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20th Eastern Regional Conference

29 octobre 2004 / October 29, 2004

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COMPTES RENDUS / PROCEEDINGS

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20E CONGRÈS RÉGIONAL DE L'EST DU CANADA DE L'ACQE
(Association canadienne pour la qualité de l'eau)
20TH EASTERN REGIONAL CONFERENCE OF THE CAWQ
(Canadian Association on Water Quality)
Université Carleton / Carleton University
Ottawa, ON

Le 29 octobre 2004 / October 29, 2004

Programme scientifique / Scientific Program

7:45 Inscription/Registration
8:45 Ouverture du congrès/Congress Opening
Southam Hall Room 403

	Session A **Southam Hall Room 520**	**Session B** **Southam Hall Room 517**	**Session C** **Southam Hall Room 403**
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9:30	Peroxidase catalyzed oxidation of bisphenol A in a reversed micellar system *Li H.-M. and Nicell J.A.*	Proposition d'un cadre de travail pour l'intégration du développement durable dans le processus de conception de systèmes *Gagnon B. et Leduc R.*	Evaluation of microbial water quality risks associated with the land application of biosolids; test on hydrologically isolated plots *Unc A., Passmore J., Goss M., Springthorpe S., and Sattar S.*
10:00	Kinetic models of laccase-catalyzed oxidation of aqueous phenol *Kurniawati S.* and Nicell J.A.*	Seawater denitrification at the Montreal Biodome *Labelle M.-A., Juteau P., Villemur R., Parent S. and Comeau Y.*	Properties of flocs in dissolved air flotation of Winnipeg tap water *Zhang G.* and Gorczyca B.*

10:30	Pause / Break	Pause / Break	Pause / Break
	Innovative traitements / Innovative Treatments	**Eaux usées / Wastewater Treatment**	**Ressources en eau / Water Resources**
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11:20	Laccase-catalyzed removal of bisphenol-A from water *Modaressi K., Taylor K.E., Biswas N., and Bewtra J.K.*	Direct detection of pathogens in municipal wastewater using oligonucleotide DNA microarray *Lee, D.-Y., Shannon K. and Beaudette L.*	Reaction-transport modeling as a tool for investigating phosphorus controls in lake sediments *Katsev S., L'Heureux I. and Rancourt D.G.*
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14:00	The effect of microwave dose on biogas production from batch anaerobic digesters treating WAS *Eskicioglu C.*, Kennedy K.J. and Droste R.L.*	Treatment of low strength aircraft de-icing fluid in an anaerobic baffled reactor *Marin J.* and Kennedy K.*	Application of CCME procedures for deriving site specific water quality objectives for the CCME Water Quality Index *Khan A.A., Tobin A., Paterson R., Khan H. and Warren R.*
14:30	Predicting nitrogen release and liquid effluent impacts for anaerobic sludge digestion upgrades *Kraemer J.T.* and Bagley D.M.*	Transformation et valorisation des boues rouges d'aluminerie par production d'un agent déphosphatant pour le traitement des eaux usées *Poulin E.*, Mercier G. et Blais J.-F.*	A GIS approach for evaluating aquifer sensitivity to climate change in Eastern Ontario *Robin M.J.L. and Daneshfar B.*
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15:50	Variabilité de la fraction de la matière organique biodégradable dans des réseaux séparatifs et unitaires *Lagarde F., Tusseau-Vuillemin M.-H., Lessard P. et Héduit A.*	Effect of leachate recirculation and sludge addition in aerobic bioreactor landfills *Rendra S.*, Fernandes L. and Warith M.A.*	UV-visible spectrophotometry for lake monitoring: application to Lake Brome, Southern Québec *Sundborg M., Pouet M.-F., Lavoie A., Lambert M. and Thomas O.*
16:20	Steam-explosion pretreatment of municipal sludge to enhance anaerobic digestion *Dereix M.*, Parker W. and Kennedy K.*	Post environmental assessment performance of municipal solid waste landfills: a case study of the Merrick Landfill *Berhe, E.G.*, Puschak R., Warith M. and Fernandes L.*	Nutrients transport in surface and subsurface runoffs from two drained fields in the South of Quebec *Simard G., Madramootoo C. and Enright P.*
16:50	Mot de la fin / Final Words Mackenzie Bldg Room 3328		
17:00	Cocktail Minto Centre Room 2014		

Les affiches/Posters

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Effect of evapotranspiration on hydrodynamics and performance of constructed wetlands

Chazarenc F., Naylor S., Brisson, J. Merlin G., and Comeau Y.

The effect of water table management on the phosphorus concentration of agricultural drainage water

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Simulation of membrane distillation processes: direct contact (MD)

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Investigating the uncertainties in heterogeneity using CFD for flow and transport in vadose zone

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Pyrolysis of sewage sludges for the production of bio-oil and adsorbent

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A.S. Ramamurthy[1], Diep Vo[2], and Magdalena Tudor[3]

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Albanna, M.[1] (mashhab@rogers.com), Fernandes, L.[1] and Warith, M.[2]

[1] Dept. of Civil Engineering, University of Ottawa, ON

[2] Ryerson University, Tornoto, ON

Biological oxidation of methane is an important constraint on the emissions of the gas from landfills, to the atmosphere. Methane, one of the primary greenhouse gases, is a radiatively active organic gas, has an atmospheric concentration that has significantly increased during the past few hundred years, and affected negatively climate changes. In addition to its radiative forcing effect on climate, methane can also influence the climate directly through chemical interaction affecting other radiatively important gases.

Landfills are among the most abundant anthropogenic sources of methane emissions. Numbers of design advances have reduced the environmental impacts of new landfills and concomitant public concern, but landfill continues to require technical and regulatory attention.

Recent researches have identified some innovative and low cost biological methods to mitigate emissions associated with the gases produced in landfills, and enhance microbial consumptions of the gas in the aerobic portion of landfill cover. The use of these methods can increase methane reductions achieved by gas collection, or can be the only means to consume methane at smaller landfills that do not have active collection system; otherwise methane will escape from water and soil environment to the atmosphere.

The rate at which methane is biologically oxidized depends on the environmental conditions. Some of the factors that influence microbial oxidation in landfills include climate variables such as moisture content, temperature, methane concentration, soil type and properties, pH, and the depth of oxygen penetration.

Several experiments have been conducted to determine the factors that influence methane uptake efficiency. Those experiments as well as predications models have been used to help finding a biosystem design that could supplement landfill gas collection or replace leaking caps and reduce landfill gas emissions. Different models were developed to determine the effects of environmental parameters on biological methane oxidation and gas transport. Models can aid in developing the design of methane oxidative soil cover systems by reducing the number of laboratory experiments required to select the optimal soil type and recommended thickness for the environment. Those models have included biochemical, biological and physical mechanisms that affect the gas generation and transportation through landfill covers.

Some of those models are one dimensional reactive- transport models describing the generation and transport of gases, some are modeling the biodegradation, biochemical, physical, geochemical and hydrological processes. Those models are simulating different parameters and their effect on the degradation and transport of gases within landfill. Many of those illustrated models had limitations. Those limitations provide opportunities for future improvements.

Although no single model will have the capabilities allowing it to be applicable to all possible scenarios, and existing models have varied scope, the focus of this study is to examine some of these different models, their objectives, modules used and factors affecting biological oxidation, experiment observation and the numerical solution used in those models. Such comparison is considered the first step towards developing comprehensive model to realistically address the physical and chemical mechanisms involved in gas transportation and oxidation through landfill covers.

Analytical Methodologies for Determination of Natural and Synthetic Steroid Sex Hormones Using Solid-Phase Extraction Followed by Liquid Chromatography–Mass Spectrometry

Auriol, M.[1,2], Filali-Meknassi, Y.[1,3] (youssesm@umre.edu), Adams, C.[1] and Surampalli, R.Y.[3]

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Endocrine systems (EDS) play an essential role in the regulation of metabolic processes, such as nutritional, reproductive and behavioural processes. Perturbation of any of these systems, involving both overactive and underactive hormone secretion, cause inevitably harmful effects on many different organs and functions of the body. Nowadays, scientists believe that EDS can be adversely affected by a variety of substances and showed that there is a relationship between the occurrence of the estrogen-active substances and malfunctions of sexual differentiation. Steroid estrogens seem to have the highest estrogenic activity including both natural and synthetic estrogens (Figure 1). The phyto- and xenoestrogens exhibit minor estrogenic activity, even if their water level concentration can be usually higher.

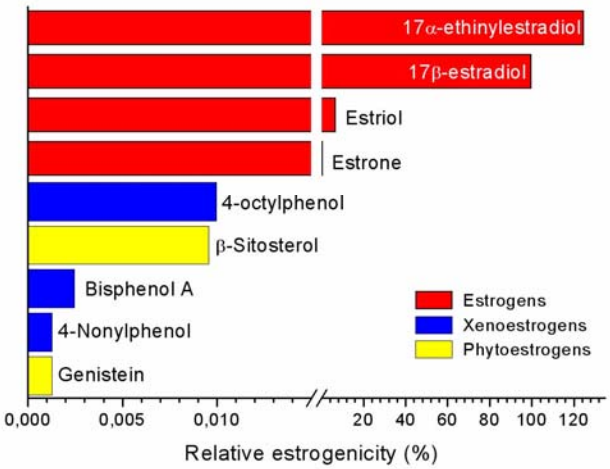

Figure 1. Relative estrogenic activity of some endocrine disrupting compounds (EDCs).

The primary source of steroid estrogens in the environment has been attributed to human release through sewage treatment. These compounds are natural estrogens: estrone (E1), 17β-estradiol (βE2) and estriol (E3) and synthetic estrogen: 17α-ethinylestradiol (EE2). In addition, emission of natural estrogens from farm animals (cattle, sheep, pigs, poultry, etc.) contributes massively to the presence of estrogens in the environment, in particular for the underground water and the rivers near the farms and the agroalimentary industries. The major compounds excreted are E1, 17β-E2, 17α-estradiol and their conjugates. Thus, the presence of these estrogens in surface waters and sediment has been attributed to their incomplete removal in the sewage treatment process and to the farm animals dejections.

The steroid estrogens detection in wastewater is a difficult analytical task, due to the wastewater matrix complexity and to the need of very low detection limits required. Few methods are available to quantify steroid hormones. Most of them rely on a solid-phase extraction (SPE) followed by a derivatization step prior to detection by gas chromatography–mass spectrometry (GC–MS). However, the derivatization is time and cost consuming and represents a critical phase of the sample preparation. Lately, a number of problems were reported with two of the more popular silylation methods [N,O-bis-(trimethylsilyl)trifluoroacetamide (BSTFA) and N-(tert-butyldimethylsilyl)-N-methyltrifluoroacetamide

(MTBSTFA)]. Indeed, EE2 is partially or near 100% converted to E1 during the derivatization and chromatography separation. Consequently the GC-MS seems not allowing a good quantification of an analytes mixture in environmental samples under the conditions described in the previous studies.

In the other hand, LC–MS or LC-MS-MS is a technology applicable to a wide range of molecules and matrices. It is generally preferred to GC–MS because of its sensitivity and specificity. Furthermore, no derivatization is required. However a few studies have been done with the LC-MS and the Limit of Detection (LOD) was very high and neither of them studied the 17α-estradiol analysis. With the LC-MS-MS, the LOD reported in some new studies are lower. However, the instrumentation required to perform LC-MS-MS analyses is expensive, and its application to environmental monitoring is still far from routine. Moreover, the cost of the analysis with this instrument is higher and a few environmental laboratories have this type of instrument.

The aim of the current study is to develop a reliable and sensitive method based on SPE followed by LC-MS in order to determine natural and synthetic hormones in various water types. The methodology proposed for analyzing the hormones in aqueous matrices involved a SPE performed with both C18 and NH2 cartridges following by LCMS using electrospray ionization.

Post Environmental Assessment Performance of Municipal Solid Waste Landfills: A Case Study of the Merrick Landfill

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We present the findings of a post-Environmental Assessment (post-EA) audit of a Municipal Solid Waste landfill. The study examined facility compliance, accuracy of EA impact predictions, and impact management and mitigation issues related to groundwater, surface water, and landfill gas and air quality impacts of the Merrick Landfill in North-Bay, Ontario.

The research included a literature review of post-implementation follow-up and monitoring studies in environmental assessment and related environmental applied science and management literature including environmental auditing, geology and hydrogeology, and landfill design and engineering concepts. Also included were project related documents and reports including Environmental Assessment (EA) documents, monitoring reports, facility permits, EA hearing submissions and decisions, and other reports on the project prepared by the proponent and the Ontario Ministry of the Environment (MOE).

The purpose of this research was to provide an up to date case study that builds on existing post-EA follow-up knowledge by:

(1) Assessing whether the Municipal Solid Waste landfill (MSWLF) operation complied with environmental quality objectives determined through the EA process and other regulatory instruments and achieved good environmental performance;

(2) Comparing actual environmental impacts with predicted impacts.

We evaluated the overall performance of the landfill with respect to compliance, effectiveness of the monitoring and impact management measures, and performance of landfill components based on monitoring and compliance data from 1995 to 2001. The results of this study indicated the weaknesses and strengths of the EA predictions, the subsurface investigations and landfill design criteria used, and mitigation measures employed in impact management. Our findings highlight the value of post-EA audits in improving the environmental management aspects of environmental impact assessments.

Traitement du phosphore d'effluents piscicoles par marais artificiels et lits de scories

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[3] Pisciculture des Alléghanys, 251, rue Commerciale, St-Damien de Buckland, (QC), Canada, G0R 2Y0

Les besoins annuels en eau d'une pisciculture, produisant 55 tonnes de poissons, sont d'environ 10.000 m^3/j. Ce fort débit permet de maintenir la concentration en ammoniac à un niveau non toxique pour les poissons mais engendre la production d'un effluent dilué et des apports massiques en phosphore importants (1000 kg P/an). Les risques d'eutrophisation des milieux récepteurs liés à ces rejets sont élevés et constituent un frein au développement de plusieurs entreprises piscicoles. C'est pourquoi, une réduction d'au moins 40 % des rejets en phosphore est exigée par le Ministère de l'environnement (Q-2) d'ici 2010.

Dans ce contexte, une filière expérimentale de traitement combinant plusieurs unités a été conçue dans une pisciculture. L'objectif est de retenir une partie du phosphore associé aux particules décantables qui ne représentent que seulement 0.1% du débit total mais qui contiennent 25% de phosphore rejeté. La pisciculture comporte une zone de décantation après chaque bassin d'élevage, permettant de retenir une bonne partie (80-85%) des déchets solides. Un nettoyage hebdomadaire permet de les diriger vers un silo de stockage. Ce dernier se comporte comme un décanteur, réduisant de 98% la charge en MES (de 2400 à 50 mg/L). Il permet de stocker les boues épaissies sur une période d'au moins 4 mois avant épandage. Après décantation, les effluents obtenus (surnageant) contiennent des composés dissous et du phosphore ayant des caractéristiques proches de celles d'effluent domestique (400 mg DCO /L, 20 mg Pt /L). Deux filières de traitement, comprenant chacune un marais artificiel (surface de 28 m^2) suivi de deux lits de scories (volume réactionnel de 450 L), permettent de traiter le surnageant. Ce système a été dimensionné pour retenir environ 150 kg P/an (20% de la quantité totale du phosphore rejeté par la pisciculture).

Le traitement préliminaire dans les marais artificiels permet l'abattement de 80% de la DCO et 55% des MES (ce qui représente une charge spécifique dégradée de 30 g DCO $m^{-2}.j^{-1}$ et 7 mg MES. $m^{-2}.j^{-1}$). Ce prétraitement assure une rétention plus efficace du phosphore par les scories en limitant la formation de biofilm et la saturation des sites réactionnels par de la matière organique. Les lits de scories permettent une élimination de plus de 99% du phosphore (de 22,0 mg/L à 0 mg/L). Toutefois, un problème de colmatage attribué entre-autre à la précipitation de carbonates a été constaté après un mois de fonctionnement. Ce phénomène semble essentiellement dû au relargage d'ions hydroxydes (pH 11-12). Des essais sont en cours avec des mélanges de matériaux (scories, gravier, calcaire). Les résultats obtenus sont prometteurs et révèlent des abattements en phosphore supérieurs à 99 %, sans montrer de signes de colmatage.

Toward the Use of the BAP-Test to Predict the Performance of Enhanced Biological Phosphorus Removal in Municipal WWTP

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[2]Ecole Polytechnique of Montréal, Dept. of Civil, Geological and Mining Engineering, Montréal, QC

The reduction of phosphorus (P) discharged by wastewater treatment plants (WWTP) is a key factor in fighting eutrophication of aquatic systems. For WWTP over 2000 pop.equiv., the most cost-efficient method to reduce the discharge of P is enhanced biological phosphorus removal (EBPR), combined with the addition of some chemicals.

The efficiency of this treatment depends on the availability of volatile fatty acids (VFAs) which can be contained in wastewater and/or produced by fermentation in the anaerobic tank or in the primary sludge digester. The biochemical acidogenic potential (BAP) of a wastewater, is determined by measuring the amount of VFAs contained in a wastewater plus those produced by fermentation at 20°C in the dark over a period of 15 days (Martin-Ruel, 2002). This potential should be useful to predict the performance of EBPR. Nevertheless, the actual BAP fraction which is used in a WWTP according to the wastewater and treatment processes is not known and can not be directly determined.

To determine this fraction, it is necessary (i) to measure the amount of P removed by EBPR and (ii) to evaluate the ratio “VFA consumed / EBRP-P removed”.

To determine the amount of EBPR-P removed, two lab-scale wastewater treatment plants (150 liters) were monitored in parallel during 7 months and kept at 20°C. They were supplied with a synthetic wastewater, prepared with primary sludge diluted with tap water and supplemented with mineral and organics compounds. The first pilot plant served as a reference (control pilot), to determine the amount of P eliminated by "standard" processes of assimilation, precipitation and adsorption. The other one (Bio-P pilot) was equipped with an anaerobic zone upstream of the aeration tank to assess its EBPR potential. The difference in P removal between the two pilots allowed to quantify the amount of P eliminated by EBPR.

Successive periods of 15 days were conducted for both treatment units with increasing levels of VFA supplements, initially with a VFAs mixture (acetic, propionic and butyric acid) then only with acetic acid.

For the ratios “VFA consumed / BioP removed”, two values were determined: 11,7 mg COD consumed / mg BioP removed with the VFAs mixture and 9,5 with acetic acid. Nevertheless, it was difficult to reach steady states conditions for the acetate supplement. The BAP fraction of the synthetic wastewater used in the BioP pilot was about 37% (gCOD/gCOD) which is rather similar to the initial concentration of VFAs in the synthetic wastewater. In our experimental conditions, the fermentation of elements which were supposed to ferment was almost nonexistent. Additional experiments will be carried out to determine the fermentation of various substrates and of real wastewaters.

The pilot experiments also led to identify the main factors which influence the EBPR for the pilot units: (i) the nitrate recirculation flowrate, (ii) the nitrates and oxygen concentration in the wastewater, (iii) the oxygen transfer due to the mixing of the anaerobic zone.

Reference

Martin, S., Comeau, Y., Héduit, A. *et al*. (2002). Operating conditions for the determination of the biochemical acidogenic potential of wastewater. *Water Research* **36** (9).2337-2341.

Ultraviolet Degradation Studies of Wastewater Sludge Based *Bacillus Thuringiensis* Biopesticides

S. K. Brar, M. Verma, R. D. Tyagi and J. R. Valéro

INRS-ETE, Université Du Québec, 2700 rue Einstein, Sainte-Foy, QC G1V 4C7

*Bacillus thuringi*ensis (Bt) based biopesticides have been registered for use for about 50 years with considerable advances in lowering production costs by using cheaper substitutes. However, formulation requirements also plague their longer residual activity in the field, in particular, ultraviolet (UV) protection additives. Natural sunlight, especially, the UV portion of the spectrum: UV-B (280-310 nm) and UV-A (320-400 nm) is responsible for inactivation of crystal protein and spores (active component responsible for entomotoxicity – Tx) of Bt. In these studies, wastewater sludge (raw and pre-treated) based Bt biopesticides when compared with soya medium gave better half lives for fermented media as well as formulations (without UV screens). The residual data (spores and Tx) of different fermented media fitted fairly well into the first order rate model (R2 from 0.8 to 0.93) with truncation at 6.5 and 125 d data. Another remarkable point was that half lives and T0.9 (90 % decay), irrespective of the type of media and formulation, were higher when the decay constants were calculated on the basis of Tx losses rather than spore mortality. The half lives (in days) of fermented media, on the basis of Tx, followed the order: hydrolysed (TH) >non-hydrolysed (NH) >soya and values were reported to be 6.2>3.99>2.63>1.19. Similarly, half lives for different formulations followed the order: NH>TH>soya as 11.14>9.51>9.02>2.08. In addition, studies on screening of different UV protectants were carried out and sodium lignosulphonate, molasses and Congo Red were found to be the best UV screens for both sludges. This study will have great impact on residual efficacy of sludge based Bt formulations and also their marketability potential.

Biosolids Management Programs

Buberoglu, B.[1] (Bilgin.Buberoglu@nrc-cnrc.gc.ca) and Duguay, L.[2]

[1]National Research Council (InfraGuide), Ottawa, ON

[2]Federation of Canadian Municipalities (InfraGuide), Ottawa, ON

Canadian municipalities spend $12-15 billion annually on infrastructure, but funds never meet the needs of the ageing infrastructure. Thus, the National Guide to Sustainable Municipal Infrastructure (InfraGuide) was formed to help municipalities identify needs, evaluate solutions, and plan long term, sustainable strategies for improved infrastructure performance at the best available cost with the least social and environmental impacts. This unique project involves a partnership between the Federation of Canadian Municipalities, the National Research Council and Infrastructure Canada.

In addition to being a national network of experts, InfraGuide pulls together Canadian experience/knowledge and summarizes it into best practice documents for use by decision-makers and technical personnel in the public and private sectors. The growing collection of published best practices in 5 technical areas are available on-line (www.infraguide.ca) and in hard copy. Volunteer technical committees and working groups, with the assistance of consultants and other peers, share the responsibility for their research and publication.

This *Biosolids Management Programs* best practice is based on information from an extensive literature review and a Canadian survey of current biosolids practices, where 22% of responders indicated that no specific compliance criteria were applicable to biosolids management programs in their jurisdictions.

While the practice of putting biosolids to beneficial use, particularly in agricultural land applications, has taken place for decades without documented adverse effects to human health or the environment, the public has become concerned and is now questioning the safety and sustainability of biosolids management programs. As a result of the changes in public perception, biosolids programs are under much greater scrutiny and should become a high priority for municipal governments that operate wastewater treatment plants and generate residual solids.

To meet the demands of today's society, biosolids management programs must be protective of the environment and public health, sustainable, cost effective, reliable, and must have some degree of flexibility and diversity to assure their success, even under changing and unforeseen circumstances.

Although some elements may be less applicable due to the municipality's size and situation, biosolids management programs are described as having 13 key elements, including:

- Regulatory framework
- Source control
- Solids stabilization
- Biosolids management
- Odour control
- Contingency planning
- Public participation/communications and others

This best practice provides a framework for undertaking the planning of a biosolids program, gives advice on technologies and end uses as well as on methods for involving the public in the planning exercise. For the purpose of this best practice, biosolids were divided in 3 basic quality categories. Furthermore, the

document may help to chart the directions that may have to be taken and the initiatives that will have to be started.

By implementing best practices for biosolids management, municipalities will improve their chances of realizing these benefits:

- Compliance with regulatory requirements
- Improved biosolids quality
- Improved odour management
- Improvements in safety
- Wider public acceptance
- Improved cost effectiveness
- Sustainability

Effect of Evapotranspiration on Hydrodynamics and Performance of Constructed Wetlands

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In constructed wetlands used for wastewater treatment, evapotranspiration (ET) represents a major parameter affecting hydraulic residence time (HRT). In horizontal subsurface flow constructed wetlands (HSSF), ET can represent up to 200 $mm.day^{-1}$ in favorable periods and under temperate climate, values ranging from 0 (winter) to 50 (summer) $mm.day^{-1}$ are generally observed. As mentioned in several studies, it seems to enhance global treatment performances and to modify significantly water flow. But basically, ET is seldom taken into account in modeling or dimensioning equations. The aim of this work was to propose hydraulic and model-based design of HSSF under high ET rate and with ET values as an input of the models. This study is based on the analysis of the HRT and the treatment performances (TSS, COD, TKN) of $1m^2$ pilot-scale units (SSF) constructed wetlands for wastewater treatment. Analyses were focused on eight units, differentiated by macrophytes (unplanted and planted with *typha sp.* and *prhagmites sp.*) and filtration media (gravel, slag and peat). Data were used to establish the relationship between HRT, treatment performances, and especially ET-related phenomena. HRT was estimated by using lithium tracer tests. The plug flow with axial dispersion model (PFD) and a conceptualized model were studied and tested using the object oriented Visim® software.

As expected, removal in planted pilot units with larger ET (more than 50% of inflow) was greater, especially for TKN and organic matter. In this study, ET average values range from 3.7 $mm.day^{-1}$ up to 17.2 $mm.day^{-1}$. Maximal values were estimated at 20 $mm.day^{-1}$.

Measured HRT are generally more important (20 to 40%) than theoretical. It could be due to the pilots size, maybe generating some edge effects, or to the assimilated part of the tracer. Hydraulics model were firstly fit, then global model including reaction rates for COD, based on a first order kinetic were proposed. The diffusion coefficient was evaluated at about 0.1 $m^2.s^{-1}$ by fitting experimental data with dispersion plug flow model (R^2=80%). It is in the same order of magnitude to what is generally estimated in constructed wetlands (value from 0.07 to 0.33 $m^2.s^{-1}$). But it did not seem to vary significantly between wetland units. The second model supposes a two layers flow. Even if correlation coefficients are less important than with the PFD model (R^2=75%), it provides a better understanding of the ET effect.

During a tracer test, tracer loss is more important under high ET rates. Into the pilots units ET influence on diffusion seems to be less significant compare to full scale units. The relationship between ET and pollutant removal rate is strong. Modelling leads to a proposal of some dimensioning elements taking into account ET.

Steam-Explosion Pretreatment of Municipal Sludge to Enhance Anaerobic Digestion

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Anaerobic digestion is commonly used in wastewater treatment plants (WWTP) for the degradation and stabilization of the large amounts of sludge produced in the primary sedimentation and activated sludge processes. During anaerobic digestion organic matter is transformed into methane and carbon dioxide and some smaller amounts of biosolids. Methane gas can be used for energy generation; therefore maximization of methane production during anaerobic digestion has been a subject of special consideration.

Slow hydrolysis during anaerobic digestion is a limitation of the anaerobic process because it results in the requirement for long digester residence times, hence large reactors are required and a high capital investment is needed. Despite this weakness anaerobic digestion is well suited for the treatment of sludge, because it can significantly reduce the amount of residual sludge as well as the pathogenic content of it, which is advantageous considering the high costs of transportation and disposal of sludge. In fact, minimization of residual sludge and production of sludge with reduced pathogenic microorganisms that can be use for purposes such as land application and landfill cover, has been recently consider a priority. Therefore, there is an incentive to research techniques to improve the rate and extent of the anaerobic hydrolysis phase in order to optimize the digestion process to minimize capital investment and operational costs.

The hydrolysis phase of the anaerobic digestion can be accelerated if the organics are pre-treated prior to digestion. Several pretreatment approaches have been investigated to hydrolyze organics before the anaerobic digestion to enhance the overall anaerobic degradation process. These technologies include, thermal disintegration, mechanical disintegration and chemical disintegration. In general, all these pretreatments attempt to burst microbial cell walls to liberate intracellular carbon sources as well as nutrients to facilitate hydrolysis. Other benefits of pretreatment include the breakup of large organic molecules and an increase in sludge surface area due to floc structure destruction leading to more sites being available for biological reaction. It is clear from the literature that disintegration pretreatments lead to solubilization of organics present in the sludge and can enhance its subsequent anaerobic digestion. However, in most cases (except with thermal pretreatment), pretreatment results in reduced dewaterability of the treated sludge leading to higher cost in the dewatering process.

This paper presents results for the steam-explosion pretreatment of sludge, which is a promising alternative for enhancing the anaerobic digestion treatment of municipal sludges being developed in conjunction with the Super Blue Box Recycling Corporation (SUBBOR). The steam-explosion process consists of the application of high-pressure steam (150-600 psi) at high temperature (180-260ºC) in a reaction vessel. The desired pressure is reached in about 10 minutes and it is maintained for 5 minutes. The high pressure and temperatures causes disintegration of the sludge and may reduced the levels of pathogenic microorginism. Also, after the reaction time, the sludge is suddenly released through a small orifice, which produces a strong explosion and shear that further aids the disintegration of biomass.

Samples containing a mixture of thickened waste activated sludge (TWAS) and anaerobically digested sludge cake (biosolids) and samples of biosolids only from the City of Ottawa wastewater treatment facility were treated at different steam-explosion conditions and anaerobically digested in batch and semi-continuous flow reactors at mesophilic temperature. Results of this study show that the steam-explosion solubilizes the organics present in the sludges, which concomitantly enhanced the subsequent ana-erobic digestion. For example, treatment at 300 psi of TWAS/biosolids mixture and biosolids alone increased the degree of solubilization (SCOD/TCOD) from 7 to 43% and by 4 to 37% respectively. Batch reactor tests showed that digestion performance of treated sludge samples was significantly better than that of the

control samples. Digestion of the TWAS/biosolids mixture after treatment at 300 psi resulted in a 66% increase of methane yield over the control and the biosolids cake treated at the same pressure resulted in a 90% increase over the control. COD destruction and volatile solids reduction did not exactly corresponded to methane production. Yet a significant improvement of treated samples over the control was consistently observed.

Valorisation des boues noires d'aluminerie

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De part ses propriétés remarquables telles que sa légèreté, sa résistance et sa malléabilité, l'aluminium demeure l'un des métaux le plus employé dans divers domaines comme celui des transports, du bâtiment ou encore de l'emballage. Sa production, par réduction électrolytique de l'alumine, génère divers résidus solides comme les boues noires. Celles-ci proviennent de l'épuration par voie humide des gaz émis au niveau des cuves d'électrolyse lors du procédé Södeberg. Elles contiennent notamment du fluorure de calcium, de l'alumine et des hydrocarbures aromatiques polycycliques (HAP). Jusqu'à présent les boues noires sont entreposées dans des sites spéciaux prévus à cet effet.

La finalité du projet est de tester une voie de traitement des boues noires afin de réduire leur coût d'enfouissement ou voire même de permettre leur valorisation dans les usines de fluorures et / ou les cimenteries. Le premier objectif ciblé est d'extraire des boues les hydrocarbures aromatiques polycycliques par un lavage, en présence de surfactant, couplé à de la flottation. Le second objectif vise à récupérer par séparation magnétique l'aluminium présent dans les boues sous la forme d'alumine, de cryolithe et de pachnolite.

Au niveau du lavage couplé à la flottation, quatre surfactants (Brij 35, Igepal CA-720, Triton X-100, Tween 80), choisis à l'issue d'une revue de littérature, sont testés dans la gamme de concentration 0.2% - 1% (masse/ masse). Cette première série d'essais, réalisée dans une cellule de flottation et sans injection d'air, a pour but de sélectionner le surfactant le plus performant en terme de solubilisation et d'enlèvement des HAP présents dans les boues. L'optimisation du lavage est ensuite effectuée, avec le surfactant retenu, dans cette même cellule de flottation mais cette fois-ci avec injection d'air. Les paramètres étudiés sont la concentration en surfactant (0.5 - 1 - 1.5 - 2 %) et le pourcentage de solides totaux (10 - 20 - 30 - 40 %). La vitesse d'agitation est fixée à 2200 rpm et le temps de conditionnement à 30 minutes. Le temps de flottation est quant à lui de 10 minutes.

En ce qui concerne la séparation magnétique, quatre intensités de champ magnétique sont testées à savoir 100, 300, 500 et 700 mT.

Le Tween 80 est le surfactant qui s'avère le plus efficace pour éliminer les HAP des boues noires et ce à une concentration de 0.5 %. Un taux d'enlèvement des HAP de 50 à 65 % est atteint à cette concentration. Cependant, il est à noter que le taux de récupération de matière solide à la fin du traitement n'excède pas 50%. Afin de réduire l'entraînement parasitaire lors de la flottation, la séquence de flottation est remplacée par une centrifugation. Dans ce cas-ci, le pourcentage de récupération de matière solide est meilleur mais l'enlèvement des HAP est nul. En ce qui attrait à la séparation magnétique, l'aluminium présent dans les boues ne peut être extrait suivant le procédé mis en place.

Le lavage des boues noires, couplé à la flottation en cellule, se révèle inefficace à cause de l'entraînement parasitaire. Les colonnes de flottation agitées sont efficaces pour réduire l'entraînement parasitaire de par leur géométrie et la possibilité d'utiliser de l'eau de lavage. Actuellement, des tests en colonne de flottation sont en cours de réalisation.

Effect of Microwave Dose on Biogas Production from Batch Anaerobic Digesters Treating WAS

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Municipal wastewater treatment plants generate large amounts of waste primary and secondary sludges that are high in organic content. Sludge management and disposal cost may increase up to 40 to 60% of the total wastewater treatment cost. Therefore, sludge management has become a key factor in wastewater management during the last two decades. Anaerobic sludge digestion is often applied to waste activated sludge (WAS) to reduce the mass of solids for disposal, to reduce the pathogen content and to generate biogas for energy recovery. However, the main fraction of this secondary sludge consists of cellular materials (microbial cells) that are resistant to direct anaerobic degradation since cell walls are physical and chemical barriers against exoenzyme degradation and hydrolysis. As a result of this resistance, hydrolysis becomes the rate-limiting step and degree of degradation achieved is limited to 30-45% volatile solids reduction in conventional anaerobic sludge treatment. Improvement of biodegradability of WAS via anaerobic digestion depends on enhanced disintegration of the cell structure and increasing the accessibility to the intracellular components. There are many pretreatment methods that have been studied and shown to be effective, such as; ultrasound, mechanical, chemical and thermal disintegration. It appears that *microwave technology* is the next horizon. Although microwave technology is an attractive alternative heating method to conventional heating due to its environmental and energy conservation properties, publications regarding the effect of microwave pretreatment on anaerobic digestion efficiency *do not exist* except for one which mostly focused on fecal coliform destruction rather than treatibility analyses. The goal of this research is to propose microwave technology as a new and an alternative pretreatment method to enhance anaerobic digestion in comparison to existing pretreatment techniques summarized above.

Before anaerobic digestion, WAS samples were transferred into a microwavable plastic container and were exposed to a microwave field for different irradiation times and at different microwave intensities. Microwave irradiation was applied by a conventional 2450 MHz frequency microwave oven. Temperature measurements were done by thermo-couple probes connected to a module for analog-to-digital conversion and recorded by a laboratory computer system. The degree of solubilization after microwave pretreatment was evaluated by soluble chemical oxygen demand (SCOD) tests at different microwave temperatures and intensities. The effects of four different variables; microwave temperature, microwave intensity, sludge concentration and percentage of sludge being pretreated, on disintegration and hydrolysis of WAS were investigated by monitoring biogas production from batch scale mesophilic anaerobic sludge digesters. Dewateribility of the sludge samples was also tested after digestion.

Solubilization tests after microwave irradiation resulted 3.65, 4.59 and 4.88 times higher SCOD values than non-pretreated WAS samples, and cumulative biogas production from batch anaerobic reactors was increased by 3.5-17%, when microwave temperatures reached to 50, 75 and 96^{o}C, respectively. Microwave intensity did not affect the degree of solubilization and biogas production significantly when WAS samples were irradiated to the same temperature. Future studies will include characterization of protein/carbohydrate/lipid and nucleic acid release along with the investigation of both the *thermic* and *athermic* effects of microwave irradiation on sludge disintegration at the cell molecular level.

Natural and Synthetic Hormones Removal by Enzymatic Degradation

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The conventional wastewater treatment systems are not designed to remove some trace elements, such as endocrine disrupting compounds (EDCs). Indeed, the presence of the EDCs in surface waters and sediment has been primarily attributed to their incomplete removal in the wastewater treatment plant (WTP) process (Filali-Meknassi et al., 2004). Since these EDCs can affect the animals and human endocrine system (Environment Canada, 1999), there is increasing concern on the effects on public health of potential EDCs. Indeed, since 1996, U.S. Environmental Protection Agency's Office of Research and Development has considered endocrine disruption as one of its top six research priorities (U.S. Environmental Protection Agency, 2003). Moreover, one of the U.S.EPA's objectives is to improve the removal of EDCs in a cost-effective manner. Further studies determined that natural estrogen (such as estrone, 17β-estradiol and estriol) and synthetic estrogen (17α-ethinylestradiol) are the major contributors to the estrogenic activity observed in sewage effluents (Aerni et al., 2004).

Several treatment processes were evaluated in the last years for EDCs removal from WTP effluent. During activated sludge treatment, some EDCs are biodegraded and/or adsorbed to the sludge. However a considerable amount remains soluble in the effluent (Mastrup et al., 2001). Moreover, when the contaminants are adsorbed on activated sludge, they accumulate in the wastewater treatment plants solid waste. And in this case, the application of the sludge on agricultural fields may cause a potential soil and groundwater contamination (Ternes et al., 1999). On the other hand, dissolved contaminants or those associated with dissolved natural organics are transported through wastewater treatment plant easily (Schäfer et al., 2002) and thus found in the STP effluent and pollute the surface water.

Additional physico-chemical treatment methods (ozonation, chloration, etc.) showed good removal of EDCs but the majority produce by-products whose estrogenicity is unknown or in some cases higher to the original product (Hu et al., 2003; Moriyama et al., 2004). Thus, more efficient treatment processes should be developed to reduce EDCs discharge into the environment.

Enzymatic processes show potential for removing aromatic compounds (Karam and Nicell, 1997) and their estrogenic activities in wastewater that are not removed effectively through conventional biological or physico-chemical treatment methods. However, only little data exists regarding enzymatic degradation of natural and synthetic estrogens, compounds including a phenol ring in their chemical structure. Thus, researches in this area need to be carried out.

In this study, we will develop the objectives and the methodology used to assess the enzymatic degradation of the main hormones as an additional treatment to WTP process.

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Proposition d'un cadre de travail pour l'intégration du développement durable dans le processus de conception de systèmes d'épuration des eaux usées

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La conception en ingénierie est traditionnellement guidée par des critères techniques, économiques et légaux. Comme c'est lors de cette phase qu'est définie l'essence même d'un projet, les décisions prises lors de la conception sont très déterminantes. Si les ingénieurs veulent participer à la mise en œuvre du développement durable par leur pratique professionnelle, ils doivent intégrer ce concept à même le processus de conception.

Le développement durable a été défini originalement comme un « développement qui répond aux besoins du présent sans compromettre la capacité des générations futures à répondre aux leurs ». Cette définition est généralement acceptée, mais est d'une aide très limitée dans le processus de conception, notamment pour les systèmes de traitement des eaux. L'objectif premier de la présente recherche est donc d'en déduire un cadre d'application plus pertinent. Précisons tout d'abord qu'il s'agit du développement durable de l'humanité dans un écosystème terrestre global. Il est généralement reconnu que ce développement met trois principaux systèmes en interaction : les systèmes écologique, social et économique. La durabilité des systèmes peut être définie comme étant la préservation indéfinie de leur existence et de leur productivité. Le développement durable requiert que la durabilité, ainsi qu'un état de développement satisfaisant, soient atteints de façon simultanée pour ces trois systèmes.

Selon la méthodologie prévue pour construire le cadre de travail, il faut premièrement déterminer les conditions de la durabilité, puis définir l'état de développement souhaité pour ensuite énoncer les principes rendant le développement durable possible. En plus de guider la conception dans sa phase préliminaire, ces principes aident aussi à définir les critères spécifiques à suivre lors de la conception détaillée. Une fois les critères définis, il est nécessaire de choisir des indicateurs rendant possible l'évaluation des décisions prises durant le processus de conception. Il est nécessaire, en autant que possible, de privilégier les indicateurs quantitatifs. Finalement, une méthode d'aide à la décision sera choisie pour faire la synthèse des indicateurs, afin de favoriser les meilleurs choix envisageables. Les principes, critères et indicateurs doivent pouvoir s'intégrer au processus de conception utilisé par l'organisation en charge d'un projet. Comme toute analyse menée dans l'optique du développement durable est multidisciplinaire, il est utile d'utiliser un processus simultané et non séquentiel. Ceci permet, entre autres, d'impliquer toutes les parties prenant part au projet tout au long de sa réalisation.

Le premier résultat anticipé est un cadre de travail complet, des principes aux indicateurs, intégrable au processus de conception utilisé en ingénierie. Les principes seront applicables à n'importe quel système d'ingénierie tandis que les critères et les indicateurs seront spécifiques au domaine du traitement des eaux. L'efficacité de la méthode développée sera ensuite validée par son application à la conception d'un système simple de traitement des eaux usées. De plus, la méthode sera utilisée pour la conception du système global ainsi que pour celle d'une de ses composantes. Ceci permettra de valider son applicabilité au processus de conception de produit autant qu'à celui de conception de procédés. Un tel cadre de travail devrait résolument permettre d'intégrer le développement durable dans la conception de systèmes d'ingénierie, plus particulièrement dans le domaine de la qualité de l'eau.

The Effect of Water Table Management on the Phosphorus Concentration of Agricultural Drainage Water

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Recent studies have shown that the use of Water Table Management (WTM) can significantly decrease nitrate (NO_3^-) concentration in agricultural drainage water. However, WTM's impact on phosphorus has not yet been comprehensively studied, even though it has been proved that phosphorus losses do occur in subsurface drainage systems. This issue is of concern since exceeding phosphorus loads in the environment can cause eutrophication of water bodies and toxic algal blooms.

A study conducted in 2001-2002 in Coteau-du-Lac (Quebec) showed that significant amounts of dissolved phosphorus were lost through tile drainage under WTM, compared to free drainage (Madramootoo and Stämpfli, 2004). Subsequent analysis of the water used for subirrigation showed total dissolved phosphorus (TDP) concentration exceeded Quebec's surface water quality standard of 0.03 mg/L. This may have influenced P concentration measured for drains under WTM treatment.

The goal of this research is to more completely investigate the effects of WTM on the migration of P in tile drains. As part of this goal, we will examine P migration using laboratory soil cores.

We will use 18 soil cores from the experimental field. Nine of them will be use to simulate subirrigation and the other 9 will represent normal field drainage. We will apply fertilizers in each core and incorporate it in the top 2 to 3 cm of the soil. Then, we will use distilled water to leach and subirrigate the cores. Water samples will be collected from the bottom of the cores and analyzed for TDP, orthophosphate and total P. The objective is to apply the same amount of fertilizer as applied in the field, and to compare the P concentration in the water samples from the field and the laboratory experiments. This will permit assessment of the influence of WTM on P migration.

Our paper will present the results from the field experiments and preliminary data from the lab experiments.

Simulation of Membrane Distillation Processes: Direct Contact (MD)

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A Monte Carlo simulation model is developed to study vapor flux through hydrophobic membrane in association with direct contact membrane distillation (DCMD). Membrane distillation (MD) processes, in general, are thermally driven separation processes characterized by heat and mass transfer and can be applied for water treatment and seawater desalination. In this process water vapor and volatile solutes evaporate at membrane feed side, diffuse and/or convect through membrane pores due to vapor pressure gradient. This pressure drop across the membrane is as a result of composition and/or temperature difference of solution in the layers adjoining the membrane surfaces. When feed solution is pure water or solute concentration in the aqueous solution is very low, vapor pressure at membrane-bulk interface is mainly governed by fluid temperature adjacent to membrane surface. In this study, the porous membrane is represented by a three-dimensional network model of interconnected cylindrical pores with distributive effective pore sizes. Vapor flux through membrane pores is described by gas transport mechanisms founded on the kinetic theory of gases for a single cylindrical tube. The vapor flux transport mechanism for each membrane pore is dictated by mean free path of transporting molecules, pore size, and operating condition(s). This model can take into consideration the effect of temperature polarization phenomenon, membrane physical properties, including porous membrane interconnectivity (topology) and the details of membrane pores description (morphology), process dynamics and applies them into MD process vapor flux prediction and process performance description. It is comprehensive in its approach and can be applied to all forms of MD processes published in the literature without resorting to any adjustable parameters. When this model was applied to direct contact membrane distillation (DCMD), the results obtained were in excellent *qualitative* agreement with available experimental data.

Reaction-Transport Modeling as a Tool for Investigating Phosphorus Controls in Lake Sediments

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Reactive-transport models (RTM) of sediment early diagenesis provide quantitative descriptions of coupled physical, chemical, and biogeochemical processes. Previous modeling efforts were largely successful in reproducing the shape of measured concentration profiles and in interpreting the underlying processes. In contrast to those site-specific data-driven studies, little attention was given to the exploratory use of RTMs. Exploratory models can be used to verify the consistency of existing theories and to identify dominant processes and most important sediment characteristics for a variety of diagenetic conditions. We use our model to investigate scenarios for phosphorus releases from lake sediments. Simulation results will be presented for the sediment system response to factors such as the interface concentrations of oxygen, sulfate, iron, and organic matter. The results indicate that phosphorus control mechanisms may differ between short term releases and long-term phosphorus budgets and that lake remediation techniques may need to be revised accordingly.

Application of CCME Procedures for Deriving Site Specific Water Quality Objectives for the CCME Water Quality Index

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The Canadian Council of Ministers of the Environment (CCME) Water Quality Index (WQI) developed by a sub-committee established under the CCME Water Quality Task Group was developed as a means to summarize large amounts of water quality data into simple terms (e.g., good; poor; etc.) for reporting to decision makers and the public in a consistent manner. An index allows the user to represent a variety of measurements of numerous variables in a single number and corresponding ranking category. This simplifies and facilitates the communication of results.

Since its development in 2001, the CCME WQI has been applied to ambient water quality data across the country and has established itself as a valuable tool for summarizing and communicating ambient water quality data. However, due to the high natural background levels of particular parameters in water bodies throughout the country it is often necessary to use Site Specific Water Quality Objectives (SS-WQOs) as opposed to generic national or provincial WQOs in the CCME WQI model to obtain truly representative rankings. The computation of SS-WQOs is generally an involved intensive process as a result of which SS-WQOs have only been developed for a limited number of ambient water quality sites. Another associated issue/challenge is the correct identification of which water quality parameters at a particular site are possible candidates for SS-WQOs.

This unavailability/absence of SS-WQOs for many ambient water quality monitoring sites has been a major hurdle to the widespread use and acceptance of the CCME WQI for these sites.

This paper presents a methodology for automatically deriving SS-WQOs for a particular site from existing water quality data for that site. The methodology also makes it possible to identify in an automated manner, which WQ parameters at a site are candidates for SS-WQOs. The methodology is an adaptation of an existing CCME approved SS-WQOs derivation method called the Background Concentration (BC) Procedure.

The Newfoundland and Labrador Department of Environment and Conservation has implemented the methodology in a Site-Specific Water Quality Index (SS-WQI) calculator/tool that can compute five different types (mean; median; mean + one standard deviation; mean + two standard deviations; and 90th percentile) of BC based SS-WQOs. This paper describes the development of the SS-WQI calculator/tool and discusses in detail the application of the SS-WQI calculator to compute WQ indices for five ambient water quality sites under the Canada-Newfoundland Water Quality Monitoring Agreement (WQMA). The effects of using the five different BC based SS-WQOs on the WQI scores and rankings are examined. The paper also discusses the challenges, benefits and downfalls of using this methodology for computing BC based SS-WQOs and WQ indices. Also described are further areas of research that have been identified as a result of this work.

Investigating the Uncertainties in Heterogeneity Using Cfd For Flow and Transport in Vadose Zone

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A CFD analysis, based on the PHYSICA's multi-physics simulation environment, has been undertaken to investigate flow/transport in macroscopic scale heterogeneity of porous media. Several one-, two- and three-dimensional numerical simulations have been performed to simulate the effects of heterogeneities in the hydrogeology on downward migration of leachate through the vadose zone by accounting for flow and transport mechanisms. Heterogeneities within landfill waste are calibrated using a time varying source term for the contaminants which represents the changes in the composition of leachate entering the unsaturated zone from the 'dilute and disperse' types of landfills. Results obtained are compared with observed borehole log information. Predictions show a decrease in concentration and mass of contaminants over time and depth due to dilution and dispersion processes. A double peak phenomenon in the pathway of the plume is observed due to heterogeneous nature of geological strata as well as the waste. The model predicts that the attenuation in leachate has a significant role in reducing the level of contaminant concentration and its potential impact on the underlying groundwater resources.

1. Introduction

Measure of water quality is an aspect of increasing concern for a wide range of environmental problems and geologic processes [2]. Most problems relating to contamination of fresh waters are the result of human impact on water chemistry in the form of waste-disposal practices or other uncontrolled activities at the land surface. To gain a qualitative understanding of fate and transport of conventional pollutants there is a need to investigate geochemical/physical processes involved as well as the rate and pathways of water movement in subsurface systems. The purpose of current study is to provide a brief description of flow/transport processes in the vadose zone employing the finite volume (FV) discretisation techniques to improve understanding of fate of contaminants and prediction of future states under various loading conditions.

2. Governing Equations

The vertical movement of water in vadose zone, described by Richard's equation [3] is given by

$$C(\psi)\frac{\partial \psi}{\partial t} = \frac{\partial}{\partial z}\left(K(\psi)\frac{\partial \psi}{\partial z} \right) - \frac{\partial K(\psi)}{\partial z}; \qquad (1)$$

K = unsaturated hydraulic conductivity

ψ = pressure head

$C(\psi) = \frac{d\theta}{d\psi}$ = specific moisture capacity

θ = volumetric water content

The solution of equation (1) requires specification of physical properties, e.g. hydraulic conductivity, water content. Several models are available to express the nonlinear relationship between these parameters and the pressure head. Here we use the models proposed by Van Genuchten [4] and Maulem [5] to present $\theta - \psi$ relationship and $\theta - K$ relationship respectively. The general transport equation describing one-dimensional advection, dispersion and degradation processes of solute through vadose zone is given as

$$\frac{\partial(\theta C)}{\partial t} = \nabla.(D\theta.\nabla C) - v\theta.\nabla C - \lambda\theta C; \quad (2)$$

C = concentration of contaminants
v = pore water velocity
λ = decay constant
$D = \alpha v + D_m$ = hydrodynamic dispersion coefficient
α = dispersivity, D_m = molecular diffusion coefficient

3. Numerical Simulation Method

The use of computational fluid dynamics (CFD) techniques is increasingly becoming popular in predicting fluid flow and transport problems in general. The technique is very powerful and spans a variety of industrial and non-industrial applications. The FV method serves as the numerical algorithm around which most CFD codes are constructed. The transport phenomena which describe the conservation of a general flow variable ϕ within a finite control volume is expressed as a balance between various processes and is represented in mathematical form by

$$\frac{\partial C_t \phi}{\partial t} + div(C_c \mathbf{u}\phi) = div(\Gamma_\phi grad\phi) + S_\phi \quad ;\mathbf{u} \text{ is the Velocity Vector} \quad (3)$$

Transient Convection Diffusion Source $;C_c, C_t, \Gamma_\phi$ convection, transient, diffusion coefficients

Results and Discussions

To investigate the spatial distribution of solute species entering the vadose zone from the landfill site, numerical simulations are performed on hydrological and geochemical data collected from an old dilute and disperse landfill site situated in Nottinghamshire (UK), see Figure 1 [6]. Results for one-dimensional transport of chloride tracer are presented in Figure 2. The hydrological quantities of volumetric water content and pore water velocity are calibrated by solving flow equations subject to constitutive relationships presented.

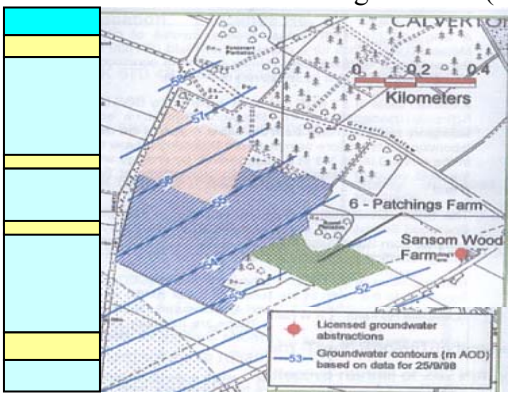

Figure 1: Landfill site and Layer configuration

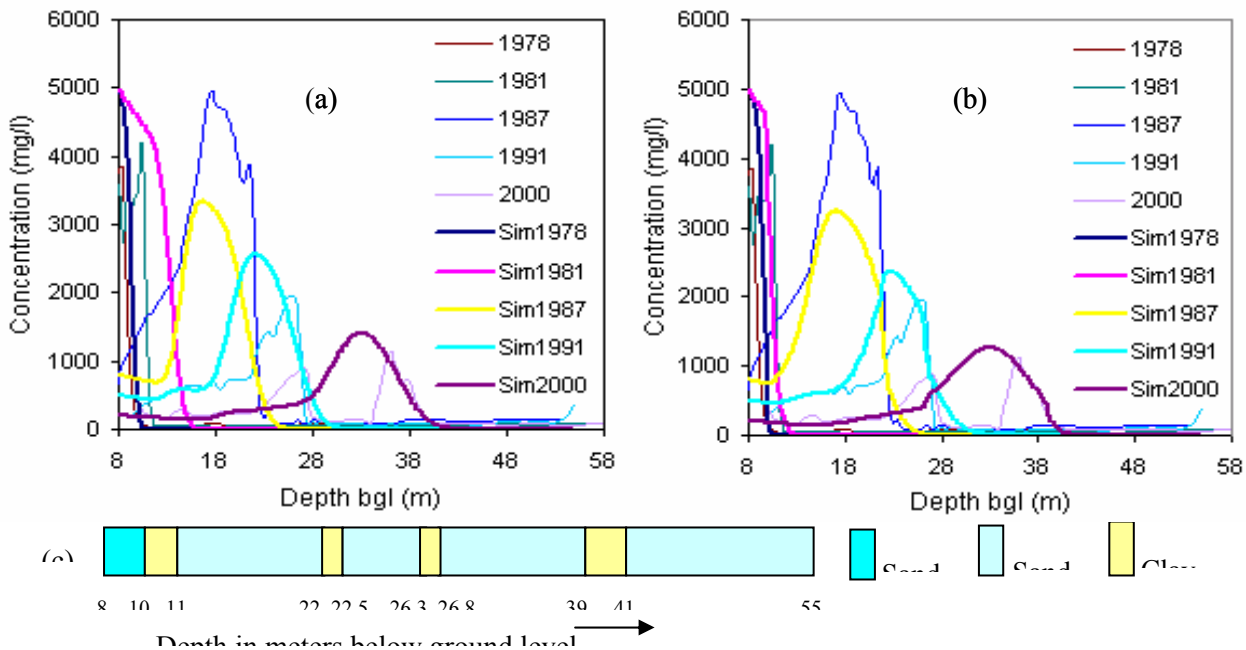

Figure 2: Comparison between observed and simulated concentration for (a) homogeneous, (b) heterogeneous cases. The setting of sand and clay bands along depth is represented by (c).

Sandstone below the landfill is modelled with two hydrological settings: (1) homogeneous and (2) layered heterogeneous in order to compare with observed migration of the plume between1978-2000. Hydrological/contaminant parameters used are listed in Tables 1 and 2. The active physical, biological and chemical processes taking place in the waste are ignored and a time dependent source term at the upper boundary of the model is used to represent the heterogeneity within the waste. The lower boundary, 1 meter below the groundwater table, is at a pressure of 100 cm.

Soil type	K_s (cmh^{-1})	θ_s	θ_r	α	n	L
Clay	4	0.4	0.15	0.03	1.5	-1.3
Sand 1	8	0.3	0.08	0.09	1.8	-1.2
Sand 2	35	0.24	0.08	0.09	2.0	-1.6

Table 1 Parameters values for the calibrated simulations.

α (m)	D_m (m^{2}s^{-1})	$T_{1/2}$ (yrs)	λ (s^{-1})
0.01	1.0E-9	12	1.83E-9

Table 2 Transport parameters and associated values.

K_s is the saturated conductivity, θ_s, θ_r, α, n and L are Van Genuchten parameters

Figure 2a, presents concentration profiles for the homogeneous model for sand 1 type soil. A half-life of 12 years was used to calibrate the non-conservative behaviour displayed by chloride plume. Although the results of simulation present good match in terms of plume peak and arrival position in most cases, the shape of plume is unable to predict the sharp leachate front. To visualize the effects of heterogeneity on vertical transport of chloride plume, Figure 2b shows the concentration profiles calibrated by utilizing two types of sand materials and clay lenses at specific locations (Figure 2c). This gives a better comparison to observed data in terms of plume's position and pronounced leachate front.

5. Conclusions

Computational techniques have been implemented within a multi-physics environment to predict the behaviour of heterogeneities within the sandstone. Predicted results are comparable to observed data in

instances where enough information is available to describe the geology. In instances where sufficient data is not available about the geology, the tool can be used to undertake "what-if" type simulations to understand the likely impact such as risk assessment of the underlying resources of groundwater.

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Pyrolysis of Sewage Sludges for the Production of Bio-Oil and Adsorbent

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Sewage sludge treatment is one of the most difficult problems in the field of wastewater treatment because of increasing expenses and environmental sensitivity. Pyrolysis to produce bio-oil and adsorbents from sewage sludge is a promising way to not only improve economical value but also reduce pollutants associated with sludge. The aim of this study was to evaluate the production of oil and adsorbents from raw, wasted activated and digested sludges. The pyrolysis was performed in a laboratory scale horizontal batch reactor. The operating temperature ranged from 250-500 °C while a gas phase residence time of 20 min was maintained with 50 ml/min of nitrogen gas as a purge flow. The maximum oil yield was achieved with raw sludge at 500 °C. Temperature was the most important factor affecting the yield of oil and char however sludge type also affected the resulting yields. Pretreatment of sludge by either acid or base did not improve the quantity of the products, though it did affect the volatile solids fraction of the samples. The use of a catalyst (Zeolite) reduced oil recovery. The phenol adsorption capacity of the char was affected by pyrolysis temperature, pretreatment and sludge source.

Baseflow Estimation for the South Nation River, Eastern Ontario, Based on Direct Seepage Measurements and Electrical Conductivity

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The objective of this project is to provide information on small-scale variability of groundwater seepage / leakage at the scale of a small basin. Direct measurement of seepage / leakage is very labour-intensive, and is therefore not feasible at the scale of a basin without a pre-screening tool. One such tool, which was used in this study, infers groundwater seepage from Electrical Conductivity and Temperature (EC&T) of water at the bottom of the river, based on the assumption that there is a contrast between the incoming groundwater and the river water. These measurements can be made very quickly by dragging an EC&T probe from a boat at a slow speed. The results of the EC&T survey can then be used to focus the more labor-intensive direct measurements.

This method was used to conduct a pilot survey of EC&T of the main branch of the South Nation River in Eastern Ontario, Canada. The mean EC values were relatively high, indicating relatively poor water quality. Several anomalies were detected along the river as sharp peaks above or below the mean EC value. Some of the peaks were later confirmed zones of seepage, by direct seepage measurements. A very important finding from this data is that areas of groundwater seepage in the SNR are very localized in areas of less than a few tens of meters, indicating that the deep recharge patterns may be the result of fracture flow in the bedrock. Several other anomalies were of anthropogenic origin. Baseflow estimates were made from direct seepage measurements in conjunction with the survey results, along with precipitation, runoff, evapotranspiration. The results compared well to those from traditional hydrograph separation techniques.

Predicting Nitrogen Release and Liquid Effluent Impacts for Anaerobic Sludge Digestion Upgrades

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Introduction

Primary and secondary municipal wastewater treatment plant sludges are often treated by anaerobic digestion (AD) before being dewatered and disposed or re-used. Conversion of the sludge digestion process from conventional to one of the "advanced" digestion schemes (e.g. thermophilic, multi-phase, etc.) will increase the volatile solids removal efficiency. However, higher solids destruction also means more ammonia will be liberated into solution. Since the dewatering filtrate is usually recycled to the liquid train of the treatment plant, the process design engineer is interested in determining how much an upgrade to advanced digestion will increase the nitrogen load to the liquid train and how the liquid train effluent will be affected.

The objectives of this study were two-fold: (i) to evaluate how improved anaerobic digestion efficiency changes the digestate nitrogen concentration, and (ii) to evaluate how higher recycle nitrogen loads affect the liquid train process effluent.

Methodology

The Biowin32 Process Simulator (EnviroSim Associates, Dundas, Ontario) was used for modelling. The volatile solids reduction was calculated by the approximate mass balance method and was controlled by adjusting the Biowin™ model parameter "Hydrolysis Rate (AD)" within the range 0.5 – 1.0 d^{-1}.

Results

The mass of nitrogen solublized during anaerobic digestion will depend on the ratio of primary sludge to waste activated sludge in the digester feed. This is due to the different nitrogen contents of each type of sludge, as shown by their different empirical formulae: $C_{10}H_{19}O_3N$ for primary sludge and $C_5H_7O_2N$ for waste activated sludge (WAS). Thus, the nitrogen content of waste activated sludge is 2 – 4 times higher than that of primary sludge and consequently more nitrogen will be released per unit of sludge mass for higher WAS fractions.

A new method, called the "Relative Prediction Method", was created to predict the nitrogen released during sludge digestion when upgrading to an advanced digestion technology. By this method, the feed sludge nitrogen content (SNC) is calculated using the primary sludge to waste activated sludge ratio and the measured or assumed nitrogen content of each sludge. Using the incremental VSR increase for the advanced digestion technology, an incremental increase in nitrogen released during digestion can be calculated using the SNC. This is added to the known nitrogen concentration of the existing digestate to obtain the predicted nitrogen concentration for the new digestion process. Although the prediction error increases as the VSR increment increases, the error is <10% for VSR increments <19%, which is sufficient for upgrades from conventional AD to any of the existing advanced AD processes.

For an activated sludge system with "sufficient" oxygen and alkalinity, the total TKN load can increase by as much as 35% without increasing the effluent NH_3 concentration (Figure 1). On the other hand, if there is insufficient oxygen and/or alkalinity, the allowable TKN increase is much lower and the effluent NH_3 will rise more rapidly.

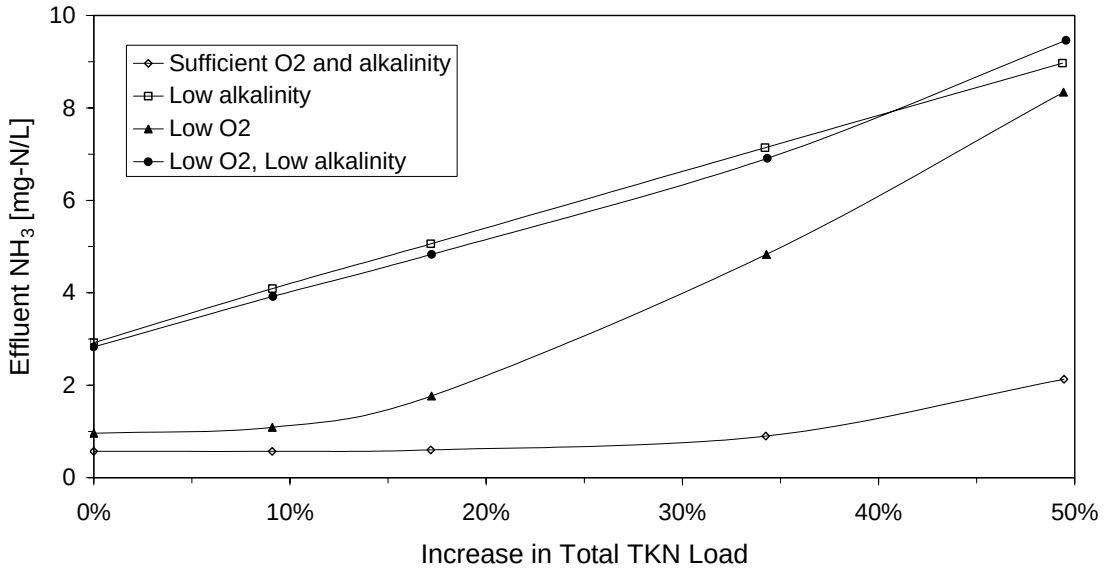

Figure 1. Effluent NH_3 concentration for increases in total TKN load.

However, the increases in total plant TKN load due to digestion upgrades appear to be relatively small. The modelled increase in total plant TKN load was 4% for a change from mesophilic to thermophilic digestion. At this load increase, the modelled increase in effluent NH_3 was only 25% under the poorest oxygen and alkalinity conditions examined.

Conclusions

1. Advanced anaerobic digestion can be modelled in Biowin™ by adjusting the "hydrolysis rate (AD)" model parameter. This change is easy to implement and is useful as long as volatile solids reduction is the desired output and not the detailed constituent composition (e.g. volatile fatty acid distribution).
2. The ammonia released during anaerobic digestion will be over-predicted if the feed sludge nitrogen content is assumed to be similar to WAS when it actually contains a significant fraction of primary sludge.
3. The Relative Prediction Method can be used to calculate an incremental increase in the nitrogen released due to an incremental increase in anaerobic digestion VSR. The error associated with this prediction should be <10% for VSR increases within the range associated with advanced digestion upgrades.
4. Increases in the liquid train effluent NH_3 appear to be modest when changing from conventional to advanced digestion.

Kinetic Models of Laccase-Catalyzed Oxidation of Aqueous Phenol

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Laccase (EC 1.10.3.2: p-diphenol: dioxygen oxidoreductase) catalyzes the oxidation of a range of substances with the simultaneous reduction of molecular oxygen to water. Wide substrate specificity, high rates of catalysis and use of oxygen as the co-factor are characteristics that have attracted the attention and efforts of researchers who seek to apply laccase for delignification, biobleaching, organic synthesis, biosensors, drug analysis, wine clarification, immunoassays, as well as in various environmental processes targeting the transformation of aromatic compounds This process has demonstrated good potential as a method for the removal of phenol and other toxic aromatic contaminants from wastewaters. An understanding of the mechanisms and kinetics of enzyme systems is essential for the design of efficient reactor systems to carry out industrial processes. However, previous work has mainly focused on evaluating the ability of laccase to catalyze numerous reactions, but relatively few studies have focused on evaluating the kinetics of those reactions under various reaction conditions and over time.

Therefore, kinetic models of this system have been developed to facilitate a better understanding of the mechanisms and rate-limiting steps of enzyme-catalyzed transformation and to assist in the choice and design of a suitable reactor system. The robustness of laccase is likely to depend on the redox potential of the enzyme. In general, fungal laccases have higher redox potentials (0.5 – 0.8 V) compared to plant laccases (0.3 – 0.4 V). For example, *Coprinus cinereus* laccase has a redox potential relative to the normal hydrogen electrode of 0.55 V whereas *Trametes versicolor* laccase has redox potential of 0.785 V. Therefore, in this study, laccase from fungi *Trametes versicolor* was chosen to establish the kinetics of laccase-catalyzed transformation of aromatic compounds. Phenol, one of the most industrially-important chemicals, was used as a model compound for this kinetic study.

A fully-transient model was derived based on the differential and mass balance equations that describe the interactions of various oxidative forms of the enzyme with the aromatic substrate and oxygen. Another model, called the pseudo-equilibrium model, was also developed. This model incorporates the assumption that, at any instant during the reaction, the enzyme achieves an approximate steady-state distribution of its various forms around the catalytic cycle. This assumption has the advantage of reducing the complexity of the model equations. Both models also incorporated an expression that accounted for enzyme inactivation over time due to pH.

Several experimental data sets were selected for calibration and others for validation of the models' predictive ability. Both models were validated by comparing model predictions with experimental observations of phenol transformation and oxygen consumption over time using a variety of enzyme concentrations. Oxygen concentrations were monitored using an electrode and phenol concentrations were measured using high performance liquid chromatography. Excellent agreement was found between experimental data and predictions of both the fully-transient and pseudo-equilibrium models. In the pseudo-equilibrium model, the assumption of steady-state distribution of the enzyme not only reduced the complexity of the model equations, but also resulted in a significant reduction in the computation time required to solve model equations while simultaneously maintaining the predictive ability of the fully-transient model.

Seawater Denitrification at the Montreal Biodome

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Nitrate accumulation in closed systems causes toxicity to invertebrates and affects the immune system of fish, thus increasing the need for frequent, costly water changes. A denitrification unit was installed at the Montreal Biodome to reduce the costs associated with artificial saltwater changes from a 3.25 million litre closed mesocosm, but was not efficient at removing nitrate. Pilot scale experiments were conducted with 110 litre moving bed biofilm reactors (MBBR) with methanol as the carbon source for denitrification and trace elements. A new hydraulic configuration of MBBR was designed to ensure complete-mix and continuous cleaning of the floating media, in order to prevent sulfate-reduction from occurring. The system seawater contained about 50 mg NO_3-N l^{-1} and over 2000 mg SO_4^{2-}-S l^{-1} at the moment of experimentation. The impact of the carbon to nitrogen ratio (C/N) on denitrification was investigated. Denitrification, methanol consumption, media fouling, alkalinity production and sludge production were monitored. Mass balances of C, N and P were also determined. Chemostat and batch experiments allowed the determination of stoichiometric and kinetic parameters such as the cellular yield ($Y_{X/S}$) and the heterotrophic maximum specific growth rate (μ) to be established. Stoichiometric and kinetic parameters obtained from the experiments were then incorporated into a model to execute dynamic simulations using the GPS-X software. Lowering of the nitrate concentration from over 50 to less than 2 mg N l^{-1} was achieved at C/N=4.2 without significant occurrence of sulfate-reduction. The maximum volumetric denitrification rate attained was 1.8 kg N·m^{-3} media·d^{-1}, corresponding to a typical value. Efficient surface denitrification rates reached over 17 g N m^{-2} d^{-1} which is superior to other reported surface rates from the literature. Denitrification rates were proportional to the applied C/N ratio. Methanol consumption complied with stoichiometry values. Alkalinity production was 2.4 mg $CaCO_3$/mg NO_x-N removed and cellular yield of 0,07 g VSS/g COD. The hydraulics of the MBBR efficiently prevented media fouling and sulfate-reduction by limiting biofilm thickness. The mathematical model used for the numerical simulation was calibrated and validated with the experimental results from the chemostat experiments, allowing virtual experimentation to predict nitrate levels in the marine system after optimization of the full scale system. With a scaled-up and optimized denitrification process, the Montreal Biodome should be able to reduce its operating costs, maintain nitrate concentrations below the toxicity level, enrich the system with more animal life and limit the nutrient loaded saltwater discharged into the sewer and ultimately the natural environment.

Sediment and Nutrient Removal Efficiencies in a Constructed Wetland in Southern Quebec

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Non Point Source (NPS) pollution is considered a major cause of water quality deterioration around the globe. A study was conducted to assess the efficiency of a constructed wetland for sediment and nutrient removal from a riverine source containing NPS pollution in a Nordic climate. The constructed wetland, built near the town of Mystic, Quebec, consists of a sedimentation basin, a sinuous subsurface horizontal flow section and an open water body or pond that continuously receives up to 2.5% of the Walbridge Creek. The plants grown in the wetland are composed of several indigenous emergent aquatic species. Flow into and through the system is controlled by gravity. There is a gate on the intake structure, which allows flow to be adjusted, along with three composite weirs; located at the outlet of each section of the wetland. Water levels at the weirs are monitored continually using submersible pressure transducers and ultrasonic sensors. There are five sampling sites: one located in the river, at the inlet of the wetland, weir 1, weir 2, and weir 3. Grab samples are taken at least once a week and more frequently when storm events occurred. Automated samplers are also used to take composite samples during storm events. Sampling will span a two year time period, winters excluded. The water samples are analyzed for orthophosphates, dissolved phosphorus, organic phosphorus, nitrates, ammonia, dissolved nitrogen, and total suspended solids. A subset of the samples are analyzed in an external laboratory for an additional suite of parameters, including bioavailable phosphorus, total suspended solids, K, Ca, Mg, Na, and pH. From these results mass balances for the sediments and nutrients and nutrient removal efficiencies for the entire system and each of the components will be evaluated. Most of the reduction in 2003 occurred during the spring and summer months. From the internal data we observed a 43.8% reduction in the median annual orthophosphate concentrations and a 22.4% reduction in the median annual total P concentrations. From the external data we observed a 47.5% reduction in the median annual orthophosphate, 14% reduction in the median annual total P and 37.8% reduction of the median annual bioavailable P concentrations. From these values (internal and external data sets) the wetland appears to be efficient in reducing mean annual phosphorus concentrations.

Variabilité de la fraction de la matière organique biodégradable dans des réseaux séparatif et unitaire

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Le contrôle de la qualité des eaux en milieu urbain implique une gestion dynamique des rejets vers le milieu récepteur, de façon à optimiser le rendement économique et environnemental des usines d'épuration. Afin de faciliter l'élaboration de stratégies de contrôle des ouvrages d'épuration, des modèles mathématiques représentant les différents procédés de traitement sont essentiels. Un nombre impressionnant de modèles mathématiques pouvant théoriquement simuler le comportement dynamique des stations d'épuration a été présenté dans la littérature. L'utilisation de plus en plus répandue du modèle ASM1 nécessite que la DCO de l'affluent soit fractionnée en DCO biodégradable et non-biodégradable, et en DCO particulaire et soluble. Ce fractionnement est généralement considéré constant dans le temps. Toutefois, dépendamment de l'heure, de la présence de rejets industriels, des conditions météorologiques, etc., le fractionnement variera ce qui aura une influence sur le comportement du modèle. Il existe très peu de littérature sur ce sujet. L'objectif de la présentation est donc de montrer des résultats décrivant la variabilité du fractionnement dans le temps. Cette étude s'inscrit dans un contexte plus large d'optimisation du comportement d'une station traitant l'azote en temps de surcharge.

Deux réseaux d'égout, un séparé et un unitaire ont été échantillonnés. L'eau usée est majoritairement de type domestique mais quelques industries sont raccordées au réseau, spécialement sur le réseau séparatif. Un total de 13 échantillons a été récolté. La DCO totale a été mesurée sur chaque échantillon. Des essais respirométriques ont été réalisés en utilisant 2 réacteurs complètement mélangés pour l'étude de deux rapports substrat/biomasse. Les fractions de DCO ont été obtenues en optimisant les données expérimentales avec les données générées par un modèle à trois substrats.

La variabilité des fractions est très importante, mais plus faible pour le réseau séparatif que pour le réseau unitaire. La dilution de la DCO en temps de pluie implique une large gamme de variation de la DCO et de composition de l'eau usée alors que la composition semble plus stable pour le réseau séparatif. La fraction inerte est supérieure dans le réseau séparatif de près de 30% à celle du réseau unitaire.

Pour le réseau unitaire, aucune relation n'a pu être trouvée entre le pourcentage de DCO biodégradable ($S_s + X_s + X_{bh}$) et la DCO totale, alors que pour le réseau séparatif, la concentration de DCO biodégradable semble relativement constante peu importe la DCO totale. Pour le réseau séparé, les fractions biodégradables et inertes sont relativement constantes indépendamment du débit mesuré, particulièrement pour la fraction inerte. Dans le cas du réseau unitaire les concentrations semblent plus variables spécialement à fort débit.

Une telle étude constitue un premier essai pour déterminer la variabilité des fractions inertes et biodégradables en fonction du type de réseau ainsi que des conditions météorologiques. Même si d'autres résultats sont nécessaires pour généraliser les tendances observées, ces résultats peuvent s'avérer utile pour aider à la simulation du comportement d'une station en temps de pluie.

Direct Detection of Pathogens in Municipal Wastewater using Oligonucleotide DNA Microarray

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Despite the advancement in water quality management technologies, waterborne pathogens still remain as one of the major concerns to environmental and human health. In the present study, two nucleic acid-based assay technologies, DNA microarray and real-time PCR, were developed and tested as accurate, comprehensive, and culture-independent tools for monitoring pathogens in wastewater and water. The DNA microarray was evaluated for the detection of wastewater pathogens by *direct* hybridization of genomic DNA. As a first step toward building a comprehensive pathogen microarray, *E. coli* and nine bacterial pathogen functional genes were targeted as a low density microarray. When the microarray was tested with genomic DNA from raw wastewater microorganisms, the only hybridization signal detected was for *E. coli*, and the failure of pathogen detection was attributed to its low sensitivity (minimum detection required 0.1 ~ 1.0 μg of *E. coli* genomic DNA or $2 \times 10^7 \sim 2 \times 10^8$ copies of the target gene). When a fluorogenic probe-based real-time PCR assay (Taqman; Applied Biosystems, Foster city, CA, USA) was applied as a research tool to ensure that pathogen target DNA was present, *Salmonella* sp., *Clostridium perfringens*, and *E. coli* were detected. Although the microarray was found to be less sensitive than desired, the high specificity and throughput design is attractive. Areas that will be investigated include coupling PCR with the microarray-based assay.

Peroxidase Catalyzed Oxidation of Bisphenol A in a Reversed Micellar System

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A significant amount of research has been conducted in recent years to explore the use of oxidative enzymes for treating aromatic pollutants in wastewaters. Recent work in the field of polymer chemistry has demonstrated that such enzymes also have the potential to be employed in non-aqueous media. This offers the possibility of developing enzymatic treatment processes for targeting the removal of compounds that are either found in non-aqueous phases or are concentrated there through contacting systems.

In order to investigate the potential of this type of approach, the oxidation of bisphenol A (BPA) by horseradish peroxidase (HRP) in a reversed micellar system was investigated. It was found that HRP that is entrapped in reversed micelles can effectively catalyze the oxidation of BPA in n-octane solvent. When the hydration degree of surfactant (i.e, the molar ratio of water to sodium bis(2-ethylhexyl) sulfosuccinate, AOT) in reversed micellar system was less than 15%, the catalytic activity of HRP was low as compared to similar reactions catalyzed in aqueous media. However, as soon as the hydration degree of the surfactant equaled exceeded 15%, the conversion of BPA revealed no striking difference with further increases of hydration. The optimal pH for HRP-catalyzed oxidation of BPA in the reversed micellar system was about 7.0, which is less than the pH optimum of 9.0 observed in aqueous media. By increasing the initial concentration of HRP, BPA or H_2O_2, the oxidation rate of BPA tended to increase. However, an excessively high molar ratio of HRP to H_2O_2 resulted in reduced conversion, which indicates that inactivation by hydrogen peroxide is an important phenomenon in non-aqueous phase reactions. According to the known reactions of peroxidase, the stoichiometry of the reaction between $[H_2O_2]$ and organic substrate is expected to be 0.5. However, maximum BPA removal was obtained by using a $[H_2O_2]$/[BPA] molar ratio that approached 2. The probable reason for high consumption of H_2O_2 relative to the expected stoichiometry is that products of this reaction, including dimers and 4-isopropenylphenol, can be further oxidized by HRP, thereby contributing to the higher apparent stoichiometry. Surprisingly, over the range of 20^{o}C to 40^{o}C, the conversion of BPA catalyzed by HRP entrapped in micelles was enhanced.

A Comparative Evaluation of Oxygen Mass Transfer Coeffficient Determined from Four Methods in Activated Sludge Processes

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The overall goal of the research was to study the impact of biochemical reactions on oxygen transfer under controlled process conditions in three different activated sludge processes, completely mixed activated sludge (CMAS), modified Ludzack-Ettinger (MLE) and enhanced biological phosphorus removal - University of Cape Town (UCT) process by varying solids retention time (SRT) and influent carbon, nitrogen and phosphorus. As part of this investigation, four different methods of measuring the oxygen transfer under process conditions, as per the guidelines provided in the American Society of Civil Engineers (ASCE 1997) were employed. They included the steady state oxygen uptake rate (OUR) method, the non-steady state changing power level (CPL) method, the non-steady state hydrogen peroxide addition (HPA) method and the off-gas method. In addition to measuring the oxygen transfer coefficient, a careful monitoring of the process performance was carried out throughout the study. The objective of this particular manuscript is to present a comparative evaluation of oxygen transfer coefficient data obtained from different methods and to comment on the testing methods.

In general, there was a good agreement between the mass transfer coefficient derived from the steady state OUR and off-gas testing methods. When the OUR and HPA testing methods were applied on the same day, the oxygen transfer coefficients were comparable. However, the process performance was negatively affected, which was attributed to the addition of hydrogen peroxide in the HPA test and production of highly toxic hydroxyl radicals (OH●) in Fenton-type reactions. Therefore, it seems the HPA method is suspect. The deleterious effects of hydrogen peroxide addition depend on the microbial culture conditions and the level of anti-oxidants enzymes (superoxide dismutase, peroxidase, catalse, glutathione, etc.) present in the process.

In the CPL method of testing, where, the level of aeration was increased and then decreased to the normal operating level, higher values of oxygen transfer coefficients were obtained and the sludge volume index (SVI) of mixed liquor increased as the testing progressed, indicating possible changes in the floc structure and characteristics. Based on the results obtained in this study, steady state OUR and off-gas methods seems to be suitable techniques for measuring the oxygen transfer under process conditions. Advantages with the off-gas method are: (i) wastewater treatment process need not be operating under steady state conditions, and (ii) mixed liquor is not directly involved in the test. The disadvantages of off-gas method are: (i) the need for specialized instrumentation and equipment, (ii) the presence of subsurface diffused aeration system, (iii) sampling a representative amount of off-gas during testing and (iv) higher testing costs. The limitation in applying the OUR technique is the requirement of steady state process performance, which may be particularly difficult to achieve in full-scale systems. Sometimes, even under the steady state conditions, it may be possible to observe spatial OUR variations within the bioreactor due to non-ideal reactor conditions that may complicate the application of OUR method. However, where feasible OUR technique may be an economical procedure to study oxygen transfer under the process conditions.

Treatment of Low Strength Aircraft Deicing Fluid in an Anaerobic Baffled Reactor

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In our modern society, flying as a means of transportation has become a necessity. As the air traffic increases, the need for safety in all its aspects is more demanding. Northern countries, face the additional challenge to provide safe traveling under severe winter conditions. To accomplish this, airports, as a part of their winter maintenance operations use Aircraft Deicing Fluids (ADF) on a regular basis to make sure that critical aircraft surfaces are free of ice, snow or frost formation before take-off. These elements can alter the shape of the wings airfoil section and its surface flow characteristics, causing a loss of lift that can prevent the plane from taking off or cause it to crash if the ice develops in flight (Transport Canada, 1994).

The fluids used to deice/anti-ice aircraft in North America are usually composed of ethylene glycol (EG) or propylene glycol (PG) combined with water and other ingredients. The formulation is proprietary, but depending on the final use of the product some, may contain wetting agents, corrosion inhibitors, colorants and thickeners.

Runoff from aircraft deicing activities has resulted in the release of large quantities of dilute glycol-based fluids to the aquatic environment. The very high biochemical oxygen demand (BOD) of deicers is their main impact on the environment. (Miller, 1979, Sabeh, 1991), there is also evidence that the toxicity of ADF is increased by the presence of additives present in the formulation (e.g. triazoles, organic amine bases, etc.) (Pillard, 1995). This indicates the need to develop systems able to remove the glycol and the additive contaminants from an airport's runoff, which can cause serious effects on the environment.

Results of the treatment of low strength ADF using an Anaerobic Baffled Reactor (ABR), will be presented. During this experiment, different ADF concentrations (0.04%, 0.07%, and 0.13% v/v) were continuously fed at different HRT (24, 12, 6 and 3 hrs) at organic loading rates (OLR) varying between 0.3 and 6 kg COD/m^3•d. The performance of the reactor was determined by the removal of influent COD, biogas production and effluent VSS. The best COD removal was reached at high COD influent concentrations and HRT, for the lowest HRT essayed COD removal efficiency dropped to an average of 65% for the 3 COD influent concentrations tested. Methane production potential was close to the theoretical value of 0.39 L CH_4/g COD removed at 35°.

The application of a first order model did not describe the performance of the ABR under the experimental conditions tested, instead a linear model was developed to describe the COD removal efficiency as a function of COD influent concentration and HRT. Model verification indicated that predicted response (COD removal efficiency) was in good agreement with experimental results.

Modélisation de la production et de l'extraction des boues à partir d'un suivi de station d'épuration à boues activées

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Le traitement des eaux usées urbaines par boues activées génère d'importantes masses de boues qui sont régulièrement extraites du système pour subir un traitement ultérieur (déshydratation, incinération, épandage,…). La plupart de la matière organique de l'effluent d'entrée constitue le substrat de la biomasse active du système. La croissance bactérienne qui en résulte et l'accumulation de matières inertes (minérales ou non) génèrent la production de boue.

Les extractions de boues doivent compenser cette production de boue pour permettre d'une part de conserver un taux de boue stable dans le système et d'autre part d'appliquer un temps de séjour moyen des boues suffisant pour maintenir les biomasses les plus sensibles (notamment les biomasses nitrifiantes).

Une étude de deux ans sur une station d'épuration (STEP) à boues activées (France, Toulouse) a permis l'acquisition de données fiables et complètes sur la problématique des boues en site réel. Parallèlement, des travaux de simulation ont été réalisés avec le modèle Activated Sludge Model No. 1 (ASM1) et le logiciel GPS-X pour obtenir des paramètres inaccessibles par mesure directe et pour construire des scénarios incluant des contraintes extrêmes. C'est donc à partir de l'ensemble de ces éléments que nous aborderons la modélisation de la production de boues puis de leur extraction.

Une bonne connaissance de la production de boue est nécessaire tant pour une perspective de dimensionnement que pour une perspective d'exploitation. Différentes techniques d'évaluation sont possibles à partir : (i) de la charge entrante (calculs simplifiés ou modélisation du système complet), (ii) de l'évaluation dynamique de la quantité de boue présente dans le système, (iii) de la pesée des bennes de boues extraites, (iv) et d'un bilan sur les matières minérales. L'application de ces quatre approches sur le suivi long terme de la STEP étudiée donne des résultats cohérents qui valident notamment la modélisation de la production de boue par le modèle ASM1.

Dans un deuxième temps, une attention particulière a été portée à la modélisation de l'extraction des boues. Plusieurs approches ont été évaluées : (i) asservissement du débit d'extraction au taux de boue du bassin d'aération (extraction continue), (ii) extraction par reproduction des temps de marche des pompes d'extraction, et (iii) asservissement de la durée des extractions au poids des bennes de boue extraites. Si les deux dernières approches se sont révélées équivalentes, la première mène à un lissage fort des conditions réelles pouvant conduire à des erreurs sur l'estimation des concentrations en biomasses nitrifiantes.

A partir de ces travaux de validation de la modélisation de la production et de l'extraction de boues, différents scénarios ont pu être simulés. Les premiers résultats présentent une étude de sensibilité soulignant l'interaction entre l'évaluation du fractionnement d'entrée et l'estimation de la production de boue. Une seconde étude porte sur la gestion des boues (mode d'extraction, fréquences,…) et son impact sur le système. Un exemple montre la sensibilité de la concentration en biomasse autotrophe (responsable du traitement de l'azote) à la répartition temporelle des extractions.

Enfin, un bilan méthodologique suggère les domaines d'application des différentes méthodes présentées dans cette étude, notamment pour l'évaluation de la production de boues.

Laccase-Catalyzed Removal of Bisphenol-A from Water

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Bisphenol-A (BPA), or 4,4'-Isopropylidenediphenol, is a building block for the production of flame-retardants, polycarbonate plastics and epoxy resins. It is suspected to be an endocrine disrupting chemical (EDC) that mimics hormonal signals in animals and has an irreversible effect on the development of the reproductive organs.

As reported to the US Toxics Release Inventory EPA, TRI, the total release of BPA in 2000 was 695,798 pounds of which almost one third was listed as on-site releases (air, land, underground injection, surface water discharge, etc.) and the remainder was off-site releases (landfills, transfers to waste treatment plants, etc.)

The standards for the discharge of BPA are becoming increasingly restrictive; therefore, it is beneficial to find an innovative method that is versatile under a wide range of reaction conditions. In recent years removal through an enzyme-catalyzed polymerization process has been explored as a new method for the treatment of aqueous BPA. The advent of new technology for the production, isolation and purification of enzymes has made their use more competitive.

Laccases, with multiple copper atoms at their active sites, can utilize molecular oxygen as oxidant for a variety of phenols such as BPA, resulting in the formation of water-insoluble polymers which can be separated by physical means. In this study the feasibility of using the enzyme process to treat a synthetic wastewater containing BPA was examined. The quantity of laccase (a developmental preparation, SP-504, from Novozymes) required for >95% conversion of BPA, along with optimum conditions such as pH in the presence and absence of polyethylene glycol was examined by using a colorimetric assay. Polyethylene glycol (PEG), a chemical additive, reduced enzyme inactivation, allowing a 5.2-fold reduction in the amount of laccase required for >95% removal of BPA in the range of 0.1-1 mM concentration. A series of HPLC tests were conducted to validate the colorimetric assay results. A comparison of the two methods showed a maximum deviation of 5%. The fate of PEG after reaction was also studied by using TOC test.

Linear relationships were found between the quantity of BPA (0.1±1 mM) and the optimum concentrations of laccase and PEG required for more than 95% removal.

Up to a certain PEG concentration, there was little PEG remaining in solution after completion of reaction and most of the PEG combined with the particles and separated from solution as precipitate. It is inferred that the interaction between the PEG and the polymeric products resulted in the protection of laccase.

Membrane Fouling Reduction by the Incorporation of Hydrophilic Surface Modifying Macromolecules in Ultrafiltration Membrane Manufacturing

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Membranes are in more widespread use currently than in the past to meet more stringent water quality criteria. However, membrane fouling by natural organic matter (NOM) has always been hinders the long-term performance of membranes. Many different approaches to reduce fouling have been tested; this study investigates the impact of membrane surface modification via the addition of a tailor-made hydrophilic surface modifying macromolecules (LSMMs) as an additive in the preparation of polyehersulfone (PES) ultrafiltration membranes. The key concept is that the migration of the LSMM to the surface (during casting) creates a more hydrophilic membrane surface, which should be less susceptible to fouling. The objective of this study is to determine the impact of the concentrations of PES, LSMM and a pore former on the membrane characteristics and performance (including fouling).

Phase one studied the reproducibility of the first type of LSMM (LSMM2) from different batches by monitoring pure water permeation rate (PWP) and solute separation efficiency. The LSMM2 from five different batches showed statistically the same results.

In phase two, different PES concentrations with and without the additive were tested. Contact angle measurement was chosen as the screening stage to determine the solution composition with LSMM2 that gave the most hydrophilic membrane. Both static and dynamic contact angles were studied. There was no statistically difference in static contact angle among the membranes with and without LSMM2. However, the dynamic contact angle shows differences between the PES membranes and those modified with LSMM2. A smaller number of membranes were then chosen for a complete filtration test including compaction, pure water permeation determinations, molecular weight cut off (MWCO) determination followed by 144-hour fouling test using Ottawa River water (ORW). Performance parameters monitored included PWP, solute separation efficiency, UV and TOC removal, and NOM deposition. The addition of LSMM2 has produced membranes capable of somewhat higher TOC removals, less fouling while achieving similar long term fluxes. Further study including the development of more hydrophilic LSMMs is needed to determine the maximum possible impact of this approach.

Modeling Phosphorus Dynamics in Tile Drained Fields

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Non-point source (NPS) pollution from agricultural watersheds is a major source of water degradation in rivers and lakes of southern Quebec (source). NPS pollution in southern Quebec is partly due to elevated concentrations of phosphorus (P), as a result of continuous application of fertilizers. A considerable percentage of P loads in these rivers is attributed to subsurface discharges from tile-drained fields (Jamieson et al., 2000; Enright et al., 2003). Therefore, a mathematical model has been designed to study P transport down the soil profile and into tile drains, under variably saturated conditions.

The proposed model aims at covering limitations of current soil P models by coupling a chemical aqueous model with a hydrological-transport model. The HYDRUS model (Šimůnek et al., 1998; 1999) is employed to simulate water flow and solute transport, and the NICA model is adopted to describe the adsorption/desorption processes of P onto the soil particles. The HYDRUS model (Šimůnek et al., 1998; 1999) is a finite element model for simulating water-flow and solute transport in variably saturated soils under both steady state and transient conditions.The NICA model (Koopal et al., 1994) describes P adsorption onto the soil charged surfaces at different pH's and ionic strength of aqueous solution, taking into account the non-ideal competitive behaviour of different species in solution.

This paper presents the conceptual and representational framework of the model. The modules that constitute the model are described in detail and the assumptions considered in this model are highlighted. In addition, the experimental setup to derive the required parameters and validate the model is outlined, and some preliminary results are presented.

Scale and Resolution Choices in Watershed Modeling

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Computer codes have become an ever-present tool in watershed modeling contexts over the last decades, and have only become increasingly important in the current TMDL regulatory context.

This poster presents a brief overview of the effects of scale and resolution on a typical non-point watershed model. The Annualized Agricultural Non-Point Source (AnnAGNPS) computer code is a continuous-simulation pollutant-loading model developed by the U.S. Department of Agriculture (USDA) for watershed-level analyses. This model is among the most commonly used models for dynamic simulation of non-point source pollutant impacts on surface water quality, and includes elements of the CREAMS/GLEAMS model family (as do SWAT and HSPF).

Transformation et valorisation des boues rouges d'aluminerie par production d'un agent déphosphatant pour le traitement des eaux usées

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Des apports massifs d'éléments nutritifs dans les cours d'eau résultent le plus souvent en l'eutrophisation et la dégradation des milieux récepteurs. Le phosphore ayant été désigné comme l'élément généralement limitant dans la croissance de la flore aquatique, celui-ci fait l'objet d'un contrôle particulier dans les effluents d'eaux usées municipales et industrielles. Les procédés utilisés pour l'enlèvement du phosphore sont de nature biologique (procédé en boues activées, par exemple) ou de nature chimique. Les agents chimiques les plus utilisés pour la coagulation et précipitation du phosphore sont des sels de fer ou d'aluminium, comme le chlorure ferrique, le sulfate ferrique et le sulfate d'aluminium (alun).

Par ailleurs, l'industrie de l'aluminium génère de grandes quantités de boue rouge, un résidu riche en aluminium et en fer. Pour la production d'une tonne d'aluminium, deux tonnes de boue rouge sont rejetées à l'issue du procédé Bayers d'extraction de l'alumine de la bauxite. Actuellement, les boues rouges sont le plus souvent accumulées sur les sites de production d'alumine, mais des équipes de recherches travers le monde ont envisagé différentes voies de valorisation de ce résidu. Par exemple, sa capacité à adsorber le phosphore a été étudiée. Cependant, en raison de la faible disponibilité du fer et de l'aluminium, les résultats ont été peu satisfaisants.

Le projet ici présenté s'inscrit dans le cadre de travaux de recherche de deuxième cycle et a pour objectif premier de produire un agent déphosphatant pour le traitement des eaux usées. Un objectif secondaire est de valoriser des déchets industriels présentement inutilisés et disponibles en grande quantité, les boues rouges.

Un procédé de transformation chimique des boues rouges a été développé, rendant le fer et l'aluminium disponibles pour réaction avec le phosphore. Afin de pouvoir implanter le procédé à grande échelle de façon économiquement viable, les conditions de production de l'agent déphosphatant ont été optimisées en maximisant sa valeur commerciale tout en minimisant les coûts de production. Le produit obtenu est un solide, soluble dans l'eau, contenant 9,2 % de fer et 3,4 % d'aluminium. Une caractérisation par diffraction des rayons X a permis d'identifier trois phases cristallines : $NaFe(SO_4)_2$, $NaHSO_4$ (phases majeures, > 15%) et $Al_5Cl_3(OH)_{12}.2H_2O$ (phase en trace, < 5%).

Des essais de déphosphatation sur des effluents synthétiques contenant de 5 à 100 mg/L de phosphore ont permis d'évaluer l'efficacité du composé. Son pouvoir déphosphatant est jugé comparable à celui de produits déjà existants et utilisés pour le traitement des eaux usées. Par exemple, pour un effluent contenant 100 mg/L de phosphore, le ratio molaire [Fe + Al ajouté] / [P enlevé] est de 1,6 pour l'agent déphosphatant expérimental, le sulfate ferrique et l'alun, tandis qu'il est de 1,7 pour le chlorure ferrique.

Pour compléter l'évaluation de la performance de l'agent déphosphatant obtenu, des essais de déphosphatation devront être faits sur des effluents réels, par exemple des eaux usées municipales ou encore du lisier de porc. D'autres types d'essais comparatifs sont à envisager, notamment en ce qui a trait au volume et à la composition des boues générées lors de la déphosphatation. Selon la composition des boues, des voies de valorisation pourraient également être suggérées celles-ci. Enfin, l'implantation à grande échelle du procédé de production de l'agent déphosphatant demeure l'objectif ultime.

A Note on Jet Mixing and Dilution

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Wastewater plant effluents discharged into a stream should undergo dilution in a short reach of the stream. The devices used to discharge the effluents should ensure its rapid mixing in the stream. Jets are simple and efficient devices that accomplish this purpose. In closed conduits, counter flowing wall jets can be used also for efficient mixing of chemicals. The increased interest in the use of cross jets and counter flowing jets to ensure proper mixing of effluents in a stream can be traced to the large scales of mixing achieved by these devices, as compared to traditional co-flowing jet devices.

In the present study, the mixing characteristics of the counter flowing wall jets were determined experimentally. Salt solution was injected into the pipeline carrying the jet flow. A conductivity meter was used to find the salt concentration. The concentration distribution of the salt was determined at several cross sections of the jet wake to determine the mixing characteristic of the counter jet. Preliminary results indicate that the counter jet provides nearly complete mixing at a distance of $2.5x_p$ in the jet wake. Here, x_p denotes the jet penetration length.

Introduction

The common modes of jet flows generally include the free jet, the plane wall jet, the cross jet, the three-dimensional jet. The counter wall jet is bounded on one side by a wall. This is a combination of two flows that include a free turbulence region in the outer region and a boundary layer region near the wall (Fig. 1). It can be used to dilute municipal and industrial effluents discharged into a stream through intense mixing. It can also be used for mixing chemicals in water treatment plants and for mixing of air and fuel in industrial burner systems.

Existing counter flowing wall jet studies are mostly limited to the determination of the mean flow characteristics of these jets [2, 8, 9]. In the past, several methods were used to measure the concentration distribution in the flow field, using Laser induced fluorescence LIF [4, 5, 9, 11] and conductivity meter. Lam and Chan [6] studied the free counter flowing jet in an open channel setting. They got the mean concentration at different axial stations upstream of 0.7 the penetration. For the counter flowing free jet, the mixing of a tracer injected into the main flow is fast and efficient.

In the present study, the mixing characteristics of the counter flowing wall jets were determined experimentally. Salt solution was injected into the pipeline carrying the jet flow. A conductivity meter was used to find the salt concentration. The parameter denoting the ratio of the jet velocity to the main velocity was in the range of 5 to 15. The concentration distribution of the salt was determined at several cross sections of the jet wake to determine the mixing characteristic of the counter jet. Studies indicated that at a distance of $2.5x_p$, the mixing in the jet wake was nearly completed. Here, x_p denotes the jet penetration distance.

Experimental Set Up and Procedure

A flume 25.4 cm wide, 121.9 cm deep and 243.8 cm long was used to conduct the jet test (Fig. 2). The counter flowing wall jet was introduced at the floor level of the flume. The jet opening h_j was equal to 2.54 cm or 1.27 cm. Proper turning vanes, screens, flow straightens and contracting sections preceded the

jet nozzle to reduce background flow turbulence. The velocity measurements were made with a DANTEC two-dimensional Laser Doppler Anemometer system (LDA). The mean velocities and the turbulent stresses of the turbulence were measured in the axial and vertical directions. The combined flow of the main stream and the jet was measured by a V-notch.

The test section (Fig. 2) had plexiglas windows. The laser probe traversing mechanism could be moved in increments of 0.0025 mm along the x, y and z directions. A stainless steel tank was used to store the salt solution. When steady flow conditions were established, the salt solution was introduced into the pipe line carrying the jet flow at P (Fig. 2). Thirty-six copper tubes with an inside diameter of 3 mm were used to get the concentration distribution over one half of the cross-section of the flume. Individual probes were connected with thin plastic polythene tubings. Sample concentrations were found by a conductivity probe (OAKTON Instruments) to the nearest 5mg/L. Conductivity was converted to salt concentration based on calibration data. The range of concentration covered was 0 to 850 mg/L.

Analysis of Results

Concentration distribution in the jet wake: The jet exit width is denoted as h_j. Water samples were obtained covering a region from $30h_j$ (AB) to $140h_j$ (MN) in the jet wake (Fig. 2) for a range of λ (= V_{jet}/V_{main}) values ranging from 5 to 15. For each flow configuration, concentration distribution data were obtained at 7 axial locations. The total salt quantity m_1 passing a cross section such as EF (Fig. 2) was calculated as follows by noting the concentration of salt at the 36 locations of each cross section.

$$m_1 = \sum_{N=1}^{36} \text{weighted area at sampling probe x velocity at probe location x measured concentration}$$

Here, N = 36 denotes the number of samples collected. Details of computations and calibration are provided in a related publication [10]. The concentration and the velocity distribution data at sections such as AB yielded the rate m_1 at which the quantity of salt was passing these sections. These quantities compared well with the quantities m_2 of salt injected at P (Fig. 2). Typically, the ratio $(m_2 - m_1)/m_2$ was in the order of $\pm$ 0.05, indicating a good mass balance.

The thick solid line of Fig. 3 shows the change in σ denoting the variation of salt concentration from section AB to section MN (Fig. 2). Extrapolation of this line indicates that mixing is nearly complete ($\sigma \rightarrow 0$) at O where, $x/x_p \approx -2.5$.

Conclusions

The studies of some mean and turbulent characteristics of counter flowing wall jet and their application in Environmental Engineering have been carried out. Results and contributions of the present study can be summarized as follows:

1. Counter flowing wall jets promote a high degree of mixing.
2. The expected total mixing distance in the jet wake and the propagation of the injected total dissolved solids (TDS) can be predicted using empirical data.

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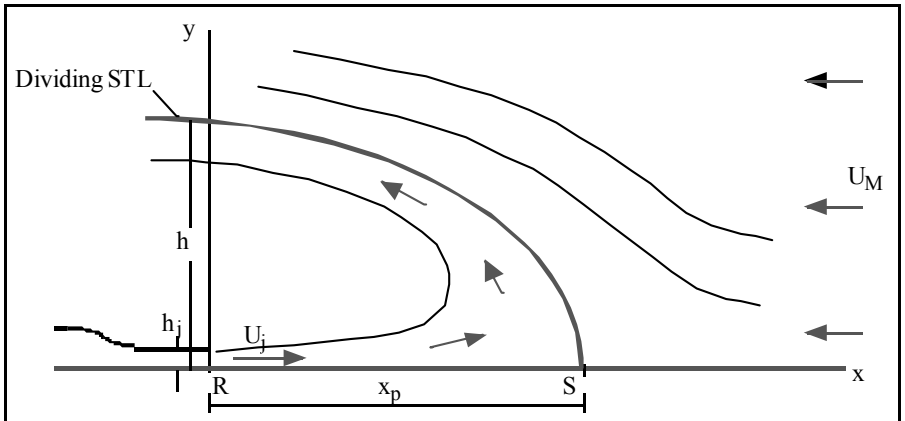

Fig. 1: Definition sketch of a counter flowing wall jet.

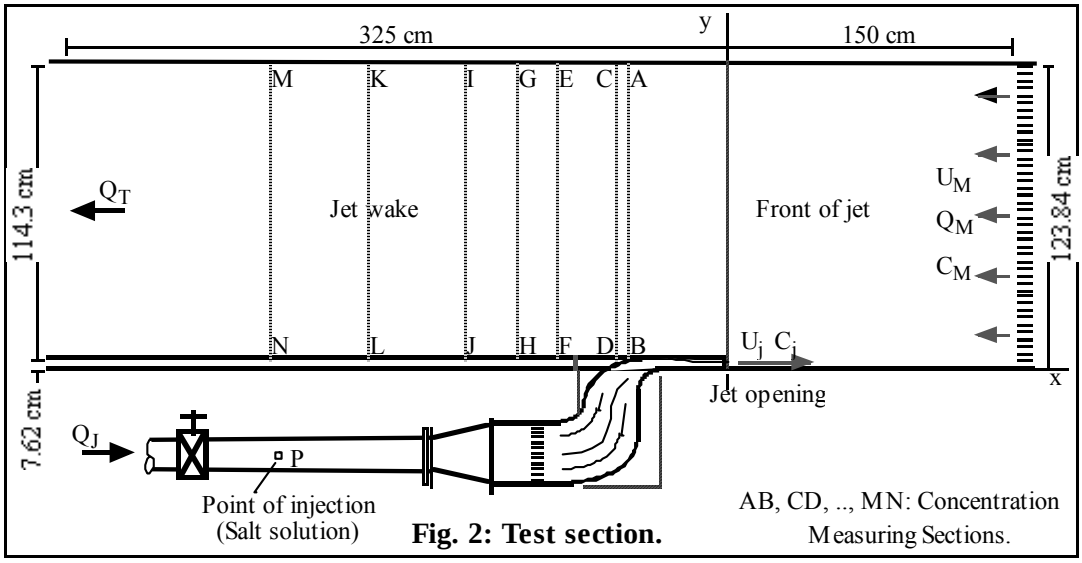

Fig. 2: Test section.

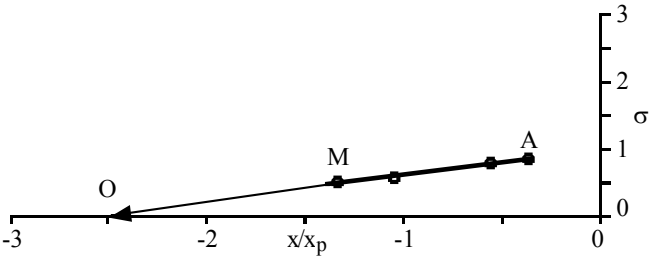

Fig. 3: Typical plot of standard deviation of C/C_{avs} versus x/x_p.

Effect Of Leachate Recirculation And Sludge Addition In Aerobic Bioreactor Landfills

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The biodegradation of municipal solid waste (MSW) was investigated in simulated bioreactor landfills under aerobic conditions. The bioreactors were operated to determine the amount of leachate recirculation and municipal wastewater sludge addition required to optimize waste degradation. The leachate generated was recycled over 47 weeks, leachate samples were collected on a weekly basis and analyzed for pH, biochemical oxygen demand (BOD), chemical oxygen demand (COD), total Kjeldahl Nitrogen (TKN), and ammonia nitrogen (NH_3-N). The temperature of the MSW in the bioreactors was measured on daily basis. The rate of leachate recirculation was 285, 570, and 855 mL/kg of MSW/d, and sludge addition rate was 28.5, 57, and 85.5 mL/kg of MSW/d. Within 27 weeks enhanced MSW degradation was observed at the leachate recirculation rate of 855 mL/kg of MSW/d and sludge addition rate of 85.5 mL/kg of MSW/d. During this period, the COD concentration in the leachate dropped from 38,000 mg/L to approximately 1,000 mg/L. By reducing leachate recirculation rate to 285 L/kg of MSW/d and sludge addition rate to 28.5 mL/kg of MSW/d, the time period for stabilization increased to 45 weeks. Fitted empirical mathematical models for COD concentration in the leachate indicated that the effect of leachate recirculation was much stronger compared to sludge addition.

A GIS Approach for Evaluating Aquifer Sensitivity to Climate Change in Eastern Ontario

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Vulnerability of groundwater and surface water resources was assessed in a GIS-based model. The study area is a portion of Eastern Ontario, east of Ottawa between the Ottawa River and the St. Lawrence River. The approach is based on monthly water budget calculations on a three-layer-system conceptual model for Eastern Ontario, and it can be used to estimate groundwater vulnerability on a monthly basis, under the monthly prevailing conditions. Aquifer vulnerability to contamination is based on Surface to Aquifer Advective Times (SAAT); flood potential is assessed by the Monthly Excess Runoff (MER); and deep aquifer depletion is assessed by the Monthly Excess Demand (MED). The key GIS layers developed for each month are: potential evapotranspiration, net available water, transmisivity, estimated volumetric flow rate, variation in groundwater storage, percent of groundwater storage, estimate for groundwater consumption, water table elevation, surface runoff, infiltration, groundwater deficit and aquifer vulnerability.

Several extreme climatic scenarios were extracted from the historical climatic records of the study area. Temperature and precipitation related to such extreme scenarios were entered into the model to calculate rasters representing potential evapotranspiration and net available water. To estimate vulnerability indices (and their spatial distribution), the water budget calculations are compared to identical calculations for the "normal" year scenario, hence the indices represent *changes* in vulnerability for a given scenario, compared to a normal. By visual and quantitative studying of these parameters within GIS for normal and extreme scenarios, it is possible to find geographical areas that are always hydrogeologically sensitive for each month of the year; and areas that are sensitive only during the extreme scenarios. All the above calculations were performed on a monthly basis.

The results of this analysis show that the most plausible climate change scenarios for Eastern Ontario do not have a large impact on the groundwater resources. The scenario with most impact on a monthly basis was the driest year. It produced large vulnerabilities and large MED values at certain times of the year but the water budget deficits were replenished by the beginning of the following year. An extremely important result from this study is that vulnerability is extremely variable from one month to another and from one geographic location to another. The GIS environment was extremely powerful at identifying geographic locations that were particularly vulnerable. In addition, generating such a GIS model enables the users to change the value of input key parameters and check the response from the system. In this way the users are able to use the model to predict new areas, which will be vulnerable if very extreme climatic scenarios occur in the future because of the continuation of global climate change. Such GIS modeling can be an extremely valuable tool to the watershed managers and municipality decision makers.

Using Quantitative Methods to Gather Small Stream Flow Data for Habitat Characterization

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The Mountain Dusky Salamander (*Desmognathus ochrophaeus*) and Northern Dusky Salamander (*Desmognathus fuscus*) both have a limited Canadian distribution. *Desmognathus ochrophaeus* in particular, is present only on Covey Hill and this appears to be it's northern limits. The species was listed as "Special Concern" by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) in 1998, however as of November 2001 their status was uplisted to "Threatened" meaning that the species is likely to become endangered if limiting factors are not reversed. Currently a project is underway to determine the characteristics of the habitat. This project is examining the small stream hydrology only in a qualitative manner, therefore this collaborative project was designed to provide a qualitative insight into the stream hydrology of the system. A total of 62 sites where salamanders had been previously observed were selected. The main problem facing this project was to determine a method that would provide the most useful hydrology data at 62 remote sites inventoried many times over the course of the summer on a small budget without disturbing the habitat. The overall objective being to provide quantitative data to supplement the qualitative data and compare the effectiveness of the two methods for this system.

During the months of June through to September, the flow of these streams was measured using the float method, the cross-sectional area was measured and then the amount of time required for a cork to travel 1m was recorded. This was repeated at each site over the course of the summer where water levels allowed. If it was impossible to locate a section where the cork could flow 1 m, an alternate site permitting the flow of 50 cm was located and the same procedure carried out.

Of the sites that were inventoried, 50 were classified as intermittent streams, and 12 as permanent. In June, 17 had measurable stream flow. It was observed that the majority of sites experienced a substantial decrease in flow from June to July, and the lower levels were maintained for the most part throughout July and August. During July and August, we were only able to measure 12 of the sites due to the decrease in stream levels. Water levels tended to rise again in September, and half of the streams had higher flows in September than June, while the reverse was observed in the other half which indicates that precipitation may play a large role in maintaining these intermittent streams.

For the most part, the streams inventoried are intermittent and have the potential to dry up completely over the course of the summer, if it is a really dry season. This study enables one to link the salamanders present with the type of hydrology that they require. In addition it can be concluded that the float method was the most appropriate method for gathering quantitative data, as the other alternatives, the propeller method would not been able to gather as much data in the streams with lower flow, or the portable flumes which would have been potentially destructive to these sensitive ecosystems.

Analysis of Microbial Diversity in Two and Three Stage Mesophilic Anaerobic Digestion of Municipal Sewage Sludge Using DGGE Technique

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Land application of biosolids is controversial because the biosolids may potentially contain human pathogens. Anaerobic mesophilic (35°C to 40°C) digestion is most widely used to stabilize primary and secondary sludges from municipal wastewaters. However, many types of pathogens can survive such treatments and modifications to the operational strategies are often needed to improve the rate of sludge stabilization and to enhance the reduction of pathogens.

In recent years, the interest in staged systems has grown significantly. Staged operation has included separation of the acid and methane production phases of anaerobic systems and also the operation of mesophilic and thermophilic reactors in series. However staged anaerobic digestion at mesophilic temperatures has received less attention. It is believed that the operation of completely mixed reactors in series would approximate plug flow and limit the effects of short-circuiting, such as the bleed-through of pathogens that can occur in a single completely mixed reactor.

This paper will present the results of a set of experiments that compared the performance of two and three stage reactors in series with single stage operation. Performance with respect to conventional digestion parameters, pathogen reduction and microbial diversity was assessed. The staging system consisted of set-ups that had either two or three reactors that were operated in series and with different temperature configurations. Two parallel three stage set ups (System I: 35ºC-35ºC-35ºC and System II: 42ºC-35ºC-35ºC), one two stage setup (System III: 35ºC-35ºC) and one conventional single-stage setup (35ºC) were operated.

The total hydraulic retention time during the staging study was 15 days. In the three stage systems each digester has an hydraulic retention time (HRT) of 5 days while the first stage of the two stage system had an HRT of 5 days while the second stage HRT was 10 days. Each reactor had a working volume of 20 L and was fed daily with a mixture of primary and thickened waste activated sludge (TWAS) from the City of Ottawa's wastewater treatment plant. The temperature of digesters was rapidly established and the digesters were operated for at least 3 SRT's prior to steady state sampling.

Performance of the digester operation was assessed on the basis of regular monitoring of process stability and solids reduction parameters for each system. After each system reached steady state, samples were taken from the influent and effluent of each reactor for process parameters and bacterial analysis. DGGE testing of digester effluents was performed to evaluate the impact of staging and temperature on the diversity of the microbial population during series operation of anaerobic digestion.

Higher solids removals were achieved with systems I, II and III as compared to the single stage digester. Systems I, II and III had solids reductions of 54, 59, and 52% respectively as compared to 36% for the single stage digester. DGGE testing revealed that an increase in operating temperature of the first stage of the three stage system from 35 to 42ºC resulted in the development of a new bacterial population and the majority of these microorganisms remained the same through the second and third stages of the three stage operation. However, no significant changes in bacterial diversity were observed during two stage operation when both digesters were operated at 35ºC.

Nutrients Transport in Surface and Subsurface Runoffs From Two Drained Fields in the South of Quebec

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Monitored rivers of the Missisquoi Bay Watershed of South Central Quebec commonly bear phosphorus concentrations above water quality guidelines for eutrophication. In the watershed, agricultural non-point source pollution is considered the dominant source of P pollution. Surface runoff is often considered the principal cause for non-point source pollution and consequently, many studies have been devoted to it. As a result of this and because subsurface runoff is difficult to measure, few studies have been done on the movement of nutrients via the subsurface tile drainage system. Since the majority of intensively managed agricultural lands in Quebec are subsurface drained, there is a great need to understand this particular phenomena.

To address this knowledge gap, surface and subsurface drainage from two agricultural fields within the Missisquoi Bay Watershed were monitored from 2000 to 2004. The two sites were instrumented to measure and sample, on a flow-weighted basis, surface runoff and tile drain flow. Flumes and flow meters linked with a datalogger were installed to measure and sample the flow exiting the field through surface and subsurface drains. Samples were analyzed for different forms of phosphorus, nitrates and other parameters. Meteorological parameters such as rainfall and air temperature were recorded on each site.

As expected, the phosphorus content in surface runoff water was quite elevated compared to the recommended limit to prevent eutrophication. The mean Total P concentration for surface and subsurface runoff were respectively 1.17 mg/L and 0.15 mg/L, largely exceeding the MENV water quality guidelines of 0.03 mg/L. Tile drainage accounted for 79% of the total volume exiting the fields and was responsible for 39% of the total phosphorus load. Consequently, the subsurface path for phosphorus transport has to be taken into account when implementing policies to reduce nutrient loads into rivers and streams.

The simulation model, FHANTM, selected to simulate the transport of phosphorus on agricultural fields uses DRAINMOD to simulate the hydrology, and GLEAMS to simulate the transport of nutrients. It is presently being calibrated to simulate the phosphorus transport. Preliminary results show that the hydrologic simulation accurately represents the water movement on the field but further test are needed to verify the accuracy of the model simulating nutrients transport. Once the accuracy of the model is established, it will be applied to simulate different management practices and view their potential impacts on nutrient loads as well as to determine how agricultural practices can be improved. Finally, the ability to measure, correlate and simulate the transport of nutrients on agricultural fields will help develop best management practices to reduce nutrients transport.

UV-Visible Spectrophotometry for Lake Monitoring: Application to Lake Brome, Southern Québec

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The monitoring of water quality of lakes is moving from the analysis of specific parameters to the integration of global ones among which absorption and reflectance properties. From the acquisition of UV-visible-(NIR) absorption spectra of samples of lake water, it is possible to globally characterise the water quality. The shape of spectra is a consequence of the presence of absorbing material, either dissolved (as organic matter or nitrate), or in suspension (solids and colloids). In this last case, the phenomenon involved is more a physical diffusion than a true chemical absorption. The optimal exploitation of spectra shape, by a semi deterministic deconvolution method gives quantitative estimation of some parameters as well as qualitative information. The concentrations of dissolved organic carbon and nitrate can be quickly given by the method, as the chlorophyll one. Depending on the amount of absorbing matter, quartz cells of 10 or 50 mm are used and the speed scan is 1800 $nm.min^{-1}$ between 200 and 900 nm. The colour of water can be obviously given by the tristimulus method. The analysis of spectra shape leads to the characterisation of the organic matter type between humic like substances and non humic. Moreover, it is possible to make the distinction between natural and anthropogenic organic matter, and to characterize the coloured dissolved organic matter (CDOM).

An application of the propose methodology was carried out in Summer 04 for the study of the evolution of the water quality of lake Brome (Southern Québec) and its tributaries. 5 campaigns were planned between mid July and the beginning of September and 16 samples were taken from the tributaries and from different sampling station on the lake. The absorption spectra were rapidly acquired with other physico-chemical parameters (pH, Conduct. , Temp.), and some samples were sent to the laboratory for chemical analysis (COD, NO3, Ntot, PO4, Ptot). The exploitation of results shows a great difference between the water quality of tributaries and between one campaign and the others, due to variations in weather condition (one campaign was carried out a rainy day).

The qualitative exploitation of the spectra shape leads to the following observations:

i) the half of tributaries shows a brown-yellow colour related to the presence of humic like substances,

ii) the presence of relatively high concentration of nitrate characterizes one tributary sampling site,

iii) there is a close relation between the spectra importance in the UV region and the concentration of COD.

No presence of blue-green algae was detected during the campaigns and the concentration of chlorophyll was very low (unfortunately green water was observed the last week of August, but no campaign was carried out). The comparison between the UV estimation of COD and nitrate, and the results of laboratory analysis gives a good correlation between the two sets of values.

This study shows the usefulness of the proposed methodology considering its simplicity and rapidity (the results are obtained within 24 hours), even if the sensitivity is not always adapted. Moreover, the fingerprinting of surface water can be envisaged and be applied to the simple follow-up of water quality evolution, particularly during the Summer time where algae blooms crises may occur.

Microwave Pretreatment of SBR Sludge to Enhance Anaerobic Digestion: (Preliminary Results)

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The disposal of biosolids produced by wastewater treatment plants is presently the most pressing problem facing the sanitary engineer. By itself, anaerobic digestion is incapable of producing stable, pathogen-free biosolids that can be safely spread on agricultural land. Instead, pretreatment processes have been developed to enhance biogas production and volatile solids destruction. This research investigates the potential of microwave irradiation as a pretreatment option for improving anaerobic digestion and pathogen inactivation.

A factorial experiment was carried out to explore the potential of microwave irradiation for improving the characteristics of sequencing batch reactor sludge for anaerobic digestion. The effects of pretreatment temperature, microwave irradiation and sludge concentration on a set of parameters were monitored. Briefly, with 95% confidence, increasing pretreatment temperature in the 45-85 ºC range increased the soluble protein content and the soluble / total chemical oxygen demand ratio while it decreased the alkalinity and the ammonia content. Microwave intensity and sludge concentration had minimal effects on the monitored parameters.

The maximum soluble chemical oxygen demand (sCOD) of the SBR sludge utilized was determined by adding a strong dose of sodium hydroxide to the sludge. Twelve bottles were thus chemically treated at the same time and opened one after the other at three-hour intervals. A plot of sCOD vs time allowed the determination of the maximum sCOD of the sludge. This result is useful in assessing the performance of microwave irradiation as a pretreatment for anaerobic digestion.

Presently, an anaerobic microbial consortium is being developed to digest microwave-pretreated SBR sludge. Upon completion of this acclimation period, this culture will be used as the seed for a biochemical methane potential (BMP) test. A total of 24 batch bottles will be used to investigate the effects of microwave pretreatment temperature, microwave intensity and partial pretreatment on the performance of anaerobic digestion. This last variable consists of treating a portion of the sludge and mixing with untreated sludge.

Evaluation of Microbial Water Quality Risks from Land Application of Biosolids: Tests on Hydrologically Isolated Plots

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There is increased pressure to dispose of treated municipal sewage or biosolids, in an environmentally safe manner. For biosolids, land application is one option in North America. Recent Ontario legislation (Nutrient Management Act) deals with the immediate risks of water pollution through rules on time of application and spatial separation between treated lands and water resources. Nevertheless, such spatial separation is mostly aimed at reducing the risks from direct surface runoff and may not be relevant to drainage tiles that drain the majority of the agricultural lands in Ontario.

Preferential flow pathways on drain-tiled lands are likely a major contributor to the impairment of the quality of surface waters. Such preferential flow may be affected by the soil's water content, the type of soil, the liquid or solid form of applied biosolids and possibly by soil management practices.

A two-year study on a series of hydrologically isolated plots on a clay soil was carried out as part of a larger investigation. The experiment evaluated the longer-term risks of microbial contamination associated with the type of land-applied biosolids and with different land application practices. Liquid and dewatered biosolids were applied to the plots in the spring and fall of 2003 and the spring of 2004. Liquid biosolids were surface-applied and incorporated or injected. Dewatered biosolids were surface-applied and incorporated. The spores of a thermophilic bacterium (*Geobacillus stearothermophilus*) were added to the biosolids as a microbial tracer. Weather conditions were monitored at the experimental site via an automated weather station. Drainage and surface runoff flow rates were automatically recorded for each plot.

Year-round automated drain-tile sampling allowed the evaluation of immediate and long-term risks from microbial contaminants under varying environmental conditions. The tile drainage was analyzed for the presence of several standard and novel microbial indicators (bacteria and viruses: *Escherichia coli, Salmonella sp., Enterococcus sp. Clostridium perfringens*, coliphages and *Bacteroides fragilis* phages) of water quality to assess their potential utility as short- and long-term indicators of microbial pollution of water resources from land application of biosolids.

Our findings indicate that even relatively small precipitation events very shortly after the land application of biosolids can lead to microbial transport under unsaturated soil conditions. The method of land application does not necessarily affect the risk for microbial transport through the unsaturated soil profile. Viral indicators of contamination are useful to indicate recent contamination events. Bacterial indicators of water contamination may be used to indicate delayed contamination events, if the newly added and soil resident microbial indicators can be clearly separated. However, for this to occur, we need to better understand the capacity for environmental adaptation and persistence of microbial indicator species. The present research indicated possible persistence in the tile drainage sediments of indicators from previous contaminant events.

Enzyme Production by Antagonistic Fungi *Trichoderma* spp.: Municipal Sludge as Potential Raw Material

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Trichoderma spp. have been well documented for their ability to produce cellulases, proteases and chitinases. These enzymes have utility in textile, surfactant, fungicide and pharmaceutical sectors. The necessity of costly raw materials like, glucose, soya, and food grains hampers economical production of these enzymes. In this study, municipal wastewater sludge was tested as raw material for the production of these enzymes using pure culture of *T.* spp. by liquid fermentation process. Raw, alkaline treated and thermal alkaline treated sludges were used as substrates for fermentation. The total solids concentration in the fermentation medium was varied as 10, 20, 30, 40 and 50 g/l (dry basis). The fermentation was carried out in 500 ml shake flasks with 150 ml working volume. Active 10% (v/v) mycelial mass was used as inoculum. Protease enzyme activity of 4.02 - 7.96 IU/ml was obtained for different sludges. The fermentation time was found to be reduced by 2 days for enzyme production as the principal objective. Factors like, sludge as raw material, high enzyme activity and reduced fermentation time indicate economical enzyme production potential of this process. Moreover, conversion of sludge to value added products like enzymes will have tridentate environmental perspective – sustainable sludge management; reduction of greenhouse gases and climate change (by reutilization of carbon in the biomass) and production of value added products from zero potential wastes.

Variation of Particle Size Distribution in Dissolved Air Flotation Process for Winnipeg Tap Water

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Dissolved air flotation (DAF) is effective in removing algae which is the main cause for the problems of taste, odor and increased levels of disinfection by-products (DBP) with the Winnipeg tap water. In this study, a bench-scale continuous DAF system was set up and operated at the University of Manitoba with the tap water in Winnipeg between 2003 and 2004.

Besides the measurements of turbidity, color, pH commonly conducted in water treat-ment, the variation of particle size distribution (PSD) in the process was investigated using a microscope and computerized image analysis system. The objective of the study was to determine the optimum dosage to reach the pin-size of flocculation flocs, which were recommended for DAF process. Three different dosages of alum were applied: 41.7mg/L, 25.5 mg/L and 15.5 mg/L while other parameters were kept unchanged.

Test results indicated that effectiveness of DAF process was dependent not only on the average size of the flocs, but also on their size distribution, especially percentage of the particles smaller than 20 μm.

Under the test conditions, 25.5 mg/L of alum was the optimum dosage. At this dosage, the DAF effluent reached a turbidity of 0.25 NTU and color of 3.8 TCU, significantly lower than that for tap water (Table-1). The average equivalent diameter of the flocs in the coagulated water at this dosage was 36.62 μm, with maximum of 175.98 μm and the minimum of 5.64 μm. About 30.5 % of the flocs or particles are smaller than 20 μm. These small particles couldn't be completely removed by DAF, the residual of which resulted in the effluent turbidity and color. Lower dosage of alum produced too many small particles, which resulted relatively higher turbidity and color in the effluent. While higher dosage created much less of smaller particles, it didn't show improved effluent quality, and needed more air for the process.

Table 1 Bench Scale Dissolved Air Flotation of Winnipeg Tap Water – Results

COAGULATION		DAF EFFLUENT		
Alum Dosage [mg/L]	Average particle size in flocculated water (μm)	Turbidity [NTU]	Colour [TCU]	% Particles smaller than 20 μm in flocculated water
0	10.99	0.46	4.0	94
41.7	54.63	0.25	3.8	14.2
25.5	36.60	0.25	3.8	30.5
15.5	26.82	0.52	4.0	40.5

As compared to the pilot study by the City of Winnipeg, the bench scale DAF system was operated at lower flocculation velocity gradient of about 40 s^{-1} and lower rapid mixing intensity of 240 s^{-1}. (In the pilot study by the city the system was operated at flocculation velocity gradient of 70 s^{-1} and rapid mix intensity of 400 s^{-1} and optimum alum dosage was 65 mg/L under cool water conditions, which was much higher than this bench scale test result.) These conditions allowed for formation of many pin-flocs in the optimum size range for DAF process and relatively lower percentage of particles smaller than 20 microns. It was quite likely that in the pilot study many large flocs were formed and high mixing intensity had to be applied to break the large flocs into smaller particles desired for DAF process. Our experiments indicated that the successful operation of DAF unit was possible at lower coagulant dosage and velocity

gradient, which could offer economical savings in the operation of the future water treatment plant in the city of Winnipeg.

It was also found that due to the difference in the size and rise velocity of the flocs in the water entering the DAF unit, further collision and agglomeration occurred during the flotation, which made the floated flocs.

The Fate of Mercury in Wastewater, Sludge and Gaseous Streams at ROPEC

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A study on the investigation of the fate of mercury in wastewater treatment plant has been carried out by combination of field scale sampling and computer modeling simulation at Robert O. Pickard Environmental Centre (ROPEC). Over 200 wastewater, sludge and solid samples and over 680 gaseous and biogas samples were collected from various points throughout the plant and analyzed for total mercury in July, August, December 2003, and March, April, May, June 2004. An approximated mass balance on mercury was performed around each unit process based on the data collected in the field sampling and the facility operation. Partition coefficients (K_p), the critical parameters, in primary and secondary treatment processes that will be employed in subsequent modeling of TOXCHEM$^+$ to predict the fate of total mercury in wastewater, sludge and gaseous streams also were calculated.

The results of this study indicate that only approximately 24% of the total mercury load entering the plant portioned into the secondary sludge (CAKE), 66% of the total mercury discharged to Ottawa River, and less than 0.002% of the total mercury excited in the form of biogas and total gaseous mercury (TGM) volatilization to atmosphere. The removal efficiency of total mercury within facility is about 34%, based on the percent of mercury leaving in the final effluent compared to total inputs. The rough total mercury loading rate to Ottawa River at ROPEC is approximately 290 g/d. The comparison between the predictions run with TOXCHEM$^+$ and observed data collected from field sampling suggests that the models of TOXCHEM$^+$ could be employed as an useful tool to evaluate and predict the fate of mercury at ROPEC after further calibration and verification.

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