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Detection of human enteric viruses in fractured bedrock aquifers

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Problem statement: More than 30% of the Canadian population depends on groundwater for domestic use. Groundwater is susceptible to microbial contamination: precipitation and surface water recharge mechanisms, in conjunction with local hydrogeology, control the microbial and chemical content of groundwater. Waterborne human viruses are considered important groundwater contaminants because groundwater is often consumed untreated and the minimal infectious dose for human viruses can be as low as one virus particle. Groundwater underlying karstic or fractured bedrock aquifers is considered particularly vulnerable to contamination. Since virus concentrations in groundwater are inevitably low, large sample sizes and sample concentration is necessary for their detection.

Objectives: The objective of the current study was to explore the occurrence of human enteric viruses in the groundwater of three fractured bedrock aquifers.

Methodology: Groundwater samples (n=48) were collected from 26 wells in three fractured bedrock aquifers in Newfoundland, Ontario and British Columbia over one year. The Ontario site included experimental wells to examine impacts from known sources of contamination, whereas in Newfoundland and British Columbia it was domestic wells that were sampled. Most samples were approximately 1000 L in size and filtered through Nanoceram (nano-alumina) positively-charged filters as a new approach for concentrating and isolating viruses. Filters were eluted with 400 mL of 1.5% beef extract (pH 9.3) and viruses were precipitated using 400 mL of 16% polyethylene glycol. The pellet, obtained after spinning at 15,000 x *g* for 30 minutes was resuspended in 10 mL of Hypure water and then filtered through a 0.2 µm membrane. Viral RNA (140 µL) and DNA (200 µL) were extracted from samples using Qiagen kits and virus detection used either RTPCR (RNA viruses) or PCR (adenoviruses). Quantification of the viruses using real-time PCR is in progress.

Results: The results show the presence of human enteric viruses in the wells – adenoviruses, including types 40 and 41 that are specifically associated with enteric infections (23%), enteroviruses (11.5%), as well as rotaviruses (47%). Norovirus was not detected in any of the samples, while hepatitis A was detected in one well. Most of the rotavirus-positive samples were collected between March and May which emphasizes the seasonality of this virus.

Discussion and Concluding Remarks. Viruses detected were identified by molecular techniques which do not indicate infectivity. However, the study is ongoing and we expect to confirm all or some of the virus-positive samples will contain infectious virus. The exact source for the viruses has for the most part not been determined, but the septic system from a health centre is perhaps implicated for one or more of the experimental wells. In fractured bed rock or karstic aquifers it is difficult to predict the direction and distance of travel, but in such rural areas as were sampled, septic systems might have a major contribution to aquifer contamination and imperfect grouting of groundwater wells could lead to direct contamination from the surface. Very little information is available on the microbial quality of groundwater in Canada, and more studies of this type need to be conducted.

A Recycled Media Passively Aerated On-Site Sewage Treatment System

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The Charlottenburgh Park on-site sewage system has been designed to provide a full-scale research system which will compare alternative design options by incorporating recycled waste products into the on-site sewage treatment matrix. The intention is to determine whether recycled products and passive treatment mechanisms are capable of producing enhanced treatment opportunities compared to conventional disposal designs through a sustainable, innovative and performance-based approach.

Charlottenburgh Park is a 40 ha recreational and interpretative park located on the northern shore of Lake St. Francis (St. Lawrence River) about 30 km east of Cornwall. The Park currently has 200 camping sites and a Day-Use area serviced by two comfort stations including showering and washroom facilities. As part of the site's re-development theme of sustainable technology, TRG designed a series of unique passive sewage treatment systems employing both conventional and recycled media. The design sewage flow for the sewage system is 30,000 L/day.

The objectives of this project have been formulated to provide a direct comparison of the on-site wastewater treatment capabilities of conventional aggregates and recycled waste products in both unsaturated and saturated wastewater flow conditions; determine whether tire shed is capable of providing a direct reduction of sewage contaminants;

- Determine whether tire shed is capable of producing a higher quality effluent when compared to conventional aggregates under similar environmental and wastewater loadings conditions;
- Determine whether oxygen diffusion plays a key role in wastewater treatment under conventional flow patterns;
- Develop design tools to facilitate routine application of this technology for various sites and development applications using performance-based standards;
- Integrate sustainable management of non-renewable resources with innovative uses of waste materials to allow for a greater degree of flexibility in on-site wastewater treatment.

The system is being evaluated by monitoring the subsurface water environment for both quantity and quality parameters as well as observing the changes in the treatment apparatus over time and space. The water quality observations will include target contaminants which are routinely used as performance indicators in current on-site wastewater design.

The sewage flow rates discharged to the recycled media absorption trenches has increased from 5,500 L/d (2008) to an average of 9,000 L/d (2009). The preliminary findings indicate that 80 to 90% of the $cBOD_5$ loading and about 90% of the total phosphorus loading to the system is being removed at the absorption trench base. It has also been reported that the pH of the effluent samples has reduced from approximately 7.1 at the onset of the study to 4.5 currently.

Continued monitoring at the design flow rates and further analysis of the analytical data is required to confirm these findings.

RESPONSE OF SOIL-BENTONITE LINERS TO LEACHATE OF BIOFUEL

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ABSTRACT: Landfill liners failure is one of the most problematic issues that face engineers and expose governments, societies, and environment to high costs. Protection of groundwater requires that natural landfill liner structure would be able to preserve its properties in harsh conditions and over a long period of time. However, the composition of disposed residuals might change in the following contemporary trends and it could contain alternative fuels, which impact on natural liners is unknown. Therefore, this research focuses on the changes within the sand/bentonite liner structure due to the percolation of biofuel and ethanol-fuel.
A series of laboratory tests were performed in 20 cm-high PVC columns where various compositions of sand/bentonite liners were placed. This paper consider test on liners 100% sand (passed mesh #40), 95% sand: 5%bentonite, and 90%sand: 10%bentonite.

The columns were subjected to different pressures (20 kPa, 40 kPa, and 100 kPa) to evaluate the transport of alternative fuels and displacement of fine particles throughout the liner samples. The same tests were done with water for comparative studies. Rising of groundwater and leakage from the landfill were carefully simulated.
The movement of fine particles within liner was demonstrated as well as its effect of on the liner hydraulic conductivity. Results showed that hydraulic conductivity decreased thorough the liners, and this decrease depended on type of liner mixture, type of liquid, flow direction, pressure, and the period of flow.

The hydraulic conductivity compared to water increased In the case of bio-fuel percolating a liner consisted of 5% bentonite: 95% sand under pressure of 40 kPa by 32 times, and 20 times under pressure of 100kPa. For liner consisted of 10% bentonite: 90% sand, the hydraulic conductivity increased by 2277 times under pressure of 40 kPa, and 1437 times under pressure of 100 kPa.

Such direct impact on liner properties affects the ability of the liner attenuation of other substances (e.g. heavy metals) contained in the leachate. Subsequently, the risk of groundwater contamination dramatically increases.

Key words: landfill leakage, sand-bentonite liner, biofuel, Ethanol, fine-grained soils, hydraulic conductivity, particle mean size, liner failure.

Operation and Hydrodynamic Characteristics of a Novel Multi-Environment Wastewater Treatment System

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A new multi-environment treatment system has been developed for the treatment of wastewater and contaminated groundwater. The technology is based on a unique design that uses two interlinked reactors containing four zones with different environmental conditions of aerobic, microaerophilic, anoxic and anaerobic for biological treatment as well as two clarification zones and a filtration unit for efficient separation of solids from liquid. The presence of these environmental conditions which are defined based on their respective concentrations of dissolved oxygen (DO) and oxidation-reduction potential (ORP), supports the growth and proliferation of a diversified group of suspended as well as fixed-film microorganisms and ensures the removal of organic contaminating compounds as well as the polluting inorganic nutrients that demand this diversity for their complete removal. Figure 1 presents a schematic diagram of the developed technology. The first reactor contains three interactive zones of aerobic, microaerophilic and anoxic plus a clarification zone. The second reactor contains an anaerobic zone, a solid-liquid separation zone and a filtration unit. This arrangement minimizes possible interferences between the biological treatment and solid-liquid separation processes while enabling proper optimization and control of each individual process. The mixed liquor continuously circulates between the aerobic, microaerophilic and anoxic zones in the first reactor, thus exposing the contaminating compounds to three different environmental conditions during each cycle. This operation strategy ensures a high biodegradation rate of organic and inorganic contaminants by a diverse group of microorganisms that accumulate at a high concentration inside various zones of the reactor. The treatment system is expected to have an odor-free operation, generate a reduced amount of greenhouse gases and produce considerably less sludge compared to conventional technologies.

The impact of operating parameters such as the hydraulic retention time (HRT) and superficial gas velocity (U_G) on the hydrodynamic characteristics of the system, including the gas hold up (ε), liquid circulation velocity, oxygen transfer coefficient (K_La) and residence time distribution (RTD) in various zones of the treatment system were investigated. The governing parameters that control the generation of zones and liquid flow pattern in the system were identified. Experimental analysis showed that at higher air flow rates, the mixing performance of the first reactor resembles the patterns observed in a continuous stirred tank reactor (CSTR).

The time-dependent changes in the volume of wastewater inside the treatment system were mathematically expressed and its dependence on the number of liquid circulations between the aerobic, anoxic and microaerophilic zones was determined. This analysis showed that for an influent flow rate of 1000 L/day, liquid circulates between 250 to 550 times between the zones before 90% of bioreactor's volume is replaced by the added wastewater. Under the same condition, liquid circulates between 500 to 1100 times for 99% liquid displacement.

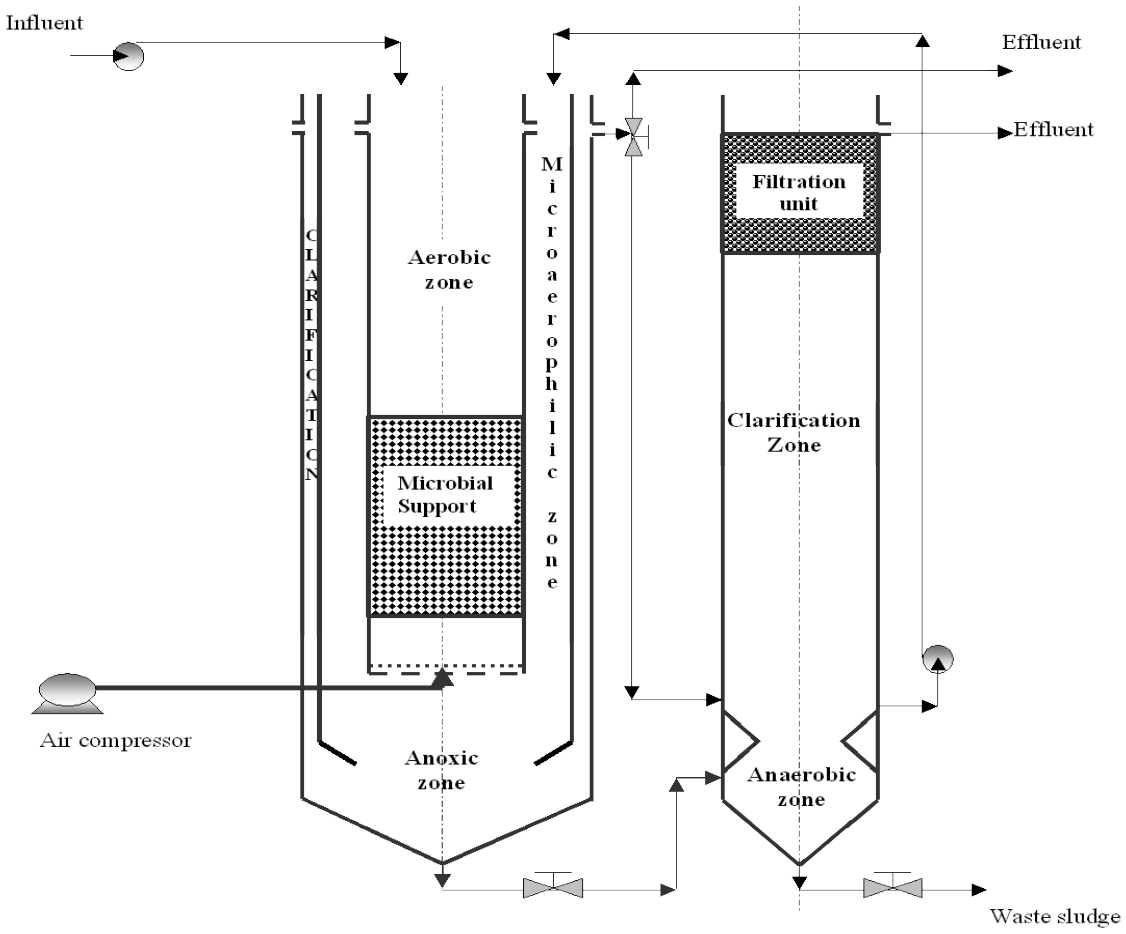

Figure 1: Schematic diagram of the new multi-environment wastewater treatment system

Modélisation d'un système de traitement individuel d'épuration

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Le traitement de l'azote des eaux usées est présentement un enjeu important, à cause des nombreux problèmes qu'il engendre dans l'environnement. Les technologies de traitement sont relativement bien connues et étudiées pour l'élimination en station municipale, mais ils le sont beaucoup moins dans le cas de petits systèmes résidentiels. De plus, bien que des réglementations sur l'azote ne soient pas présentes partout, il est fort possible, voire certain, que cette situation change dans un avenir proche. D'ailleurs, au niveau des applications communautaires et institutionnelles, l'engagement no 40 de la Politique Nationale de l'eau vise à diminuer la toxicité des effluents municipaux. Depuis le 16 février 2009, les stations d'épuration qui reçoivent de fortes charges en azote ammoniacal devront éventuellement en fonction des priorités à établir, prendre des mesures pour réduire leurs rejets de ce contaminant.

La modélisation est un outil de plus en plus souvent utilisé pour, entre autres, étudier et optimiser les diverses étapes du traitement des eaux d'une station d'épuration. Toutefois, la simulation n'a jamais vraiment été envisagée dans le cas d'un traitement individuel. Son utilisation dans cette situation risque pourtant d'être fort utile si le besoin de se conformer à une norme sur les rejets en azote apparait.

L'objectif de ce travail est d'étudier et de modéliser le comportement de l'azote pour un procédé de traitement résidentiel d'eau usée.

Une unité pilote traitant des eaux grises et noires a été installée dans les locaux de la compagnie produisant le procédé. Le système étudié comportait une fosse septique ainsi qu'un réacteur biologique à support fixe, dont une partie est aérée. La sortie de ce réacteur était en partie recirculée vers l'entrée de la fosse. Un suivi sur plusieurs semaines de plusieurs paramètres (DCO, NH_3, O_2…) a été effectué quotidiennement et/ou hebdomadairement sur chaque entrée et sortie ainsi que dans chaque étape du traitement. Le suivi a été réalisé à la fois en fonctionnement normal, en surcharge ainsi qu'en fonctionnement sans recirculation. La modélisation est quant à elle réalisée à l'aide du logiciel de simulation GPS-X™. Les différentes étapes du traitement réel y sont représentées par un décanteur primaire (fosse) ainsi qu'un réacteur hybride, permettant la croissance fixe et suspendue (réacteur). Une étude de sensibilité a été réalisée pour cerner quels paramètres influencent le plus les prédictions du modèle. Celui-ci a par la suite été calé en comparant les résultats obtenus sur le pilote sous différents régimes à ceux simulés.

Les résultats obtenus montrent que le système étudié élimine en moyenne 90% de l'azote ammoniacal et de l'azote total Kjeldahl. Les mesures de DCO ainsi que des MES effectuées à l'effluent du système n'ont également jamais dépassé les 36 mg O_2/L et 3 mg/L, malgré des valeurs moyennes à l'entrée de 271 mg O_2/L et 218 mg/L respectivement. Le modèle construit et calé montre également une bonne fidélité par rapport aux valeurs mesurées sur le pilote en sortie de chaque étape du traitement. La modélisation semble donc pour le moment être un bon outil pour faciliter la compréhension et l'étude des performances d'un système de traitement résidentiel des eaux usées.

Comprehensive Wastewater Treatment Plant and Sludge Pretreatment Model

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Organic matter hydrolysis prior to anaerobic digestion has been shown to improve biogas production (30-50%) and reduce solids (20-60%) by ultrasound, chemical, conventional heating, and microwave pretreatments. Numerous studies have been performed to determine the extent of digestion improvement but few focus on financial feasibility of these processes. A comprehensive model was created using Microsoft Excel and its Visual Basic Assistant to evaluate pretreatment permutations for conventional wastewater treatment plants. The four above-mentioned processes were evaluated for energetic and financial demands. Well-established energy equations and wastewater characteristics, both average and high, were used. Average and high flows were 460 and 750 × 103 m^3/d, respectively. Net costs per influent flow for ultrasound, chemical, conventional heating, and microwave were 0.0166, 0.0217, 0.0124, 0.0119 \$/m^3 and 0.0264, 0.0357, 0.0187, and 0.0162 \$/m^3 for average and high conditions, respectively. The average cost increase from results excluding pretreatment use for all processes was 0.003 and 0.0055 \$/m^3 for average and high conditions, respectively. No matter the permutation, pretreatments requiring more energy to achieve required hydrolysis levels were costlier. If energetic recoveries are substantial, dewaterability is positively affected, and solids meet environmental constraints to be handled and disposed at lower costs, pretreatments can be viable.

Captage des métaux lourds d'un lixiviat de lieu d'enfouissement de matières résiduelles après sa biofiltration sur support organique

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Résumé

Plus de 27 millions de tonnes de déchets solides non-dangereux (DS) ont du être éliminées au Canada en 2006 (Statistiques Canada, 2006). Une importante portion de ces DS est destinée à l'enfouissement. Un des inconvénients majeurs de cette méthode de disposition est la génération de lixiviats causée par la percolation des eaux de précipitations à travers les cellules d'enfouissement. Sur la plupart des sites, ces lixiviats sont captés et traités avant d'être rejetés vers un milieu récepteur. Les procédés de traitement conventionnels utilisés peuvent s'avérer dispendieux en plus de nécessiter un personnel spécialisé pour leur opération. D'autre part, une nouvelle réglementation sur les lieux d'enfouissement de DS (MDDEP, 2008) est entrée en vigueur au Québec en 2009. Le resserrement de certaines normes de rejet, plus particulièrement en ce qui a trait au zinc et à l'azote ammoniacal, risque de rendre inadéquats des systèmes de traitement présentement utilisés.

Compte-tenu de ces considérations, il s'avère important de développer des systèmes de traitements capables de répondre aux nouvelles normes. Des essais en laboratoire ont donc été effectués au Centre de recherche industrielle du Québec, en collaboration avec l'Université Laval, pour développer un tel système. Les objectifs des essais étaient d'observer la performance d'une technologie de biofiltration sur support organique pour le traitement des lixiviats de lieux d'enfouissement de DS et d'évaluer l'efficacité de différents médias pour le captage des métaux lourds pouvant s'annexer au système de biofiltration.

Un lixiviat prélevé en début de la chaîne de traitement d'un site d'enfouissement existant, à la sortie d'étangs de rétention, a été alimenté sur un biofiltre ayant un diamètre de 20 cm et une hauteur de garnissage de 150 cm. Les paramètres normés par le règlement sur l'enfouissement et l'incinération des matières résiduelles (REIMR) (MDDEP, 2008) ont fait l'objet d'un suivi bihebdomadaire sur une durée d'opération de plus de 300 jours. De plus, différents médias ont été mis à l'essai pour évaluer leur capacité à capter les métaux résiduels à la sortie du biofiltre. Cinq colonnes ayant chacune un diamètre de 7,6 cm et une hauteur de garnissage de 30 cm ont été alimentées avec le lixiviat biofiltré. Un suivi hebdomadaire de la teneur en différents métaux a été fait sur cet effluent.

La biofiltration combinée au captage de métaux a permis d'atteindre les normes stipulées par le REIMR pour deux des cinq médias de captage mis à l'essai, et ce pour toute la durée des expérimentations. Les principaux résultats seront présentés lors de la conférence.

L'influence de l'aération et du milieu filtrant sur la production de CH_4 et de N_2O dans un biofiltre à milieu organique traitant du lisier de porc

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Depuis une dizaine d'années, la production porcine québécoise s'est dotée de moyens pour répondre aux enjeux environnementaux, économiques et sociaux auxquels elle doit faire face (FPPQ)[1]. Un de ces moyens consiste à utiliser une technologie de traitement du lisier, qui se retrouve en surplus, en vue de réduire les risques de contamination des eaux. Parmi ces technologies, on retrouve la biofiltration sur support organique permettant de traiter et de désodoriser le lisier de porc et l'air vicié des bâtiments porcins.

L'efficacité de la biofiltration dans le traitement du lisier motive la poursuite des recherches dans l'optimisation des conditions d'opération qui, selon les conditions usuelles, peuvent entraîner la production de gaz à effet de serre (GES) dont le protoxyde d'azote (N_2O) et le méthane (CH_4).

À cet effet, certains aspects de la configuration du biofiltre (aération, milieux filtrants et source d'alcalinité) ont été modifiés afin d'en vérifier l'impact sur les performances épuratoires et la production de GES. L'objectif de cette présentation est de montrer les principaux résultats de cette étude.

Les conditions expérimentales ont impliqué un suivi de 380 jours de trois biofiltres pilotes (1,2 m x 0,13 m^2) ayant des milieux filtrants différents. Ils ont été soumis, en alternance, à une aération continue et intermittente. Les charges appliquées en carbone (DCO) et en azote ($N\text{-}NH_4^+$) sur chaque prototype ont été respectivement de : 0,15 et 0,03 $kg.m^{-2}.j^{-1}$. Le débit d'air, appliqué à contre-courant, a été de 2,3 $m^3.m^{-2}.h^{-1}$. L'effluent gazeux a été suivi 2 fois par semaine (N_2O, CH_4 et débits gazeux) tandis que les affluents et effluents liquides ont été analysés 2 fois par mois (pH, alcalinité, DCO, NTK et NO_3^-).

Les résultats des analyses liquides démontrent une bonne efficacité d'épuration pour l'enlèvement de la DCO (85 %) et du NTK (99 %) pour les conditions d'opération testées. Les concentrations en nitrate des effluents ont variées de façon cyclique. Quant aux émissions gazeuses, le comportement du CH_4 et du N_2O ont été différents. D'abord, la production de CH_4 a varié entre les biofiltres lesquels présentaient des propriétés mécaniques différentes (compaction, pertes de charge). Par ailleurs, l'effet de l'aération sur l'émission de CH_4 n'a été observé que pour le biofiltre 1; les émissions étant supérieures sous aération continue que sous aération intermittente (800 versus 120 g $C\text{-}CH_4/m^3$ de lisier traité). Quant aux émissions de N_2O, elles n'ont pas été autant influencées par le type d'aération et le type de milieu filtrant. Elles ont progressé jusqu'à 800 g $N\text{-}N_2O/m^3$ de lisier traité et pourraient être reliées à la compaction et l'augmentation des pertes de charge du biofiltre.

Finalement, dans le contexte actuel où la lutte aux changements climatiques représente un enjeu majeur pour un développement économique, social et environnemental durable, les

[1] Fédération des Producteurs de Porcs du Québec (FPPQ). [En ligne]. http://www.leporcduquebec.qc.ca/fr/fppq/envir-1.html (Page consultée le 18 septembre 2009)

résultats obtenus dans cette étude s’avèrent importants puisqu’ils contribuent à l’amélioration des connaissances en matière de gestion des GES issues de la biofiltration aérobie du lisier de porc.

Immobilized laccase for the elimination of endocrine disrupting chemicals: characterization of the biocatalysts formed and their utilization in continuous bioprocesses

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Investigations have been performed on the use laccase to eliminate xenobiotics and endocrine disrupting chemicals (EDC) found in wastewater effluents. Applications of laccase in industrial or municipal wastewater treatment plants are limited by the difficulty to reuse the enzyme and its susceptibility to denaturants. These difficulties may be overcome by using appropriate immobilization strategies.

Our group developed different immobilization/insolubilization approaches: 1) the covalent immobilization of laccase on a diatomaceous earth support Celite® R-633, 2) on the natural biopolymer chitosan and 3) by the insolubilization of the laccase as cross-linked enzyme aggregates (CLEAs). All these immobilizations have been prepared by chemical reaction with glutaraldehyde, a dialdehyde reacting with primary amine groups. This reaction gives strong amide covalent bonds. It's a much used method to immobilize enzymes but glutaraldehyde is known to be toxic to aquatic organisms.

The elimination of bisphenol A (BPA), triclosan (TCS) and nonylphenol (NP) by the biocatalysts has been tested. We used a packed bed reactor (PBR) for the enzyme immobilized on diatomaceous earth, a fluidized bed reactor (FBR) and a novel perfusion basket reactor (BR) for the CLEAs. The different reactors were used for the elimination of solution containing 5 mg l^{-1} of NP, BPA or TCS at a pH of 5 and a temperature of 20°C. The results obtained using the PBR demonstrated that all of these EDCs could be eliminated by using 3.75 units (U) of activity of laccase for BPA and TCS and 1.88 U for NP. These performances of elimination were maintained over 5 consecutive treatment cycles without changing the biocatalyst.

To overcome the toxicity problem of glutaraldehyde, we immobilized laccase aggregates on chitosan with a carbodiimide, 1-Ethyl-3-(3-dimethylaminopropyl)carbodiimide (EDAC). Chitosan is obtained by a deacetylation of chitin, a structural polymer found in crustacean shells. The EDAC is a zero-length cross-linker that activates laccase which then react with chitosan or with an amine part of another laccase. The laccase is therefore immobilized as aggregates on the chitosan. The biodegradable product is harmless to the aquatic environment.

The development of different biocatalysts and the design of simple reactors for the continuous elimination of these contaminants are important steps towards the goals of developing a cost-competitive and easily operable treatment schemes to render the enzymatic processes more widely applicable to environmental applications. From this point of view, these results offer excellent starting point for the development of laccase based bioprocesses for xenobiotics elimination.

Reducing Pollutant Discharge into Urban Rivers by Controlling the Retention Time in a Stormwater Pond

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Preserving urban river ecosystems while providing access to riverbank parks is a goal shared by many Canadian municipalities in order to improve the quality of life of their citizens. The development of cities and increase of impervious landscapes has caused stormwater runoff to have a direct and major impact on river hydraulics through point discharges at relatively high velocities during rainstorms, which tend to disturb or damage river ecosystems in the vicinity, as well as downstream of the storm outlets. Stormwater ponds have hence been built in many new housing development projects for many years now in order to diminish the impact of stormwater runoff on riverbank erosion and flooding. But stormwater runoff also accounts for the discharge of important quantities of potentially damaging contaminants from runoff on the urban landscape and can also negatively impact river ecosystems.

The objective of this contribution is to quantify the effect of the integration of outlet control in stormwater management to reduce the impact of urban runoff on local aquatic ecosystems. This is achieved by equipping existing stormwater ponds from a typical urban catchment with a dynamic sluice gate. The goal is to increase retention time in the pond from minutes to several hours or even days in order to increase sedimentation and thus the removal efficiency of suspended solids and the pollutants attached to them. The study was conducted on a stormwater pond situated in a typically urban 15.1-ha catchment in Quebec City. Based on the comparison of 2 sampling campaigns on water quality and quantity, firstly without and then with outlet control, control is proving to be an effective solution for reducing the suspended solids discharge in the urban river. The challenge resided in correctly predicting the trajectory, time of arrival, duration and intensity of storm events and sampling of runoff entering the pond while the outlet was closed in order to correctly evaluate the quantity of pollutants entering the pond while preventing overflow of the pond. The sampling campaigns included measurement of rain intensity on the catchment, inflow and outflow of the runoff in the stormwater pond, time- or flow-controlled grab and composite sampling of inflow and outflow, as well as site-specific sampling inside the stormwater pond once the outlet was closed. Lab work on these samples included TSS and heavy metal analyses of grab and composite samples as well as sedimentation tests of TSS and heavy metals on the composite samples using the ViCAS protocol (Chebbo et al., 2009**)**. These campaigns permitted to quantify the removal efficiency of a stormwater pond as constructed, without outlet control, the effect of the implementation of outlet control, the dynamics and effect of opening the stormwater pond on resuspension of settled particles, the dynamics of TSS and heavy metals settling in the stormwater pond as well as determining the time required for further settling of particles present in the outflow once the pond outlet is opened.

This study showed that the proposed solution to integrate outlet control in stormwater ponds has the potential to considerably reduce the load of contaminants released into the receiving waters, improve water quality in urban rivers and lakes and decrease the impact on aquatic ecosystems in typical residential catchments by extending the retention time in stormwater ponds and increasing sedimentation of fine particles, on which the majority of contaminants are agglomerated (Characklis et al., 1997) while allowing for a more efficient dual use of existing infrastructures for stormwater quantity and quality management.

Phytoreclamation of Trace Metal Contaminated Dredged Sediments Using Organic Amendments

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Abstract

Sediments contaminated with trace metals have been a long-standing problem in rivers, lakes and oceans, and contribute in many forms of environmental degradation. The use of old beacon batteries by riverside residents of Île-aux-Corbeaux (Sorel, Québec) to control shoreline erosion has contaminated adjacent surface sediments (0-10 cm) with trace metals. Ex situ phytoextraction, in which the shoot material of terrestrial plants is harvested and removed from the contaminated site, was considered an interesting alternative for extraction of Zn and Mn from dredged contaminated sediments. This approach usually entails seeding with plants combined organic amendment and/or inorganic fertilizer treatment to alleviate nutrient deficiencies. Organic amendments such as mature compost, which contain a high proportion of humified organic matter, are often used as metal stabilizers to allow the direct establishment of commercially available plants onto contaminated substrates. In this approach, the bioavailability of nutrients is an important factor. This research was carried out in order to determine the effects of commercial compost and synthetic organic chelator (DTPA) on the uptake of Zn and Mn by ryegrass (*Lolium multiflorum* L.) grown on a slightly alkaline dredged sediment under greenhouse conditions. Surface sediment (0-10 cm) was collected from a site near Île-aux-Corbeaux on the St. Lawrence River (Quebec, Canada). The experimental design consisted of fifteen treatments resulting from the combination of five rates (0, 2.5, 5, 10 and 20 %, by weight) of peat moss-chicken manure compost and three rates (0, 2 and 4 g) of DTPA (diethylene triamine penta acetic acid) applied as a 0.005 *M* solution during seven days before each cut. Concentrations of Zn and Mn in shoot tissues were significantly different between control and treated sediments. Except for Mn, the compost rates generally decreased the concentration of Zn in shoot tissues. Compared with the control (without compost), DTPA rates significantly increased the contents of Zn and Mn in shoot tissues. The highest uptake of Zn and Mn (total of three cuts) was recorded for sediments receiving the highest rates of compost + DTPA. The results indicate that slightly alkaline dredged sediment present a suitable substrate for cultivation of ryegrass and organic amendments favor this production. Phytoreclamation using peat moss-chicken manure compost and DTPA can decrease total Zn and Mn levels in dredged sediments. However, Zn and Mn accumulated more in roots than in shoots. This suggests that ryegrass is more suitable for phytostabilization of sediments containing low to moderate amounts of Zn and Mn.

Keywords: phytoextraction, chicken manure, peat moss, compost, ryegrass, chelation, sediment.

Etude d'impact de la recharge artificielle de la nappe de la Côte Orientale du Cap Bon (Tunisie) par les eaux usées traitées

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Résumé

Un modèle numérique d'écoulement et de transport de soluté dans la nappe de la Côte Orientale du Cap Bon est utilisé pour prévoir l'impact de la recharge artificielle par les eaux usées traitées de la station de Korba. La région du Cap Bon s'insère sous un climat méditerranéen aride à semi-aride. La nappe à surface libre de la côte Orientale est logée dans des formations plio-quaternaires dans sa partie avale. A l'amont, elle est contenue dans des formations miocènes. Les ressources en eau renouvelables de la nappe sont de l'ordre de 50 $10^6 m^3$/an. L'analyse des variations piézométriques et de la qualité des eaux de la nappe montre une forte sollicitation de ses ressources en eau dépassant souvent sa capacité de renouvellement. En effet, de fortes baisses piézométriques sont enregistrées, surtout au niveau des zones surexploitées. Ceci a engendré l'envahissement de la frange côtière par les eaux salines de la mer. La recharge artificielle de la nappe par les eaux usées traitées a été projetée par les gestionnaires des ressources en eau afin de remédier à ces problèmes. Des modèles d'écoulement et de transport de soluté dans la nappe sont calés en régime permanent et transitoire durant la période 1971-2006. Ils sont par la suite utilisés pour réaliser des simulations prévisionnelles et évaluer l'impact de la recharge artificielle envisagée à l'horizon 2050. Ces simulations ont montré que cette recharge contribuerait à remonter les niveaux piézométriques pour une zone s'étendant sur 30 Km^2 et avec un maximum de 2m. La nappe bénéficierait en plus d'une réduction de sa salinité de 6 g/l au niveau de la zone limitrophe de site.

Mots clés : Eau usée traitée, recharge artificielle, modèle numérique, Nappe de la Côte Orientale, Tunisie.

Fate of Steroid Estrone (E1) in Natural Aquatic Environment

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The rapid increase in the level of emerging persistent organic contaminants to the environment is a widespread concern in today's world. Such compound includes steroid hormones, which are a group of endocrine disrupting compounds (EDCs) that can interfere with the normal function of hormones by interacting with endocrine system in different ways and present a potential threat to aquatic life and human health. Natural steroid estrone (E1) with a solubility of approximately 13 mg/l is the most commonly detected among the steroid estrogens group in the swage treatment plant (STP) effluent and in river water in different countries. For example, estrone (E1) was detected with average concentration of 49 ng/l in the raw sewage of Canadian sewage treatment plants (STP) (Ian, 2006). Once they are released into environment, the environmental degradation of these compounds may dictate their ultimate fate and transport.

The fate of steroid estrone (E1) due to photodegradation under natural aquatic environment was investigated using simulated sun light (solar simulator) between 250 and 790 nm with different solar intensity. The photodegradation of estrone (E1) followed pseudo-first-order reaction kinetics and significantly depends on solar intensity; as expected the rate decreases with lowering solar intensity. The photodegradation rate increased with the increase of pH from 3-6.3, beyond photodegradation rate decreased over a range of pH 6.3-9.0 suggesting an optimum pH value at 6.3. Humic acid, a complex mixture of different constituents including solids, detergents, salts, oil as well as dissolved organic matter, present in river and waste water has significant effect on photodegradation on steroid estrone (E1) in natural aquatic environment. The presence of humic acid over a rage of 2 - 8 mg/l accelerated the photodegradation rate of estrone (E1) in aquatic environment. The preliminary experiments indicate that environmental half-life of estrone in natural sunlight can be 1.5 days. At present, the intermediates of the degradation product of estrone (E1) are being characterized.

Keywords: EDCs; Estrone (E1); Photodegradation

Sludge retention time and pretreatment conditions effects on mesophilic and thermophilic sludge digestion

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Keywords: Sludge pretreatment; microwave; mesophilic; thermophilic; SRT

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INTRODUCTION

One of the main parameters in activated sludge treatment plant operation is sludge retention time (SRT). Usual SRT values are between 3 to 6 days for carbonaceous matter removal. However, for nitrification, SRT values need to be higher (>10d) to allow the growth of nitrifiers. The increase in SRT can cause a decrease in the biomethanization potential of sludges, in subsequent anaerobic digestion of waste sludge, due to partial stabilization of sludge (Bolzonella et al, 2005). To address low biogas production of sludges, microwave pretreatment was applied to increase the biogas production of waste activated sludges and reduce pathogen content, and results showed a positive correlation between pretreatment temperature and biogas production for low SRT sludge (Toreci et al, 2009). Thermophilic anaerobic digestion was applied by other researchers with higher reductions in VS and biogas productions (Ros and Zupancic, 2003). The goal of this work was to determine the impact of microwave pretreatment at different pretreatment temperatures to sludges with a range of SRT (low to high) and combined with different temperatures in digestion (mesophilic and thermophilic).

MATERIALS AND METHODS

Activated sludge produced from systems operating at different SRTs namely 4,7 and 15 days were subject to microwave (MW) thermal pretreatment at different final temperatures. The MW pretreatment temperatures were 100, 150 and 175ºC. These sludges were then digested at mesophilic and thermophilic conditions and the evolution of the digestion process was monitored. A factorial design was used in order to test all the conditions and possible interactions between the type of sludge, pretreatment condition and digestion temperature. After pretreatment, several parameters were measured to evaluate the efficiency of microwaves to solubilise and destroy the sludge cells (total and soluble COD, soluble protein and soluble sugar, particle size distribution). Pretreated sludges were then subjected to digestion at mesophilic and thermophilic tempertatures. Biogas production, pH and VFA evolution, and methane content of biogas were monitored throughout the tests. After digestion, analyses were performed in order to calculate the solids removal efficiency, COD conversion and dewaterability in each of the conditions tested.

RESULTS

Microwave pretreatment increased soluble COD, from a minimum of 101.9% (SRT 4d, 100°C) up to a maximum of 234% for SRT 15 d and 175°C. Sludge age was positively correlated with soluble COD increase and with pretreatment temperature.

The digestion results show that thermophilic digestion always produces more biogas than mesophilic digestion of the same type of sludge subject to the same pretreatment conditions. On mesophilic tests, biogas production was higher in the initial days and reached the final value sooner than the thermophilic tests. Thermophilic tests showed slower production rates in the

initial stage of digestion, as a result of inhibition phenomena. This inhibition was reversible since production rates increased after an initial lag phase.

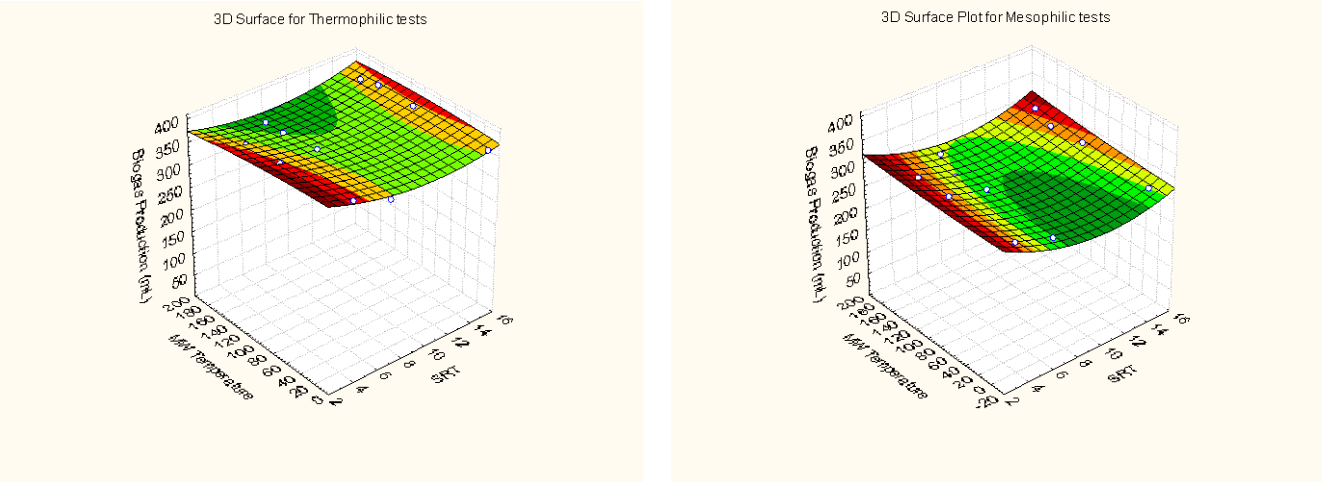

Figure 1.1 Mathematical modelling of methane production potential as a function of SRT and pretreatment temperature for thermophilic (left) and mesophilic (right) tests.

Tests proved that microwave pretreatment can increase biogas production in comparison with the control tests for all SRT sludges tested. The greatest improvement was measured in the sludge with higher SRT that theoretically had lower biodegradability. Increase was higher with higher pretreatment temperatures, although higher pretreatment temperatures also cause longer lag periods especially for thermophilic tests.
Mesophilic conditions showed higher sensitivity to change in sludge type and pretreatment conditions, with higher biogas productions associated with higher pretreatment conditions and increase of biogas production associated with higher SRT sludge. For thermophilic tests, variation of both parameters (SRT and MW pretreatment temperature) also caused change in the performance of the digestion, but the magnitude of change was significantly lower, suggesting less influence of tested parameters on digestion performance, as was confirmed statistically by the model parameters for the response surfaces. Post digestion sludge characteristics also show significant dependence on treatment parameters such as SRT and digestion temperature. Capillary suction time (used as a measure of dewaterability) is heavily dependent on the digestion temperature, being significantly higher for all tests conducted at thermophilic temperature and dependent on microwave pretreatment temperature.

FREEZE-THAW TREATMENT OF RBC SLUDGE: A SUSTAINABLE OPTION FOR SLUDGE DEWATERING IN COLD REGIONS

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Sludge dewatering is one of the most challenging processes during sludge treatment. Particularly in cold climates, sludge dewatering becomes a major problem for treatment plants because mechanical equipment such as centrifuges and filter presses are difficult to maintain and operate. The equipment ices up often, skilled operators are scarce, treatment plants are in remote locations and large amount of chemicals are needed to condition the sludge.

Attention has been placed on freeze-thaw technology in an attempt to solve the dewatering problem in cold and relatively cold regions. Freeze-thaw technology works on the principal that ice crystals grow by incorporating water molecules only. Because the structure of ice crystal is highly organized and symmetrical, it cannot accommodate any other atoms or molecules. Each ice crystal continues to grow as long as water molecules are available. All other impurities and solids are forced to the boundaries of the ice crystal, where they become compressed or dehydrated. During thaw, the meltwater drains away between the consolidated particles leaving a dewatered sludge. Previous research has shown that freeze-thaw technology is effective in reducing the quantity of pathogens and indicator bacteria as well.

Sludge freezing beds together with a storage facility, such as a lagoon, tank, or digester to store the sludge in summer, can be used as the sole method of dewatering in cold regions. In temperate climates, freezing beds can be used in combination with drying beds to freeze the sludge in winter and dry it in summer. Most of the United States and Canada can use the freezing beds.

The goal of this study was to evaluate the effectiveness of freeze-thaw conditioning on RBC sludge generated at a remote mining exploration facility (Matoush, Strateco Resources Inc.) located in Northern Quebec, Canada. The site is only accessible by air, and there is very limited opportunity for transportation which limits the treatment options. Wastewater is collected from the living areas and eating facilities of the personnel and does not contain any mine waste. A portable, containerized wastewater treatment system (Seprotech Systems Incorporated) that includes an RBC unit is used for the treatment of wastewater and options are being considered for sludge treatment and disposal on site. During this study, freeze-thaw conditioning was considered as one of the effective and low-cost options that can solve the dewatering problem and reduce the indicator and pathogenic microorganisms in sludge. A pilot-scale freezing bed that can fit in a freezer truck was designed and built, and sludge samples were flown in from the site once every two weeks during the summer months. Sludge was frozen in layers of approx. 10 cm to ensure complete freezing. Several sludge characteristics such as total solids, volatile solids, COD, and dewaterability of sludge were measured before and after freezing. In addition, fecal coliform and *Salmonella* numbers in sludge were also quantified using EPA Methods 1681 and 1682. The results show that freeze-thaw treatment is effective in conditioning and dewatering RBC sludge as a simple, sustainable, and cost-effective method, and a containerized freezing bed can be installed on site. The dewatered sludge can also be used for land application on site after treatment with lime.

2-D Numerical Multimedia Environmental Analysis System and Its Validation

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Abstract:
All pollution issues involve potential impacts on the surrounding interconnected air, water, and soil (i.e., multimedia) environment. Effectively addressing a wide range of multimedia pollution problems is of crucial importance to major socioeconomic sectors. This study presents an attempt to develop a new Numerical Multimedia Environmental Analysis System (NMEAS), which incorporates numerical analyses of pollutants fate and transport in the multimedia environment. Specifically, Three different approaches were evaluated for solving two dimensional coupled pollutants advection-diffusion-reaction equations using experimental data from the literature: a) NMEAS/FEM (numerical finite element method); b) NMEAS/FDM (numerical finite difference method); and, c) NMEAS/analytical method. Preliminary validation of the proposed NMEAS method has been conducted through a 2-D cases study. In the case study implementing the NMEAS/FEM solution is found to be better than that of NMEAS/FDM, especially at low concentrations of pollutants; and both pollutant fluxes across and distribution in the interconnected compartments are simulated in both numerical spatial and temporal scale for complex multimedia environment. The new NMEAS will be an innovative risk assessment tool aiming to formulate effective strategies of managing environmental impacts on multiple compartments resulting from pollution emissions.

Keywords: Contaminants, Environmental Multimedia Modeling, Numerical Analysis, Risk Assessment.

Evaluation of carbon-footprint of an ozonation process to reduce sludge production by an activated sludge wastewater treatment plant.

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Wastewater treatment facilities are increasingly looking for technologies to reduce excess sludge production by biological units such as activated sludge reactors. This is mainly in response to the recent increase in the cost of landfill disposal of excess sludge in Canada and across the world. In addition to their economic impact and in the context of a changing climate, these technologies can also be evaluated for their impact of the carbon-footprint of the plant. The goal of this paper is to develop an approach to evaluate the variation of plant carbon-footprint due to the installation of a ozonation process that solubilises a portion of the return activated sludge (RAS) which generate biodegradable soluble COD and reduces excess sludge production. In order to evaluate the impact on the activated sludge process, the IWA-ASM3 model was extended to describe the O_3 solubilisation process. The extended IWA-ASM3 showed that the performance of the ozonation process is mainly dependent on the biomass yield, hence the type of activated sludge process (e.g., conventional vs. nitrification/denitrification) utilized, and the solids retention time (SRT) before the installation of the ozonation process. The model showed that for a typical conventional plant with a SRT of 10 days, a commonly guarantied 40% reduction in sludge production by the ozonation process would produce a 20% increase in oxygen consumption rate. Consequently, the ozonation process operates a conversion between CO_2-equivalent emissions for sludge disposal to emissions between for activated sludge aeration.

Using Canadian and American data and considering energy usage, CO_2-equivalent emissions are approximately 550 g/m^3 of wastewater treated for a plant without anaerobic sludge digestion and disposing of the produced sludge in landfills. The emissions come directly from the plant operation at 64% and from sludge disposal at 36%. Note that the disposal emissions include long term fugitive methane emissions from landfills. An initial estimate of the effect of the reduction of 40% of excess sludge production by the ozonation process suggests a reduction in the overall footprint for a retrofitted plant to 523 g/m^3 of wastewater. This estimate neglects the increase in electricity consumption for the production of O_3. If we consider a plant that would digest the excess sludge in anaerobic digesters before final disposal, the carbon-footprint of the plant before the installation of the ozonation process is approximately 472 g/m^3 of wastewater, while it increases to 476 g/m^3 of wastewater after installing the ozonation process. Therefore, the net effect on the carbon-footprint of an ozonation process for sludge production is highly dependent of the processes already in use. The presentation will discuss various plants scenarios on the impact of the ozonation process of the carbon-footprint of the plant.

Mercury Speciation and Transport in the Wagigoon-English River System

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A detailed literature review of fluvial fate and transport of mercury species will be presented, with particular emphasis on transport of mercury contaminated sediments downstream from Dryden, in northern Ontario, where a chlor-alkali plant dumped 10 metric tonnes of mercury between 1962 and 1970 into the Wabigoon-English River system. We are initiating a research project to measure and model the current levels of mercury species in the system. Mercury found in sediment cores from Clay Lake were dated using radio-isotopes and found to agree well with known historical discharges from the Dryden chlor-alkali plant (Lockhart et al, 2000). Mercury tends to become adsorbed to organic particles in the river, thus river sediments become both a sink and a source, with deposition and mobilization due to erosion respectively. Total mercury concentrations in a river have been found to peak dramatically during the spring flood when the contaminated sediments were remobilized in the Nura River (Ullrich et al, 2007) and the Idrijca River (Zagar et al, 2006). Mercury is a very reactive element, and its speciation between elemental, inorganic and organic forms is important because it is the organic form, methylmercury, that bioaccumulates through the food chain. Many studies have found that the methylation of mercury by bacteria to be enhanced in reservoirs (Ullrich, 2007; Tomazelli et al, 2007; DeLaune et al, 2004, Zagar et al, 2006). An inverse relationship between total Hg and organic Hg was discovered in the sediments of the Nura river study (Ullrich et al, 2007), which showed that although total Hg levels rapidly decreased with increasing distance downstream, organic Hg levels in the sediment increased with increasing distance downstream from the contamination source. The research project would include measurement of total and organic Hg levels in sediments, and total Hg levels in water, suspended sediment, fish, and vegetation along the length of the river, including lakes and hydro reservoirs along the river system.

Fermentation à l'état solide de déchets agroindustriels pour produire des enzymes ligninolytiques par *Phanerocheate chrysosporium*

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Bisphénol A (BPA) est un composé employé dans la fabrication des résines époxydes et des plastiques. Il est produit à grande échelle et ses utilisations sont répandues au Canada. BPA est également un perturbateur endocrinien et les études ont confirmé son estrogenicité et ses effets sur le comportement reproductif des animaux et des êtres humains. Ce composé indésirable est libéré, consciemment ou inconsciemment, dans le milieu aquatique, ce qui affecte la faune. Le système actuel de traitement des eaux usées n'est pas efficace dans l'élimination totale des contaminants émergents. Les enzymes ligninolytiques ont été connus par leur efficacité dans le traitement du BPA. Toutefois, la production de ces enzymes, qui sont souvent instables, est coûteuse. Ainsi, cette étude visait à l'utilisation des déchets agro-industriels comme substrat de fermentation pour la production d'enzymes ligninolitiques. Ces déchets ont été choisis en raison de leur omniprésence, haute biodégradabilité et richesse en nutriments. La production d'enzymes ligninolytiques par des cultures à l'état solide de *Phanerochaete chrysosporium* BKM-F-1767 a été étudiée en utilisant les déchets suivants : les résidus de poisson, les rejets de microbrasserie, les déchets de jus de pomme (Pomace) et les boues de pâte à papier. Différents inducteurs enzymatiques, tels que le veratryl alcool, Tween-80 et $CuSO_4$ à des concentrations de 2 mmole/kg, 0,5% v/W et 3 mmole/kg, respectivement, ont également été testés. L'addition du veratryl alcool et du Tween-80 a conduit à des maximums d'activités de manganèse peroxydase (MnP) de 17,36±0,5 U/gss, 540,2 ± 5,1 U/gss, 631,25±14 U/gss, 507,5±26,87 U/gss (unités/gramme de substrat sec), respectivement, pour les différents déchets. Des maximums d'activités de lignine-peroxydase (LIP) de 141,38±3,39, 14,1±0,5 U/gss ont étés obtenus avec les déchets de jus de pomme et les rejets de microbrasserie, respectivement. La production de la laccase était négligeable dans tous les déchets. Les activités maximales de MnP obtenus quand le tween-80 et le $CuSO_4$ ont étés ajoutés aux milieux ont étés 17,4±0,6, 291±2,8, 213,5±3 et 213,2±3,2 U/gss dans les résidus de poisson, les rejets de microbrasserie, les déchets de jus de pomme et les boues de pâte à papier, respectivement. L'ajout de $CuSO_4$ au milieu de culture améliore la production de laccase. Des activités maximales de laccase de 738,97±9,2, 719,97±14,6, 308,8±12,1, 94,44±1,2 U/gss ont été obtenus dans les rejets de microbrasserie, les déchets de jus de pomme, les boues de pâtes à papier et les résidus de poisson, respectivement.

TRANSPORT OF SURFACE-MODIFIED NANOIRON PARTICLES IN POROUS MEDIA

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Abstract

Nano scale zero-valent iron particles (nZVI) have been shown to be very efficient in the transformation of chlorinated hydrocarbons, chromium and nitrate to innocuous end products. Therefore, nZVI are considered to be an excellent reactive 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 nZVIs for in situ remediation of contaminated sites has been hindered by their poor transport in groundwater due to their tendency to be retained by porous media during transport due to their tendency to deposit on soil grains and to agglomerate. Surface modifications of nZVI that minimize this aggregation behaviour are likely to make nZVI effective for *in situ* remediation.

Synthesis conditions were altered to manipulate the size (5.5 nm – 75 nm) and structure of CMC-nZVI. Different types of surface modifiers such as carboximethyl cellulose (CMC), poly styrene sulfonate (PSS) and sodium butanesulfonae (BS) are used to enhance colloidal stability of nZVI . Transmission electron microscopy (TEM) image analysis showed that the average particle sizes of bare and surface modified particle ranges between 55nm to 130nm. Sedimentation tests show that the CMC modified nZVI has the best colloidal stability.

Transport experiment of CMC-nZVI through a sand packed column was studied to evaluate the effect of surface property after modification by carboxymethyl cellulose (CMC). Monitoring of the nanoiron concentrations in the column effluent shows that bare nZVI did not transport through the sand medium. In contrast, the 5.5nm CMC-nZVI transported very well without much deposition. The 75nm CMC-nZVI transports significantly as well but breakthrough curves from column experiments indicates a higher extent of particle aggregation and deposition. The effects of nZVI particle concentration, ionic strength and flow rate of the flushing solution on transport will be presented.

The feasibility of field implementation issues of nZVI-based remediation technologies will be discussed, based on the above findings.

ADSORPTION OF ARSENIC FROM A NOVA SCOTIA GROUNDWATER ONTO WATER TREATMENT RESIDUAL SOLIDS

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Background: There are elevated groundwater arsenic concentrations in some areas along the east coast of North America. Arsenic contamination in Nova Scotia was first discovered in 1976, when an ill patient exhibited symptoms of arsenic poisoning and an analysis of the patient's private well revealed an arsenic concentration of 5,000 □g As/L. Presently, Nova Scotia Environment recommends that residents of the province on private wells are either *very likely* to have arsenic contamination in their well water or that they *may* have arsenic contamination in their well water. Previous researchers have found that one of the mechanisms for arsenate removal during coagulation was arsenate adsorption onto iron or aluminum hydroxide flocs.

Objectives: The objective of this presentation is to evaluate arsenic adsorption by adsorbents developed from a waste product common to Nova Scotia, water treatment residual solids, and evaluate the adsorption of arsenic from a Nova Scotian groundwater in batch adsorption and column experiments.

Methodology: Water treatment residual solids (WTRSs) were examined in batch adsorption and column adsorption experiments using a groundwater from Halifax Regional Municipality that had an average arsenic concentration of 43 □g/L (± 4.2 □g/L) and a pH of 8.1. The WTRSs studied in this chapter were from five water treatment plants, four surface water treatment plants that utilized either alum, ferric, or lime in their treatment systems, and one iron removal plant.

Results: There are three types of systems in Nova Scotia that are affected by arsenic contamination: municipal water, semi-private water systems, and private groundwater wells. Approximately 20% of the private groundwater wells exceed a groundwater arsenic concentration of 10 μg/L, indicating that there is a need for safe and cost-effective treatment of arsenic in Nova Scotia. In batch adsorption experiments with the residual solids, iron WTRSs and lime WTRSs preformed similarly to granular ferric hydroxide (GFH), a commercially-available adsorbent, while alum WTRSs performed poorly. Langmuir isotherm modeling showed that ferric residuals had the highest adsorptive capacity for arsenic (Q_{max} = 2,230 - 42,910 mg/kg), followed by GFH (Q_{max} = 640 mg/kg), lime (Q_{max} = 160 mg/kg) and alum (Q_{max} = < 1 - 3 mg/kg). In a column adsorption experiment, ferric WTRSs achieved arsenic removal of > 26,000 bed volumes before breakthrough past 10 mg As/L, whereas the effluent arsenic concentration from the GFH column was under the method detection limit at 28,000 bed volumes.
Conclusions and Recommendations: Overall, ferric and lime WTRSs were promising adsorbents for arsenic adsorption from the groundwater, and alum WTRSs did not achieve high levels of arsenic adsorption. Ferric residuals were more effective at removing arsenic from the Nova Scotia groundwater than the alum residuals. At the concentrations of arsenic found in the groundwater, the ferric and lime residuals performed similarly to GFH in batch adsorption experiments. Ferric water treatment residual solids may provide for a cost effective treatment option for adsorption of arsenic from wastewaters and brines containing arsenic, while at the same time providing a reuse option for residual solids from drinking water treatment plants.

Diètes produites à partir des eaux usées agro-industrielles pour l'élevage de *Cydia pomonella* – bilan nutritionnelle

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La présente présentation fait partir du concours pour le prix **Philip H. Jones**

Résumé

L'utilisation rationnelle et utile des rejets pour remplacer certains composants (Farine de soya, Levure de bière, Germe de blé) de la diète servant à la culture des larves du carpocapse de pomme (CP) est une solution réalisable qui peut réduire le coût des diètes et a améliorer la production de l'insecticide biologique, le *Baculovirus* qui est produit en infectant, par des *granulovirus* des larves de CP cultivés sur ces diètes. Cet insecticide permet de lutter contre le CP qui détruit les vergers. Cette étude a permis d'évaluer la capacité nutritive en g/L des eaux usées d'amidon-EUA (7.5±2.5 glucides; 4.4±1.5 protéines; 3±0.5 lipides et des métaux en mg/Kg), des eaux usées de micro brasserie-EMB (15.5±8.5 glucides; 31±2.1 protéines; 6±1.6 lipides et des métaux), et des rejets de pulpes de pomme-PP (1.2±0.03 glucides; 7.5±0.13 protéines; 2±0.2 lipides et des métaux) utilisées pour la production de 9 diètes semi-synthétiques. Le bilan de masse des nutriments assimilés par les larves a été effectué afin d'évaluer leur influence durant la période de croissance. A l'échelle de laboratoire, dans les conditions industrielles (16:8 h de photopériode; 25°C±1 et 50±0.5% d'humidité), la culture des œufs du CP sur les diètes préparées avec les EMB (emb/Fs, emb/El et emb/Gb) ont fournie les résultats les plus intéressant (en moyenne 60% d'éclosion après 6 jours; 52% de survie des larves en 28 jours, et 10% de survie de papillons de masse 17-40 mg en 14 jours). Ainsi, cette étude confirme que l'obtention d'une diète pour la culture du CP à partir des rejets agroindustriels est possible, et peut être une option économique pour l'industrie de la diète et la production des *Baculovirus.*

Mots clés: Eaux usées, boues, rejets agro-industrielles, diète, bio insecticide viral, *Cydia pomonella.*

Ontario's Water Source Protection Plans: Is Adaptive Management the Missing Element?

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This research answers the question: Does the Ministry of the Environment's proposed regulation entitled: *Source Protection Plans under the Clean Water Act, 2006: A Discussion Paper on Requirements for the Content and Preparation of Source Protection Plans, June 2009* achieve the objective of protecting existing and future water sources? The paper considers from an interdisciplinary perspective whether an adaptive resource management strategy should be adopted to respond to the environmental challenge of climate change.

Climate change research is not only explicitly linked to water quality and quantity issues, but also identifies the consequences of climate change as a risk to drinking water sources. Recognizing climate change as a watershed management issue re-orients the analysis of how and in what ways can resource specific legislation, such as Ontario's Clean Water Act, 2006 (*CWA*), be responsive to the threat of climate change. Perhaps, adopting an adaptive management strategy is the answer?

In the water resource management literature, adaptive management is viewed as an appropriate strategy to address the uncertainty and complexity associated with existing and emerging watershed problems. It is premised upon quantifying the watershed's issues of concern while also creating continuous adaptive processes that are responsive to new information and potential changes to the condition of the water source that are identified through the testing of viable scenarios and options.

This paper presents climate change as a threat to the quality and the quantity of Ontario's drinking water sources. The Ministry's proposed source protection plan (SPP) regulation falls short by failing to incorporate a comprehensive, eco-resilient based policy that is responsive to the temporal and spatial uncertainty presented by climate change. It is doubtful that the proposed regulation will protect the existing and future drinking water sources from the threat of climate change.

An adaptive management approach is put forth in the jurisprudence and the resource management literature and is reinforced by the practices of water resources managers, as an appropriate management response when uncertainty frames the problem. The broad regulatory structure of the *CWA* allows for an adaptive management policy to be enacted under *s.*7(5)(b). The results of this paper can be used to inform policy makers on the need to integrate a comprehensive adaptive management policy into the Ministry's SPP regulation.

ACTIVATED SLUDGE MODELLING IN PRACTICE – AN INTERNATIONAL SURVEY

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Activated Sludge Models (ASM) are now widely used for Wastewater Treatment Plant (WWTP) design, optimisation, operation and training. The decisions used in the design and optimisation of WWTPs have significant financial and environmental impacts; therefore they should be based on high quality models. Reaching the correct level of quality is thus a key topic for all model users. The Good Modelling Practice Task Group (GMP-TG) of the International Water Association (IWA) is developing guidelines for the use of Activated Sludge Models (ASM). As part of this work the group created and sent out a questionnaire to current and potential activated sludge model users. The objectives of the questionnaire were (i) to better define the profile of ASM users, (ii) to identify the tools and procedures that are actually used and (iii) to highlight the main limitations while building and using ASM-type models.

Ninety-six completed questionnaires were received, 80% of the respondents were ASM users. 65% were returned from European countries and 20% from North-America. The European respondents are mainly from universities and public research centres whereas North-American ones mainly from private companies. About 86% of the respondents have an engineering background, and their knowledge about modelling is acquired predominantly from self-training (78%), that reveals a lack of university training and continuing education programs.

The main objectives cited for building and using a model are: optimisation (59%), design (42%) and prediction of future operations (21%). Europeans are more concerned with daily plant operation and control strategies, while North-Americans use models more for plant design (and re-design).

To meet the modelling objectives the most used biokinetic models are ASM1 (Henze et al., 1987) (57%), and ASM2d (Henze et al., 1999) (32 %). The three most time-consuming steps are data collection and reconciliation, calibration and validation, and simulation and results interpretation (including reporting).

Modelling projects are limited by a number of obstacles. Furthermore, respondents have some reservations about the usefulness and accuracy of models. Two main misuses were identified and are corroborated by the results:

- Spending too much time on calibration without ensuring high quality data. For ASM users this is reflected by the time allocated to calibration.
- Lacking methodology for the validation step. Skipping this step can result in a model with a limited or unknown prediction capability, which could subsequently lead to a general mistrust in models.

The development of standardised modelling procedures and better knowledge transfer e.g. by making some practical case studies available should address such obstacles as:

- the complexity (apparent or actual) of the model theories and modelling procedures,
- the time consuming steps and therefore the cost of modelling, and
- the modellers' trust in the models.

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To Swim or Not To Swim? A Simple Tool for Deciding if a Beach

Should Be Closed due to Bacterial Contamination

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Keywords: Beach, bacteria, combined sewer overflow, urban, pollution.

INTRODUCTION

The central, older part of the City of Ottawa is drained by a combined and partially separated sewer system. It has a service population of 350,000, is approximately 11 km by 26 km and has a drainage area, shown of Figure 1.1, of 105 km2. During rainfall and snowmelt, combined sewers in that system overflow into the Ottawa River.

A new beach has been opened on the Ottawa River, approximately 25 km downstream of the closest combined sewer overflow (CSO) discharge location. Given that separation distance, and dilution factor of over 1,000 for most rainfall events, it was initially believed that the CSO impact would be negligible at the new beach.

After a few years of operation, and upon review of data collected during that time, it became clear that certain rainfall events could cause bacteria levels at the beach to rise above regulated levels. While there are multiple sources of bacteria, it was determined that beyond a given rainfall threshold, the impact of CSOs became dominant.

THE PROBLEM

Bacteria samples are taken at the beach every morning, but the test results become available a day later – too late to close the beach if the test shows high concentrations of bacteria. The City's Public Health Department attempted to develop a simple rainfall rule to decide if the beach should close or remain open after rainfall events. That rule would see the beach close if there was more than X mm of rain in the previous 24hours. This type of simple rule proved to be inadequate and unreliable for the given situation, resulting in many false positives (where the beach was closed when it could have remained open) and false negatives (where the beach remained open when it should have been closed).

Public Health Department turned to the City's Water Resources Unit to develop a better predictive tool. Public Health asked that the tool:

- Be very simple and easy to use, even by summer students
- Require as little input data as possible – hopefully only rainfall depth
- Rely on simple calculations to avoid the need to purchase specialized software
- Provide good performance in terms or reducing false positives and negatives

THE SOLUTION

A very simple tool was developed. The tool, based on the concepts of Unit-Pollutograph and half-life die-off of bacteria, had only 4 parameters to calibrate, and required only three readily available input variables: the rain depths of the two previous days (measured by the City and readily accessible to Public Health) and the previous day's measured bacterial concentration at the beach, from samples taken by Public Health. The tool was calibrated using three years of data and validated with a fourth year of data. Specifically, model parameters were calibrated using a multiobjective genetic algorithm optimization process, which aimed at minimizing both the false negatives and the false positives.

Upon completion of that analysis, Public Health Department were offered the results in terms of a trade-off between minimizing unnecessary closures (false positives) and minimizing unsafe openings (false negatives). The trade-off was presented as a whole set of optimal false-negative/false-positive pairs, as shown on Figure 1.2. Public

Health Department chose an optimal false-positive versus false-negative pair that was deemed to strike an appropriate balance between the two conflicting goals. Water Resources Unit provided a half-hour training session to Public Health Department staff. The tool was used for the 2009 bathing season with great success. By providing reliable predictions of conditions at the beach, it enabled the City of Ottawa to reduce health risk to bathers while at the same time maximize the use of the beach. Public Health Department asked that similar tools be developed for other beaches.

Figure 1.1 City of Ottawa Central Sewer System Service Area

Figure 1.2 Risk of Unnecessary Closure versus Risk of Unsafe Opening – Set of Optimal Pairs

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Downscaling of Daily Temperature Extremes for Climate-Related Impact Assessment Studies.

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Abstract
Assessment of climate change impacts frequently requires downscaling methods to describe the linkage between the global scale climate variables and local climatic conditions. In general, there are two broad categories of downscaling techniques: the dynamical downscaling based on high-resolution Regional Climate Models (RCMs), and the statistical downscaling, privileged by its ease of implementation and use. In addition, it has been widely recognized that the statistical downscaling methods offer several practical advantages over dynamic downscaling procedures, especially in terms of flexible adaptation to specific study purposes and inexpensive computing resource requirements. These statistical downscaling methods include three principal techniques: regression methods, weather typing approaches, and stochastic weather generators. Furthermore, most of the statistical downscaling methods have been developed for the case of downscaling for a single site, but very few methods have been dealing with the more complex multi-site downscaling issues. The present paper proposes therefore a statistical approach for multi-site downscaling of daily maximum (Tmax) and minimum (Tmin) temperature series.
The proposed approach consists of a combination of a multiple regression method with a stochastic moving average model to account for both observed at-site temporal persistence and observed spatial dependence between different locations. This second condition is often ignored by most existing downscaling techniques. The stepwise regression method was used to identify the significant climate predictors, for both Tmax and Tmin, based on the National Centre for Environmental Prediction (NCEP) reanalysis data set.
To assess the feasibility of the proposed multi-site downscaling approach, daily extreme temperature data from a network of 10 weather stations located in the southwest region of Quebec and southeast region of Ontario in Canada were selected for this study. The 30-year daily temperature records for each station were partitioned into calibration period from 1961 to 1975 and validation period from 1976 to 1990. The performance of the model will be judged based on various statistical indices such as inter-station correlations between different stations, spatial and temporal variability of Tmax and Tmin, and inter-annual temperature anomalies.
Results of this illustrative application have indicated that the proposed multi-site downscaling approach was able to reproduce accurately the observed temporal persistence of daily temperature extremes at a given site as well as the observed interstation correlations of these temperature extremes at different sites for both calibration and validation periods. In addition, it was found that the suggested method could provide extreme temperature characteristics that are more comparable to

Importance of hospitals as point sources of pharmaceutical releases to the environment

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Hospital wastewater is often implied to be a significant point source for the release of pharmaceutically active compounds (PhACs) to the environment. However, its importance as a point source has only been quantified for a few select PhACs. Hence, there exists a need to consider a larger data set to better grasp its significance as a point source. In order to address this knowledge gap, the significance of hospitals wastewaters as point sources was evaluated for 301 selected PhACs, covering 58 therapeutic classes.

A mass balance analysis based on the relative mass of yearly prescriptions sold to Canadian hospital pharmacies compared to the net total annual prescriptions sold within Canada suggested that on average 21% ± 32% (σ) of the selected PhACs were consumed in Canadian hospitals and, therefore, are expected to be found in hospital wastewaters. However, extreme variability was found with respect to the relative fraction consumed within hospitals and hence the importance of hospital wastewaters as point sources. The variability was profound not only between different therapeutic classes but also within some classes. Despite the inherent variability it was found that certain therapeutic classes (i.e., anesthetics, contrast media and antineoplastic agents) are almost exclusively consumed in hospitals. Furthermore, an analysis considering the mode of administration demonstrated that PhACs that are predominantly injected are likely to be utilized and therefore be sourced at hospitals. In all, the data suggests that hospitals are a significant point source for only some PhACs. Hence, treating hospital wastewater at source will only partially address issues associated with the release of PhACs into the environment.

Start-up and operation of a mobile pilot-scale anaerobic digester

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With the support of the Canadian Biomass Innovation Network (CBIN), the environmental bioengineering group of the Biotechnology Research Institute (BRI) has designed and built a mobile laboratory for on-site anaerobic digestion (AD) of industrial/municipal effluents. The main objective of this project is to demonstrate the potential of AD in wastewater and sludge treatment as an effective way for reducing the COD of an effluent while producing renewable energy and reducing CO2 emissions. In its first assignment, the mobile laboratory was used to assess AD of primary sludges of a municipal wastewater treatment plant (La Pinière plant, Ville de Laval). The experiment was performed over a period of six months between April and September 2009. The start-up of the one-phase mesophilic process lasted about two months. The inoculum ,which consisted in 1.4 m3 of industrial granular sludge (5% solids), was first added to the 2.7 m3 CSTR-type digester. The granules were slowly brought up to temperature from 10oC to 35oC in about four days. Two additions of 0.5 m3 of sludge were made, the first one 24 hours after the granules were put into the digester (day 1), and the second one on day 8, bringing the volume of material up to 2.4 m3, a volume that would remain constant for the rest of the experiment. Between day 10 and day 21, the digester was fed with 50 litres batches of sludge/day and the same volume of material was withdrawn from the digester. From day 22, the digester was operated on a quasi-continuous basis, starting at a flow rate of 100 litres/day (HRT = 24 days), and gradually increasing to reach 190 litres/day (HRT = 12.6 days) on day 83. During the start-up period some minor mechanical issues mostly due to the nature of the sludge (presence of a large quantity of fibres) had to be resolved to ensure smooth operation of the process. Throughout the project, efficiency of the digestion process was assessed by analyzing incoming and outcoming material (pH, VFA, VSS, CODs, biogas composition) three times per week. Analyses of TVS, CODt, alcalinity, and NH4 were performed on a weekly basis. Average values of steady state (between days 83 and 127) performance indicators are as follows: OLR = 2.6 ± 0.5g TVS/l/day, HRT = 12.0 ± 1.0 days, solids elimination = 54 ± 5%, methane production = 1632 ± 179 l /day, VFA out = 263 ± 86 mg/l. On day 127, for a reason yet to be determined, a sudden rise in the outlet's VFA content (up to 1600 mg/l) was observed. After reduction of the load rate, the digestion quickly recovered and the value of outlet VFA went back to normal values within a few days, showing the resilience of the bacterial consortium.

L'enlèvement de l'azote ammoniacal dans les étangs aérés facultatifs dans le contexte de la Stratégie pancanadienne

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L'ammoniac est une substance dont le potentiel toxique est officiellement reconnu au Canada depuis son inscription sur la *Liste des substances toxiques* de l'annexe 1 de la *Loi canadienne sur la protection de l'environnement* en 1999. La toxicité pour les organismes aquatiques est associée à la portion non ionisée NH_3 de l'azote ammoniacal total, qui présente à la fois un risque de toxicité aigüe et chronique chez les organismes aquatiques (poissons notamment). La fraction non ionisée est négligeable (moins de 1%) pour des pH sous 7,5 et atteint l'équilibre avec la fraction ionisée NH_4^+ à un pH de 9,3.

Environnement Canada [2004] a émis une *Ligne directrice* sur le rejet d'azote ammoniacal sous forme dissoute dans les effluents d'eaux usées. Elle s'applique aux effluents de plus de 5 000 m^3/d et fixe les objectifs suivants : a) atteindre et maintenir une concentration en ammoniac dans l'effluent qui ne manifeste pas de létalité aiguë pour les poissons ; b) atteindre et maintenir une concentration d'ammoniac dans l'effluent qui assurera la protection des organismes vivant en eau douce. Les réseaux d'assainissement ne devraient pas rejeter d'ammoniac en quantité ou en concentration menant à une concentration d'ammoniac non ionisé supérieure à 0,019 mg/L dans l'environnement aquatique. Par ailleurs, les installations d'assainissement émettant plus de 10 tonnes par année d'azote ammoniacal doivent déclarer leurs rejets à l'Inventaire national des rejets de polluants INRP [Environnement Canada, 2007].

Se situant dans cette catégorie, les étangs aérés facultatifs de la Ville de Rouyn-Noranda font l'objet de la présente étude. La station est conçue pour desservir une population équivalente de quelque 26 800 habitants, à laquelle correspond un débit de conception de 15 000 m^3/d et un temps de rétention de 29 jours. Les principaux objectifs de l'étude visaient à caractériser le processus d'enlèvement de l'azote ammoniacal au cours du printemps et de l'été 2008 (mars à septembre), d'estimer la toxicité aigue globale de l'effluent par l'intermédiaire d'un indicateur (l'inhibition de la fluorescence de complexes enzymatiques photosynthétiques, CEP) et de dresser une liste sommaire des technologies disponibles pour augmenter la nitrification dans les étangs de Rouyn-Noranda, le tout dans le contexte de la nouvelle *Stratégie pancanadienne sur la gestion des eaux usées municipales* adoptée en février 2009 par le Conseil des ministres du gouvernement fédéral.

La *Stratégie pancanadienne*, retient deux « résultats » : a) Résultat 1 – renforcement de la protection de la santé humaine et de l'environnement; b) Résultat 2 – clarification du mode de gestion et de la réglementation des effluents d'eaux usées. Elle établit des normes de performance nationales pour quelques paramètres typiques : demande biochimique en oxygène carbonée après 5 jours, matières en suspension et chlore résiduel total. La *Stratégie* émet également un cadre de gestion du risque qui permet d'établir des objectifs environnementaux de rejet (OER) propres à chaque site d'autres contaminants en complément des normes nationales. On note que l'absence de toxicité aigüe à l'effluent et de toxicité chronique dans le milieu récepteur dus à l'azote ammoniacal fait partie des OER.

De manière complémentaire à la *Stratégie pancanadienne*, le ministère du Développement durable, de l'Environnement et des Parcs du Québec (MDDEP, 2006) a établi un critère pour la valeur aigüe finale (VAF) à l'effluent liée à l'azote ammoniacal total [$NH_4^+ + NH_3$] exprimé en azote.

Les résultats montrent que la période de nitrification dans le système d'étangs de la Municipalité de Rouyn-Noranda s'est étendue de la mi-juillet jusqu'à la mi-octobre, soit environ trois mois.

Selon l'indicateur de toxicité globale utilisé, soit l'inhibition de la fluorescence, l'azote ammoniacal n'est pas la seule substance à laquelle la toxicité peut être due à l'affluent ou l'effluent. L'ICC (indice de contamination chimique) utilisé indique qu'il y a un risque nul (0 à 20% d'inhibition) à l'effluent pour tous les mois de l'étude et aucun dépassement de la VAF n'a été observé durant cette période, alors que l'affluent présente un risque faible.
La *Stratégie* influencera la gestion des stations d'épuration à l'échelle canadienne au cours des prochaines décennies. Les stratégies d'intervention sur une station de traitement comme celle de Rouyn-Noranda, en ce qui concerne la protection du milieu aquatique récepteur des déversements contenant de l'ammoniac, devront entre autres être guidés par la nouvelle *Stratégie pancanadienne*. Toute intervention sur le procédé épuratoire devrait être faite de manière cohérente avec le contenu et l'échéancier de la *Stratégie*. La caractérisation de l'effluent prévue au cours des premières années d'application de la *Stratégie pancanadienne* permettra d'évaluer de manière plus poussée le potentiel toxique de l'affluent.

L'approche visant l'ajout d'une étape (technologie) à la chaîne de traitement pourrait être la voie la plus prometteuse pour réduire les charges d'azote ammoniacal déversées par l'effluent d'un système d'étangs. Les réacteurs biologiques à support fluidisé ou fixe pourraient être, parmi les technologies recensées, celles qui sont le plus en mesure d'assurer une meilleure nitrification sur une base annuelle.

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Real-Time Monitoring of Water Supplies

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This presentation will lay out the findings of an extensive literature review that examined new and innovative water monitoring strategies and technologies that have improved the time required to perform water quality analysis.

Modern water quality issues are complex and include the risk of intentional contamination and the continuous discovery of new contaminants of concern. Ideally, all water quality monitoring would be performed in real-time to view quality parameters before, during and after treatment; as well as in the distribution system. However, there are few technologies that are able to provide true real-time measurements. This review examines strategies that use existing *in-situ* sensors and new or improved biological and chemical testing methods.

In-situ sensors are now readily available for certain parameters. Large deviations from baseline conditions of certain parameters, such as free chlorine, total organic carbon (TOC), specific conductance and oxidation-reduction potential (ORP), are able to signal a contamination event. Biological testing methods reviewed include flow cytometry, immunoassays, conventional and real-time polymerase chain reaction, DNA microarrays and ATP bioluminescent assays. Scatter and absorbtion patterns of particles during flow cytometry allow for correlations to the size, shape and density of microorganisms. Immunoassays provide qualitative results to the microbial quality of the water but can detect only high concentrations of contaminants. To lower the detection levels, concentration methods are necessary but this would increase the time requirements to complete the analysis. Conventional polymerase chain reaction (PCR), real-time PCR, and DNA microarrays are able to identify the presence of species-specific strands of DNA but are not able to determine the viability of microorganisms. ATP bioluminescent assay kits are readily available, easy to use, require only a small amount of sample volume and produce results within an hour. ATP assays are also able to determine the viability of microorganisms.

Recent research efforts surrounding chemical contaminants focus on the development of new detection methods for contaminants of low concentrations though most methods require pre-concentration steps. However, on-line solid phase extraction (SPE) units reduce sample preparation time, increase of sample throughput and decrease risk of contamination. Chemical detection methods reviewed include Liquid Chromatography (LC) coupled to Mass Spectroscopy (MS), DNA microarray and immunoassays. LC-MS techniques are being refined to reduce sample pre-treatment and enhance selectivity. DNA microarrays utilize a transformed gene to detect a particular chemical. Enzyme-linked immunosorbent assays (ELISA) are popular to detect cyanobacterial toxins and are being developed for the detection of other contaminants of emerging concern.

The review found that there is a great effort to develop a tiered and strategic approach to monitoring in order to screen for large scale contamination events and to allow for time to mediate the problem discovered. Compared to DNA-based methods, ATP-based methods are able to give insight into the viability of microorganism and thus to the level of threat posed by contamination. For chemical contaminants, the current focus is to develop new detection methods for low-concentrations of emerging contaminants. Processing time remains limited by the development of rapid pre-concentration techniques.

Experimental Investigation of Biological Clogging In Different Soils with Different Pore Structures

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Abstract
Biological clogging of unsaturated soils is an important process that can lead to the development of a biomat and failure of biofilters used to treat various wastewater streams. Septic beds and peat filters used to treat septic tank effluent are important applications. Several conceptual models have been developed to simulate clogging in saturated soils; however, limited effort has been conducted to develop similar models for unsaturated soils. Mostafa and Van Geel (2007) introduced three different relative permeability conceptual models to simulate biological clogging in unsaturated systems. These relative permeability conceptual models include the impacts of biomass growth on the relative permeability term for unsaturated flow. They implemented these conceptual models in a one-dimensional finite difference fully explicit flow and transport model but no experimental data were used to validate either the relative permeability models or the flow and transport model. In a recent study by Mostafa and Van Geel (2009), they conducted column experiments to study the clogging process in five soils; loose and dense peat, filter media sand, concrete sand, and septic bed sand. They also evaluated the Monod kinetic parameters in a separate experiment for the same feed solution used in the column experiment study. The column experiment data showed how different pore structures impact the distribution of microbial growth and the vertical saturation profile over time, eventually leading to complete clogging and the formation of a biomat. For the peat columns, a general shifting trend in the vertical saturation profiles was observed with time over the entire depth of the columns. However, the saturation profiles for the sand columns demonstrated a sharp increase in saturation at the top of the columns over time indicating the development of a biomat with time. The experimental data were then used by Mostafa and Van Geel (2009) to numerically simulate biological clogging in the five soils which lead to the validation of the relative permeability models introduced earlier by Mostafa and Van Geel (2007).

ANAEROBIC TREATMENT OF SPENT AIRCRAFT DE-ICING FLUID

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Independent of weather conditions, air travel remains high all through the year. Airports in northern countries use de-icing and anti-icing agents as part of their winter maintenance operations to ensure that critical aircraft surfaces are free of ice, snow or frost formation before take-off. The accumulation of such elements before or during flight modifies airplane aerodynamic characteristics, which can cause it to crash (Transport Canada, 1998). Aircraft deicing fluid (ADF) formulations consist mainly of a freezing-point depressant (ethylene, propylene or diethylene glycol), water, and proprietary additives (Switzenbaum et al., 2001). It has been estimated that to de-ice a large commercial aircraft requires between 500 to 1000 gallons of ADF (EPA, 1995); such high application rates have lead to the release of large quantities of spent ADF to the environment.

Environmental concerns associated with spent ADF are: oxygen depletion in receiving waters and aquatic toxicity. Glycols, due to its high microbial biodegradability, present high biochemical and chemical oxygen demands (BOD and COD respectively); COD concentrations of up to 60,000 mg/L have been reported at airport vicinities (USEPA, 2000). In addition, the proprietary additives ingredients (surfactants, wetting agents, corrosion inhibitors, flame retardants, foam suppressors, dyes, etc) can be toxic to aquatic organisms (Mcleese et al., 1981, Hartwell et al., 1995; Pillard, 1995) and some of its degradation products are suspected endocrine disruptors (Joblings et al., 1996; Staples et al., 2004; van Miller, et al., 2005). Hence, collection and treatment of spent ADF is mandatory under federal regulations. To date, spent ADF treatment options are biological (aerobic and anaerobic) and recycling.

Results of mesophilic (33 ± 2 ºC) anaerobic treatment of spent ADF from a medium size airport in northern USA, using bench scale up-flow anaerobic sludge blanket (UASB) reactors are presented. During continuous studies, an equalized ADF concentration (7g COD/L) was fed at different hydraulic retention times (HRT), generating organic loading rates (OLR) ranging from 1.2 to 7.3 kg COD/m^3 d. UASB performance was determined by influent COD removal, biogas production and effluent total suspended solids (TSS). The system reached 80% COD removal at the highest OLR and concomitant increase in biogas production with the OLR was observed. Due to a combination of hydraulics and biogas production, effluent TSS also increased at the highest OLR, however, such concentrations had no major impact on biomass inventory, which remained high during the study.
UASB proved to be a suitable technology for the anaerobic treatment of spent ADF; showing a robust performance under varying operation conditions, producing methane gas, which can be used to mitigate energy costs associated with its treatment and generating an effluent that can reach sewer discharge permits.

INTEGRATION OF PHOTOCHEMICAL AND BIOLOGICAL PROCESSES FOR WASTEWATER TREATMENT: AN OVERVIEW OF TRENDS, ADVANCES, AND FUTURE

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ABSTRACT

One of the greatest challenges of water and wastewater treatment technologies is the use of combined processes to achieve the most advantages of each process alone. The choice of the process and/or integration of the processes depend strongly on the wastewater characteristics, concentrations, and the desired efficiencies. It has been observed that the coupling of a biological process with advanced oxidation processes (AOPs) could reduce the final concentrations of the effluent to the desired values as well as the total cost of the organic removal. Advanced oxidation processes are mainly based on the production of highly potent hydroxyl radicals which attack organic compounds and produce carbon dioxide and water. However, optimizing the total cost of the treatment is a challenge, as AOPs are much more expensive than the biological processes alone. Therefore, an appropriate design should not only consider the ability of this coupling to reduce the concentrations of organic pollutants, but also try to obtain the desired results in a cost effective process. To consider the total cost of the treatment, the residence time in biological and photochemical reactors, the kinetic rates, and the capital and operating costs of the reactors play significant roles. In most case studies, it has been shown that the integration processes were more efficient than individual processes. However, slight changes in the configuration of the reactors, temperature, pH, treatment time, concentration of oxidants, and microorganism colonies could lead to a great deviation in results. Hence, in some cases, the coupling of these processes lowered the total efficiency of the system. It is important to consider the possibility of coupling different processes in lowering the total cost of the system while maximizing the rate of total degradation of organic pollutants. In this study, recent developments and trends on the integration of photochemical and biological processes for the degradation of organic pollutants in wastewater will be discussed. Case studies for the treatment of selected organic compounds will be also addressed.

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Interaction *Sinorhizobium meliloti-Trichoderma viride* produits dans les eaux usées d'amidon sur la luzerne.

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Mots Clés : *Sinorhizobium meliloti*, *Trichoderma viride*, interaction, Luzerne.

Résumé

L'intensification de l'agriculture est une source de dégradation de l'environnement qui touche précisément la perte de productivité des sols et la contamination des eaux. Ainsi la valorisation des eaux usées s'est avérée intéressante pour la production de biofertilisants et de biopesticides, qui sont de plus en plus utilisés en agriculture. En effet, des recherches scientifiques ont montré que les bioinoculants de rhizobium produits dans les eaux usées favorisent la fixation d'azote chez la luzerne (Ben Rebah et *al*, 2001) et que ceux de *Trichoderma* produits dans les eaux usées servent comme agent d'amélioration de croissance et de lutte biologique pour la tomate (Verma et *al*, 2007). De plus, des mélanges des différents bioinoculants sont de plus en plus employés pour évaluer les stratégies d'amélioration des plantes et de lutte contre les agents pathogènes. L'objectif de cette étude consiste à évaluer l'efficacité de l'interaction *Sinorhizobium-Trichoderma* produits dans les eaux usées d'amidon sur la luzerne. La méthodologie consiste à appliquer les bioinoculants *Sinorhizobium* et *Trichoderma* produits dans les eaux usées d'amidon ainsi que dans leurs milieux standards, seuls ou en mélange (*Sinorhizobium, Trichoderma*, mélange *Sinorhizobium-Trichoderma*) à une dose de 10^4 cellules par semence pour les deux microorganismes sur des plants de luzerne cultivés en sachets de croissance. Les résultats montrent que le nombre d'UFC de *Sinorhizobium* et de *Trichoderma* produits dans les eaux usées d'amidon est similaire à celui obtenu avec les milieux standards. Le *Trichoderma* ralentit la nodulation de la luzerne lorsqu'il est appliqué 24 h après le *Sinorhizobium* et cause une inhibition complète de la nodulation lorsqu'il est appliqué 24 h avant le *Sinorhizobium.* Par contre, la nodulation de la luzerne est moins affectée lors d'une inoculation simultanée *Sinorhizobium* et *Trichoderma* De futurs essais seront conduits avec des doses plus élevées de *Sinorhizobium* afin d'optimiser les conditions qui favorisent la nodulation; d'autres essais avec un agent pathogène permettront d'évaluer le pouvoir de lutte biologique de *Trichoderma.*

Influencing Factors on the Paranitrobenzoic Acid Wastewater Treatment by Ozone and Chlorine Dioxide Processes Using Granular Activated Carbon as the Catalyst

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Ozone (O_3) and cholrine dioxide (ClO_2) processes combined with granular activated carbon (GAC) respectively were investigated as the pretreatment methods for paranitrobenzoic acid wastewater with high-concentration organics in this paper.

The effect of ozone dosage, pH value and UV light irradiation on the operational performance of O_3/GAC process was analyzed. And the influencing factors, such as chlorine dioxide dosage, activated carbon dosage, pH value and reaction time were also considered in the ClO_2/GAC catalytic oxidation process. Furthermore, the efficiencies of the two processes to remove COD and increase biodegradation capacity (BOD_5/COD ratio) were examined under the optimum conditions.

The results showed that the COD removal efficiency of paranitrobenzoic acid wastewater by ozonation using GAC as the catalyst was much higher than that of either ozonation or GAC catalytic treatment alone. The removal efficiencies of long chain aromatic organics in wastewater, such as paranitrobenzoic acid and guanine, were much better than those of short chain organics, such as acetaldehyde and ethanolamine. It was also found that COD removal increased with increasing pH values in neutral and alkaline solutions, while excessive alkalinity weakened COD removal, with the most suitable pH value of 9.0. The COD removal of paranitrobenzoic acid wastewater by the O_3/GAC/UV process was 52%, and the BOD_5/COD ratio increased from 0.10 to 0.32, indicating that the biodegradation capacity was greatly improved.

In the case of ClO_2/GAC process, the COD removal efficiency of the ClO_2/GAC catalytic oxidation system was 10% higher than that of the system with only ClO_2 when the COD concentration of paranitrobenzoic acid wastewater was 10960 mg/L. It was also found that the COD removal was decreased by 35% with the concentration of 7100 mg/L under the conditions of pH value 4.1, GAC dosage 200 g/L, reaction time 30 min and ClO_2 dosage 300 mg/L. In addition, the BOD_5 concentration was increased to 1810 mg/L and the biodegradability was improved greatly with the BOD_5/COD ratio increased from 0.10 to 0.25.

In a word, the catalytic oxidation processes of ozone (O_3) and chlorine dioxide (ClO_2) with the catalyst of granular activated carbon (GAC) are all the effective pretreatment methods for paranitrobenzoic acid wastewater treatment.

Experimental Study on the Control of By-products by the Innovative Complex Pre-oxidation (CPO) Technique

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Ozone has been widely applied in the pre-oxidation process for drinking water treatment. However, pre-ozonation technique has caused many problems, especially the high cost and formation of ozonation by-products, such as assimilable organic carbon (AOC), bromate, formaldehyde, etc. So an innovative pre-oxidation technique -ozone/potassium permanganate (O_3/$KMnO_4$) complex pre-oxidation (CPO) technique was proposed in this study, and the removal efficiencies of disinfection by-products (DBPs) precursors and ozonation by-products with the CPO technique (O_3=0.6 mg/L, $KMnO_4$=0.4 mg/L) and pre-ozonation technique (O_3=1.5 mg/L) were also analyzed by bench-scale experiments.

The results showed that the ability of coagulation/sedimentation to remove the increased DBPs precursors could be significantly enhanced by the CPO technique, with the same total removal efficiency as that of pre-ozonation technique. In addition, the formation of AOC, bromate and formaldehyde was also reduced by CPO technique with the reduction of 43%, 78.4% and 21.2% respectively compared to pre-ozonation technique.

Impact of Mining Activities on Surface and Ground Water Quality Parameters

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One of the major problems associated with mining operations is the release of pollutants to surface water. Several major environmental problems caused due to mining operations are deforestation, land degradation, groundwater pollution, surface water pollution and dust pollution. Ground-water pollution can occur both directly and indirectly as a result of surface mining. In this context, keeping all the above facts in mind the present study was initiated to study the effect of mining in India on temporal variation of water quality parameters and to develop a water quality index map of the study area.

Water quality data for 23 physical and chemical parameters were measured from 23 samples collected from water sources around a few iron mines (Fig. 1). The water samples were collected during February, May, August and November 2006 representing the pre-monsoon, monsoon and post monsoon seasons and were analyzed to study the effect of mining on temporal variation of water quality parameters.

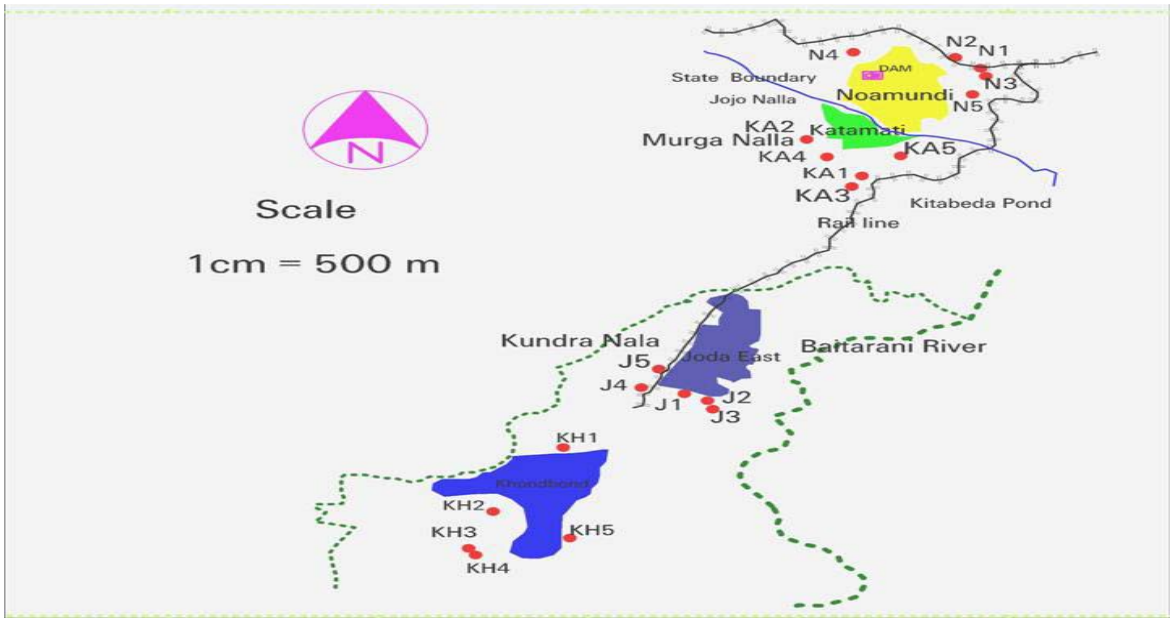

Fig.1. Map of the study area and location of different sampling points.

Using the observed water quality data, Canadian Water Quality Index (WQI) was found out. The WQI consisted of three measures of variance from selected water quality objectives (Scope; Frequency; Amplitude). The index produces a number between 0 (worst water quality) and 100 (best water quality). Once the WQI value has been determined, water quality is ranked by relating it to one of the following categories: **excellent**: (WQI Value 95-100), **good**: (WQI Value

80-94), **fair**: (WQI Value 65-79), **marginal**: (WQI Value 45-64), **poor**: (WQI Value 0-44). Moreover a water quality contour map (Fig. 2) was generated for the entire study area.

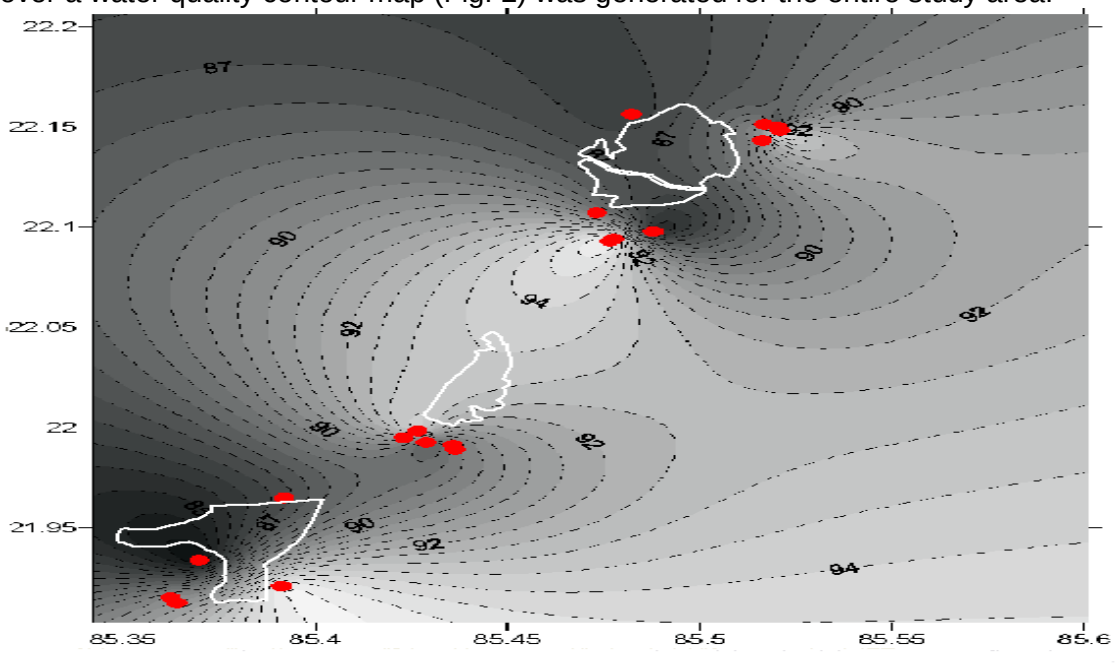

Fig.2. Contour map of Water Quality Index

From the map it was observed that the ground water quality is within the acceptable limit. Spatial distribution of pH, electrical conductivity (EC), total dissolved solids (TDS) and iron content of ground water samples were studied for pre monsoon and post monsoon periods of year 2006. Based on the results of the present study the following major conclusions could be drawn. The surface and ground water at most of the locations around the mining site in a radius of 10km are acidic in nature with high iron concentration. Stagnant water samples show more iron concentration than flowing water samples. The extent of the contamination depends on many factors such as duration of the industrial operation, atmospheric conditions, height of the stack, physical and chemical properties of the emitted particles, the amount of metals released to the atmosphere. Based on the value of water quality index the groundwater in the study region in general was good for drinking purpose. The low concentration of EC and TDS in the groundwater reveals the shorter groundwater rock contact time.

Keywords: Canadian water quality index, principal component analysis, temporal and spatial variation, water quality

EFFECT OF ULTRASOUND PRE-TREATMNET ON RAW WAS DEWATERABILITY

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Worldwide it is well recognized that sludge management is one of the biggest challenges facing wastewater treatment plants (WWTPs). Increased sewage expansion, upgrading of existing plants and implementation of more stringent environmental regulations have contributed to a dramatic increase in the per capita sludge production (UN-HABITAT, 2008). Currently, sludge management accounts for as much as 50% of a WWTP's operating cost (UN-HABITAT, 2008). The high water content of sludge is the main factor contributing to such high disposal costs. Sludge dewaterability, is considered to be the bottleneck of sludge handling and one of the least understood aspects of WWT. Thus, optimization of the dewatering process has become one of the main priorities being explored by stakeholders and researchers, looking to reduce WWTPs operation costs.

Ultrasound pre-treatment is an advanced disintegration technology that is being implemented to decrease the water content of sludge. It is believed that by disintegrating the sludge cells and disrupting the floc matrix, the interstitial water held inside extracellular polymer substances (EPS) is released, and this may lead to an improvement of its dewaterability (Erdincler and Vesilind, 2000; Erdincler and Vesilind, 2003; Skidmore, 2005). To date, the role of ultrasound on sludge dewaterability is contradictory; with some studies reporting a positive effect, while others have concluded that ultrasound has negative effect on dewatering. These contradictions may be attributed to the complex dynamics of the floc structure, the lack of well-defined sonication threshold to be applied and the use of different criteria to evaluate sludge dewaterability.

This study presents results describing the effect of ultrasound pre-treatment on dewaterability of raw waste activated sludge (WAS). Different operational parameters such as ultrasound specific energy and total solid concentration were assayed. Effect of ultrasound on WAS dewatering was assessed by measurement of capillary suction time (CST), compactability, moisture distribution, particle size distribution and cation release. Results showed that ultrasound pre-treatment deteriorates sludge filterability (measured as CST) as a result of clogging effects of fine particles. However, a slight increase in sludge compactability and free water was observed as measured by centrifugation at relative centrifugal force (RCF) of 8000g for 1 hour. These results imply that moisture distribution methods are more efficient to predict sludge dewatering than CST since they allow determining the maximum removable water that can be extracted by dewatering equipments. These results and other dewatering characteristics will be discussed in the presentation.

Evaluation Non-Imprinted Polymer Nanoparticles for Removal of Endocrine Disrupting Compounds from Surface Water and Wastewater

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Presenter will be competing for the P.H. Jones Student Award

ABSTRACT

Endocrine disrupting compounds (EDCs) are trace contaminants of growing concern for both the water and wastewater industries. Suspected effects of endocrine disruptors on humans include: breast cancer, decrease in sperm quality (Maffini et al, 2006), obesity (Newbold, 2008), and early puberty for girls (Euling et al, 2008), among others. This study investigated the use of non-imprinted polymeric nanoparticles (NIPs) for removal of endocrine disruptors both from surface water and wastewater. The objectives of the study included an evaluation of the effectiveness of NIPs for removal of a variety of EDCs as well as other emerging compounds from treated wastewater.

The effectiveness of NIPs for generalized treatment of endocrine disruptors was tested by evaluating the removal efficiency for 17β-estradiol (E2), 17α-ethinylestradiol (EE2), bisphenol A, atrazine, and diethylstilbestrol from distilled-deionized water samples. High-performance liquid chromatography (HPLC) was used for all water analysis. For ratios varying from 1 to 5 mg of endocrine disruptor/ g of particles, removal efficiencies were: 59-94% for E2, 42-99.7% for EE2, 53-75% for atrazine, 92-97% for bisphenol A, and 27-44% for diethylstilbestrol.

The NIPs were also tested for removal of unidentified compounds from both surface water and wastewater samples in presence of organic material and other competing compounds. Surface water samples were taken from the Rideau River and secondary clarifier effluent samples were taken from Robert O. Pickard Environmental Centre (ROPEC). Both samples showed visible peaks. The HPLC indicated the presence of an unknown compound at significant concentrations. The peaks could not be identified with HPLC alone, but addition of increasing concentrations of NIPs led to decreases in the magnitudes of the peaks, showing the ability of NIPs to treat contaminants in both surface water and wastewater.

Lastly, the NIP particles were tested for the removal of E2 from a secondary clarifier effluent sample. The wastewater was spiked with 10 ppm E2 and increasing concentrations of NIP particles were applied for removal. Increases in NIP particle additions led to decreases in the magnitudes of the peaks.

In conclusion, NIPs were shown to remove a variety of endocrine disrupting compounds and unidentified contaminants from both surface water and wastewater samples. These particles represent an innovative and cost-effective technology for removal of endocrine disruptors which is important for the protection of human health and the environment.

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Impact of climate freeze-thaw variability on soil water flow and nitrogen transport

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Transport models that track changes in soil water states (or ‘phases’) and their transition over time may better predict the spatial distribution of nutrients by better accounting for seasonal climate variability. Likewise, how agricultural nutrients are used most efficiently by crops depends on root water and nutrient uptake within the dominant soil water phase and its contribution to preferential flow.

The model is formulated as a non-equilibrium transport model with additional equations that describe how soil water phases regulate the dynamical behaviour of coupled soil-water physical and chemical processes. Freeze-thaw cycling via soil temperature drive transitions in soil water phase. Resultant water and solute flow are then phase-dependent regulated by soil porosity, permeability and kinetics.

We outline the structure of our model and how it is being implemented in Hydrus-2D/3D. Preliminary results are obtained by simulating the model against two years of recent data available from six agricultural plots with detailed soil characteristics, soil-water and nitrogen vertical concentration.

River catchment microbial dynamics under storm event conditions and human health protection: From a curative to a preventive strategy

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Problem statement: Extreme rainfall events, such as those experienced in parts of England in 2007 and 2008 (EA, 2009), can cause considerable amounts of faecal material to be washed into rivers. A detailed knowledge of the extent and origin of faecal pollution, and an understanding of microbial dynamics is crucial for cost-effective river catchment management (Farnleitner *et al*. 2007; Meays *et al*., 2004) in order to deal with potential risks and to protect human health.

Objectives: To apply a quantitative microbial source tracking (QMST) method to detect and quantify sources of human impact and understand the dynamics of enteric microbes in a rural catchment.

To develop models that could predict exceedance of the European Union (EU) Bathing Water Directive threshold value for *Escherichia coli* (*E*. *coli*) and intestinal enterococci (ENT).

Methodology: Traditional water quality parameters were measured in conjunction with a novel QMST method based on the phage lysis of a human-specific strain of the anaerobic gut bacterium *Bacteroides*. One-litre grab samples of stream water were collected from three sites within a sub-catchment of the River Ouse (England, UK), each morning and evening for one week during storm events. All samples were tested for suspended solids (SS), turbidity, presumptive *E*. *coli*, ENT, *Clostridium perfringens*, phages of *Bacteroides* (GB-124) (the human-specific marker), and somatic coliphages. Rainfall and stream discharge data were provided by the UK Environment Agency.

Results: All sites consistently failed to achieve the *E*. *coli* and ENT EU Bathing Water Directive (900 and 330cfu/ 100 ml respectively) standards (EU, 2006). *Escherichia coli* and ENT levels were 1.1–1.2 logs higher than during non event periods. Interestingly, the human-specific QMST marker showed significantly higher levels only downstream of WWTWs. Based on the correlation (r = 0.05) between *E*. *coli* and phages of *Bacteroides* (GB-124), the dominant source of faecal contamination was non-human. Turbidity, SS, and *E*. *coli* levels were significantly correlated. 83% (R^2 = 0.83) and 84% (R^2 = 0.84) of the variation in *E*. *coli* and ENT levels was explained by predictive models developed for *E*. *coli* and ENT respectively. *Escherichia coli* model contained a faecal material transport-related parameter (rainfall).

Conclusions: Heavy rainfall events may represent a temporal ‘critical control-point’ of concern for drinking water abstraction from the streams within the Ouse catchment. The QMST method can play a key role in predicting human faecal pollution dynamics during future extreme rainfall events. Multiple regression models can be used as early warning systems to predict exceedance of *E*. *coli* and ENT threshold values at bathing water sites. The information

gathered during the study can assist with the development of Water Safety Plans by water abstraction companies operating in this catchment.

Recommendations: Turbidity could be used as a surrogate for SS, and *E*. *coli* levels. Either *E*. *coli* or ENT could be analysed for since the two have a high positive significant correlation. Monitoring and management design should be simple, cheap, rapid, but the QMST method outlined here fulfils these criteria. QMST could therefore have a role to play in future Water Safety Plans.

Potential for aluminium to influence detection of *Escherichia coli*

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Problem statement: *Escherichia coli*, a gut commensal, is relied upon as a microbial indicator for potable water. It is important to be able to detect it when present, and its persistence in different water matrices is of significance for risk management. In potable water, the presence of even a single *E. coli* can lead to significant consequences and costs for water utilities.

Survival of *E. coli* in sterile Ottawa River water (RW) and in sterile undisinfected effluent from the filters (FEW) at a treatment plant using the Ottawa River as its sole water source showed much longer apparent survival in the source water than in water exiting the filters. We hypothesized that one or more substances in filtered water might be detrimental to *E. coli*.

Objectives: Conventional water treatment that uses alum as coagulant usually leaves a slight aluminium residual after treatment. The objective was to understand whether the presence of this residual aluminium in drinking water was responsible for the observed decline in *E. coli* cultivability. To test this, we examined the effect of an aluminium chelator, Tiron, for its ability to relieve the inhibition of cultivability of *E. coli*.

Methods: Aliquots from a stationary phase E. coli K12 culture were placed inside sterile dialysis sacs supported in four 2.2 L constant volume semi continuous reactors continuously fed with fresh 200 mL/h RW (2 reactors) and FEW (2 reactors) with or without different Tiron concentrations. The input water at 24±1 ºC was filtered through on-line 0.2 µm sterile hollow fibre filters. Both FEW and RW feed waters were collected fresh daily from the Lemieux Island Treatment Plant, Ottawa. Reactors were sampled at selected times and measurements were made of total cell numbers (microscopy), viable cell numbers (culture) and total aluminium content (ICPMS).

Results: E. coli in FEW declined in cultivability much more rapidly than in RW. In FEW most aluminium was free as Al^{3+} whereas in RW most Al was complexed. First, *E. coli* cells in FEW accumulated Al while cultivability remained constant. Aluminium then began appearing in the water coincident with a drop in cultivability. Very little aluminium accumulated in RW. Before working with Tiron to relieve inhibition of the cultures, it was important to determine that Tiron itself caused no culture inhibition. Inhibitory effects were seen only at 150 mM and above; we used only low µM concentrations. Chelation with Tiron of Al^{3+} in FEW prior to exposure of the cells maintained *E. coli* in a cultivable state similarly to RW. Throughout experiments, total cell numbers and numbers of apparently viable cells remained more or less constant in all reactors.

Discussion and Concluding Remarks: Aluminium is universally toxic and *E. coli* in this study is rapidly accumulating aluminium. Data is consistent with such accumulation affecting cultivability at natural levels. The main question is whether *E. coli* uncultivable after aluminium exposure remain viable (acridine orange), or whether they are dead, but with intact membranes. As a corollary, can aluminium mask the presence of *E. coli* as an indicator?

Improved PVDF ultrafiltration membranes for water treatment.

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Our group has been working for the past 15 years in development of polymeric additives to manufacture surface modified polyethersulfone (PES) ultrafiltration(UF) membranes. Recently we conducted an evaluation of the compatibility and effectiveness of one of these modifying polymeric additives, LSMM-600, with other common polymers used in the preparation of membranes. LSMM-600 was compatible with all the base polymers, did not make the membranes more hydrophilic as expected but it significantly increased the flux of membranes prepared with other base polymers (Dang et al, 2009). The objective of this study is to prepare and evaluate the performance polyvinylidene fluoride (PVDF) ultrafiltration flat sheet membranes prepared with LSMM-600 and compare their performance with that of three commercial PVDF membranes (HFM-100 and HFM-707 from Koch Inc., and PHVG supplied by Millipore Inc.). Experimental membranes were prepared using 0, 0.5 or 3% LSMM-600, 18% PVDF and 1-methyl-2-pyrrolidinone (NMP), the solvent, making up the rest of the casting solution. The current evaluation is based on contact angle measurements, pure water permeation (PWP) and solute transport tests. The later is used to determine mean pore size, pore size distribution, porosity, and the molecular weight cut off (MWCO).

As reported by Dang et al. (2009) the addition of LSMM-600 did not significantly impact the membrane's contact angle, however the contact angle changed with time indicating the membranes were either more porous. The most important finding was the PWP tests confirmed that significantly improved the stable (50 hr) flux of PVDF membranes, adding 0.5 % (wt) and 3% (wt) LSMM-600 improved the stable pure water flux by 210% and 324%, respectively. The flux of the later membrane (86 $l/m^2/hr$) was also 40% higher than that of the best commercial PVDF membrane tested. Modeling of the solute transport tests showed that the addition of LSMM-600 slightly decreased the mean pore size and increased the surface porosity five fold from 0.06% to about 0.36%, which is consistent with the higher fluxes. Thus, these results confirm that LSMM-600 has great potential as an additive in the manufacturing of PVDF membranes and the additive primarily modifies the membrane body rather than the membrane surface. On going research will optimize the PVDF membrane composition, compare LSMM-600 to more common pore forming additives and expand the testing to fouling tests with natural organic matter laden river water.

Simulations by AnnAGNPS of Controlled Tile Drainage on Water Quality in the South Nation River Watershed

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Abstract
Sediment nitrogen (N) and phosphorus (P) from agricultural areas can contribute to impairment of water quality. Agricultural best management practices (BMP) can reduce pollutant loadings below water quality objectives. Controlled tile drainage (CTD) is a BMP that has been shown to improve water quality and crop yields by reducing water and nutrient losses from tile-drained fields. Most studies have examined CTD on a field or plot basis and the potential impact of such practice to water quality has not been rigorously examined at river basin scales. In order to evaluate CTD at this scale, the Annualized Agricultural Nonpoint Source model (AnnAGNPS) was used to assess the impacts of CTD on water quantity and quality parameters such as discharge, sediment, nitrogen, and phosphorus loads. Simulations were restricted to 1971-2006 because of data availability. The simulation period was further split into a calibration period and validation period for each water quantity or quality parameter depending of the length of observation time series. The final fit was satisfactory for all parameters and both calibration and validation periods with Nash-Sutcliffe coefficients > 0.5 for these parameters. Preliminary modelling results show that applying CTD to all croplands can reduce runoff, sediment, N, and P loads by 2.30 mm (2.7%), 0.8 kg/ha 90.6%), 5.36 kg/ha (74%), and 0.0029 kg/ha (1.5%), respectively.

Détermination des paramètres biocinétiques du modèle de respiration endogène pour un système de boues activées alimenté en acétate

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Résumé

La fraction organique d'une liqueur mixte dans un système de boues activées renferme trois fractions particulaires : biomasse active, résidu endogène et matière non biodégradable apportée par l'affluent. La biomasse et le résidu endogène, résultant des différents processus microbiens, constituent la composante biologique des boues générées. Deux modèles mathématiques décrivant la production des boues biologiques existent dans la littérature : modèle de respiration endogène (McKinney, 1960) et modèle de mort-régénération (Dold et al, 1980). Le formalisme mathématique des deux modèles est similaire et requiert la détermination de trois paramètres biocinétiques: le rendement de croissance (Y), le taux de respiration endogène (b) et la fraction de résidu endogène générée (f). Expérimentalement, la détermination de b et f n'est possible que pour le premier modèle. Des paramètres équivalents (b' et f') pour le modèle mort-régénération sont calculés en fonction de b, f et Y considérant une consommation identique d'oxygène dans les deux modèles.

L'objectif de ce projet était d'évaluer les paramètres Y, b et f pour un système de boues activées alimenté en acétate et de les comparer avec les paramètres recommandés pour des systèmes alimentés en affluent réel.

Deux types de tests en cuvée ont été réalisés dans cette étude. Les premiers, de courte durée (≈30 h), visaient la détermination du paramètre Y en conditions aérobie et anoxie utilisant l'acétate comme substrat. L'inoculum pour ces tests provenait d'un pilote de laboratoire mais aussi d'une station d'épuration des eaux usées. La détermination de Y a été réalisée par suivi de l'évolution de la COD particulaire en fonction du donneur d'électrons mais aussi en fonction de l'accepteur d'électrons. Le deuxième type d'essais visait la détermination du paramètre b. Ces essais reposaient sur une digestion aérobie en cuvée (21 d) des boues issues du pilote de laboratoire et suivi des matières volatiles en suspension (VSS) et/ou du taux d'utilisation d'oxygène (OUR). Pour la majorité des essais, des bilans de masse (COD) ont été établis pour confirmer la concordance des méthodes et la consistance des paramètres déterminés.

Les résultats ont permis de déterminer des valeurs de Y de 0.565 et 0.400 mg COD/mg COD en aérobie et en anoxie respectivement et un taux de respiration endogène b de 0.235 d^{-1} (à 20°C).

Par ailleurs, la production de boues dans le pilote de laboratoire alimenté en acétate a été simulée avec le logiciel BioWin®. Les simulations ont été réalisées en régime permanent (SRT de 5.2 et 10.2 d) avec les paramètres déterminés expérimentalement pour l'acétate mais aussi avec ceux de la littérature. Une surestimation de la production de boues de 17 à 20% a été enregistrée dans le second cas.

Cette investigation a permis de conclure que les rendements cellulaires (aérobie, anoxie) avec l'acétate sont inférieurs à ceux reportés dans la littérature pour un affluent réel (0.666 et 0.540 mg COD/mg COD). La valeur du taux de respiration endogène reste proche de celle suggérée par la littérature (0.24 d^{-1} à 20°C). Ces résultats constituent un apport intéressant pour la modélisation des systèmes incluant une alimentation en acétate. Les paramètres Y et b

obtenus seront utilisés pour évaluer la fraction de résidu endogène f dans une phase subséquente du projet.

Traitement de résidus d'abattoirs par digestion anaérobie bi-phasique

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Depuis la crise de la vache folle, les frais de disposition des résidus d'abattoirs ont augmenté de façon substantielle. Ces coûts de disposition sont tels que certains abattoirs sont intéressés par la gestion de leurs propres déchets, et la digestion anaérobie de ces résidus s'avère une possibilité intéressante. Cependant, peu de recherche sur le traitement des résidus d'abattoirs ont été réalisés jusqu'à présent. En effet, ce type de résidus, particulièrement le sang et les viscères, comporte des caractéristiques qui les rendent difficiles à traiter par voie anaérobie, soit leur teneur élevée en protéines (azote organique) et en lipides. Il est possible d'utiliser un réacteur unique anaérobie pour traiter ce type de résidus. Toutefois, pour réduire les problèmes d'inhibition causés par les acides gras à longue chaîne et l'ammoniaque, l'utilisation d'un procédé en deux phases, soit un réacteur d'acidification et un réacteur de méthanogénèse, s'avère potentiellement intéressante et plus performante. Une étude sur la comparaison des performances de ces deux types de procédés a donc été entreprise et les résultats seront présentés ici.

Deux réacteurs (CSTR) en série de 14 litres, représentant le procédé biphasique (RA-2P et RD-2P), et un réacteur (R1-P) également de 14 litres ont été construits pour les expériences. Un analyseur en ligne à gaz méthane a été installé à la sortie gazeuse de chaque réacteur. Les réacteurs ont été ensemencés avec de la boue anaérobie d'un digesteur traitant des boues de station d'épuration. Les résidus bruts constitués de sang et de viscères de veaux de lait ont été récoltés dans un abattoir. Ces résidus ont été broyés et dilué 5 fois pour alimenter les réacteurs. Les conditions d'opération ont été dans un premier temps les suivantes; R-1P: TRH = 50 jours et S_o 123300 mg DCO/l; RA-2P et RD-2P: TRH = 10 et 40 jours respectivement, S_o 123300 mg DCO/l. Les conditions d'opération varient selon un plan factoriel d'expériences sur deux variables: le temps de rétention hydraulique et la concentration en substrat. Dans tous les cas, la température de digestion à été maintenue à 35°C.

Une caractérisation détaillée du substrat a été réalisée. La production de biogaz et de méthane a connu d'importantes variations. Pour le R-1P la production a varié entre 6 à 8L CH_4/jour. En ce qui concerne le RD-2P la production a augmenté progressivement jusqu'à un maximum de 12L CH_4/j. Le pourcentage moyen de méthane produit par le R-1P est de 74% et celui du RD-2F de 78%. Quant aux rendements de production de biogaz et de méthane par rapport à la DCO d'alimentation, le rendement du RD-2P a été supérieur à celui du R-1P, son rendement étant de 350 l CH_4 /kg$DCO_{intrant}$.

Les expériences se poursuivent et les résultats sont prometteurs ; le procédé à deux phases donnant de meilleures performances et semble plus stable, en plus, les concentrations de CH_4 sont assez constantes depuis 30 jours et le volume du biogaz produit a connu une tendance croissante.

CHEMICAL CHARACTERISTICS OF STORMWATER PONDS IN THE OTTAWA REGION

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Stormwater ponds (SWP) are built in urban areas to retain and treat water runoff that would otherwise move into downstream aquatic systems. Although high SWP pollutant removal rates have been reported, pond performance varies widely from one facility to another. The purpose of this study was to characterize nutrient levels and various other chemical parameters of ponds in order to build up knowledge of their biogeochemical behavior and treatment efficiency as a function of landscape characteristics and design features. In the City of Ottawa, 17 ponds out of a possible 94 wet ponds were sampled and selected based on their accessibility, present monitoring, permanent water flows, and low number of inlets. Surface water, bottom water and outflow water were analyzed for nutrient (total phosphorus, reactive phosphorus and nitrate) levels. Surface water and bottom water exhibited a wide range in TP and RP (0.016 to 0.420 mg/L and 0.001 to 0.034 mg/L respectively) and there was no relationship between June and August measurements for these parameters. Furthermore, 7 ponds had outflows with TP levels exceeding the Ontario provincial guideline of 0.03 mg/L and could lead to the degradation of downstream water quality. Nitrate levels also varied widely between ponds (0 to 2.09 mg/L) and no relation was observed between June and August indicating a possible low retention. Pond conductivity ranged from 383.23 to 2824.67µS/cm suggesting variable influences of road salt. Mid-morning dissolved oxygen ranged from 16.84% to 199.62% indicating high rates of primary productivity related to both high algal biomass and in some cases high macrophyte abundance. Dissolved oxygen and temperature stratification was observed in over half the ponds and chemical (conductivity) stratification in 6 ponds in June and none in August. The gradients suggest a wide range in biological production and trophic status. Characteristics of the "sewershed" which may explain these differences will be further examined as well as internal processes related to morphometric and biological features of each system.

Valorisation des rejets de l'industrie d'extraction d'amidon pour la production de bio-inoculants : Développement de formulations de *Sinorhizobium meliloti*

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Les effluents industriels représentent une menace continue pour l'environnement. Vu leur composition et leur abondance, la contamination des sols et la perte de fertilité des terrains agricoles ont été signalées autour des zones de rejets depuis longtemps. Dans ce travail, nous avons essayé de valoriser les effluents provenant des industries d'extraction d'amidon (SIW), pour des fins à orientation agricole, la production de bio-inoculant. En première partie, on a étudié la production de *Sinorhizobium meliloti*, bactéries fixatrices d'azote et nodulant la luzerne, partant des SIW comme milieu de croissance. Les résultats ont montré l'intérêt de l'exploitation de ces effluents (SIW) : la concentration finale en cellules dépassait les $4x10^9$UFC/ml.

En deuxième lieu, et pour parvenir à maximiser la récolte des bactéries par centrifugation, on a optimisé les conditions relatives à ce fait (pH, température, vitesse et durée de centrifugation) en utilisant la méthode de réponse de surface. Le modèle obtenu a permis de localiser une zone où il est possible de maximiser la récolte jusqu'à 20 fois. L'analyse statistique a montré que seule la vitesse et la durée de centrifugation sont déterminantes pour ce qui est rendement lors de la récolte.

Dans la seconde partie de ce travail, on a développé des formulations en suspension partant du bouillon fermenté obtenu des SIW, et conservées à 4°C. Les agents de suspension étudiés étaient le sorbitol (1,2 et 5% wt/v), les alginates de sodium (0.2,0.3 et 0.5% wt/v), le sucrose (2, 5 et 10% wt/v), le polyéthylène glycol 8000(PEG)(1,2 et 5% wt/v), le polyvinyle pyrroldine 10000 (PVP) (1,2 et 5% wt/v), des mélanges de :PEG (1%wt/v) plus sorbitol (2% wt/v), sucrose (5% wt/v) ou alginates (0.3% wt/v), de PVP (1% wt/v) plus sorbitol (2% wt/v), sucrose(5% wt/v) ou alginates (0.3% wt/v) ont été également testés. La stabilité de ces formulations à été suivie pour 13 semaines, les paramètres étudiés étaient le pH, la viscosité et le nombre de cellules viables. Les résultats ont montré que les formulations développées se sont caractérisées par la stabilité et ont permis de maintenir la survie de S*inorhizobium meliloti* à des concentrations supérieures à 10^9UFC/ml (la norme de qualité des inoculants étant de 10^7 à 10^9UFC/ml, selon la dose appliquée).

Dans le cadre de l'évaluation de l'efficacité pratique des formulations développées, des grains de semences de la luzerne ont été enrobés avec, en premier lieu des formulations fraîches et en deuxième lieu les formulations conservées pendant 13 semaines; les grains ont été conservés à la température ambiante et la viabilité des cellules a été suivie pendant trois mois. Les résultats obtenus montrent que les formulations fraîches développées à partir de mélange de polymères et de sucre (PVP+ sorbitol, PVP+ sucrose ; PEG+ sorb, PEG+ sucrose) permettent de maintenir une concentration de cellules viables par graine dans la marge des normes canadiennes de la qualité des inoculants pour la luzerne (10^3UFC/graine).

Mots clefs : effluent, bio-inoculant, formulation, *Sinorhizobium*, stabilité

GROUNDWATER-BORNE ADVECTIVE TRANSPORT OF A CHEMICAL FROM A BURIED SOURCE

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ABSTRACT

The advective mode of migration of chemicals in fluid saturated porous media becomes dominant in instances where the Peclet Number is greater than unity. This implies that the transport processes involving velocity driven mechanisms dominate the diffusion driven mechanisms. In this paper we examine the problem of the advective transport of a chemical from a three-dimensional cavity located in a fluid saturated porous medium. The boundary of the cavity is maintained at a constant potential to initiate a steady flow pattern consistent with Darcy flow. The chemical is introduced at the boundary of the three-dimensional cavity and maintained at a prescribed time-history. The mathematical modeling also takes into consideration the existence of a natural attenuation with constant intensity. Certain exact closed form solutions are presented for the time-dependent variation of the chemical concentration within the fluid saturated porous medium [1]. The results for the advective transport three-dimensional cavity are utilized to generate a series expansion solution for the problem of a disc shaped crack in an infinite medium, and the boundary of which is maintained at a constant potential and a constant concentration. The model is intended to simulate conditions that can be encountered during the deep geological disposal of contaminants and other hazardous materials by hydraulic fracture processes [2]. The results can be applied in the preliminary estimation of the extent of movement of the chemical due to the disposal activity, where the governing permeability parameter can be varied to establish the extent of the created plume [3]. Most importantly, the exact solutions for the three-dimensional problems discussed can be used to benchmark computational solutions for the advective transport problem. In the absence of the diffusive term, the computational treatment of the purely advective transport problem requires sophisticated numerical schemes that can deal with issues related to stability and accuracy of the solution in a satisfactory manner. The generalized three-dimensional *exact closed form solutions* presented here are novel and provide the necessary means for the validation of computational solutions. The mathematical approach can also be extended to include flow velocities that display exponential time decay. Such developments have applications to deep geologic disposal of contaminants under gravity feed.

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THE REMOVAL OF HUMIC SUBSTANCES IN THE EFFLUENT ORGANIC MATERIAL (EFOM) BY APPLYING ELECTRICAL FIELD

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Abstract
Humic substances comprise 40 to 50 % of the EfOM (Amy et al., 1987). This high percentage of refractory organics comes from the drinking water or formed during wastewater treatment process (Bouwer, 1995; and Chobda, 1985). Humic materials are deemed more resistant to biodegradation, moreover, they are of great concern because they are capable of forming harmful disinfection by-products (DBPs) as they combine with the free chlorine during disinfection such as trihalomethane and halo-acetic acid (Quanard et al., 1996). The objective of this study was to investigate of removal of humic substances by applying DC field to activated sludge during electro-coagulation process.
A series of batch reactors of 1-L volume equipped with aluminum anode and iron cathode, aerated to maintain aerobic conditions, were designed. Three mixed liquor suspended solids (MLSS) of 5000, 9000 and 14000 mg/l concentrations and five electrical exposure time modes (5'-on/5'-off, 5'-on/10'-off, 5'-0n/15'-off, 5'-on/20'-off and continuous-on) were tested at current density ranging between 20 to 35 A/m^2. Each reactor runs for 70 hours at least for electrocoagulation process.
The above mentioned humic substances can absorb UV at 254 nm. Singer et al. (1981) found a strong relationship between UVA254 and trihalomethane formation. Thus, analysis of UVA254 was applied in this study. Measurements were performed in supernatants in order to assess the existence of humic substances in potential effluents and to predict the formation of organic halogens.
The results showed a substantial reduction of humic substances. Minimum of 47% was achieved for all electrical exposure modes and for all MLSS when the current density ranged between 20 to 35 A/m^2. The percentage of removal was different between the reactors, depending on the concentration of suspended solids and mode of operation. Exposure mode of 5'-on/10'-off exhibited the maximum removal efficiency at MLSS of 4700 mg/l (93%) and at MLSS of 14,000 mg/l (96.8 %), while at MLSS of 9000 mg/l at 5'-on/5'-off electrical mode showed the highest removal efficiency of 89.5%. This high removal of humic substances, which are extremely resistant to biodegradation, is most probably attributed to the electrocoagulation of organic materials, microbial flocs, and aluminum hydroxides (formed as a result of Al^{+3} ions released from the aluminum anode). The removal efficiency of humic substances depends on the operation time. This process is not instantaneous and there is a minimum time span of operation before a substantial reduction is witnessed.
Applying an accurate DC field has a potential of high removal of humic substances (potential formation of hazardous compounds in waters). The best removals were achieved when the magnitude of current density and the electrical exposure mode were selected based on the concentration of suspended solids.

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Etude des réacteurs à boue granulaire aérobie : effet du mode d'aération et de l'alternance anoxie/aérobie sur les performances

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Mots-clés: granules aérobies; nitrification; dénitrification; SBR;

Le procédé à boues granulaires aérobie constitue une technologie prometteuse pour le traitement de la pollution organique, de l'azote et du phosphore dans les eaux usées. Cependant son application industrielle nécessite encore l'étude de certains verrous mécanistiques afin de fiabiliser les performances et minimiser les besoins énergétiques.

L'objectif de ce travail est d'évaluer comment les conditions opératoires, en particulier l'alternance anoxie/aérobie, peuvent permettre d'améliorer la formation des granules, de minimiser les besoins en aération et de mieux stabiliser la nitrification-dénitrification.

D'une part les résultats obtenus dans deux réacteurs SBR (sequencing batch reactor) seront synthétisés (thèse Junfeng Wan, Wan et Spérandio, 2009 ; Wan *et al.,* 2009). Les résultats démontrent que l'alternance entre des conditions d'excès de substrat « anoxie » et de famine « aérobie » permettent de favoriser le développement des granules (entre 500-1000 µm) et la stabilisation des performances (nitrification en particulier). La concentration en biomasse atteint jusqu'à 10 g/L. Une nitrification stable est ainsi obtenue malgré une charge volumique importante en matière organique ($2.8 KgDCO/m^{-3}.d^{-1}$). La caractérisation physique (taille et cohésion) des agrégats biologiques montre que la formation des granules est caractérisée par plusieurs étapes : une phase de densification, une phase de croissance avec érosion (distribution bimodale), puis une phase de croissance et de maturation.

Les premiers résultats de simulation seront présentés et confrontés aux données expérimentales. Un modèle mathématique permet de décrire les gradients de concentrations dans les granules (1 dimension) et l'évolution des espèces au cours du temps dans le réacteur. En présence d'une alternance anoxie/aérobie, non seulement le profil de biomasse hétérotrophe montre une croissance plus en profondeur mais ceci génère également plus de stockage de composés de réserve (favorable à la formation des granules). L'analyse de ces données simulées permet de mieux comprendre comment s'organisent les différents groupes bactériens (hétérotrophes, autotrophes) dans l'épaisseur du biofilm constitutif des granules.

Au final, cette étude ouvre de nouvelles perspectives pour le développement d'installations compactes de traitement des eaux usées mais aussi minimisant les besoins énergétiques.

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Influence of nitrate concentration on aerobic biological aggregates densification in SBR for granular sludge formation
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Impact of spring melt on phosphorus and sediment losses in agricultural watersheds of Eastern Canada

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**The presenter will compete for P.H. Jones student award.

Snowmelt is a significant hydrological event in cold temperate climate. However, snowmelt impacts on sediment and phosphorus (P) losses are poorly documented in Eastern Canada. This study aimed at exploring the links between winter conditions and spring melt erosion, quantifying the sediment and P losses and improving the knowledge and practices of controlling sediment and P losses during snowmelt period in Eastern Canada. The data from field monitoring, remote sensing and mathematical modelling in two agricultural watersheds in Quebec (2007-2009 in Bras d'Henri, BHW) and New Brunswick (2008-2009 in Black Brook, BBW) will be discussed.

Water samples were collected manually or automatically in watershed outlet during snowmelt periods and analyzed for suspended sediment and P (TP, PP, DP or DRP). Soil temperature at various depths was continuously monitored. Frozen soil maps were developed from SAR images to classify soil frozen status, and compared with soil temperature measurements to test classification accuracy. The overall classification accuracy was 90% (K=0.81) over the BHW and 89 % (K=0.78) over the BBW. Due to the difficulty to collect winter hydrological data, hydrological processes (snow equivalent water, precipitation, runoff and flow rates) were predicted by the model WaSiM-ETH. The prediction accuracy was reasonably good based on the correlation analysis between simulated and measured discharges.

The results revealed that 1) sediment and P losses during snowmelt highly depended on specific winter conditions such as soil frozen status and precipitation, and most of the significant sediment and P losses were associated with unfrozen soil or rain-on-melt event; 2) DP and PP losses during snowmelt could be equivalent and significant in BHW while PP dominated TP loss in BBW; 3) snowmelt total P export represented between 20 and 40% of the total annual TP export in BHW, and approximately 25% of the annual DRP export in BBW. Therefore we recommend that adapted and effective BMPs should be implemented in the highly erosive land or plots to decrease soil and P losses from agricultural lands during snowmelt period.

The effect of liquid and solid manures under controlled drainage with sub-irrigation recycling systems on water and nutrient movement and crop performance

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Agricultural production practices have a substantial impact on water quality by affecting the amount and timing of surface runoff, tile drainage and movement of nutrients. Almost all manure produced on Canadian farms is applied to agricultural land.

In Ontario most of the precipitation occurs during the non-growing season and generally most of tile drainage volume, nitrate and phosphorus leaching occurs during this same period. During the growing season, there also can be periods in wet years that heavy rainfall would cause surface runoff and tile drainage to carry crop nutrients (P, N) and other agricultural chemicals into drainage ditches which eventually enter the aquatic systems and cause damage to water quality and biota. By controlling water flow in the tile drained land, the excess water which contains the nutrients can be maintained in the lower portion of the crop root zone. Furthermore, during the dry growing season, improved soil moisture conditions under controlled tile drainage and sub-surface irrigation recycling system enhance crop production and reduce adverse off-site water quality and quantity impacts.

The experiment was initiated in the spring of 2008 on a Brookston clay loam (28% sand, 35% silt, 37% clay). The treatments included two manure sources (solid, liquid dairy cattle manures), a P drawn down (inorganic fertilizer N and K if necessary), a inorganic fertilizer control (inorganic fertilizer N, P, and K), and two water management strategies (traditional free drainage vs. controlled drainage and sub-irrigation) with two replications in a factorial design. Four separate reservoirs and water recycling system have been constructed at the existing experimental field. The surface run-off and tile drainage water from the treatments are routed into 4 separate reservoirs. In Nutrient Management Act (Ontario Regulation 267/03) phosphorus is the only factor which is regulated for maximum rate of manure application. Each manure source will be applied at the rate containing 100 kg P/ha based on crop requirement. The balance of crop N requirement will be supplied by inorganic fertilizer if necessary. The two manure sources were applied in the spring of 2008, then disced in to a depth of approximately 3 inches in a corn phase of the corn-soybean rotation. No manure will be applied in the soybean cropping season in 2009. The objectives of this study are to determine the effects of two manure sources under traditional free drainage and controlled drainage/subirrigation with water recycling in a corn and soybean rotation on water, nutrient (P, N) movement in surface runoff and tile drainage and crop performance.

Agriculture and Agri-Food Canada at Harrow has developed the most extensive and sophisticated run-off and water samplings capabilities for monitoring and collecting surface and sub-surface flow all year round. This world class water quality facility will provide the Agri-Food Industry with new knowledge and technologies that will lead to enhanced more sustainable agriculture environmental system, and improved crop nutrient and water use efficiency. Some limited results will be discussed in relation to the effectiveness of controlled drainage with sub-irrigation water recycling for mitigating the impacts of two manures on surface and sub-surface water quantity and quality and crop performance.

Comparison of regular free drainage and controlled drainage/sub-irrigation water recycling systems on nitrate, phosphorus losses and crop production

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Across Canada areas of intense agricultural production face challenges associated with profitability, sustainability and off-farm environmental impacts. Of particular concern is the severe growing season drought associated with global warming and non-point source agricultural pollution. Connecting tile drainage to a water reservoir can help increase yields and offer substantial environmental benefits. In a controlled drainage/sus-irrigation and water recycling system, tile drainage water and surface runoff water from agricultural fields are routed into a wetland reservoir, rather than into open-ended streams and drainage ditches. The collected water is then recycled back through a controlled drainage-subsurface irrigation system to provide subsurface irrigation during times of crop water deficit. The reservoir serves as a sink to prevent off-site movement (loss) of water and sediments, and also provides a means for intercepting and recycling agricultural nutrients and chemicals via return irrigation. As a result, precipitation water is used more efficiently, and the discharge of agricultural sediments and chemicals into off-site surface and ground water resources is reduced substantially.

The experiment was initiated in the spring of 2000 and consisted of two treatments: controlled tile drainage/subirrigation (CDS) and regular/traditional free tile drainage (DR). The experimental site is located on the Essex Region Conservation Authority Demonstration Farm at Holiday Beach, Ontario. The two plot size, each 25 m by 131 m, and enclosed by a raised surface berm. Corn was planted in 2000, 2001, and 2003. Soybean was planted in 2002 and 2004. Surface runoff and tile drainage flow volume were measured using four stainless steel custom fabricated tipping buckets connected to data-logger system. Water samplers were collected by ISCO auto-samplers. Nitrate samples were analyzed using TRAACS 800 auto-analyzer. The dissolved inorganic phosphorus and total dissolved phosphorus were analyzed using a QuickChem Flow Injection auto-analyzer.

The objectives of this study were to determine the effectiveness of the integrated wetland-reservoir and controlled drainage-subsurface irrigation water recycling system for: i) mitigating nitrate and phosphorus losses from agricultural fields; and ii) improving corn and soybean yields with supplemental subsurface irrigation.

The controlled drainage/sub-irrigation and water recycling system (CDS) reduced total nitrate loss by 41 % compared to the free drainage system (DR). The CDS system reduced dissolved inorganic, dissolved organic and thus the dissolved total phosphorus losses in tile drainage water by 18 %, 47 % and 36%, respectively, relative to the DR system. The water from the reservoir was used for subsurface irrigation of grain corn and soybean during the droughty growing seasons of 2001 and 2002. It was found that the CDS system increased corn grain yield in 2001 by 91 %, and soybean yield in 2002 by 49 % relative to the DR system. Thus, the CDS system can be highly effective for improving crop yield and reducing non-point source pollution from agricultural fields.

ON Downscaling OF RAINFALL PROCESSES for Climate-Related Impact Assessment Studies

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ABSTRACT

This paper provides an overview of various downscaling methods that could be used for assessing the potential impacts of climate change and variability on hydrological regime. In general, two broad categories of these downscaling procedures currently exist: dynamical downscaling (DD) techniques, involving the extraction of regional scale information from large-scale circulation data based on the modeling of regional climate dynamical processes, and statistical (or empirical) downscaling (SD) procedures that relied on the empirical relationships between large-scale atmospheric variables and surface environment parameters. While neither DD methods nor SD methods were found to outperform the other, the SD techniques have several practical advantages.

In view of the above-mentioned issues, two SD methods based on the regression-based Statistical Downscaling Model (SDSM) and the stochastic Markov Chain-Mixed Exponential (MCME) model were selected for testing their feasibility in the simulation of daily precipitation time series. The SDSM is mainly relied on the empirical statistical relationships between large-scale climate predictors given Global Circulation Models (GCMs) and local-scale parameters; while the MCME model requires a combination of two components that describes, respectively, the persistence of daily precipitation occurrences at a local site based on the first-order Markov Chain (MC) and the distribution of rainfall amounts on wet days using the mixed exponential (ME) probability distribution.

Results of the evaluation using available climate and daily rainfall data at Dorval Airport in the Montreal region (Quebec, Canada) have indicated that both models were able to describe adequately some basic statistical characteristics of the underlying daily rainfall process. In addition, the proposed MCME model was able to reproduce more accurate description of the local daily precipitation properties than the SDSM. However, none of these models appears to be able to simulate very well the properties of daily annual maximum precipitations (AMPs). Hence, an innovative approach was proposed to combine the estimation of daily AMPs by the MCME model with those given by the downscaled GCMs using the SDSM method. The combined model was found to be able to provide AMP estimates that were comparable to the observed values at the local study site. Furthermore, it can be seen that the suggested linkage between the MCME and SDSM-based GCM outputs could be useful for various climate-related impact studies involving rainfall extremes.

Hydrodynamic Simulations of Flash Flood Using a Minimal Intervention Strategy

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Flash floods caused by stormwater of intense rainfall can result in severe property damage as well as loss of lives. The challenges in routing of the flood water have been in the capturing of the shock-wave front where the flood flow changes from super-critical to sub-critical flow and in the advancing front where the flood water meets the dry land. Computations may collapse as a consequence of numerical instability when the depth of water becomes negative at these fronts. The artificial numerical oscillations have to be suppressed for long-term computational stability. A stable and robust hydrodynamic routing model would determine the flood velocity and depth for each street and building in an urban area. Precise risk maps are needed for the mitigation of the floods which has increased in magnitude and frequency due to climate changes.

This paper shows how a flood routing model with long-term computational stability is developed by controlling the numerical oscillations using a minimal intervention (MI) strategy. The MI is a strategy to implement a shock capture scheme in the classical finite volume method. The shallow-water equations are solved on the staggered grid. The face value of the velocity flux is determined by a third-order upwind bias interpolation. Numerical oscillations are controlled for total variation diminishing using flux limiters. The accuracy is maintained using a fourth order Runge-Kutta time integration scheme. The shock capturing capability of this MI strategy is verified by the simulation of one-dimensional and two-dimensional dam-break flood waves and their comparison with the exact solutions. The long-term computational stability of the strategy is demonstrated by the simulation of flood waves at super-critical speed and its propagation through the streets of an idealized city. With MI strategy, the accuracy and robustness of the classical finite volume method is greatly enhanced. Therefore the method with the MI strategy is well suited for flood routing through complex terrain.

Improved Environmental Multimedia modeling and its sensitivity analysis

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Abstract:

All pollutant contamination problems have both short and long term impacts on ambient air, water, and soil environments. For example, an aged landfill or oil drill may concurrently pollute the local air, groundwater, and soil resources. Previous environmental pollution control models and software mainly focused on a single environmental medium (e.g. groundwater). Consequently, a comprehensive understanding and characterization of the natural behavior of pollutants in the environment, using multimedia models, are essential tasks for environmental risk assessment and management. Following a review of environmental multimedia modeling methodologies, performance and limitations of such a multimedia model are discussed. In particular, a number of testing problems related to three-phase-dissolved adsorbed, and vapour phase contaminant transports in unsaturated and groundwater media and their flux are examined and compared with each other with standard numerical and analytical methodologies. The results indicate the output of new model is lesser in the unsaturated zone and groundwater zone compared with the traditional environmental multimedia model. Furthermore, about 90% of the total benzene flux was distributed to the air zone from the landfill sources and only 10% of the total flux emitted into the unsaturated, groundwater zones in non-uniform conditions.

The comparisons highlight the accuracy, applicability, and limitations of different environmental multimedia models. This paper also includes functions of model sensitivity analysis to optimize model parameters such as retardation factor, Peclet number (Pe), hydraulic conductivity, bulk density and porosity. Preliminary studies on model sensitivity analysis have been conducted for part of the example and literature cases. Those variables are analysed their sensitivities to the transport of contamination in liquid, gas and soil phases to the different media. The analyses results show that the Peclet number can be considered as deterministic input variables for transport output. The oscillatory behaviour is eliminated with the Peclet number (Pe) decreased. Also the numerical methods are more accurate than analytical methods with the Peclet number (Pe) increased. Other variables such as unsaturated retardation and saturated hydraulic conductivity have a significant influence on the probability outcome as well.

In conclusion, the improved environmental multimedia model system can be used as a tool to address the fate and transport of the three-phase (water, air, and solid) contaminant transports.

Key words:
Environmental Multimedia Model; Landfill, Fate of benzene; Retardation; Hydraulic Conductivity; Peclet Number

Kinetic Formulations for Growth and Substrate Uptake in Biological Wastewater Treatment

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The Monod or hyperbolic kinetic formulation became the de facto kinetic descriptor in activated sludge models in the '80s-'90s. It still plays a prominent role in activated sludge models; however, a dual hyperbolic formulation (with respect to both substrate and active biomass) that implicitly accommodates storage as well as more rationally describes metabolic kinetics is more prominent in governing metabolic functions in activated sludge models (ASMs) promulgated by working groups under the aegis of the International Water Association (IWA).

The Monod hyperbolic formulation can be justified from mass transfer and first-order kinetic formulations but it only weakly describes dynamic variation in biotreatment processes. Recognition of substrate storage and the more rational basis of the dual hyperbolic formulation dramatically improved the efficacy of new models. But ASMs ignore the mass transfer function in metabolism. The dual hyperbolic formulation only improves description of metabolic kinetics but bypasses mass transfer considerations from liquid to biomass. A model incorporating mass transfer is proposed here as an alternative approach to modelling biotreatment kinetics. Adsorption of particulates has been recognized in models that underlie ASMs but the influence of adsorption on readily degradable substrate was ignored.

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).

This paper examines conceptualizations that include hyperbolic metabolic expressions of Monod or Michaelis-Menten forms but also incorporate specific equations related to mass transfer.

Various theoretical formulation for RBCOD (glucose) and SBCOD (soluble starch) metabolism were developed in this paper. A justification for the Monod formulation was given. Other formulations based on the Monod rate formulation and first-order kinetics were developed. Diffusion and storage were also considered in the development of the models. A justification for the dual hyperbolic formulation was developed.

A fully active acclimated aerobic culture acclimatized to RBCOD (glucose) and SBCOD (starch) was developed in the laboratory. This culture together with repirometry test was used to determine the true K_S and μ_H when grown on simple RBCOD. Many bartch studies with vary8ing concentrations of glucose and active mass were monitored to evaluate over 249 models. The Monod model gave a good fit to the data.

Using the results of the RBCOD assays and repirometry of SBCOD the relationship between SBCOD and active biomass accounting for RBCOD metabolism was evaluated using

a one-phase decay model. An addition conclusion from this evaluation was support for the enzyme reaction site theory that increase starch concentration results in increased rates of reactor due to greater number of reaction sites.

Another series of batch tests were conducted using only starch as a substrate. Again substrate concentration and active mass concentration were varied in the batch tests. The results from the above evaluation were used to determine the adequacy of 2 starch hydrolysis models based on a Monod type relationship and a dual hyperbolic relation that allowed for determining the true reaction constants accounting for starch concentration, biomass concentration and taking into account degradation of RBCOD. Both of these models are fairly simple in terms of concept as well as determination of parameters and have scientific sensibility in describing hydrolysis of SBCOD.

Determination of phosphorus source coefficients for animal manures

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Manure varies in P forms and contents, which can result in significant differences in P losses after land application, depending on the sources. Weighting factors must be determined to reflect the differences in risk of P loss from various types of manures. The objective of this study was to determine the P source coefficients (PSC) of major types of manures and biosolids for Ontario soils using an incubation approach. Treatment factors included six predominant soil series distributing in the major manure production areas of Ontario, four types of manure P sources (solid beef, liquid swine, solid poultry, and liquid dairy) with 3 sources of each collected across the province, an inorganic fertilizer P control, a zero-P control, and four incubation stages (2 days and 2, 8 and 26 weeks). PSCs were determined using the measurement of water extractable P. The values of PSCs varied, depending on manure and soil types, as well as the incubation period. PSCs for liquid swine manures were very high and often exceeded 100%, but decreased in most soils with the prolonged incubation time, while they remained consistently the highest amongst the four types of manures. The temporal changes in PSCs for solid beef, liquid dairy, and solid poultry manures were with less fluctuation, relative to those for liquid swine manures. The values of PSCs for four types of manures averaged across six soils for the entire incubation period of 26 weeks were 97.8, 45.4, 45.0, and 25.0% for liquid swine, solid beef, liquid dairy, and solid poultry, respectively.

Sub-surface flow: a significant pathway for soil phosphorus loss?

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Soil phosphorus has been historically believed to be lost to the environment through pathways of surface runoff and erosion. However, recent studies have increasingly shown that sub-surface runoff or title drainage can account for 22 to 98% of the total soil P loss. Partition of soil P loss between tile drainage and surface runoff is a function of tile spacing, but the optimum tile spacing can vary with soil types. Particular P often plays an important role in soil P loss in tile drainage water, followed by the dissolved reactive P. Variation of P loss in tile drainage water, including seasonality, magnitude, and relative importance to total soil P loss, is significant. Factors affecting P form distribution and their concentrations and magnitudes of loss in tile water can include those (soil, weather, crop, management practices) that are eventually related to soil P status (i.e. degree of P saturation, solubility), dispersibility, and hydrological properties (i.e. porosity and size distribution, amount of discharge and flow rate). Large dataset is required to quantify the cause-effect relationships, and enable us to increase the power of prediction.

Thermophilic and Mesophilic Sequencing Batch Reactors for TMP Pressate Treatment

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Problem Statement: In striving to achieve closed cycle operation and subsequent reuse of treated effluent, individual steams of pulp and paper mill effluents are being evaluated for their suitability for in-mill treatment.

Thermomechanical pulping (TMP) pressate is a warm (60-70˚C) and high strength wastewater generated in the TMP process where mechanical processes use steam to soften chips and pressure to refine them, producing a very high yield product, with 85 ~ 95% of the original wood components in the final pulp, including lignin, while 2% ~ 5% of the wood material is dissolved, or dispersed as colloidal particles, into the process water. The main contaminants in TMP process water are resin acid, fatty acid, and neutral wood extractives. TMP pressate is the most concentrated flow and contains most of the COD generated in the TMP plant. In-mill treatment of TMP pressate would maintain a good heat balance, promote “zero effluent” technology, and thus reduce the final environmental impact. No studies have been reported yet on biological treatment of TMP pressate to achieve closed cycle operation and subsequent reuse of TMP pressate.

Objectives: The objectives of this study were to investigate the performance of sequencing batch reactors (SBRs), under thermophilic and mesophilic conditions, for TMP pressate treatment. COD removal efficiency, sludge flocculating ability, settleability, and microbial community were investigated and compared between thermophilic and mesophilic temperatures.

Methodology: Two parallel laboratory-scale SBRs were operated at 55^{o}C and 35 ^{o}C, respectively, for the treatment of TMP pressate from a local pulp and paper mill for 4 months. Measurements of mixed liquor suspemded solids, effluent suspended solids, sludge volume index, chemical oxygen demand were conducted according to Standard Methods (APHA, 2005). Floc morphology and filaments levels were evaluated using a conventional optical microscope. Floc size distribution and zeta potential of sludges were determined using a Mastersizer 2000E and zeta meter, respectively. Microbial community was determined using the PCR-DGGE method.

Results and Conclusions: 1.) Under tested conditions, with a total influent chemical oxygen demand (COD) of 3700 ~ 4100 mg/L for TMP pressate, a COD removal efficiency of about 60-70, 80-90, and 80-90% was achieved at an hydraulic retention time of 6, 12 and 24 hours, respectively, under both thermophilic and mesophilic conditions; 2.) Excellent sludge settleability (a small sludge volume index) was obtained at both thermophilic and mesophilic SBRs; 3) A higher level of effluent suspended solids was usually observed in the thermophilic SBR; 4) PCR-DGGE study showed that there were significant differences in microbial community between thermophilic and mesophilic sludge; and 5.) the results suggest that treatment of TMP pressate in both thermophilic and mesophilic temperature is feasible.

Recommendations: Further studies should focus on an improved fundamental understanding of the causes of poorer flocculating ability of thermophilic sludge. Of particular interest are the

role of extracellular polymeric substances (EPS) in flocculation in thermophilic sludge and the use of membrane bioreactor technology for achieving closed cycle operation.