants and environment related institutions indicated that over 90% were of the opinion that water quality was not a problem. This suggests that the prospect of currently initiating water quality assessment and management practices by the local institutions is very slim. Therefore a water quality assessment must be urgently conducted and the results used to inform the population of water quality risks and hence make a case for water quality protection based on a watershed approach.

Investigation of Water Quality Improvement Option in Jajrood River

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Jajrood is one of the most important rivers northeast of Tehran (Iran). It originates from the Koolan Bastk Mountains. The Latyian dam has been constructed on this river to supply 30% of the total water demand of 11 millions people in this city. Recent urban developments in this area have coincided with increasing the level of point source pollution to the river. Among possible problems, the only existing wastewater treatment systems are individual's seepage wells in building. Rapid changes in the river water quality during the last years correlated with the rise in urban developments persuaded governmental organization that there was a need to change from the decentralized wastewater treatment approach to centralized like activated sludge. Currently there are four wastewater treatment plants under construction to control the point source pollution in the area. Operation of these wastewater treatment plants in new future will not be a reliable approach in water quality improvement in river.

In this research the 21 water quality parameters in river have been sampled monthly during a year. The profile of chemical and biological water quality parameters such as Coliforms, BOD_5, dissolved oxygen and heavy metals have been investigated in different period. The river water quality has been modeled with QUAL2E model for a short period and then different water quality scenarios have been simulated in the next 15 years. In the meantime, the water quality index (WQI) has been mapped through the river by application of inverse distance weighting of GIS tools (IDW) for current and future condition.

The results indicated that shifting from the existing wastewater treatment to centralized treatment will not necessarily improvement the water quality of Jajrood River. In fact, we identified that the main problem with the water quality of Jajrood River is related to non point source pollution. Our modeling exercise found no significant difference between decentralized and centralized wastewater treatment mainly because the pollution load reductions achieved by both approaches are similar. It is clear that application of point source pollution control should not regard as unique controlling practice in pollution reduction in river.

Risk assessment of using domestic greywater for the irrigation of food crop

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A growing world population with a higher demand for water requires the development of recycling technologies such as the use of domestic greywater for the irrigation of home gardens. Nevertheless, the sanitary implications of reusing greywater for the watering of edible crops remain uncertain. The objective of this study was to examine the benefits and risks associated with domestic greywater reuse for the purposes of vegetable garden irrigation. Collected from a family household, untreated (settled only) and treated (settling and slow sand filtration) greywater was analyzed for basic water quality parameters over a period of eight weeks and used to irrigate individually potted plots of lettuce, carrots and peppers in a greenhouse. Tap water was used as control. The characterization of both the untreated and treated greywater indicated no detectable levels of heavy metals, but both Fecal Coliforms and Fecal Streptococci were present in high levels, averaging 4 x 10^5/100mL and 2 000/100mL of greywater, respectively. After irrigating peppers, carrots and lettuce with both greywaters and tap water for 45 days, plants were harvested and the edible portions tested for Fecal Coliforms and Fecal Streptococci, common indicators for the presence of pathogenic microorganisms. Despite the high counts of indicator organisms in the untreated and treated greywater, as compared to tap water, no significant difference in contamination levels was observed between crops irrigated with the different source of water. Fecal Coliform levels were highest in carrots and Fecal Streptococcus levels highest on lettuce leaves. However, contamination levels for all crops were low and do not represent a significant health risk. Plant growth and productivity were unaffected by the water quality, owing to the low N, P and K levels of the greywater. These results reinforce the potential of domestic greywater as an alternative irrigation source.

Non-invasive visualization of bacteria in porous media using X-ray Computed Tomography

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Contamination of groundwater by animal wastes has lead to outbreaks such as the Walkerton, ON incident in 2000 where the pathogenic strain *Escherichia coli* 0157 :H7 contaminated the drinking water supply leading to the death of several residents of the town. In order to determine the groundwater contamination potential by the release of microorganisms in the ground, it is essential to study their transport, retention and viability in soil and porous media.

X-ray computed tomography (CT) scanning is employed in medical research for non-invasive imaging of nanoparticle tracers or drug delivery agents in animals or humans. We have recently determined that a medical X-ray CT scanner can be used to quantitatively determine the spatial distribution of gold and other metal nanoparticles in packed porous media. The ability to non-invasively detect metal nanoparticles in saturated packed sand columns using X-ray CT was used to develop a technique for assessing bacterial density distributions in sand columns by labelling bacterial cells with gold nanoparticles. Bacterial cells have densities close to that of water, and thus they are not directly detected by X-ray CT.

Traditionally, the transport of microbes and other colloids has been studied in experiments with packed columns filled with a porous media, and the changes in effluent concentration are monitored as a function of time and compared to the influent concentration (Tufenkji, 2007). Non-invasive visualization of columns could potentially provide additional valuable data for improving our understanding of colloid transport and deposition behaviour in porous media.

In recently concluded experiments, gold nanoparticles which were attached externally to the cell wall of *Bacillus subtilis* (ATCC 6633) using synthetic surfactants. The spatial distribution of the gold-labelled cells retained on the porous media was clearly detected. The gold nanoparticles provided a good contrast agent for the X ray CT detection, however, they altered the surface characteristics of the bacterial cell and thus may have influenced its transport behaviour under certain conditions. To overcome this shortcoming, we have biosynthesized gold nanoparticles using *E. coli* DH5α and retain the gold crystals within the cell wall, thus keeping the cell surface characteristics relatively unaltered. The biosynthesis was achieved by reduction of the chloroauric acid by the proteins on the cell surface. The characterization of the gold nanoparticle containing bacteria was done by TEM imaging, zetasizer and X-ray diffraction. Results from column experiments where the spatial distributions of gold doped bacteria are determined by X-ray CT and the bacterial density distribution are determined, will be presented.

The use of fluorometric probes for monitoring of cyanobacteria blooms in two sources of potable water

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In Quebec, the recent documented increase of potentially toxic cyanobacteria blooms have prompted a re-evaluation of the safety of sources of potable water and of waterfronts used for recreational activity. In addition to evaluating the toxicity of cyanobacterial blooms, the spatial-temporal dynamics of the blooms are an important factor in determining the level of risk to an affected community. The research aims to evaluate potential risks to consumers where there is a proliferation of potentially toxic cyanobacteria blooms in sources of potable water. The monitoring plan uses submersible online fluorometric probes measuring the concentration of phycocyanine (pigment present in freshwater cyanobacteria) to monitor the occurrence of cyanobacterial at the entrance of two potable water treatment centers and in two sources of potable water feeding them. Two YSI 6600V2-4 fluorometric probes were installed at the entrance of two potable water stations, and took measurements of Ph, conductivity, temperature, dissolved oxygen, turbidity, chlorophyll a and phycocyanine continuously every 30 minutes. Two other probes were used to take continuous measurements and vertical profiles of the same parameters in the source water near the intake points of each station. Bi-weekly water samples were taken to validate the readings of the probes and measure the toxicity of the blooms. The mean seasonal concentration of cyanobacteria in 2007 at then entrance of both treatment centers was less than 2000 cells/ml (the first suggested warning threshold for cyanotoxins in drinking water). However, during that season, two cyanobacteria blooms were detected, one of which was measured by the probe at approximately 99 000 cells/ml and was highly toxic. This concentration approached the second suggested warning threshold for drinking water of 100 000 cyanobacteria cells/ml at which an alternative source of water should be considered. Yet, at the same moment of this bloom, only negligible concentrations of cyanobacteria were detected at the entrance of the stations (under 2000 cells/ml). Hence, the results from 2007 suggested that if potable water intake points were sufficiently deep in source waters, cyanobacteria contamination seemed unlikely. However, preliminary results from 2008 indicate that windy conditions can create a homogeneous mixture of cyanobacteria throughout the water column, raising the risk of contaminating the water intakes of the monitored treatment centers. This was demonstrated on two days in August when throughout the water column above one station's intake point the phycocyanine probe measured relatively homogeneous concentrations of approximately 20 000 and 34 000 cyanobacteria cells/ml. On both monitoring days, a second probe taking parallel measurement inside the station measured similar concentrations of cyanobacteria. This could suggest that water intake points in sources which are more exposed to windy meteorological conditions could be at higher risk of cyanobacterial contamination. Spatial-temporal variation and changing meteorological conditions must be taken into account when assessing the possible risks potentially toxic cyanobacteria can pose to the quality of a community's potable water. Further research aims to validate the probes in various water matrices.

Session D
Wastewater Treatment : Physicochemical Technologies

Analyse granulométrique des débris inorganiques (*grit)* des boues activées séparés par hydrocyclonage

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Le traitement et la disposition des boues représentent 50% des coûts d'opération des stations d'épuration (STEP) biologiques. L'enlèvement des matières particulaires inertes qui s'accumulent dans les boues permettrait aux STEP d'augmenter le temps de rétention des boues (TRB), diminuant ainsi la quantité de boues à traiter et disposer. L'utilisation d'un microtamis pour l'enlèvement de la matière particulaire inerte organique (*trash*) suivi d'un hydrocyclone pour l'enlèvement de la matière particulaire inerte inorganique (*grit*) a été proposée. Le procédé a été testé en laboratoire avec des résultats prometteurs.

Un montage expérimental comprenant un hydrocyclone et un microtamis (3 tailles ont été testées). Les échantillons de liqueur mixte et de boues recirculées provenaient de huit STEP de la région du Grand Montréal. Les échantillons ont été analysés pour les matières en suspension (MES), les matières volatiles en suspension (MVES), les matières inorganiques en suspension (MIES) et la distribution granulométrique par diffraction laser.

Le microtamis a principalement retenu des matières organiques (MVES/MES des rétentats =78 à 92%, moyenne 87%), peu importe la fraction volatile de la boue brute (MVES/MES=57 à 85%, moyenne 71%). Les rendements réduits (E_T') de l'hydrocyclone sur les MIES variaient entre 8 et 33%. L'analyse des données de granulométrie a permis de tracer des courbes de sélection (E_T'pour chaque taille de particules) ainsi que de calculer le seuil de coupure de l'hydrocyclone. Ces paramètres sont d'importance à l'étude d'une nouvelle application pour l'hydrocylone car ce dernier sépare les particules selon leur densité et leur taille.

Le microtamis et l'hydrocyclone sont des unités permettant donc de séparer efficacement le *trash* et le *grit* des boues activées. La mise à l'échelle du procédé est présentement en cours avec une usine pilote installée à la STEP de Saint-Hyacinthe. Par ailleurs, la modélisation du procédé en régime permanent donnera des pistes quant à la réduction de la production de boues attendue sur une base annuelle.

Génération *in situ* d'acide hypochloreux pour le traitement électrolytique d'effluents contaminés par des colorants synthétiques

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Les eaux résiduaires issues des industries textiles, de pâtes et papiers ou de l'industrie du cuir contiennent divers types de colorants synthétiques et constituent une importante source de contamination de l'environnement. La décharge de tels effluents dans le milieu récepteur cause une demande excessive en oxygène et une coloration des eaux de surface. Pour faire face à cette importante problématique, la technique d'électro-oxydation combinant à la fois les effets direct et indirect du courant électrique, a été mise à profit afin de soumettre ces effluents résiduaires à des traitements plus poussés avant tout rejet dans le milieu récepteur. L'intérêt de ces techniques réside dans leur aspect non polluant et leur facilité d'automatisation. Les traitements électrochimiques constituent également l'une des méthodes visant à réduire l'emploi des réactifs chimiques qui conduisent très souvent à une augmentation de la salinité.

Pour ce faire, une cellule électrolytique a été conçue à l'aide de matériaux d'électrodes appropriés (Ti/IrO_2 et Ti/SnO_2) pour la production *in situ* d'oxydant (HClO). La première partie de cette étude a consisté à caractériser la cellule électrolytique en termes de sa capacité de production de chlore actif nécessaire à la dégradation de colorants synthétiques. Une vitesse de production de chlore actif allant jusqu'à 165 mg $h^{-1}.A^{-1}$ a été obtenue en présence d'une concentration en ions chlorures de 600 mg L^{-1}. Par la suite, l'efficacité de dégradation du système électrolytique a été vérifiée sur quatre types de colorants industriels, le méthyle violet 2b ($C_{24}H_{28}ClN_3$), le trypan bleu ($C_{34}H_{28}N_6O_{14}S_4$), l'acridine orange ($C_{17}H_{19}N_3$) et l'eosin yellowish ($C_{20}H_6Br_4O_5$). Différents paramètres tels que la densité de courant, le temps d'électrolyse, la concentration initiale en colorant ainsi que la concentration en électrolyte ont été évalués. Les mesures d'absorbance par spectrophotométrie visible ont montré que pour les quatre colorants, des rendements de décoloration supérieurs à 99 % pouvaient être obtenus au bout de 40 min d'électrolyse. La constante de vitesse (k_D) de dégradation de colorants se situait entre 0.09 et 0.30 min^{-1} dépendamment de la densité de courant imposée et de la concentration initiale de colorant. Un rendement d'élimination de 75 % de DCO a été enregistré, alors qu'un taux de dégradation de 51% de COT a été mesuré au bout de 40 min d'électrolyse.

Improvement of the Activated Sludge Mixed Liquor Properties by Electrocoagulation Process

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This study highlights the effect of electrocoagulation (EC) phenomenon on activated sludge mixed liquor by applying direct current (DC) fields. The main objective of this study was to generate information on the changes of the physiochemical properties (pH, temperature, and the concentration of the mixed liquor suspended solids) and biochemical proprieties (COD, nutrients) of the mixed liquor activated sludge when it is exposed to DC fields.

The experimental work was achieved in small electro-bioreactor in which 200 ml of MLSS samples were evaluated by applying voltage gradients of 0, 1, 2, 4, and 6 V/cm. The experiments were carried out for 15 and 30 minutes of electrocoagulation time with and without air effect.

The results showed that the application of DC fields did have significant change in pH and ORP at both cathode and anode in batch experiments and the effect was more significant at high voltage levels (4 and 6 V/cm). An injection of air stream reduced the pH effect at anode. The COD was monitored to assess potential inhibitory/stimulating conditions of electrical field on COD removal in an aerobic suspended culture. It was found that low voltage gradient (1V/cm) did not have a significant impact on COD reduction; the COD removal efficiency was 15 % and 18 % for 15 minutes and 30 minutes of electrocoagulation time respectively. Exposure the MLSS solution to moderate voltage of 2 V/cm increased the COD removal efficiency to 25 % and 36 % for 15 minutes and 30 minutes respectively. The aeration showed little effect on the COD removal efficiency during the proposed EC times. However, when the MLSS solution exposed to high level of DC fields (i.e. 6 V/cm), the COD removal efficiency increased to 41 % and 76 % for 15 minutes and 30 minutes of exposure time respectively. Moreover, the results showed that DC fields can enhance the phosphorus removal up to 98.5 % while DC fields did not show positive impact on the ammonia-nitrogen removal.

Furthermore, this study showed that energy and electrode consumptions in EC process increased by increasing the electrocoagulation time and the applied voltage. In the commercial application of EC, these two parameters should be optimized from economical point of view.

Rheological changes during Fenton oxidation and ultrasonication of wastewater sludge

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Sludge production is increasing markedly as a result of expansion of wastewater treatment plants incurring disposal costs. At this stage, bioconversion using wastewater sludge as raw material for value addition is an economical and eco-friendly solution. One of the most important steps in bioconversion is pre-treatment to improve nutrient availability of wastewater sludge. Besides, rheological properties are also useful as a control parameter in wastewater sludge treatment such as pumping design, transporting facilities, sedimentation and, dewatering. Viscosity, in particular, is of crucial importance during sludge bioconversion, affecting mass transfer during fermentation process. The aim of the present work was to study the influence of pre-treatment processes including ultrasonication and Fenton oxidation on the rheological characterization of wastewater sludge. The correlation between improvement of dewaterability, decrease in viscosity, and change in particle size as a function of sludge pre-treatment process was also investigated. Rheological measurement was performed by a rotational viscometer. The rheological models, namely, Casson law, Power law, Bingham plastic were evaluated to characterize sludge flow at different solids concentrations ranging from 10-40 g/L. Particle size analysis was carried out by using Fritsch Laser particle sizer analysette 22. Dewaterability, as resistance to filtration was measured by capillary suction time (CST) method. Pre-treated and raw sludge displayed non-Newtonian rheological behaviour with shear thinning as well as thixotropic properties for total solids ranging from 10 g/L to 40 g/L. The CST values increased linearly with solids concentrations, but decreased with the pre-treatment processes. The decrease in dewaterability and particle size resulted in lower viscosity. Further, decreased viscosity and consistency index resulted in improved flow behaviour of sludge which will be subjected to value addition. Thus, pre-treatment of wastewater sludge modified the rheological properties so that: 1) the dewaterability of wastewater sludge was enhanced for eventual disposal and; 2) assimilation of nutrients by microorganisms during value addition was increased.

Effect of particles and bioflocculation on ultraviolet desinfection

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UV disinfection units are becoming increasingly popular in the water and wastewater treatment industry as an alternative to chemical disinfection methods. UV disinfection does not cause the formation of harmful chlorinated disinfection by products and is very effective on protozoa that are known to be resistant to chlorine disinfection. However, the effectiveness of UV disinfection is closely related to the water quality and parameters, and inactivation of microorganisms has been shown to decrease in presence of particles. Several studies have reported results on the effect of particle size on UV disinfection, but the importance of the bioflocculation process and the effect of final floc size and structure on UV disinfection has been largely ignored. This study aims to provide a good understanding on how and to what degree particles and flocs limit the efficiency of UV disinfection. Bioflocculation process determines the final size and structure of flocs, which is far more important than particle size alone for its impact on disinfection. In order to study the effect of bioflocculation on UV disinfection, it is important to use a stable, well-defined and well-controlled surrogate that can simulate the particle characteristics, and coagulation and flocculation properties of water and wastewater samples. Such a system can be created by using latex particles, alginate, and divalent cations. Latex particles can be purchased at selected particle sizes and surface characteristics, and they are very uniform in their size which provides an important advantage in studying the particle effects. Extracellular polymers (e.g., alginate) and divalent cations play a key role in bioflocculation and help to form the bridges between particles and bacteria that keep the floc structure together. Three different sizes of latex particles were used: 1, 10, and 45 microns. E. coli bacteria were spiked in water samples containing the desired particle counts and alginate concentration, and samples were flocculated by adding Ca+2 ions. In order to vary the floc size, different concentrations of alginate and Ca+2 were used. Finally, the samples were exposed to different UV doses (0-150 mJ/cm2) by using a LP-UV collimated beam apparatus, and E. coli were enumerated using the membrane filtration (MF) method according to Standard Methods (APHA, 2005). The survival rates of E. coli were compared to assess the relationship between particle and floc size as well as alginate and Ca+2 concentrations. The results of this research indicate that bioflocculation process significantly impacts the UV disinfection, and the effect of flocs on UV disinfection is very different from the effect of particles that was previously reported in the literature. The findings indicate that it is not only the size but also floc structure and porosity that determine the effectiveness of UV disinfection. Extracellular polymers also appear to influence the UV disinfection by shielding the bacteria, absorbing the UV irradiation, and aiding the flocculation of particles.

Session E
Water Quality :
Issues with Phosphorus and Pathogens

Karaj River water quality assessment with TMDL approach

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The Karaj River is one of the main water supplies in Tehran (Iran). The mainstream of this river has 74 km length and its watershed area is about 86000 ha . Amir Kabir dam has been constructed on this river to produce electrical energy and supply some part of Tehran drinking water demand. Bilegan reservoir as a first pretreatment unit is located 18 km after the dam to intake raw water to water treatment plant. This river supplies near 35% of Tehran drinking water demand. Although there is no significant point sources pollution between dam and reservoir, quantity of water quality parameters such as NH3 and organic nitrogen are above normal conditions in this section. The results of 4 years river water quality assessments in this research show that the Amir Kabir dam has a main role in ammonium pollution in down stream. During the last two decades by accumulation of organic material in the reservoir of dam it is now conducting a secondary pollution source to a main river.

In this research, collected data from 7 sampling stations with different water quality parameters through the river has been investigated for 4 years (2002-2007). The river has been divided in six segments and all point and nonpoint source have been regarded in this 18 km. The water quality of river has been simulated by application of Qual2k model for summer times. Further more total Maximum Daily Load, or TMDL, approach has been used to investigate the maximum amount of a pollutant that the Karaj River can receive and still safely meet water quality standards.

The result of water quality assessment and modeling shows that the river has high self-purification capacity. The DO concentration in summer, low flow condition, was not less than 5.5 mg/l in simulated and observed data. Also other water quality parameters except NH3 were lower than maximum permissible amount. The result of NH3 modeling shows that the 0.02 mg/l target concentration for NH3 in river water was not met without 60% of headwater load reductions for nitrogen inputs. It is clear that to avoid water quality deterioration in the Bilegan intake reservoir the major actions should be taken to control the released organic nitrogen loads from Amir Kabir dam.

Examining the Influence of Cell Concentration on Bacterial Migration in Granular Porous Media

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There is a considerable ongoing effort aimed at understanding the transport and deposition behavior of microorganisms in granular porous media. A mechanistic understanding of these processes is of interest in various environmental applications such as deep-bed granular filtration for drinking water treatment, riverbank filtration, and protection of groundwater supplies. The classic filtration model used to evaluate microbial transport in granular porous media assumes that microbe deposition follows first order kinetics, and hence, the extent of removal is independent of the suspended microbe concentration. However, recent studies of microbe removal at the field-scale report concentration dependent removal rates.

Well-controlled laboratory column experiments were conducted to better understand the role of cell concentration on bacterial transport and retention in saturated granular porous media. Experiments were carried out using a glass chromatography column packed with quartz sand as a model system. Two strains of *E. coli* were used in the study; the commonly studied laboratory organism *E. coli* K12 D21 and a non-toxigenic mutant of the waterborne pathogen *E. coli* O157:H7. Bacterial transport was examined for varying influent cell concentrations of each organism and cell numbers in the column effluent were evaluated using both spectrophotometric and plate counting methods. The two bacteria show significantly different transport behaviour in the saturated granular matrix, as well as clear, concentration-dependent removal rates. The causes and environmental implications of this behaviour will be discussed.

Treatment of surface water by nonwoven geotextile filtration for removal of suspended and dissolved solids

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To improve water quality, removal of organic matter and nutrients from the water is one of the useful methods. Generally, organic matter and nutrients in the water are defined as a particulate matter and dissolved matter by particulate size. For aquatic biota, dissolved organic matter and dissolved nutrients are important for growth. However, excess amounts of substances inputted in to a water area can lead to eutrophication. Subsequently this causes a decrease in transparency and a reduction of dissolved oxygen, which also may cause algal blooms. Thus, removal of the substances which include dissolved matter from the water is required to improve the water quality. Suspended solids (SS) are one of substances which have been discharged into the water. SS which consist of inorganic and organic matter can adsorb various substances such as nutrients and heavy metals by physical adsorption, chemically bonding and biological assimilation. For this reason, SS concentrations are associated with chemical oxygen demand (COD) and total phosphorus (T-P) concentrations in water. Therefore, by the adsorption ability of SS, dissolved matter may be removed from the water.

In this study, to develop a technique for treatment of surface water that includes dissolved matter, laboratory filtration tests were performed. A 25 L water sample was taken from the des Hurons River which is located 35 kilometers east of Montreal, and used for the laboratory filtration tests. A downward filtration system was used and a nonwoven geotextile (Layfield Ltd.) was used as a filter medium. The pore size and the thickness of the filter were 150 μm and 0.2 cm, respectively. The cross-sectional area of the filtration system was 50.2 cm^2. Measurements before and after filtration were made for SS, total chemical oxygen demand (T-COD), dissolved COD (D-COD), T-P, and dissolved total phosphorus (D-T-P).

The results showed that SS were completely removed from 32.0 mg/L by the nonwoven filter. By this filtration, COD and T-P concentrations in the container were also reduced from 22.3 mg/L to 11.8 mg/L, from 0.165 mg/L to 0.02 mg/L or less, respectively. The T-P concentration which is 0.02 mg/L or less corresponds to mesotrophic of the T-P trigger ranges for Canadian lakes and rivers. In addition, it was found that D-T-P could be removed by this filtration with a clogged filter. Also, the concentrations of dissolved COD showed a decreasing trend through this filtration process. Thus, a clogged filter with SS can be used as a good absorbance filter for removal of dissolved matter from the water. The COD and the T-P removal efficiencies of 42.2% and 91.5% were obtained, respectively. In this study, the amount of T-P removal per filtration area was 0.078 mg/cm^2. Therefore, the filtration can remove not only particulate substances, but also dissolved matter. Furthermore, the filtration system can be used for various types of engineering work along coastal regions and lakes, including the prevention of algal growth and red and blue tides.

Hydrologic, seasonal and management controls on water quality response in Fourchette twin watersheds experiment, Beauce region, Québec

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Participatory, adaptive research under a twin watersheds experimental design (< 3 km2) in Etchemin River's basin provided a better comprehension of the non point sediment and nutrient transfers between the landscape and the stream, as well as evaluations of the effectiveness of riparian buffers and structural runoff control in reducing sediment and nutrient transfers to the stream. A detailed biophysical characterization of the *experimental* (treatment) basin included airborne multi-spectral images, field scouting for erosion marks, precision modelling of the topography, soil survey and farm census of cropping practices. The integration of these spatially-referenced data provided a global perspective on the watershed hydro-pedologic environment and supported the planning and systematic implementation of runoff and erosion controls. Watershed treatment included the implementation of riparian buffer strips with trees or shrubs along every stream banks, as well as punctual drainage and erosion controls, including stream bank bioengineering, rock linings, grass waterways or catch basins with tile inlets. The monitoring protocol of experimental watersheds included continuous hydrometric observations, discrete samplings for water quality as well as continuous multi-probe monitoring of the geochemical signal (conductivity and turbidity). The conductivity mass balance (CMB) procedure applied to multi-probes data supported the separation of 30 runoff events during the period of study and provided contrasting estimates of surface runoff activity at the outlets of *experimental* and *control watersheds.* Sediments and nutrients flux at watersheds outlets were reliably estimated through concentration:flow statistical relations developed for individual watersheds, distinct streamflow strata and seasons. Detection of seasonal and treatment effects and interactions on water quality was supported through covariance analysis (ANCOVA) of sediment and various nutrient parameters using stream flow or *control* basin data as covariable. Despite an important inter-annual variability in hydrological conditions, the ANCOVA indicated a 35 percent reduction in TSS flow-weighted concentration in response to watershed treatment during the production season (May to November). Phosphorus loadings did not follow the same trend. One of the practical implications of this study is the importance of combining structural and cropping BMP's to obtain significant phosphorus P loadings abatement from agricultural watersheds.

Influence des microorganismes aquatiques sur les flux de phosphore au sein d'élevages piscicoles en étangs

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Au Québec, dans le cadre de la STRADDAQ (Stratégie de développement durable de l'aquaculture en eau douce au Québec) la limite maximale de rejet du phosphore (P) dans l'environnement a été fixée à 4,2 kg de P par tonne de poissons produits. Plusieurs pisciculture ne respectent pas cette exigence mais il a été observé qu'à production piscicole égale, les étangs d'élevage dont le temps de renouvellement des eaux est plus long arrivent à respecter cette exigence sans autre système de traitement qu'un étang de sédimentation. Il a été postulé qu'un facteur clé à l'origine de ce phénomène serait le développement d'une flore (micro- et macro-algues) et d'une microfaune semblables à celles que l'on retrouve parfois dans les procédés de traitement biologique des eaux usées. Toutefois, peu d'information concernant le rôle de ces microorganismes sur les flux de phosphore dans une pisciculture en étangs d'élevages est disponible. L'objectif de ce projet était donc de caractériser la densité, l'activité et la diversité des microorganismes dans la colonne d'eau et dans les sédiments d'une petite pisciculture en étangs afin d'en étudier l'impact sur les flux de phosphore. Quatre différents types de bassins piscicoles d'une même pisciculture ont été choisis pour caractériser l'influence des paramètres suivants : le temps de rétention hydraulique, le temps de rétention des boues, la présence de poissons, la nature du fond de l'étang (bétonné ou non) et la saison (été, automne, hiver) sur la densité, l'activité et la diversité de ces mircoorganismes. En parallèle, une étude de laboratoire a été amorcée pour préciser le rôle de trois types de microorganismes (vers: Tubifex sp.; métazoaires: Brachionus calyciflorus; microalgues: Selenastrum capricornutum) sur la minéralisation du phosphore. On s'attend à ce que l'absence de poissons, le fond bétonné, une saison avancée (été) ainsi que des âges de boues et un TRH élevés favorisent la présence d'organismes supérieurs tel que les métazoaires. Les métazoaires et les algues contribueraient au stockage du phosphore particulaire tandis que les vers contribueraient plutôt au relargage de phosphore soluble. Cette étude devrait contribuer à indiquer s'il est nécessaire d'installer des unités de traitement supplémentaires à un étang de sédimentation pour les pisciculture à long temps de séjour hydraulique.

Session F
Wastewater Treatment :
New Technologies and Modeling

Production de laccase à l'aide de boues d'épuration pour la biorémédiation des polluants récalcitrants dans les eaux usées

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Les eaux usées municipales et industrielles contiennent de nombreux polluants organiques récalcitrants. Les procédés physico-chimiques pour traiter les eaux contaminées par des polluants tels que les composés phénoliques (polyphénols, alkyphénols, phénols substitués), les HAPs, les polyamines, les colorants et les pesticides organophosphorés demeurent dispendieux, inefficaces, et impraticables pour plusieurs types d'eaux usées. Par contre, la biorémédiation par les enzymes s'avère très appropriée pour ce genre de pollution et apparaît aujourd'hui comme une alternative de choix pour l'avenir. Le coût de production des enzymes ligninolytiques, en majeur partie relié au coût des ingrédients du milieu de culture, demeure un obstacle majeur à leur application en biorémédiation des eaux usées. Le but du projet en cours consiste à développer une méthode de production économique pour une de ces enzymes, la laccase, en utilisant des eaux usées industrielles et des boues secondaires municipales comme milieu de culture. Les boues d'épurations municipales se sont avérées être un milieu très favorable pour la croissance des champignons producteurs de laccases, et ce, sans ajout de nutriment ou de pré-traitement des boues. La structure et la composition des boues secondaires apparaît comme idéale pour la fermentation de champignons, car elle offre un support pour la croissance et contient des inducteurs qui augmentent la production de laccases. Plusieurs espèces productrices de laccases ont été isolées des boues et des eaux usées. Certaine de ces souches andogènes peuvent produire des niveaux de laccases comparables aux espèces basidiomycètes reconnues comme étant des producteurs remarquables. Notre équipe a déjà démontré par le passé que l'ajout de laccases commerciales à des eaux usées permet une dégradation efficace des oestrogènes. La plupart des polluants phénoliques présent dans les eaux usées municipales ont une concentration de l'ordre du ng/l et peuvent donc être oxydés avec un titre de laccase relativement peu élevé. Il en résulte donc que l'ajout de bouillon fermenté moyennement concentré en laccases directement aux eaux usées devrait s'avérer efficace et suffisant pour compléter le traitement, ce qui élimine automatiquement les coûts de purifications des enzymes et diminue le coût de production. L'ajout direct du surnageant ou du bouillon fermenté contenant les laccases dans des eaux usées pour décontaminer les polluants phénoliques sera discuté. En développant une méthode de production de laccases à la fois simple et moins coûteuse, ce projet ouvre la voix pour une décontamination des polluants organiques abordable et écologique.

Simulation du comportement d'une station par biofiltration

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Apparus il y a environ 30 ans à l'échelle industrielle, les biofiltres font aujourd'hui partie des systèmes à cultures fixées les plus performants et représentent une alternative fiable aux procédés en suspension tels que les boues activées. Ils sont de plus en plus utilisés dans les filières de traitement des eaux usées.

L'usage de la simulation mathématique pour aider à opérer ou concevoir des systèmes est de plus en plus répandu. Ce procédé est fréquent pour les systèmes à boues activées mais demeure assez rare pour les procédés à milieu fixe de type biofiltre. Peu de modèles existent et le seul logiciel sur le marché permettant de simuler le comportement complexe d'un biofiltre est GPS-X®.

L'objectif de cette étude est de simuler et d'optimiser le fonctionnement des installations de traitement des eaux usées de la station Seine-Centre (située en France, en région parisienne) qui met en œuvre trois étages de biofiltration. Ce travail est effectué dans le cadre d'une collaboration entre l'Université Laval et le SIAAP (Syndicat Interdépartemental pour l'Assainissement de l'Agglomération Parisienne), qui gère plusieurs usines de traitement utilisant la biofiltration, dont la station Seine-Centre. Le but ultime est de livrer un simulateur complet de la filière de traitement de Seine-Centre, ce qui permettrait de faciliter la gestion de la station.

Traitant un débit de l'ordre de 250 000 m^3/j, la station Seine-centre comporte des unités de traitement physico-chimiques, des biofiltres secondaires de type BIOFOR, des biofiltres tertiaires nitrifiants de type BIOSTYR et des biofiltres dénitrifiants de type BIOFOR. Les données utilisées ont été récoltées sur 6 ans de manière journalière, à plusieurs endroits de la station et pour les principaux polluants (DCO, MeS, NH4 et NO3). Le comportement des composés est donc simulé sur une base de temps journalière, en utilisant le modèle ASM1. Les simulations ont été faites dans un premier temps en considérant chaque biofiltre séparément, puis dans un deuxième temps en prenant en compte l'ensemble des biofiltres de la station Seine-Centre, de manière à représenter la filière de traitement au complet.

L'applicabilité de GPS-X® au cas de la station Seine-Centre a été vérifiée, en comparant les résultats fournis par le modèle aux données de terrain de temps sec, pour les différents types de biofiltres présents sur la station (BIOFOR et BIOSTYR). Les résultats obtenus permettent de valider la capacité de GPS-X® à modéliser chaque biofiltre, mais ils restent à améliorer pour la simulation de la station au complet. Certaines limites du logiciel de simulation, liées principalement au temps de calcul, ont d'ailleurs été mises en évidence. La modélisation de la nitrification pourrait également être plus précise si le simulateur tenait compte des variations de l'oxygène dissous, qui n'a pu être intégré comme les autres paramètres et a du être défini comme constant. Après avoir été validé en temps sec, le modèle a aussi été vérifié en temps de pluie et les résultats sont encourageants.

Caractérisation du résidu endogène de boues activées produites dans un bioréacteur à membranes aérobie

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Les systèmes de boues activées opérés en pratique avec limitation en substrat, génèrent un résidu endogène suite à l'oxydation de la biomasse. Peu d'informations existe dans la littérature quant à la nature et la composition chimique de cette fraction de boues.

L'objectif de ce projet était de caractériser le résidu endogène d'une biomasse produite dans un bioréacteur à membranes BRM de taille pilote. À cette fin, un affluent synthétique soluble et complètement biodégradable dont la source de carbone est l'acétate de sodium a été utilisé pour alimenter ce BRM. Cet affluent sans matière non biodégradable (organique ou inorganique), a permis de générer des boues constituées de seulement deux fractions : une biomasse hétérotrophe X_H et un résidu endogène X_E, la biomasse nitrifiante étant négligeable.

Le système du BRM a été utilisé dans cette investigation en tant que support de production de boues à caractéristiques constantes en termes de matières volatiles en suspension, d'âge de boues TRB, de X_H et de X_E. Pour s'assurer de la constance de ces paramètres, une caractérisation sur base hebdomadaire a été réalisée sur ce système pour dresser un bilan hydraulique et des bilans de masse pour la demande chimique en oxygène, l'azote et le phosphore.

La détermination de la fraction active des boues issues du BRM a été réalisée par des tests de digestion aérobie prolongée (21 d) de ces boues mais aussi par des tests de respirométriques (21 d). Dans la première méthode, l'évolution de la concentration des matières volatiles en suspension a été suivie dans un digesteur aérobie opéré en cuvée alors que dans la seconde, les taux d'utilisation d'oxygène par la biomasse ont été observés au fil du temps. Les résultats ont montré d'une part, la concordance des deux méthodes et d'autre part, que le BRM opéré à un TRB de 5 d renfermait 69 % et 31 % de X_H et de X_E respectivement.

Par ailleurs, des analyses élémentaires de carbone, d'azote, de phosphore et de soufre ont été effectuées sur les boues du BRM et sur le X_E produit par digestion aérobie prolongée et concentré par centrifugation. Les résultats ont permis de déterminer par rétro-calcul le contenu en ces éléments pour X_H sur base d'une fraction active de 69 %. Ces analyses ont aussi révélé que le résidu endogène possède une structure chimique assez différente de celle de la biomasse active et des boues du BRM. En effet, le X_E a un contenu plus faible en matières inorganiques que la biomasse active et un contenu en carbone légèrement supérieur. Ces contenus se présentent comme suit : 1:4.2 pour les matières inorganiques, 1:2.7 pour l'azote, 1:5.3 pour le phosphore, 1:3.2 pour le soufre et 1:0.97 pour le carbone. La composition typique d'une biomasse de boues activées est $C_5H_7O_2NP_{0.083}$. Pour les composés mesurés, les compositions chimiques suivantes ont été déterminées: X_H : $C_5H_{6.442}O_{1.966}N_{0.978}P_{0.080}S_{0.030}$, X_E : $C_5H_{6.445}O_{2.420}N_{0.357}P_{0.015}S_{0.009}$ et boues activées du BRM : $C_5H_{6.427}O_{2.115}N_{0.771}P_{0.059}S_{0.023}$.

Cette investigation a permis de cibler et caractériser le résidu endogène produit dans le BRM. Elle constitue un apport significatif pour la modélisation et permettra d'affiner les aspects relatifs au contenu minéral, en azote et en phosphore du X_E et de X_H et de déterminer avec plus de précision les ratios typiques tels que DCO/MVES pour ces fractions. L'approche développée dans ce travail aidera à caractériser au mieux la fraction organique non biodégradable acheminée par un affluent de station d'épuration X_I.

Novel aspects in mathematical modeling of activated sludge wastewater treatment systems

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Mathematical modeling to predict and optimize the operation of biological wastewater treatment processes have greatly progressed over the past two decades. However, the current activated sludge models (ASM) remain limited in their ability to predict microbial activity during rapid (over few hours) transitions between operation modes forcing the microorganisms to change physiological status. This is because the models consider only a few biochemical conversions in a lumped-reaction black-box approach. We suggest studying extensions to the current models by adopting a genomic approach. By taking into account genomic information, we are reconstructing in silico the entire biochemical network of Rhodococcus strain RHA1, our model activated sludge microorganism. We then studied the metabolic phenotype (distribution of fluxes through the reactions in the metabolic network) to the genotype in different growth conditions. The main question here is to identify what pathways are being utilized under various physiological regimes and to determine if it is possible to understand the regulation of the metabolic network in terms of global optimization principles. It is these principles that will allow us to propose valid extensions to the current models. The characterization of the pathways used under various physiological conditions was accomplished by 13C-Flux Balance Analysis (13C-FBA). In these experiments, microorganisms are grown on 13C-labeled substrates and the distribution of 13C in amino acids is analyzed. This provides the necessary information to compute the flux through all the reactions in the biochemical network. As a case study, we used data on the growth of phenol to determine which of the two possible phenol degradation pathways (ortho-cleavage or meta-cleavage of catechol, the first metabolic intermediate) are utilized under different oxygen tensions. Laboratory and modeling results suggest that the ortho-cleavage pathway is always used.

We hope that this work will lead to the proposition of a new generation of activated sludge wastewater treatment models based on comprehensive metabolic investigations of microbial systems.

Multi-variable model of pre-treatment processes for anaerobic digestion of primary and secondary sludge

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Anaerobic digestion (AD) has long been used for waste stabilization. Biodegradable matter in the waste is primarily converted to insoluble methane and carbon dioxide. Methane is a useful end product that can be utilized in the wastewater treatment plant (WWTP) as an energy source. Reductions in sludge mass, low nutrient requirements, and an improvement in dewatering properties are other main benefits of AD. Absence of an oxygen demand lessens power requirements but drawbacks to AD include sensitivity to shock loads and toxic materials. A long hydraulic residence time (HRT) of 20-30d is also needed to complete the four stages of digestion: hydrolysis, acidogenesis, acetogenesis, and methanogenesis. Sludge handling and disposal costs have been reported between 30-60% of the total construction, operation, and maintenance costs of WWTPs. Complying with increasingly stringent EU or EPA policies on sludge stabilisation and land application completes the demand for an improvement in the AD treatment train.

Organic matter hydrolysis is identified as the rate-limiting stage in WAS degradation. Pre-treatments can ameliorate anaerobic digestion performance by lysing sludge cells and releasing extracellular and intracellular matter. This matter is now more accessible to the anaerobic microorganism consortium. Six pre-treatment categories include mechanical, thermal, chemical, biological, ultrasound and combinations of these.

An evaluation and compilation of the quantitative benefits and drawbacks to establish the suitability of pre-treatment steps for the anaerobic digestion of primary and/or waste activated sludge is proposed. The goal is to create a multi-variable model capable of handling user-inputted data (e.g. sludge characteristics and digestion parameters), observed treatment trends, and energy/economic balances to prescribe a preferred process. Data from the on-going literature review has been dissected for reproducibility, cost, energy demands, full-scale applicability, WWTP variability (e.g., sludge characteristics and retention time). Both mesophilic and thermophilic anaerobic digestion are considered for the model. Field-contacts will be established to obtain average AD results as well as equipment, operation and maintenance, sludge handling, and energy costs.

In the papers reviewed thus far, chemical oxygen demand (COD) is solubilized and volatile suspended solids (VSS) are reduced at a greater rate. This typically leads to added pathogen reduction, shorter hydraulic residence times, reduction of residual solids, and smaller reactor volume requirements. Dewaterability can be positively or negatively affected but increased access to the intracellular matter by the methanogenic bacteria generally improves the production of biogas by 30-50%. Since the efficacy of pre-treatment typically increases with an increase in the concentration of solids in the feed, it will be important to also consider the cost and energy demands of concentrating the sludge prior to pre-treatment. As underlined numerous times in the reviewed literature, more extensive research is needed to ascertain the significance of treatment improvement under full-scale conditions.

Session G
Groundwater Quality and Bioremediation

Aggregation of titanium dioxide nanoparticles: Role of a Fulvic Acid, pH and Ionic Strength

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The increasing use of nanomaterials in consumer products has resulted in increased concerns about their potential environmental impacts [1]. To better understand the likely fate and behaviour of nanoparticles in aquatic systems, it is essential to understand their interactions with components of natural waters including environmental colloids and natural organic matter (NOM) under a variety of physicochemical conditions such as pH and ionic strength.

Fluorescence Correlation Spectroscopy (FCS) [2] was used to determine the diffusion coefficients of TiO_2 nanoparticles having a nominal size of 5 nm. The effects of a various concentrations of a well characterized fulvic acid, the Suwannee River Fulvic Acid (SRFA), pH and ionic strength were evaluated. Aggregation of the bare TiO_2 nanoparticles increased with increasing pH (from pH 2 to 8), even for pH values that were far from the zero point of charge. At a given pH, an increase in ionic strength generally resulted in increased aggregation. Conditions which favoured the adsorption of the fulvic acid by the TiO_2 nanoparticles resulted in less aggregation, presumably due to increased steric repulsion for most environmentally relevant conditions of pH and ionic strength.

One advantage of FCS is the ability to perform the experiments at low, environmentally relevant concentrations of nanoparticle. Under these conditions, the nanoparticle dispersions were often stable for environmentally relevant conditions of organic matter, pH and ionic strength. The study suggests that the dispersion of TiO_2 nanoparticles in the natural aquatic environment might occur to a greater extent than previously predicted.

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Bare and modified nanoiron characterization and transport in sand packed column

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Zero-valent iron nanoparticles (ZVINs) have been shown to be very efficient in the transformation of chlorinated hydrocarbons, chromium and nitrate to innocuous by-products. Therefore, ZVINs are considered to be an excellent active agent for *in situ* remediation of contaminated sites if they can be injected into the subsurface and transported with the groundwater.

However, the use of ZVINs for in situ remediation of contaminated sites has been held back by their agglomeration that hinders their transport through soil and lowers their chemical reactivity. Surface modifications of ZVINs that minimize this aggregation behaviour are likely to make ZVINs effective for *in situ* remediation. In this study, the transport efficiency of ZVINs through a sand packed column was studied to evaluate the effect of their surface property modification using carboxymethyl cellulose (CMC) and poly acrylic acid (PAA). Transmission electron microscopy analysis of synthesized nanoparticles showed that bare ZVINs had an average size of 55 nm, whereas the average particle sizes of CMC-ZVINs and PAA-ZVINs were 5.7 nm and 4.6 nm, respectively.

Flow-through column experiments were conducted using packed sand columns and employed interstitial velocities of 0.02, 0.2 and 1 cm min^{-1}, nanoiron feed concentrations of 0.1, 0.5 and 3 mg L^{-1} and column length of 4.5 and 9 cm. Monitoring of the nanoiron concentrations in the column effluent revealed significant aggregation of the bare ZVINs and the bare ZVIN did not transport to a significant extent through the sand medium. In contrast, substantial transport of CMC-ZVINs and PAA-ZVINs were observed. The spatial distribution of nanoiron inside the packed columns were characterized by X-ray computed tomography (CT) scanner to gain further insight on the nanoiron transport process and the locations of nanoiron deposition. In contrast to PAA-ZVINs, even at elevated feed iron concentrations CMC-ZVINs did not aggregate in the test columns demonstrating thus an application potential of such modified nanoparticles.

A laboratory study of bacterial pathogen transport in Quebec agricultural soil

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The contamination of drinking water by microbial pathogens is recognized as one of the most pressing water supply problems of our day. Two important sources of pathogen contamination are animal fecal deposits associated with intensive livestock production and manure spreading in agricultural applications. In May 2000, in Walkerton, Ontario, 2300 people were infected with *E. coli* O157:H7 and several individuals were also co-infected with *Campylobacter jejuni*. Seven people died as a result of this outbreak which was linked to the infiltration of bacteria from cow manure into the aquifer supplying the municipal well water. Although agricultural waste disposal near potable water supplies has been linked with outbreaks of disease, the physical, chemical, and biological factors controlling pathogen filtration in the complex subsurface environment are not well understood.

Well-controlled laboratory column experiments were conducted to better understand the transport potential of selected bacterial pathogens in Quebec agricultural soils. Experiments were carried out using a glass chromatography column packed with (i) quartz sand as a model system, and (ii) soil taken from an agricultural field. The transport behaviour of the following waterborne pathogens was examined in the laboratory study: (i) *E. coli* O157:H7, (ii) *Enterococcus faecalis*, (iii) *Yersinia enterocolitica*, (iv) *Microcystis aeruginosa*, and (v) *Anabaena flos aquae*. The latter two organisms are toxin-producing cyanobacteria whereas the first three are pathogens commonly associated with faecal deposits. Column experiments conducted using two different solution chemistries revealed significant differences in the transport and retention behaviour of the selected organisms. In an effort to better understand the factors controlling bacterial migration, the organisms were characterized using microelectrophoresis to determine cell surface (zeta) potential and microscopy to determine cell size (equivalent spherical diameters). These data are used in an effort to interpret the bacterial transport behaviour within the context of the classical theory of colloid stability.

Petroleum hydrocarbon biodegradation in extreme environment: effect of cold temperature fluctuation and seasonal freezing

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Petroleum contamination of soil and groundwater has occurred at many sites in northern Canada. Large spills of petroleum liquids persist in the ground for long periods of time and serve as a source of long-term environmental contamination. The restoration of these sites is necessary to protect water and land resources, human health, and wildlife populations in northern regions.

Bioremediation of petroleum contamination involves microbial degradation processes that are dependent on temperature, availability of nutrients and hydrocarbons, and the presence of sufficient numbers of viable hydrocarbon-degrading microorganisms. Given that ambient temperatures in northern regions occasionally reach freezing or low temperatures (<10°C) in the warmest summer months, and are frozen for 8-9 months of the year, and that soils usually encountered in these regions contain low levels of organic matter and nitrogen (N) and phosphorous (P) nutrients to support biological growth, the efficient implementation of bioremediation in northern sites will require biostimulation strategies to address these extreme environmental conditions.

This research investigated the biodegradation of petroleum hydrocarbons in contaminated soils from Resolution Island (RI), Nunavut, using 1 m × 0.6 m × 0.35 m soil tanks that served as pilot-scale landfarming bioremediation reactors. The experiments were conducted in a cold room at McGill University where the temperature was programmed to match the daily average temperatures, ranging from -5 to 10°C for the summer months (July & August) and seasonal freezing conditions (September & October) at RI. Parallel experiments were also conducted where a stable average temperature of 6°C was maintained. Comparison of the petroleum hydrocarbon biodegradation patterns provided an understanding of how temperature fluctuations and seasonal freezing in the field, influence biodegradation rates and extents.

In experiments where the soil tanks were subjected to variable temperatures ranging from 1 to 10°C, representative of daily average temperatures of the summer season at the site, total petroleum hydrocarbon (TPH) concentrations were reduced by 55% by biodegradation, compared to only 21% in soil tanks which were subjected to a constant, average temperature of 6°C. Carbon dioxide production in soil was generally temperature dependant. Significant biodegradation of semi- (C10 to C16) and non-volatile high-molecular-weight fractions (C16 to C34) were observed, in both systems. However, biodegradation of TPH and high-molecular-weight fractions was greater under the field temperature fluctuations rather than the constant temperature incubation. A residual TPH level of ~500 mg/Kg was obtained after a 60-day treatment period in the soils subjected to temperature fluctuations and was attributed largely to hydrocarbons present in the fraction of soil particles with diameters ranging from 0.6 to 2 mm.

Biodegradation of semi-volatile fractions of TPH was also observed occurred at freezing temperatures up to -2°C, and the biodegradation activity was correlated with the availability of unfrozen water. Also, under these conditions the CO_2 soil gas concentrations in the treated- and non-treated system were significantly correlated to O_2 concentrations, providing further indication of the activity of cold-adapted populations at freezing temperatures.

Faisabilité de l'utilisation des déchets pour la production de la diète d'insecte (*Cydia pomonella*)

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La pyrale de la pomme (PP), le *Cydia pomonella* (L.1758) est le principal insecte ravageur des vergers (95% d'infestation), en particulier de la pomme dans les régions tempérées. Les méthodes de contrôles utilisées conventionnellement pour lutter contre ce ravageur sont les insecticides chimiques. Mais, compte tenu de leur impact négatif sur l'environnement et la santé des êtres vivants non ciblés, la lutte biologique contre la PP par l'insecticide biologique, le *Baculovirus* s'est avéré le plus optimal et le plus sécuritaire. Ce biopesticide, produit en infectant, par des *granulovirus* des larves de PP, est cultivé sur des diètes spécifiques. Mais, le coût élevé de ces diètes, limite la production du *Baculovirus*. La disposition et le traitement des eaux usées et des boues d'épuration agroindustriels et municipaux posent aussi un problème de coût. Face à ces difficultés, la possibilité d'utiliser de façon rationnelle et utile les rejets pour remplacer certains composants (Farine de soya, Levure de bière, Germe de blé) de la diète servant à la culture des larves de la PP est faisable. Cette étude a permis d'évaluer la capacité nutritive des eaux usées d'amidon-EUA (5,73% Nt; 50,8% Ct; 7,1% glucides; 35,8% protéines; 14% lipides et des métaux), des eaux usées de microbrasserie-EMB (5,9% Nt; 47,7% Ct; 15,3% glucides; 36,8% protéines; 10% lipides et des métaux) et des boues de municipalité-BSM (4,5% Nt; 36,3% Ct; 6,7% glucides; 28,2% protéines; 9% lipides et des métaux) utilisés pour la préparation de la diète alternative. La culture des œufs de PP sur les diètes préparées avec les EUA et les EMB ont donnés des résultats satisfaisants (soit en moyenne un taux de 40% d'éclosion après 4 jours; 17 larves après 14 jours, soit 25% de survie; 2 papillons de masse 17-33 mg après 6 jours de croissance, soit 20% de survie) à partir des conditions environnementales suivantes : 16:8 photopériode; 25°C±1 et 60% d'humidité. Ainsi, cette étude confirme que l'obtention d'une diète pour la culture de la PP à partir des rejets est possible, et peut être une option économique pour l'industrie de la diète et la production des *Baculovirus.* Ceci peut faciliter la protection des forêts et des cultures de vergers contre les insectes ravageurs.

Session H
Drinking Water Treatment

Recycling membrane backwash water: effects on recovery, coagulant demand and organic removal in UF membrane filtration

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In this age of climate change and population expansion, Canadian municipalities are demanding rigorous and reliable forms of drinking water treatment that are also efficient. Ultrafiltration (UF) membrane processes fulfill many of those demands. However, UF systems are generally operated at 85 to 95 % recovery with production losses resulting from waste streams such as backwash water and clean-in-place (CIP) residuals. Currently, common options for the disposal of the backwash water generated in UF plants include direct discharge to sewer or pretreatment prior to surface water discharge. Alternative plant design configurations are necessary to increase recovery rates and minimize water loss, particularly in drought-prone regions or areas with poor incoming water quality. This alternative design could consist of adding a secondary stage membrane for the treatment of first stage residuals or recycling a portion of the residuals back to the head of the plant. For small systems, the second option may be a more cost effective solution. The purpose of this study was to investigate the impact of recycling backwash water on UF permeate water quality and coagulation pretreatment process performance.

A bench-scale UF membrane system (ZeeWeed-1, GE-Zenon, Burlington, ON) with a 0.04 μm nominal pore size and a 0.1 μm absolute pore size operated in an outside-in (O-I) dead-end flow configuration was used to simulate a full-scale membrane filtration system. Runs were conducted using source water from two full-scale surface water treatment plants (WTP) in Nova Scotia (Hantsport and Bridgewater, NS). The effects of backwash water recycling on process performance were evaluated by supplementing the raw water with 10 % by volume of membrane backwash water (no residual coagulant) or 10% spent filter backwash water (including alum residual). In the latter trials, alum was added to the system in varying doses to investigate the possibility of reducing the primary coagulant dose through recycling of backwash streams. Total organic carbon (TOC), turbidity, colour, UV absorption from 200 to 500 nm and specific UV absorbance (e.g., SUVA) were analyzed on feed water and UF permeate samples for all trials. Permeate flux, temperature and transmembrane pressure (TMP) of the system were monitored throughout the 2-hour batch trials.

In general, the results of the study showed that overall finished water quality was not negatively impacted by the addition of 10 % backwash water to the feed stream. In some cases it was improved. In the trials without coagulation pretreatment, turbidity, UV absorption and TOC were not significantly affected by adding a recycle stream. In the coagulation pretreatment trials, results were mixed. When the raw water was naturally amenable to coagulation (i.e., high SUVA) the addition of a recycle stream improved organic removal at low (less than ideal) coagulant doses and slightly reduced it at ideal coagulant doses. However, when the source water being used was not amenable to coagulation (i.e., low SUVA), the addition of a 10 % recycle stream had a slight negative impact upon the permeate water quality. These results suggest that introducing a 10 % backwash water recycle stream does not have a measurable negative impact on water quality in direct filtration or coagulation pretreatment membrane water treatment systems unless the raw water is innately difficult to coagulate. Therefore, adding a recycle stream will not only improve system recovery but may also in some cases minimize coagulant dose.

Control of Manitoba's potable water with chlorine dioxide

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Manitoba's drinking water legislation demands that trihalomethanes (THM), a by-product of chlorine disinfection not exceed 100µg/L. In efforts to minimize the production of THM content, treatment plants may resort to an alternative primary disinfectant method such as the application of chlorine dioxide. While the standard method employing N,N-diethyl-p-phenylenediamine (DPD) has been prescribed for estimating the residual concentrations of chlorine dioxide, literature has established its caveats. For instance, DPD characteristically has a low oxidation reduction potential (ORP), making it susceptible to a high degree of interference from unintended oxidizing reactants. Non-specific oxidation may occur as the result of reactions involving chlorites, hypochlorites, monochloramines and some metals, all of which, in addition to time sensitive measurements, can lead to significant deterrents to the application of this method.

The goal of the current study is to develop a more specific and easily administered chlorine dioxide and by-products monitoring process. The use of chromogenic reducing agents such as, DPD and N,N,N,N′-tetramethyl-p-phenylenediamine (TPD) as redox indicators for oxidase reactions is investigated. Use of TPD in exchange for DPD is hypothesized to provide superior oxidization specificity as well as colour stabilization; both shortcomings to the current spectrophotometric DPD protocol. As with DPD, the mechanism for the oxidization of TPD relies upon the loss of two electrons forming a radical cation and giving rise to a bluish hue, as opposed to the reddish colour associated with the introduction of DPD. The use of DPD for spectrophotometric residual testing is common at water treatment facilities; yet similar protocols involving TPD are largely unknown.

Consequently, the three trials proposed within the current study examined the reactions of chlorine dioxide, chlorite, and chlorate with various reagents. In the first series of trials, chlorine dioxide residual was measured using 2-dihydroxyanthraquinone (alizarin red) or potentially with para-aminophenol. Secondly, the experiment sought to determine if the levels of the by product chlorite could be measured using an introduction of copper(II) sulfate. The third trial hypothesized that by measuring a combined residual (chlorite and chlorate) using the standard DPD method, while concurrently measuring chlorite using copper(II) sulfate, one could establish a chlorate concentration based on logical subtraction. Methods developed from this study will be field tested at the chlorine dioxide treatment plant in Holland, MB.

Preliminary results from the experimental study have demonstrated some promise. The oxidization of the red colour present from alizarin at 516nm in an ammonia/ammonium chloride buffered solution at a pH of 8 allowed for the quantification of residual chlorine dioxide present (0.25-4.00mg/l ClO_2) as hypothesized. The use of para-aminophenol as a quantitative reducing agent remains questionable. In the second trial, the introduction of copper(II) sulfate for the detection of chlorate was determined to show sensitivity to chlorite, but the limits of sensitivity are not sufficient for drinking water treatment applications. Further studies are required to establish whether the third hypothesis holds value.

Preparation of an alum water treatment residual solid as an adsorbent for arsenate

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Research into the reuse of water treatment residual solids has increased in recent years. One reuse application frequently researched is the reuse of alum and ferric residual solids, commonly called alum or ferric sludge, as an adsorbent material for phosphate or arsenate removal from different water matrices. Residuals are commonly air dried after dewatering, resulting in a dry solid. Previous research has shown that oven dried alum residual solids dried at 100 °C for 24 hours were a more effective adsorbent for phosphate adsorption from phosphate-spiked deionized water and municipal wastewater effluent than air dried or freeze dried residual solids. The current research has compared arsenate adsorption on alum residual solids that have been air dried at 20 °C and dried in an oven at 100 °C, 180 °C, or 250 °C, to determine if drying residuals with heat produces a more effective arsenate adsorbent. Coupled with a characterization of the solids, the differences in arsenate adsorption between alum residuals dried at these temperatures will be identified. Arsenic adsorption will be evaluated in batch adsorption experiments with adsorption isotherm modeling. Preliminary results have shown that maximum arsenate adsorption onto alum residuals dried at 100 °C, 180 °C, and 250 °C was similar. Maximum arsenate adsorption onto alum residuals dried at 20 °C was lower than the adsorption achieved with the three oven dried residuals. Residual solids dried at higher temperatures may contain more surfaces for adsorption, due to the rapid removal of water from the solid compared to solids dried slowly at ambient room temperature. Since removal at 100 °C, 180 °C, and 250 °C was similar, 100 °C was chosen as the optimal drying temperature for further experiments to minimize potential drying costs in a large-scale operation.

The detection of water quality aberrations after the injection of Escherichia Coli into tap water

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A water distribution system is vulnerable to contamination by chemicals and pathogens. Potential causes for water quality degradation include, but are not limited to, intentional malicious contamination, ingress during a pressure loss or a cross-connection. To ensure water quality is maintained, ongoing research is focused on development of a continuous, online detection system. The system being developed consists of two parts: a primary system for the initial detection of a contamination, and secondly a confirmatory system to verify the presence of a contamination. Free chlorine, total chlorine, turbidity, pH, conductivity and TOC have been selected as primary parameters in determining water quality. Importantly, the instruments used to detect these parameters are inexpensive and have the ability to operate continuously in an 'online' setting. The research described in the paper incorporates tests to determine the extent to which these general water quality parameters have the ability to detect aberrations in water quality caused by a contamination event. Firstly, tap water has been tested daily to establish variability for each of these parameters. Secondly, the research describes the ability to detect variations using the above parameters, following the introduction of Escherichia Coli into tap water at various concentrations. Experimental results from these tests show that turbidity and free chlorine are the most important parameters for determining a difference in water quality (while avoiding a false positive). An ANOVA done on turbidity data shows a significant difference at a 0.05 confidence level. The purpose of this testing is see if a signature can be created for when a contamination event has occurred, while keeping false positive identifications at an acceptable level. Multiple secondary systems are also being tested to confirm a contamination event detected by the primary sensors. Initial results using the Laser Diagnostics Instruments spectral fluorescence signature equipment are demonstrated as being effective. Detection of Escherichia Coli using this machine is possible in concentrations greater then 10^4 CFU/mL. Also, work with the Micro Flow Imagine machine from Brightwell technologies demonstrates promising findings. Particle counts generally increased when water contained Escherichia Coli at concentrations greater then 10^4 CFU/mL.

Multi-stage response and probability metric selection in data mining for identifying contaminant source ingress to a water distribution system

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The potential for intrusion of contaminants into water distribution systems has been a concern for water utilities due to aging infrastructure, potential for contamination arising from backflow and cross-connection, and the potential for bioterrorism (e.g. Preis and Ostfeld, 2008). In response, many procedures have been proposed to identify the possible nodes at which ingress might occur. Of these procedures, data mining has been demonstrated as a promising technique. Huang et al. (2008) have proposed a data mining procedure to locate the injection nodes and their corresponding probability, where the procedure is based on database query and the maximum likelihood method. The database contains injection and detection information. The injection information includes injection node, injection time, duration and mass rate, and the detection side includes time and sensor response as: normal, high, medium and low corresponding to 0, 3, 2 and 1 in database. In identifying possible ingress locations for the contaminant, elapsed time prior to being able to detect the location is a major concern, since reduction of human risk is the major objective. The earlier the contaminant is located, the lower exposure risk will be for consumers of the drinking water. This paper describes a multi-stage response procedure to locate the contamination event. Once the first response sensor, S1, indicates a contamination, the query sentence 'Find injection event in the database with S1 has response and other sensors do not' is executed.The procedure returns the probability of the injection event corresponding to a large number of possible injection nodes (denotes set A1). In the 3-D coordinate system (Time, sensor, response) with distance metric, which is the distance between centers of observed sensor responses and records in the database, the probability of each possible location of contaminant ingress is calculated; the shorter the distance and the larger the probability (denotes the 2 highest probability nodes set A1-2). Of interest is that technicians available in the utility can be sent to the set A1-2. In the second stage, a second response sensor alarm will greatly refine the estimates of the probability of the nodes at which there is ingress. The second identification of contamination ingress may be two hours later than the first one for large distribution networks, but significantly narrows the range of possible injection nodes (denotes set A2), with the query sentence 'Find injection event in the database with S1 and S2 have response and other sensors do not'. With the same distance metric, the two highest probability nodes can be identified as A2-2. Additional stages, if necessary, will follow, as additional sensors indicate the presence of contamination at other locations within the network. If the set A1-2 equals A2-2, then the utility of the procedure is highly favorable. In this context, two metrics for quantification of the probability of possible injection nodes in each stage, Euclidean distance and Mahalanobis distance, are compared. The Mahalanobis distance is expected to be the better metric for its ability to eliminate the range of time, sensor and response. The methodology is demonstrated through application to a water distribution network case study.

POSTER PRESENTATION ABSTRACTS

(By alphabetical order of presenter)

Municipal and industrial wastewater treatment by adsorption onto inert solid biomaterial derived from *Launea arborescens* plant

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Untreated or partially treated wastewaters and industrial effluent discharges into natural ecosystems pose a serious problem to the environment. In recent years, the removal of heavy metal from sewage, industrial and miningwaste effluents has been widely studied. Their presence in streams and lakes has been responsible for several types of health problems in animals, plants and human beings. Among the many methods available to reduce heavy metal concentration from wastewater, the most common ones are chemical precipitation, ion-exchange, and reverse osmosis. Most of these methods suffer from some drawbacks such as high capital and operational costs, incomplete metal removal, low selectivity, high energy requirements.

In order to reduce the concentration of the heavy metals ions, nitrate and orthophosphates, the process described in this work is rather simple, cheap and easy to extrapolate at larger scale for a practical application to the treatment of real wastewater or saltwater. It consists of the use of natural organic matter issued from dried *Launea arborescens* plant, under the form of a bed of small particles obtained by crushing, and put in contact with ions aqueous solutions [1-2]. These plants are also known to be non toxic as some of them are used in medical treatments, making them good candidates in such a process for production of drinkable water or at best for a reuse in agriculture or domestic applications [1,3].

The aim of the present paper is to study the efficiency of a new process for wastewater treatment by adsorption onto grinded and dried *Launea arborescens* plant using the batch equilibration technique. The results show that the micro- particles *of L. arborescens* plant present a good retention of heavy metals, nitrate and orthophosphate ions from real wastewater. This retention increased with increasing of contact time. The maximum adsorption capacity was depending on the type of ions (atomic weight, ionic radius and structure…). The results indicate that the chemical oxygen demand (COD) values decrease after contact with micro-particles of dry plant. The results obtained are compared with those obtained from laboratory solutions with various concentrations and from distilled water. These results also indicate that the inert solid biomaterials could be used for removal of heavy metals and pollutant minerals from wastewater.

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Traitement physicochimique des biofilms adhérant sur des installations agroalimentaires afin d'éviter la contamination des eaux usées industrielles

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Dans l'industrie agroalimentaire, la présence de microorganismes adhérents et formant des biofilms présente une source de contamination, qui peut se traduire par l'altération des produits et la contamination des eaux usées rejetées par ces industries agroalimentaires. Afin de garantir une bonne qualité microbiologique des aliments transformés et préserver la qualité de l'eau rejetée, il est nécessaire d'étudier la cinétique de formation de ces biofilms et trouver des méthodes efficaces permettant leur élimination.

Pseudomonas fluorescens (souche a et b) et *Kocuria varians* sont des souches isolées sur des chaînes agro-industrielles et qui ont des capacités importantes à adhérer et former des biofilms.

Une étude de la cinétique de formation des biofilms sur des coupons en acier inoxydable placés dans un bécher contenant du lait écrémé dilué au 1\10 et soumis à une agitation, a été faite pour les trois souches différentes, afin de tester leur résistance aux procédures de nettoyage. Cette étude montre que les souches testées possèdent des capacités d'adhésion et de formation des biofilms importantes, avec des cinétiques de formation différentes. De plus, il a été montré que le changement du milieu n'a pas d'effet significatif sur la cinétique de formation des biofilms des trois souches testées. De plus, il a été mis en évidence que les biofilms de *Kocuria varians* sont plus résistants à l'action de la soude 0.5% pendant 12 min et à température ambiante que les biofilms des deux autres souches.

Lors des expériences de l'étude de l'effet du rinçage à un débit de 100 $l.h^{-1}$ (régime transitoire, nombre de Reynolds=2350), nous avons utilisé une boucle de rinçage formé d'une pompe péristaltique, d'une cuve de 10 litres et des tubes carrés contenant les coupons. Par la suite, nous avons pu montrer que ce rinçage a permis la diminution de moins d'une puissance de 10 de la population initiale. De plus, nous avons mis en évidence le fait que les biofilms formés sans renouvellement du milieu sont plus résistants à l'action mécanique que ceux formés avec renouvellement du milieu.

Au total, les biofilms de *Kocuria varians* sont plus résistants a l'effet du nettoyant que les biofilms des deux autres souches. *Kocuria varians* constitue un risque de contamination des milieux agro-industriels et leurs eaux usées rejetées plus important que les deux autres souches. Pour cette raison, il s'avère nécessaire d'utiliser des conditions de nettoyage plus strictes, pour éliminer cette souche des circuits agroalimentaires et par la suite des eaux résiduaires.

Réponse du bassin versant de la rivière aux Brochets en termes d'érosion et de perte de nutriments, sous deux scénarios de changement climatique, modélisés à l'aide de SWAT : le calibrage

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Au Québec, les cyanobactéries, plus communément appelées algues bleues, font la une des journaux depuis plusieurs étés. Lors des grandes chaleurs estivales, ces micro-organismes toxiques, mi-algues mi-bactéries, prolifèrent dans les plans d'eau soumis à de forts apports en nutriments, étant pour l'essentiel de l'azote et du phosphore. Ces éléments ont majoritairement pour origine la pollution diffuse causée par les activités agricoles. En effet, le phosphore, facteur limitant la croissance des plantes et des cyanobactéries, s'associe aux particules de sols facilement érodables, entrainées par les pluies et le ruissellement de forte intensité. Le cheminement du phosphore, de la parcelle agricole jusqu'au plan d'eau se fait aussi par ruissellement. Les conséquences de cette contamination des lacs par un surplus de nutriments et, par les cyanobactéries ne sont pas à prendre à la légère : non seulement elles témoignent de l'eutrophisation accélérée du plan d'eau, mais surtout met en danger la santé publique lorsque celui-ci est source d'eau potable ou une aire récréative de baignade. Dans le contexte des changements climatiques, les événements de fortes précipitations se font de plus en plus récurrents et s'intensifient. Ajouté à une hausse des températures, autre facteur important initiant la prolifération des algues bleues, les futurs scénarios climatiques prévoient un aggravement de la situation actuelle. L'étude menée vise donc à établir un premier portrait de l'évolution de la réponse du bassin versant de la rivière aux Brochets, en termes d'érosion et de perte de nutriments, sous différents scénarios de changement climatique. Le bassin versant de la rivière aux Brochets, situé à cheval entre le Vermont et le Québec en Montérégie , est très agricole et ses eaux se drainent dans la baie Missisquoi, sujette depuis de nombreuses années à de graves épisodes de contamination par les cyanobactéries. C'est une région déjà longuement étudiée par l'équipe du Centre Brace (Centre de recherche pour la gestion des ressources en eau) de l'université McGill ainsi que par l'équipe de bassin versant et géomatique de l'IRDA (Institut de recherche et réveloppement en agroenvironnement inc.). Ces derniers ont déjà effectué de nombreux travaux de modélisation hydrologique du bassin versant à l'aide du logiciel SWAT (Soil and Water Assessment Tool). En partant de ces travaux, la modélisation du bassin versant sera réentreprise avec des données de deux scénarios climatiques provenant du MRCC (Modèle Régional Climatique Canadien) fourni par OURANOS (Consortium ayant pour but de développer les connaissances sur les changements climatiques ainsi que leurs impacts au niveau régional). Les périodes retenues sont 1971-2000 et 2040-2069. Précédent cette étape, le modèle aura été testé et calibré avec un autre ensemble de données simulées par le MRCC, couvrant cette fois-ci la période 1990-2001. Les données de ruissellement, d'érosion et perte de nutriments (N et P) simulées par SWAT sur les deux périodes de trente ans pourront ensuite être analysées. À ce stade du projet, une partie du calibrage est terminée et les futurs scénarios climatiques pourront être commencés ultérieurement. En terme de résultats, un accroissement de l'érosion et de la perte des nutriments est à prévoir sur les zones les plus sensibles du bassin. Ce type d'étude est une étape préliminaire pour comprendre et dresser un portrait possible de l'évolution futur des cyanobactéries dans la baie Mississquoi.

Stochastic and deterministic approaches of climate data to evaluate the potential climate change impacts

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To analyse potential climate change impacts, long time series of present and future climate data are required. A stochastic multi-site weather generator and a Canadian Regional Climate Model (CRCM) are tested in this study. The first approach is increasingly being used in hydrology, agriculture, environment and climate change studies to simulate series of climate data for any length of time with similar statistics as observations. The multi-site nature of this generator is required to take into account the spatial dependence exhibited by the observed data.

The CRCM is a downscaling tool to create limited scale climate scenarios from coarse resolution Global Circulation Models (GCM). The CRCM version used for this study is CRCM (4.1.1) driven by ERA40 global atmospheric reanalysis provided by the European Centre for Medium-Range Weather Forecasts (ECMWF).

The multi-site weather generator is applied to generate precipitation, maximum and minimum temperature data using twenty weather stations located on South-West of Quebec and South-East of Ontario. The climate data are generated, while maintaining efficient spatial dependence. These results are compared to those obtained by the CRCM as well as the observed data for the same area.

Performance indices are used to test the efficiency of models. Using the multi-site weather generator, sufficiently accurate performance indices are obtained for all the climate data. Using the CRCM, some discrepancies are obtained in the reproduction of the performance indices, mainly due to the differences between the regional scale of the CRCM and the local scale of the weather stations. A current work aims to develop a statistical downscaling methodology to evaluate the climate change potential impacts.

Transport and retention of engineered nanomaterials in model groundwater systems

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Engineered or manufactured nanoparticles are used in the fabrication of a wide range of consumer products. For example, oxide nanoparticles (TiO_2, ZnO) can be used as pigments, sunscreens, cosmetic additives and optoelectronic materials. In Quebec, more than 400 million dollars have already been invested in nanotechnology, with projections that by 2015 the market may attain 20 billion dollars. The use and disposal of engineered nanoparticles will inevitably result in their accumulation in soils, water, air and organisms. In spite of their growing and widespread use, the impacts of these materials on the environment and human health remain largely unknown.

Well-controlled laboratory column experiments were conducted to better understand the transport potential of TiO_2 nanoparticles in model groundwater environments. Experiments were carried out using a glass chromatography column packed with quartz sand as a model granular porous medium. Two detection methods were used to evaluate the concentration of nanoparticles in the column experiments: (i) UV/vis spectrophotometry, and (ii) inductively coupled plasma optical emission spectroscopy (ICP-OES). The two measurement techniques demonstrated comparable results. Experiments conducted over a broad range of water chemistries revealed significant differences in the transport and retention behaviour of the TiO_2 nanoparticles. Moreover, the particle preparation procedure was found to play an important role in nanoparticle physicochemical properties (i.e., zeta potential and size) and nanoparticle migration potential. These data are interpreted within the context of the classical theory of colloid stability to evaluate the relevance of this theory to nanoparticle transport behaviour.

Role of water chemistry on the groundwater contamination potential of Quantum Dots

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Engineered nanoparticles, generally accepted to be materials having one characteristic dimension less than 100 nm, are used in the fabrication of numerous consumer goods including paints, soaps, coatings, cosmetics, sunscreens and tires. For example, quantum dots (QD) (e.g., CdTe, CdSe) are widely used in medical imaging and in sensors. In Quebec, more than 400 million dollars have already been invested in nanotechnology with projections that by 2015, the market may attain 20 billion dollars. The use and disposal of engineered nanoparticles will inevitably result in their accumulation in soils, water, air and organisms. In spite of their growing and widespread use, the impacts of these materials on the environment and human health are largely unknown.

In spite of the risks associated with the release of nanomaterials in the environment, studies have only recently begun to address their transport, fate or bioavailability. To better understand the migration potential of QDs in natural subsurface environments, a well-controlled study was conducted to examine the transport and deposition of this nanomaterial onto model sand (SiO_2) surfaces. A quartz crystal microbalance with dissipation monitoring (QCM-D) was used to measure QD deposition onto clean silica. Nanoparticle deposition kinetics onto silica are determined by following changes in the resonance frequency of the quartz crystal over a broad range of environmentally relevant water chemistries, including variations in ionic strength, pH and ion valence. QD deposition behaviour in different water chemistries is related to variations in nanoparticle charge and nanoparticle size, analyzed by Dynamic Light Scattering and Nanoparticle Tracking. Complementary studies conducted with laboratory-scale packed column experiments examine the migration behaviour of the nanoparticles in model granular porous media. The environmental implications of this experimental study in relation to the protection of natural aquatic systems will be discussed.

Effects of unsaturated long chain fatty acids (LCFAs) and volatile fatty acids (VFAs) on hydrogen consumption

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During anaerobic degradation, carbon substrates are oxidized in a series of sequential reactions to C1 compounds such as methane. Electrons liberated during oxidation are used to reduced protons and carbon dioxide to hydrogen and methane, respectively. Hydrogen and carbon dioxide are ultimately combined to yield methane. Microorganisms mediating the degradation reactions include hydrolytic microorganisms, acidogens, acetogens and methanogens. Complex reduced carbon substrates such as carbohydrates undergo a series of degradation reactions which convert them into reduced carbon intermediates plus hydrogen. The intermediate carbon substrates are further oxidized and eventually converted into methane plus carbon dioxide.

Another carbon substrate which is oxidized by hydrogen producing acetogenic anaerobes is long-chain fatty acids (LCFAs). LCFAs are a byproduct of lipid hydrolysis and are inhibitors of anaerobic microorganisms at threshold concentrations. LCFAs exert irreversible inhibitory effects on several anaerobic microbial populations and consequently, decrease the treatment efficiency. However, the latter could be advantageous if the electron fluxes arising from carbon oxidation can be diverted to produce hydrogen. LCFAs are unique substrates which are useful in achieving this objective. These chemicals are inhibitory to many hydrogen consuming anaerobic microorganisms such as hydrogenotrophic methanogens, homoacetogens and sulfur reducing bacteria (SRB).

Short chain volatile fatty acids (VFAs) are byproducts from carbohydrate degradation and produced by the action of acetogenic microorganisms. At elevated levels, VFAs such as acetate, propionate, and butyrate are inhibitory to many anaerobic populations. During the anaerobic conversion of dairy effluents containing lactose and oleic acid, high concentrations of LCFAs and VFAs will inhibit hydrogen consumers and hydrogen will accumulate.

In these studies, hydrogen consumption by a mixed anaerobic culture was assessed in the presence of LCFAs and VFAs. LCFAs (2000 mg l^{-1} LCFA (linoleic acid (LA) and oleic acid (OA)), VFAs (500, 1000, and 1500 mg l^{-1} of acetate, propionate, butyrate) plus hydrogen (500 μmole) were added to an anaerobic mixed culture which was maintained at pH = 7.6-7.8 and at 23±2^{o}C. Both OA and LA were inhibitory to hydrogen consuming microorganisms. However, the level of inhibition was greater with LA compared to OA. All three VFAs (acetate, propionate, butyrate) when added individually were not inhibitory. The presence of VFAs at all concentrations enhanced the inhibitory effect by LCFAs on hydrogen consuming microorganisms. The inhibition of hydrogen consuming microorganisms was also dependent on VFA concentration. An increase in the incubation time (from 0 to 2 days) with OA significantly increased the inhibition of hydrogen consumption.

Etude de la biodégradabilité des effluents de l'industrie papetière à base de pâte d'alfa

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La fabrication du papier est l'une des activités industrielles qui non seulement exploitent directement des ressources forestières comme matière première en les appauvrissant, mais aussi elles font partie des plus grandes consommatrices d'énergies et des plus polluantes des ressources d'eau. Cet état de faite provient des processus multiples que nécessitent les premières phases d'extraction (cuisson, lavage…) et de l'emploi des adjuvants chimiques dans ce processus. Les effluents générés se caractérisent par une DCO (demande chimique en oxygène) qui dépasse largement les 3500g/l, par des odeurs et couleurs très prononcées et par la présence de substances toxiques (dioxines, furannes…). Le traitement de ces effluents s'avère indispensable pour éviter une possible contamination des eaux de surface ou de profondeur. Dans cet objectif, une étude a été menée dans le but de tester les possibilités de l'application de la digestion anaérobie pour le traitement de ces effluents, une méthode qui permet à la fois de remédier aux problèmes de pollution et en même temps qui a un avantage économique intéressant grâce à la production de méthane par la microflore présente. Les échantillons dans cette étude ont été récupérés après la première phase d'extraction (lessive noire), et vers la fin du processus. Les tests de biodégradabilité ont été faits selon la norme allemande DIN-EN -ISO -11734. Le suivi de la biodégradabilité de ces effluents a été réalisé moyennant les mesures des quantités et de la composition de biogaz produit, des acides gras volatils totaux (AGVT), des teneurs en solides totaux (ST) et en solides volatils (SV), du pH et de l'azote ammoniacal, et ce pendant deux semaines. L'inoculum employé provient d'un digesteur fonctionnant en continu et qui traite les ensilages de maïs. Les résultats obtenus ont démontré que la flore anaérobie était capable de réduire les teneurs en ST et SV entre le début et la fin du test. Aucun effet inhibiteur n'a été signalé au cours de ce suivi, la diminution du pH en témoigne. Les teneurs en méthane dépassent les 60 % après une semaine, aussi bien pour l'inoculum (la référence) que pour les deux types d'effluents étudiés. La production du biogaz est reliée à la disponibilité des nutriments. En effet, l'effluent à teneur en matière organique la plus élevée génère le plus de biogaz**.** L'application de la digestion anaérobie permet de réduire la charge polluante des effluents de l'industrie papetière, aussi bien pour les effluents de la première étape d'extraction (lessive noire) que pour ceux de la sortie de l'usine. Le pourcentage de méthane obtenu prouve l'intérêt de ce procédé en termes tant de dépollution que de création de nouvelle source d'énergies.

Effects of lauric acid (C_{12}) on hydrogen production from glucose by an anaerobic mixed culture

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Improving hydrogen production in anaerobic mixed cultures requires inhibiting hydrogen consumers such as hydrogenotrophic methanogens and directing excess electron equivalents towards hydrogen. Long chain fatty acids (LCFA) such as linoleic acid (LA) and oleic acid (OA) have been reported to successfully decrease methane production and subsequently increase the hydrogen yield to approximately 2.5 mole H2/mole glucose. During degradation, LA degrade by β-oxidation into shorter chain LCFAs, (C16, C14, C12, C10, C8 and C6). This research examines the effects of lauric acid (C12) on hydrogen production from glucose by mesophilic (37oC) anaerobic mixed cultures at pH 5 and 7.6. In comparison to control cultures, lauric acid enhanced hydrogen production at initial pH 7.6 while at pH 5 less hydrogen was produced. The combined effects of 2000 mg/l lauric acids and pH 5 reduced methanogensis greatly. A hydrogen yield of 0.78 mole H2/mole glucose was obtained in cultures inoculated with 2000 mg/l lauric acid plus 5000 mg/l glucose an initial pH of 7.6. Culture inoculated with lauric acid at pH 5 produced more propionate than the controls and this was accompanied with a decrease in hydrogen production. Control samples at an initial pH value of 5 showed acetate and butyrate accumulations. In the presence of lauric acid, glucose degraded at a slower rate than in control samples. In the lauric acids control samples, negligible hydrogen production was observed at both initial pH values.

Methane production was inhibited in culture receiving lauric acid at initial pH 5 but the electron flux was not efficiently directed to hydrogen production and a mild metabolic shift to other byproducts was observed. In the presence of lauric acid, more methane was produced in cultures at initial pH 7.6 compared to cultures at initial pH 5, but more electron equivalents were directed to hydrogen production. In comparison to C18 LCFAs, lauric acid is not as effective as linoleic acid and oleic acid in inhibiting methanogens at initial pH 7.6 and also in directing the electron flux towards hydrogen at initial pH 5.

Biopile bioremediation of petroleum hydrocarbons in soils from a Northern site

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Petroleum contamination of several sites in the northern arctic and sub-arctic regions of Canada has occurred as a result of activities related to petroleum oil exploration and production, and due to uncontrolled discharges during the extensive use of petroleum fuels for heating, transportation and electricity generation. Petroleum contamination can persist in the ground for long periods of time and be a source of long-term environmental contamination. Rapid treatment of contaminated active layer soils and prompt replacement over underlying permafrost layers limits damage to permafrost and helps with environmental preservation. Successful remediation of sites in northern regions has wide spread benefits to the resources of land and water.

Bioremediation is often considered for clean up of petroleum-contaminated sites in northern regions because it is a non-disruptive and cost-effective technology for remediation of petroleum contaminated sites. Although research has shown that indigenous microorganisms in soils from northern sites can achieve significant biodegradation of petroleum hydrocarbons, the biodegradation rates are slower at cold temperatures. Strategies to accelerate biodegradation rates under cold temperatures are thus needed.

In this research, the biodegradation of petroleum hydrocarbons in crude oil-contaminated soils from a site in Norman Wells, Northwest Territories, were monitored in microcosm, and pilot-scale biopile systems. The systems were maintained at 6 C, a temperature representative of the site in summer months. Characterization the site soils revealed low levels of inorganic nitrogen, and thus microcosm and pilot-scale experiments were conducted to evaluate the effects of biostimulation by addition of various concentrations of ammonium. Petroleum hydrocarbon concentrations in biostimulated systems were reduced by approximately 20% over a one month period whereas there were no reductions in the untreated control systems. The changes in ammonium and nitrate concentrations were determined in the biostimulated systems by ion chromatography and spectrophotometry to determine the rates of nitrification. The presentation will include an evaluation of interrelationship between the rate of nitrification and the rate of petroleum hydrocarbon biodegradation.

Kinetic formulations for growth and substrate uptake in biological wastewater treatment

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The hyperbolic kinetic expression proposed by Monod (1949) is omnipresent in models of biological wastewater treatment, becoming the de facto standard. It well-describes biomass growth of mixed cultures in a batch environment in the growth and substrate limited phases of the culture where endogenous decay is of minor importance. In the '60s-'80s other kinetic formulations were used in models but by the '90s, the Monod model had become dominant.

Models used in biological wastewater treatment are Eulerian gross descriptors of a process involving mass transfer, many substrates, and metabolic pathways and their enzymes, contained within many microorganisms. Any model at this level is merely a fit of mathematical formulations to data. As number of processes in biotreatment models increases along with mathematical descriptors and their associated coefficients, fitting an overall model improves to a point. But beyond this there has been little justification of the Monod expression. The formulation has been roundly criticized by many authors as being inadequate for dynamic simulations in particular (Blackwell, 1971).

The following formulation is for the rate of substrate removal expression.

$$r_S = -\frac{kX_H S}{K+S} \qquad (3)$$

where k is maximum rate (velocity) constant; K is the half-velocity constant; r_S is rate of substrate removal ($ML^{-3}T^{-1}$)

Models comparition:

International Water Association (IWA) proposed ASMs(Activated Sludge Models No1,No2 and No3) which are the most important advancement in modeling biotreatment. ASM 1 first introduced dual hyperbolic kinetic expression to describe hydrolysis of slowly degraded organics. The expression is hyperbolic with respect to both substrate and viable biomass:

$$r_h = -\frac{k_h X_H X_S}{K_X X_H + X_S}$$

where k_h is hydrolysis rate constant; K_X is the half-velocity constant; r_h is rate of hydrolysis; X_S is concentration of slowly degraded substrate

ASM3 was a significant modification of ASM1 where some changes were made for issues of parameter identifiability and other reasons, although the number of parameters increased in ASM3 compared to ASM1. Storage was explicitly incorporated into ASM3 as a state variable. The dual hyperbolic control kinetic expression also played a more prominent role in ASM3. Flow charts of ASM1 and ASM3 are shown in Fig. 1.

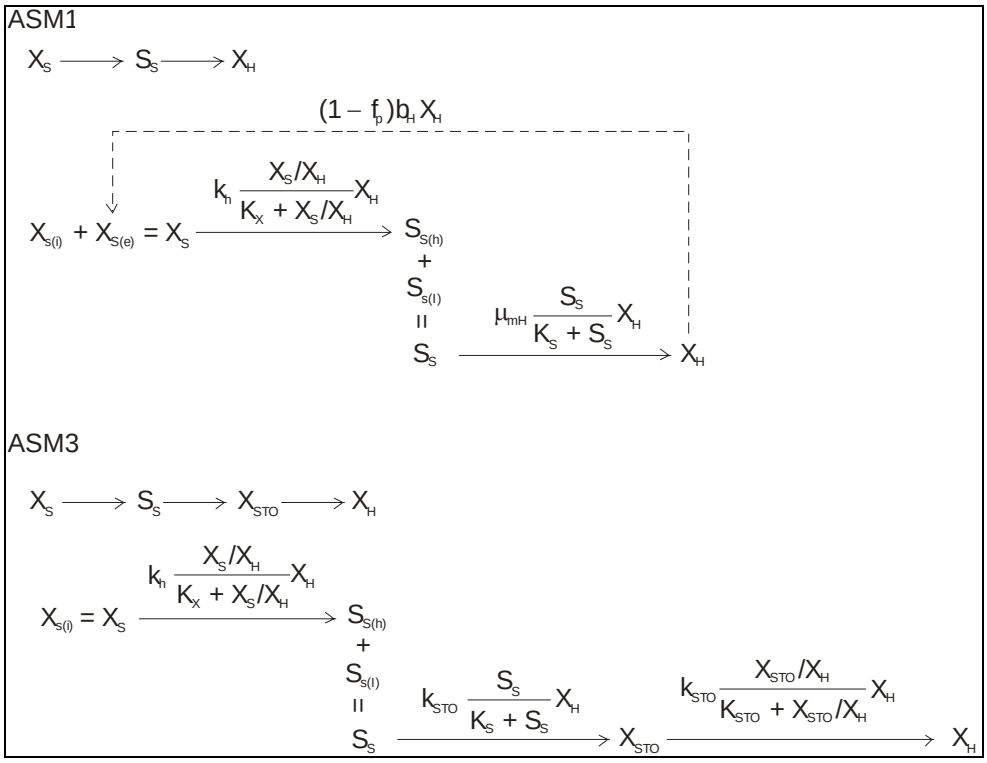

Figure 1.Susbtrate flow charts and kinetic expressions in ASM1 and ASM3. Subscript i refers to influent entities.

Although ASMs models can describe biological process well, they didn't take into account mass transfer. This paper examines conceptualizations that include hyperbolic metabolic expressions of Monod or Michaelis-Menten forms but also incorporate specific equations related to mass transfer.

Mass transfer or substrate capture is a process that is independent of metabolism. Captured substrate is metabolized according to a reasonable kinetic expression. The substrate flow chart proposed here is given in Fig. 2.

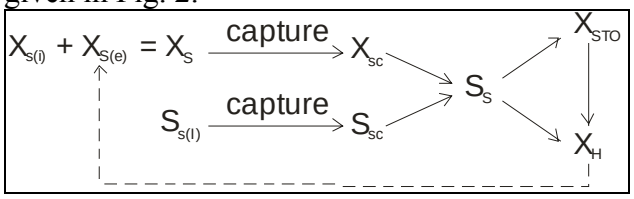

Figure 2.Substrate flow in the proposed model. X_{SC} and S_{SC} are captured slowly degraded and simple substrates, respectively

A justification for the dual hyperbolic expression is given. A model where mass transfer affects both slowly degraded and simple substrates is also proposed for exploration.