Thirty-Fourth Central Canadian Symposium on Water Pollution Research

February 8 and 9, 1999
Canada Centre for Inland Waters
Burlington, Ontario

ABSTRACTS

Themes
Water Treatment - Technology Trends
Novel Technologies
SBRs
UV Disinfection of Waters and Wastewaters
Water Quality as Affected by Agricultural Practice
Groundwater/Subsurface Remediation
Lessons Leaned Through Great Lakes 2000 Projects
Wastewater/Storm Water Treatment

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Canadian Association on Water Quality
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Canadian Association on Water Quality
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34th Central Canadian Symposium
February 8 & 9, 1999
Canada Centre for Inland Waters, Burlington

PROGRAM
Monday February 8, 1999

07:30 – 08:45 Registration, Entrance Hallway
08:45 – 09:00 Opening Remarks, Dr. Peter Jones, President CAWQ

Monday, February 8	**Session 1** **North Seminar Room** **Water Treatment – Technology Trends** **Session Chair: H. Guttman**	**Session 2** **South Seminar Room** **Novel Technologies** **Session Chair: J. Nicell**
09:00 – 09:30	*K. Roberts* Emerging Technologies and Trends in the Drinking Water Industry	*P. F. Henshaw, J. K. Bewtra and N. Biswas* Development of a Biological Process for Removal of Hydrogen Sulphide from Industrial Wastewater
09:30 – 10:00	*(S) X. Liu, R. M. Slawson and P. M. Huck* Investigation of Factors Affecting Drinking Water Biofiltration Processes	*(S) A. A. El-Agroudy and M. Elektorowicz* Kinetics of Inorganic Mercury Removal from Surface Water by Water Hyacinth (*Elchhornia crassipes*) and Reeds (*Phragmites communis*)
10:00 – 10:30	*(S) M. Zheng and S. Andrews* Effect of Medium Pressure UV and UV/H_2O_2 on Subsequent THM and HAA Formation During Drinking Water Treatment	*(S) Y. Fu and T. Viraraghavan* Removal of a Dye from an Aqueous Solution by Fungus *Aspergillus Niger*
10:30 – 11:00	**Coffee & Poster Sessions, Main Mall**	**Coffee & Poster Sessions, Main Mall**
	Session 1, Continued **North Seminar Room**	**Session 2, Continued** **South Seminar Room**
11:00 – 11:30	*(S) L. Ballantyne, R. C. Andrews and C. Chauret* Factors Affecting the Inactivation of Microbial Surrogates for Giardia and Cryptosporidium when Disinfecting with Chlorine Dioxide	*K. Kaiser, R. L. Breton, S. P. Niculescu and D. Moore* Prediction of Fathead Minnow Toxicity Data from Structural Descriptors
11:30 – 12:00	*(S) C. Korn, R. C. Andrews and M. D. Escobar* Development of Chlorine Dioxide Related By-Product Models for Drinking Water Treatment	*(S) M. K. Jarecki, C. Chong and R. P. Voroney* Compost Run-off Water for Irrigation of Grasses and Ornamental Trees
12:00 – 12:30	*J. Murrer and R. Price* Treatment of Algal Laden Waters Using Ultrafiltration	*(S) K. Ikehata and J. A. Nicell* Characterization of Tyrosinase Enzyme for the Treatment of Aqueous Phenols
12:30 – 13:15	**Lunch & Poster Sessions** **Main Mall**	**Lunch & Poster Sessions** **Main Mall**

(S) Student Presentation

34th CAWQ Central Canadian Symposium
Monday February 8, 1999

	Session 3 North Seminar Room SBRs Session Chairs: D. Bagley & P. Dold	Session 4 South Seminar Room UV Disinfection of Waters and Wastewaters: New Technologies and Research to Address Problems of Particulates, Fouling, and Energy Efficiency Session Chair: J. Stephenson
13:15 – 13:45	*(S) A. Tremblay, R. D. Tyagi and Y. Comeau* Biological Treatment of Food Industry Wastewater Rich in P: in An SBR	*D. Lu and Y. A. Lawryshyn* Validation of a Numerical Model of a UV Disinfection Reactor
13:45 – 14:15	*(S) I. Shizas and D. M. Bagley* Maximizing the Organic Loading Treatable by AnSBRs	*K. G. Bircher and K. M. Simms* Field Case Studies of the Disinfection of Wastewater Using High Powered Medium Pressure UV Lamps
14:15 – 14:45	*(S) C. S. Tripathi and D. Grant Allen* Thermophilic Sequencing Batch Reactor Treatment as an Alternative Treatment of Bleached Kraft Pulp Mill Effluent	*C. Hsu, K. F. Denning and P. Z. Colak* New UV Technology Applied in Treating Municipal Wastewater with High Iron (Fe) Content
14:45 – 15:15	*(S) J. A. Lalman and D. M. Bagley* Methanogenic Inhibition Caused by Linoleic Acid	*J. L. Clancy, Z. Bukhari, T. M. Hargy, J. R. Bolton and B. Dussert* Inactivation of Cryptosporidium parvum by Ultraviolet Light: Dose Response Curves for Low- and Medium-Pressure Lamps and Pilot Scale Demonstration Studies
15:15 – 15:30	**Coffee & Poster Session, Main Mall**	**Coffee & Poster Session, Main Mall**
	Session 3, Continued North Seminar Room	**Session 4, Continued South Seminar Room**
15:30 – 16:00	*J. Cigana, M. Couture, R. Rivet and M. Lauzon* Achieving Constant Flow for Disinfection in SBRs: Utilization of the Thistle Tube Throttle (TTT)	*(S) M. Sheriff and R. Gehr* Laboratory-Scale Tests on Inorganic Fouling of Ultraviolet Mercury Lamps used in Wastewater Disinfection
16:00 – 16:30	*(S) M. T. Elliott, Y. Y. Zheng and D. M. Bagley* Sensitivity Analysis of Kinetic Parameters for Anaerobic Sequencing Batch Reactor Simulations	*(S) D. Pinto, M. Santamaria and R. Gehr* Pilot Plant UV Tests at a Full-Scale Wastewater Treatment Plant with Ferric Chloride Addition
16:30 – 17:15	**CAWQ Annual General Meeting and 1998 Philip H. Jones Award for Best Student Presentation to Chris Cousin, University of Toronto North Seminar Room**	
17:15 – 18:30	**Annual Wine & Cheese Main Mezzanine**	

(S) Student Presentation

34th Central Canadian Symposium
Tuesday February 9, 1999
08:00 – 09:00 Registration, Entrance Hallway

Tuesday, February 9	Session 5 South Seminar Room Water Quality as Affected By Agricultural Practice Session Chair: Mary Jane Conboy	Session 6 North Seminar Room Groundwater/Subsurface Remediation Session Chair: S. Ghoshal
09:00 – 09:30	*(S) D. Millman and M. J. Goss* Reducing Environmental Contamination by Improving N-use Efficiency on Farms: Measurement and Estimation of Nitrogen Fluxes for a Dairy Farm	*(S) El-Sadi and M. Elektorowicz* Efficiency of PAH Removal from Clayey Soil Using Supercritical Fluid Extraction
09:30 – 10:00	*(S) A. Unc, M. J. Goss and H. R. Whiteley* Transport of Faecal Bacteria from Manure Through the Vadose Zone	*T. W. Sheremata, S. Thiboutot, G. Ampleman and J. Hawari* Cyclodextrins for Desorption of 2,4,5-Trinitrotoluene and Metabolites from Soil
10:00 – 10:30	*(S) J. W. Roy, G. W. Parkin and C. Wagner-Riddle* Transport of Nitrate and Chloride Applied to Turfgrass: Observations and LEACHM (within EXPRES) Predictions	*(S) A. Hill and S. Ghoshal* Surfactant Solubilization of Polycyclic Aromatic Hydrocarbon Compounds from Nonaqueous Phase Liquids
10:30 – 11:00	**Coffee & Poster Sessions, Main Mall**	**Coffee & Poster Sessions, Main Mall**
	Session 5, Continued North Seminar Room	**Session 6, Continued South Seminar Room**
11:00 – 11:30	*(S) D. Nikkami, M. Elektorowicz and G. R. Mehuys* Prediction of Soil Erosion in a Semi-arid Zone of Iran by the Integration of Musle and Spans-GIS	*J. F. Lascoureges, L. Yerushalmi, C. Alvera and S. R. Guiot* Bioremediation of Hydrocarbons under Oxygen-Limited Conditions
11:30 – 12:00	*(S) Chan-Hee Park & P. M. Huck* Development of Conceptual Model for the Transport of Cryptosporidium Oocysts in Watersheds	
		Session 7 South Seminar Room Lessons Learned Through Great Lakes 2000 Projects Session Chair: Sandra Kok
12:00 – 12:30	*(S) X. Zhang, P. M. Huck and R. M. Slawson* Development of a Conceptual Model for Defining Source Terms of Cryptosporidium Oocysts in Watersheds	*J. Shaw* Getting to the Bottom of It – Sediment Cleanup in the Great Lakes
12:30 – 13:15	**Lunch & Poster Sessions, Main Mall**	**Lunch & Poster Sessions, Main Mall**

34th CAWQ Central Canadian Symposium
Tuesday February 9, 1999

	Session 8 North Seminar Room Wastewater/Storm Water Treatment Session Chair: R. Gehr	Session 7, Continued South Seminar Room Session Chair: S. Kok
13:15 – 13:45	*A. G. Werker and E. R. Hall* Using Microbial Fatty Acids to Quantify Population Dynamics for Biofilm and Suspended Microbial Communities in Wastewater Treatment Systems	*V. Cairns* Bringing Fish and Wildlife Back to Hamilton Harbour
13:45 – 14:15	*(S) A.-E. Stricker, A. Héduit and P. Lessard* Wastewater Characterization : Evaluation of a Bio-Chemical Method and Preliminary Results	*B. Jones* Controlling Agricultural Non-Point Source Pollution in the Bay of Quinte
14:15 – 14:45	*J. Kochany* Development of Technology for Leachate Treatment	*F. Stride* Actions to reduce Phosphorus from Urban Discharges in the Bay of Quinte
14:45 – 15:15	*(S) V. Campbell, K. Bolton and M. Diamond* Effect of Chloride and Temperature on Metal Partitioning in an Urban Stormwater Detention Pond	
15:15 – 15:45	**34th CAWQ Central Canadian Symposium Wrap up & Award for Best Student Presentation at the 34th Central Canadian Symposium South Seminar Room**	

(S) Student Presentation

Student Presentations
The students must make their presentations on their selected topic of on-going or completed research. A jury will evaluate the presentations on the basis of form, content and interest to the audience. The student winner will be announced at end of the symposium and will be awarded a one-year free membership to the CAWQ (current members will have their membership extended for one year). The presenter and co-authors will receive a certificate of the award. The winning presenter becomes eligible for the Philip H. Jones CAWQ National Award which is given to the best student presentation of the three CAWQ regional conferences (Central, Western and Eastern Canadian). The winner of the National Award will be announced at the next Annual General Meeting and will receive a plaque of the award.

Canadian Association on Water Quality

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Poster Session Displays
Main Mall Area

S. Burr, G. Parkin, D. Rudolph and T. Svensson
A Comparison of Six Techniques to Measure Nitrogen Flux Below the Root Zone

J. Ganczarczyk
Methodology of Investigations on the Structure of Particle Aggregates

B. Gorczyca and J. Ganczarczyk
Porosity Structure of Alum and Activated Flocs

P. T. Srinivasan and T. Viraraghavan
Method Development for Drinking Water Aluminum Measurement Using Graphite Furnace Atomic Spectrophotometer

L. R. Rozema, T. Braybrook and E. R. Lemon
Sewage Treatment in a Vertical Flow Constructed Wetland – A Success Story

4.Chai and R. C. Andrews
Application of Neural Networks to the Modeling of Water Treatment

S. Vickers, K. Bolton and M. Diamond

I. Bojanowska, A. Smoczynska, M. Elektorowicz and W. Smoragiewicz
Reclamation and Recycling of Chromium (VI) as a Method for Water Protection and Raw Materials Reuse

E. Klimiuk, M. Kuczajowska-Zadrozna, A. Smoczynska and A. El-Agroudy
The Removal of Cadmium from Aqueous Solutions
I. The Application of Bipolymers for Cadmium Uptake

E. Klimiuk, M. Kuczajowska-Zadrozna and M. Elektorowicz
The Removal of Cadmium from Aqueous Solutions
II. Uptake and Release of Cadmium by Bipolymers in Sorption-Desorption Cycles

M. Kuczajowska-Zadrozna, E. Klimiuk and W. Smoragiewicz
The Removal of Cadmium from Aqueous Solutions
III. Extraction of Cadmium from Sewage Sludge

E. M. Siedlecka, D. Downar and M. Elektorowicz
Treatment of Pulp and Paper Industry Wastewater in an Aerobic Moving Bed Biofilm Reactor

SESSION 1

North Seminar Room

Water Treatment - Technology Trends

Session Chair: H. Guttman

KEN J. ROBERTS
XCG Consultants Ltd.

Dr. Ken Roberts of XCG Consultants Ltd. will discuss "Emerging Technologies and Trends in the Drinking Water Industry". The discussion will highlight new technologies and procedures presented by delegates from 18 countries at the Bi-annual American Water Works Association Research Foundation meeting on Emerging Technology. This information will be supplemented by an overview of current concerns and the drinking water industry future direction The presentation will be cover the areas of: Program; Treatment; Environmental Assessment/Integrated DW Management; and, Health.

Biography

Ken Roberts began his working career teaching science at the High School level in the U.K followed by lecturing in chemical engineering at the University of New Brunswick. Ken has been active in the field of water resources management and engineering for more than 30 years. His professional experience in both the Ontario Ministry of Environment (and Energy) and with XCG Consultants Ltd. has encompassed both water and wastewater policy, treatment and research with a focus in the drinking water area. His work has covered technical advice/troubleshooting of processes at treatment plants; research into treatment technologies; operational optimization; drinking water certification training course development; groundwater resource management; and policy development for drinking water, groundwater and watershed planning.

Ken maintains many international contacts and supports the drinking water industry in numerous capacities through his American Water Works Association (AWWA) and AWWA Research Foundation (AWWARF) professional involvement.

Ken is a Professional Engineer and has degrees in Chemical Engineering from the University of Manchester, England and from the University of New Brunswick, Canada.

Investigation of Factors Affecting Drinking Water Biofiltration Processes

Xibo Liu, Robin M. Slawson and Peter M. Huck
NSERC Chair in Water Treatment
Department of Civil Engineering
University of Waterloo

BOM (biodegradable organic matter) in drinking water can be removed by biofilms attached on the media in drinking water biofilters. A 2_{IV}^{6-2} fractional factorial design experiment of biofiltration is being carried out to investigate factors affecting BOM removal performance in drinking water biofilters. These factors include: presence/absence of non-biological particles in the influent, presence/absence of coagulants, presence/absence of chlorine in backwashing water, presence/absence of air in backwashing, anthracite/sand media vs. GAC/sand filter, and low/high temperature operation. The influences of these factors are being quantitatively analyzed and evaluated in terms of the results of the fractional factorial design experiment. Further experimental investigation regarding biofilm detachment/inactivation during filtration runs and especially during backwashing, which is nested in the fractional factorial design experiment, will provide a better understanding of BOM removal performance in drinking water biofilters.

Half of the fractional factorial design experiment results will be included in this presentation. Results to-date suggest that backwashing and temperature may have significant influences on drinking water biofiltration processes, and significant two-factor interactions may exist between media, backwashing and temperature.

A biofiltration simulation model will be developed to evaluate the non-steady-state or dynamic steady-state characteristics of BOM removal performance of biofilters during the initial biofilm development period and during dynamic steady-state operation period under a variety of operating conditions. Significant insights into the mechanisms of biofiltration processes and optimization of design and operation of biofilters in drinking water treatment can be expected from both the experimental and modelling work.

DEVELOPMENT OF A CONCEPTUAL MODEL FOR DEFINING SOURCE TERMS OF *CRYPTOSPORIDIUM* OOCYSTS IN WATERSHEDS

XIURONG ZHANG, PETER M. HUCK, AND ROBIN M. SLAWSON

NSERC Chair in Water Treatment
Department of Civil Engineering, University of Waterloo, Waterloo, Ontario, N2L 3G1

Due to the increasing awareness of outbreaks of cryptosporidiosis in public water supplies throughout the world recently, water utilities are trying to better understand the occurrence and density of *Cryptosporidium* in their watersheds. The research reported in this paper represents the initial steps in a long-term project to establish a framework to define the source terms of *Cryptosporidium* in watersheds.

Farms, wildlife, wastewater treatment plant effluents, and combined sewer overflows are all potential contributors of oocysts in source waters. However, all these source terms are watershed-specific. The oocyst production rate from cattle farms, for example, is a function of the specific farm operations and watershed characteristics (e.g. topography). Watershed characteristics and the degree of watershed protection can be judged important controllers of oocyst levels in source waters.

A framework for defining source terms is a very complex decision problem involving analysis of source terms, watershed characteristics and their inter-relationships. The approach used here is to first decompose the complex problem into two sub-problems - source terms and watershed characteristics, then understand the main effects of each sub-problem, and finally come up with the overall framework through studying the inter-relationships. In this paper, application of the model is illustrated using the examples of cattle farms and wastewater treatment plant (WWTP) effluents.

Preliminary work showed that young calves make most contribution to oocyst production from cattle farms due to their high infection rate and high shedding rate. Oocyst contributions from different WWTPs depend on the operation practices, capacities, sources of wastewater, etc. Data from the literature are used to estimate the order of magnitude of oocyst production for different categories of WWTP, such as domestic wastewater, domestic and industrial wastewater, and domestic and slaughterhouse wastewater treatment plants. The exact value may not be accurate due to the need to make assumptions and use of data from the literature. However, the results give the order of magnitude of oocyst contribution, which is the information of interest.

A sensitivity analysis of the proposed model is also performed. It is anticipated that through this analysis, we can gain a better understanding of the factors which affect oocyst production from a given source and determine the most sensitive factors which need to be manipulated carefully to reduce oocysts release into a watershed. Sensitive factors also need to be determined more accurately to refine the framework.

Treatment of Algal laden waters using Ultrafiltration

John Murrer Project Manager Membranes Anglian Water
Dr Robin Price Innovation Technologist Anglian Water

Background

Surface water is the source of over 50% of the potable water supplied to Anglian Water's 5 million customers in the East of England.
The most common water treatment process is coagulation using ferric salts and polyelectrolyte , clarification and multi media rapid gravity filtration.
In the last 10 years this has been supplemented by the use of ozone and granular activated carbon to remove pesticides and herbicides and to improve taste and odour during algal blooms in the impounded storage reservoir.
There are concerns in Europe that future proposed legislation will lead to tighter standards that cannot be achieved with conventional water processes. The use of membranes in water treatment may be the most cost effective solution.

New treatment concepts

In 1996 the Membrane team in the Innovation Group started trials with mobile ultrafiltration pilot plant to see if a chemical free, physical process could be developed to replace clarification and filtration.
The major advantage of ultrafiltration is that it provides a physical barrier to all parasites, bacteria and virus as well as producing a high quality water with very low turbidity and suspended solids.
The trials were carried out at a number of sites during a range of water conditions including very cold water in the winter and warm water with high algae in the summer.
The results of these trials were very encouraging and further more detailed work was undertaken at 3 separate sites in Great Britain.

Current studies

The mobile pilot plant was used for direct treatment of surface water during the summer of 1998 an the Island of Jersey. The water quality produced was compared with the water from the existing treatment works with a particular interest in the passage of zooplankton.

A large water treatment research facility has been built near Nottingham to evaluate the ultrafiltration and reverse osmosis to treat the highly polluted River Trent. The results obtained are compared to conventional treatment.

A large pilot plant has been installed to treat water from Grafham impounded storage reservoir. This study will operate for at least 2 years comparing the ultrafiltration permeate with the filter outlet water at the main works. Spiking trials will take place to determine removal efficiency of parasites, bacteria and virus, and a series of taste and odour trials will be carried out during the periods of high algae in the feed water.

The results of both the early trials and an update of the latest results will be presented in the paper.

SESSION 2

South Seminar Room

Novel Technologies

Session Chair: J. Nicell

DEVELOPMENT OF A BIOLOGICAL PROCESS FOR REMOVAL OF HYDROGEN SULPHIDE FROM INDUSTRIAL WASTEWATER

P.F. Henshaw, J.K. Bewtra and N. Biswas

Civil & Environmental Engineering
University of Windsor, Windsor, Ontario, Canada N9B 3P4

Hydrogen sulphide (H_2S) gas is highly toxic and malodorous. "Sour" water is produced in petroleum refineries wherever process water comes in contact with gas streams containing hydrogen sulphide. In most petroleum refineries, elemental sulphur is recovered from sour water by steam stripping followed by one of many catalytic sulphur recovery processes. Elemental sulphur, S^0, is nontoxic and is used as a feedstock for the chemical, fertilizer and materials manufacturing industries. The use of a biological process is potentially less expensive than conventional chemical processes for sulphur recovery because it acts at low temperatures and pressures, generates its own catalyst, and can remove sulphide (S^{2-}) to concentrations less than 1 mg/L. This research program has focussed on the biological removal of sulphide directly from aqueous solutions without the necessity of stripping H_2S into the gas phase.

Chlorobium limicola is a naturally occurring green sulphur bacterium (GSB) capable of oxidizing sulphide to S^0. The elemental sulphur produced is attached to the outside of the cells. This photosynthetic bacterium requires light, CO_2, inorganic nutrients and sulphide for growth and is strictly anaerobic. Experiments with batch reactors have demonstrated the sequential convertion sulphide to elemental sulphur to sulphate by GSB. The complete oxidation of S^{2-} to SO_4^{2-} is to be avoided in a continuous-flow reactor if the S^0 is to be recovered.

A suspended-growth once-through continuous-flow stirred-tank bioreactor was successfully operated under five different experimental conditions. The conversion of sulphide to elemental sulphur was related to the light input. Under proper conditions, nearly complete conversion of sulphide to elemental sulphur can be achieved. A parameter was developed to relate the results from these experiments to those reported in the literature, where smaller reactors and higher bacterial concentrations were used in batch reactors fed with $H_2S_{(g)}$. This parameter described the capacity of the bioreactor to consume S^{2-}, and was calculated as the product of the radiant flux per unit reactor volume and the bacteriochlorophyll concentration. In addition, the electron transfer rate was corelated to the light input per volume of the reactor.

The separation of elemental sulphur from the bioreactor contents is essential to realize its value as a chemical industry feedstock. Separations of elemental sulphur by plain settling, settling at elevated pH, filtration and centrifuging were tested at bench scale using the contents of several batch bioreactors. Centrifuging resulted in the best separation between elemental sulphur and bacteria; 90% of the elemental sulphur and 29% of the bacteria could be removed from suspension.

A fixed-film tubular bioreactor is currently being tested as a means to increase the elemental sulphur production per unit volume of reactor and thereby decrease the overall cost of the process.

Kinetics of Inorganic Mercury Removal from Surface Water by Water Hyacinth (*Eichhornia crassipes*) And Reeds (*Phragmites communis*)

Amr A. El-Agroudy and Maria Elektorowicz
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Wastes from various industrial sources containing wide range of mercury concentrations used to be discharged to open water bodies. Several rivers and lakes are found to be contaminated with different mercury compounds. Inorganic mercury is converted to the toxic methylmercury compounds in the aquatic ecosystems where the microbial methylation can occur under both aerobic and anaerobic conditions. However, some aquatic plants have the ability to bioconcentrate different metals to certain levels.

In this paper, two aquatic plants: Water Hyacinth (*Eichhornia crassipes*) And Reeds (*Phragmites communis*) were experimentally investigated for their ability to remove inorganic mercury compounds from water. The experiments were conducted in a laboratory-controlled environment for a period of 72 hours. The kinetics of mercury uptake by floating and rooted plants in the concentration range of 5 to 150 ppb were investigated. Water samples were analyzed for total mercury contents using Cold Vapor Atomic Absorption Spectrophotometry.

Floating plants (Water hyacinth) were able to remove approximately 75% of a 50 ppb-Hg contaminated water compared to approximately 50% removal by rooted plants (Reeds). For the highest mercury concentration of 150 ppb Hg, both plants appear to be able to remove approximately 85 - 90% of the mercury from the water. The paper demonstrates a comparison between the kinetics of mercuric chloride uptake by different plants when the concentration of the contaminant is changed.

It could be concluded that Water hyacinth and reeds have high affinity to bioconcentrate the inorganic mercuric chloride from water in the concentration range of 5 to 150 ppb in a reasonable short period of time after their first exposure to the contaminant.

REMOVAL OF A DYE FROM AN AQUEOUS SOLUTION BY FUNGUS *ASPERGILLUS NIGER*

Yuzhu Fu and T. Viraraghavan

Faculty of Engineering, University of Regina, Regina, Saskatchewan, S4S 0A2

Abstract

Among the industrial wastewaters, dye wastewater from textile and dyestuff industries is one of the most difficult to be treated. The conventional biological treatment process is not very efficient in treating dye wastewater. It is usually treated by physical- or chemical- treatment processes. Among these processes, adsorption is an effective one. Many studies are directed in developing low-cost adsorbents in the place of an expensive activated carbon. But these low-cost adsorbents generally have low adsorption capacities and can not be regenerated. In recent years, biosorption is becoming a promising alternative to replace or supplement the present treatment process. Living and dead cells or derived products are usually called biosorbents. Because fungal biomass can be produced cheaply and obtained as a waste from various industrial fermentation processes, they can be used as a potential biosorbent to remove dye from dye wastewater. Dead cells possess various advantages compared to living cells. In this study, dead fungal biomass of *Aspergillus niger* was used as a biosorbent to remove a dye, basic blue 9, from an aqueous solution. Batch kinetic and isotherm studies were conducted to evaluate the adsorption capacity of live and pretreated (dead) biomass.

Basic blue 9 is a cationic thiazine dye. The initial concentration is set at 50 mg/l. In order to compare the color removal on the same basis, the pH of all the samples has to be adjusted to 7.6 before measurement. The concentration of dye solution is determined by spectrophotometer. *A. niger* was cultured in the laboratory. The growth media are (in g/l): dextrose, 20; peptone 10; yeast, 3. Pelletized forms were harvested after 4 days of cultivation. In this study, eight pretreatment alternatives were investigated for increasing the biosorption capacity of live *A. niger* biomass. In order to decrease the cost of the pretreatment and be able to apply these pretreatment methods to the practice in future, this study used the routine chemicals to treat *A. niger* biomass. At the same time, all *A. niger* biomass undergoing chemical pretreatment were autoclaved so as to confirm that all *A. niger* biomass used in the study was dead cell. Compared with living biomass (adsorption capacity 1.17 mg/g), the biosorption capacity of each pretreatment method showed an increase. Autoclaving was the most effective one with the biosorption capacity 18.59 mg/g. Therefore, all biomass was autoclaved for basic blue 9 biosorption studies.

pH studies of dye solution showed that at very low pH = 2, no biosorption occurred. In the range of pH = 4 to 12, biosorption occurred with a high adsorption capacity. At pH = 6, it had the highest adsorption capacity (17.86 mg/g). Kinetic studies at different pH showed that the pH of the solution strongly affected the degree of biosorption of basic blue 9. The higher the pH, the faster the biosorption at an early stage. For basic blue 9 solution at pH = 10, biosorption achieved 87% color removal efficiency after 4 hours sorption. Due to the big dye molecule, basic blue 9 biosorption is relatively a slow process. The equilibrium was reached in 30 hours. Isotherm studies at different pH indicated that at pH = 4, the biosorption fitted the Langmuir adsorption model best (R^2=0.94) compared to BET (R^2=0.90) and Freundlich (R^2=0.72) isotherms models. At pH =10, the biosorption followed BET isotherm adsorption model best (R^2=0.93) compared to Freundlich (R^2=0.77) and Langmuir (R^2=0.62) isotherm models.

Title of paper: **Prediction of fathead minnow toxicity data from structural descriptors using neural network methodology**

Authors: Klaus L.E. Kaiser, Burlington,
Roger L. Breton, Ottawa
Stefan P. Niculescu, Burlington
Dwayne Moore, Ottawa

Abstract: Recent advances in probabilistic neural network methodology have been applied for the prediction of 96-hr LC50 values for several hundred chemicals to the fathead minnow (*Pimephales promelas*). Approximately 50 parameters, all of which are strictly derived from molecular composition and structure of the chemicals, serve as input for these predictions. The chemicals under consideration are being categorized and screened for persistence, bioaccumulation and toxicity under the new *Canadian Environmental Protection Act* and include substances of many different chemical classes. Preliminary results of this work are presented and compared with values measured or otherwise estimated for these compounds.

COMPOST RUN-OFF WATER FOR IRRIGATION OF GRASSES AND ORNAMENTAL TREES

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Run-off water from composting operations can contain low concentrations of contaminants, such as ammonia, organic carbon, potassium, sodium, phosphates or sulfates, that exceed water quality standards. Irrigation offers an excellent solution for treatment of this polluted water by using it as a water source for plant production. The water can also act as a source of plant available nutrients. A field experiment was established in 1997 to evaluate the use of compost run-off water derived from a large-scale commercial composting operation. The research was a split-plot design planted with different species of ornamental trees and grasses, and receiving three levels of irrigation with run-off water and two levels of fertilization (nitrogen and phosphorus). The results obtained from the 1998 season show beneficial effects of irrigation and fertilizer application to plant production. The plant species including poplars, black locust, silver maple and green ash responded with a significant increase in trunk diameter and growth for irrigation. The differences between levels of irrigation were not significant for trees but were significant for grasses. Generally higher levels of fertilization significantly increased tree growth and yield of grasses. Measurements of leaf chlorophyll showed a significant increase in metre reading in treatments receiving a higher level of fertilization compared to the low level. Irrigation treatments also affected chlorophyll levels in leaves of black locust and hybrid poplar but not in silver maple and green ash. The field research will be continued in the 1999 season.

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CHARACTERIZATION OF TYROSINASE ENZYME FOR THE TREATMENT OF AQUEOUS PHENOLS

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Phenolic compounds are present in the wastewaters of a number of industries such as coal conversion, resins and plastics, petroleum refining, textiles, dyes, iron and steel, among others. Nearly all of these compounds are considered to be toxic and some are suspected carcinogens. The process of enzyme catalyzed polymerization and precipitation of phenols and aromatic amines has attracted a great deal of attention since the idea was first proposed in 1980. To-date research has focussed extensively on the use of peroxidase enzymes to catalyze the oxidation of the aromatic substrates by hydrogen peroxide. Recent studies have demonstrated that the reagent costs associated with the enzyme can be reduced through appropriate reactor design and through the use of protective additives (including polyethylene glycol and chitosan) to preserve the catalytic activity of the enzyme.

Reagent costs could also potentially be reduced through the use of polyphenol oxidase enzymes which catalyze the oxidation of aromatic compounds by oxygen, which is certainly less expensive than hydrogen peroxide. Polyphenol oxidases also have the advantage of being a plentiful enzyme which is widely distributed in fruits, vegetables, fungi and seafood products. Therefore the objective of this research was to investigate the potential of a polyphenol oxidase from mushrooms, also known as tyrosinase, to accomplish the removal of phenols from aqueous solutions. This potential was assessed by performing a characterization study of the enzyme and by measuring the treatment efficiency achieved for a variety of different substrates. Treatment efficiency was measured in terms of conversion of the substrate, residual colour and toxicity.

The maximum catalytic activity was observed at neutral pH; however, significant activity was observed at pHs ranging from 5 to 8. Tyrosinase was unstable under acid conditions and at elevated temperatures. The activation energy for thermal inactivation of tyrosinase was determined to be 1.85 kJ mol^{-1} at neutral pH. The transformation of phenols was investigated as a function of pH, initial phenol concentration, and in the presence and absence of protective additives. Phenol was transformed successfully with tyrosinase over a wide range of pH (pH 5 to 8) and a wide range of initial concentrations (0.5 to 10 mM, or 50 mg/L to 1000 mg/L). Some chlorinated phenols were also successfully transformed with tyrosinase. Polyethylene glycol and chitosan did not improve the transformation efficiency of phenol. However, chitosan was successfully used to remove coloured products resulting from treatment. Since coagulation with aluminum sulphate failed to result in colour removal, the colour removal induced by chitosan appeared to be the result of sequential adsorption and coagulation mechanisms. Minimum doses of chitosan required to achieve 90% colour removal were logarithmically related to the quantity of phenol treated. All solutions of phenol and chlorophenols treated with tyrosinase had substantially lower toxicities than their corresponding initial toxicities. Chitosan addition had the added benefit of enhancing the reduction in toxicity very effectively. The toxicities of phenol solutions treated with tyrosinase were markedly lower than previously reported toxicities of solutions treated with peroxidase enzymes.

SESSION 3

North Seminar Room

SBRs

Session Chairs: D. Bagley and Peter Dold

Biological treatment of food industry wastewater rich in P: in a SBR

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An actual problem is the optimisation of SBR system for the efficient biological removal of P, to achieve effluent concentrations lower than 1 mg P/L. An efficient treatment of municipal wastewater is well defined, however, nutrients removal of high strength industrial wastewater, like those from the food industry, is still a challenge for the future. Typical concentrations of municipal wastewater in North America in P are about 3 to 4 mg P/L, but in milk parlour wastewater P content is very high, as much as 6.9 to 113.8 mg P/L, meanly 43 mg/L (Schaack *and al.* (1985).

The sludge age is a fundamental parameter in the design of activated sludge process. The goal to achieve an optimal sludge age is to produce a well setting floc sludge. A minimal sludge age of 3 days is required for a good separation, but a longer sludge age allow the growth of the nitrifiers bacteria and the sludge is more mineralised and the sludge production is reduce (Orhon and Artan, 1994). Also, Matsuo (1994) demonstrated that the biological removal of nutrients is rising with the sludge age. The objective to keep an higher sludge age (between 15 and 20 days) is to maintain a stable mixture culture (Lesouef *and al.*, 1990).

From those observation, the determination of an optimal sludge age for SBR activated sludge system for industrial wastewater seems essential. A short sludge age inhibit nitrification and a longer one could cause sludge bulking or the presence of pin point floc in the effluent (Edeline, 1993).

Our principals objectives are:

1. At first, to study the feasibility of the biological removal of nutrients (C, N, P) of a high strength wastewater in a SBR.
2. Then, to study the effect of varying the sludge age on the efficiency of nutrients removal of a milk parlour wastewater in a SBR.

Methods

The SBR used for laboratory experiences is operated on a basic cycle of 8 hours: three cycles per day. The total volume is 3.8 L and the sludge volume is 2,6 L. The hydraulic residence time is 25 hours. In this study, a principal parameter was optimised: the sludge age. Sludge age was studied at age between 5 and 30 days, at each 5 days. The following parameters were measured in the influent, the effluent and the mixed liquor: COD, TKN, NH_4, Ptotal PO_4 and NO_3. The wastewater was sample from the Coopérative fromagère Agrinove (Groupe Lactel, Beauceville, Québec). The mean composition of wastewater is (mg/L): COD - 1418,3; TKN - 56,5; NH_4 - 28,0; Ptotal - 34,2; Portho - 20,9; Alkalinity - 743,0 (mg $CaCO_3$/L); SM - 303,9; VSM - 230,8; pH - 6,8; VFA - 369,7.

Maximizing the Organic Loading Treatable by AnSBRs

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Anaerobic wastewater treatment technologies have become widely used in industry for the treatment of various high-strength wastewaters. The anaerobic sequencing batch reactor (AnSBR) has yet to be fully developed as a technology that can successfully compete against other reactor configurations such as the upflow anaerobic sludge blanket (UASB). Computer simulations performed by our group have predicted that the AnSBR is capable of treating organic loadings of at least 24 kg $COD \cdot m^{-3} \cdot d^{-1}$. The objective of this research project is to determine the maximum organic loading that can be successfully treated by a laboratory-scale AnSBR.

The AnSBR treatment process typically operates with four stages per cycle; fill, react, settle, and decant. For rapidly acidified constituents, such as glucose, the relative lengths of the cycles are important, and are expected to significantly impact the maximum loading achievable. Previous work in our laboratory (Bagley and Brodkorb, 1998; Brodkorb, 1998), showed that short fill times with glucose as the feed produced significant "spikes" of lactic acid early in the cycle. The lactic acid was then transformed to propionic acid which was degraded slowly, hindering the overall rate of treatment. Longer fill times, however, resulted in much lower lactic acid and propionic acid concentrations, which improved the treatment rate.

As part of the laboratory analyses on the AnSBR, the following parameters will be monitored: biogas production and composition; volatile fatty acids (VFAs); biomass particle size and distribution; glucose (enzymatic hexokinase method); temperature; pH; alkalinity; soluble COD; suspended solids; specific methanogenic activity (SMA).

A 13 L capacity AnSBR is being used for this work, with a liquid volume of 12 L. At the present time, the cycle length is 24 hrs with a fill volume of 6 L. As soon as it becomes practicable, the cycle time will be reduced to 8 hrs, giving an HRT of 16 hrs. The longer cycle time is being used initially in order to better acclimate the microorganisms to the glucose feed, thus reducing the accumulation of VFAs in the reactor. The organic loading rate will be increased each time that the soluble COD removal efficiency reaches 90%.

Initial acclimation of the biomass in the AnSBR has been slow. Since the seed sludge was obtained from an anaerobic digester operating at 37 °C, the microorganisms have had difficulty adjusting to the operational temperature of 21 ± 1 °C and the rapidly acidifying glucose feed. At the present time, at a loading rate of approximately 0.53 kg $COD \cdot m^{-3} \cdot d^{-1}$ (1 g/L glucose as influent) the COD removal efficiency has been steady at 75 to 80% with >90% removal for a cycle length of 2 days. The influent glucose concentration has recently been increased to 2 g/L, and the reactor performance will continue to be monitored. Eventually, the organic loading rate treatable by the lab-scale AnSBR should reach or exceed the maximum level of 12 kg $COD \cdot m^{-3} \cdot d^{-1}$ presently reported in the literature for AnSBRs (Sung and Dague, 1995; Wirtz and Dague, 1996).

References:

Bagley, D.M. and T.S. Brodkorb. 1998. Modeling the Microbial Kinetics in an AnSBR – Model Development and Experimental Validation. Submitted to *Water Environ. Res.*

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Sung, S. and R.R. Dague. 1995. Laboratory Studies on the Anaerobic Sequencing Batch Reactor. *Water Environ. Res.*, **67**, 294-301.

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Thermophilic Sequencing Batch Reactor Treatment as an Alternative Treatment of Bleached Kraft Pulp Mill Effluent

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Recently system closure has become a priority in the pulp and paper industry as a way to reduce water consumption. However, closure has led to the generation of warmer and concentrated effluents which would be more economically reused if treated thermophilically. However, one of the problems encountered in thermophilic biological treatment is poor sludge settleability. Therefore, a better understanding of microbial flocs and effect of some physico-chemical conditions becomes important for improving the performance of thermophilic treatment systems. The objective of present research was to test the potential of thermophilic biological treatment for bleached kraft pulp mill effluent (BKME) by using sequencing batch reactors. The specific objectives are: (1) to compare pollutant removal (BOD, AOX, TOC, COD, toxicity, and colour) between mesophilic and thermophilic treatments; (2) to study the effect of change in temperatures on microbial floc structure and its relationship to sludge settling characteristics; (3) to study the effect of anoxic selectors on floc formation and settleability of microbial floc at various temperatures; and (4) to study alternative treatment strategies (oxygen and nutrient level) to improve sludge settling.

Four parallel sequencing batch reactors (SBRs) were operated at different temperatures (35, 45, 55 and 60^{0}C) using 6000 litres of BKME over the period of 16 months. Each SBR consists of a 2 litre reactor and a 2 litre holding tank, as well as feeding and withdrawing pumps. The desired temperatures in the reactors are maintaind by circulating hot water around the jacket of the reactor. All SBRs were initially inoculated with mesophilic sludge obtained from mill scale activated sludge reactor and temperature of the reactors were raised slowly to give enough time for acclimatization of the sludge. The treated effluent and mixed liquor from these reactors were analyzed regularly for AOX, BOD, COD and colour of the effluent and the settling velocity, porosity, density and extracellular polymer substances (EPS) and filaments of the flocs.

This research indicated that COD removal percentage varied from 50-76% with averages of 70±10%, 68±9.3%, 56±7.6% and 56±8.2% for SBRs operationg at 35, 45, 55 and 60^{0}C, respectively. AOX removal varies from 40-70% and does not show any significant difference at mesophilic and thermophilic operation. Lignin, colour and toxicity removal do not show any significant difference with temperature. Chemical compound analysis of feed and various treated effluent show a better removal of long chain fatty acids at 60^{0}C in comparison to the 35^{0}C. In terms of settling characteristics, the SBRs operation at 45^{0}C is more consistent and better. Smaller pinpoint flocs are observed at 55 and 60^{0}C SBRs, which are responsible for an increase in suspended solids concentrations in the treated effluents from 10 to 40 mg/L. Sludge Volume Index (SVI) results varied from 50-150 ml/g at different temperatures. Phenotypic fingerprinting results for community identification indicate a clear shift in microbial communities at different temperatures and similar communities on effluents from different mills. Anoxic SBR filling and reduction in sludge age were able to control filamentous bulking. Filamentous bacteria are in baundance even at 55^{0}C, however they do not interfere in settling. As anticipated, oxygen is not limiting at thermophilic treatment. Also the study on nutrient effect suggests that the conventional ratio of BOD and phosphorous used in biological treatment can possibly minimized for biological treatement of BKME.

All these results clearly suggests that BKME can be treated upto 60^{0}C, however, the most efficient SBR operation in terms of pollutant removal and settleability take place at 45^{0}C with 30 minute of anoxic filling and no additional phosphorous in the feed as nutrient.

METHANOGENIC INHIBITION CAUSED BY LINOLEIC ACID

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Vegetable oils contribute a large portion of the total chemical oxygen demand (COD) in food processing wastewaters. The remaining COD fractions are derived from the presence of additional constituents such as carbohydrates and proteins. The high COD characteristics of these wastewaters make them attractive for anaerobic treatment. An emerging technology to treat these wastewaters is the anaerobic sequencing batch reactor (anSBR). anSBRs are favoured in comparison to other anaerobic reactor configurations because of their operational flexibility and simplicity of construction. However, anSBR operation may be hindered significantly by long chain fatty acids (LCFAs), a component from vegetable oils hydrolysis.

The operational problems of primary concern are slow LCFA degradation rates, by-product accumulation and microbial inhibition. Previous research in our laboratory has shown that a typical LCFA such as linoleic acid (C18:2) at 100 $mg \cdot L^{-1}$ is degraded into palmitoleic (C16:1), palmitic (C16), myristic (C14), hexanoic (C6), trace quantities of butyric (I-C4 and n-C4) and propionic (C3) and large amounts of acetic (C2) acids. The objective of this work was to determine the aceticlastic and hydrogenotrophic methanogenic inhibition caused by linoleic acid (C18:2), a common LCFA found in vegetable oils.

Experiments were conducted using anaerobic sludge from digesters at the Toronto Main Treatment Plant (TMTP) and a 1:6 mixture of crushed granulated sludge and sludge from the TMTP. Granulated sludge was obtained from an upflow anaerobic sludge blanket reactor (UASB) treating food processing wastewater in Cornwall, Ontario. Sludge was diluted to 1600 $mg \cdot L^{-1}$ volatile suspended solids (VSS) and maintained with glucose. A stock linoleic acid / diethyl ether solution was prepared and added to serum bottles containing 100 mL of anaerobic sludge to provide linoleic acid concentrations from 10 $mg \cdot L^{-1}$ to 100 $mg \cdot L^{-1}$. Either acetic acid (100 $mg \cdot L^{-1}$) or hydrogen was added and then incubated with agitation at 20 °C. Samples for LCFA analysis were extracted with a 1:1 mixture of hexane and MTBE and analysed via gas chromatography. VFAs samples were filtered and analysed via ion chromatography.

At 10 $mg \cdot L^{-1}$ linoleic acid, aceticlastic methanogens were temporarily inhibited although acetate consumption was observed within 7 days. In comparison, more extensive inhibition was observed at 100 $mg \cdot L^{-1}$ linoleic acid. In previous studies conducted with a different culture, inhibition of aceticlastic methanogens was established, as acetate derived from -oxidation of linoleic acid (100 $mg \cdot L^{-1}$) was not completely degraded until 100 days.

Inhibition caused by linoleic acid on hydrogenotrophic methanogens was also concentration dependent. At all linoleic acid concentrations examined, hydrogen consumption was observed. However, the rate of methane production decreased as the linoleic concentration increased from 10 to 100 $mg \cdot L^{-1}$.

Hydrogenotrophic methanogenic inhibition caused by linoleic acid appears to be small and may have little impact on the operation of an anSBR. However, linoleic acid inhibition of aceticlastic methanogenic is more severe and is expected to significantly reduce the anSBR performance. Further research is currently in progress to examine the effects of other C18 carboxylic acids as well as to devise strategies to mitigate the inhibition.

ACHEIVING CONSTANT FLOW FOR DESINFECTION IN SBR's : UTILIZATION OF THE THISTLE TUBE THROTTLE (TTT)

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Sequential batch reactors or SBR's have grown in popularity in Canada and the USA. A recent article (Nolasco,1998) has re-introduced the SBR as a efficient and inexpensive method of treating wastewater, especially for very small flows. Many of these SBR's need to desinfect the clarified effluent, through UV or chemical means. Desinfection of these effluents require very precise flow control under varying water level conditions of the upstream tanks. The development of a passive flow regulator capable of attaining a constant discharge flowrate was investigated in the 1970's by German and Swiss scientists. This paper will discuss the operating principle of such a device in application of existing SBR units : the Thistle Tube Throttle or TTT.

OPERATING PRINCIPLE

Figure 1 shows a schematic view of a simple throttle hose. Performing the Bernouilli equation between points 1 and 2 in this figure, it is possible to see that the total energy (static water head) in the basin is transformed in velocity component and head loss.

$$h_1 = \frac{V^2}{2g} + h_{loss}$$

If a constant discharge is to be maintained, the cross-sectional area will have to vary in function of the static water head. The orifice equation in point 3 becomes:

$$Q_{\text{constant}} = (A_0 - A_{\text{decrease}}) C_d \sqrt{2gH}$$

It was determined that the replacement of a section of the pipe by a flexible deformable elastic band could modulate the flow (Vischer (1979), Brombach (1982)). Indeed, the action of the static water head would crush the membrane to restrict the flow.

APPLICATION TO SBR's

In the last few years there have been many applications where TTT have been installed in the United States to regulate the flowrate from the clarified effluent to the UV desinfection. Table 1 shows a list of the projects where this type of static flow regulator has been used and the range of flowrates that were specified.

Table 1. List of installation where TTT regulate the flow out of the clarified effluent

Project name	Type of installation	Year of installation	Location	Design Flowrate
Webb Creek	SBR	1996	North Carolina	8.8 l/s @ 2.44 m
Blue Ridge	SBR	1997	Georgia	32.9 l/s @ 2.44 m
Ellinwood	SBR	1997	Kansas	28.4 l/s @ 2.13 m
Pratt	SBR	1998	Kansas	50.5 l/s @ 3.35 m
Baconton	SBR	1998	Georgia	4.4 l/s @ 2.44 m
Greenville	SBR	1999	Georgia	21.0 l/s @ 2.44 m

The flexible membrane on the TTT has proven to be long lasting. De Vries (1991) has shown that this regulator has a precision of 10% over the entire flow curve. Over 150 of these units have been installed in Europe. These were usually used to regulate the flow out of stormwater retention basins. Some of these european installations have been in service for over 10 years.

CONCLUSIONS

The advantages of using a TTT in SBR's are many : maintaining a constant flowrate with no moving parts, little too no maintenance and durable membranes. It is a reliable flow regulator based on physical parameters. Furthermore the unit can be retrofitted to existing SBR's. This device has now shown its capacities in Europe as well as in North America.

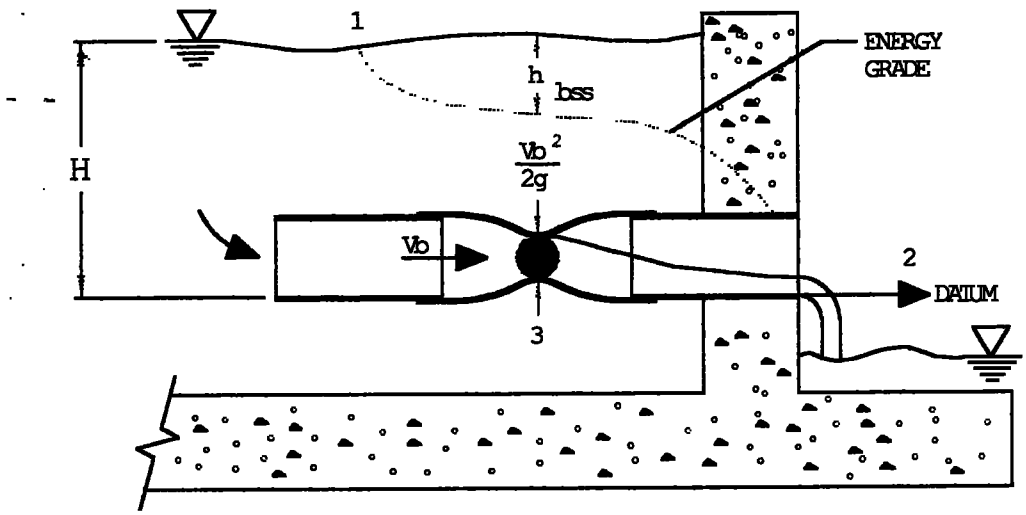

Figure 1. Simple Throttle Hose

Sensitivity Analysis of Kinetic Parameters for Anaerobic Sequencing Batch Reactor Simulations

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The anaerobic sequencing batch reactor (anSBR) is a batch reactor that is operated in a sequence of stages – fill, react, settle, decant. A numerical model has been developed for simulation of the anSBR (Bagley and Brodkorb, 1998). The model considers the different microbial populations within an anaerobic community and predicts the formation and consumption of intermediate products. This model was validated with experimental results from a laboratory-scale anSBR receiving glucose, and was shown to be a useful tool for quickly examining the design and operational parameters of an anSBR.

The anaerobic degradation of organic substrates present in a wastewater involves several anaerobic microbial processes. The rates of these microbial processes are described by Monod kinetics equations. The equation describing conversion of glucose to lactic acid is presented as an example.

$$\rho_{GL} \propto \frac{k_{GL} Y_{XFGL} X_F S_F}{K_{SF} + S_F}$$

Where: ρ_{GL} = process rate of conversion of glucose to lactic acid (mg/L/time), Y_{XFGL} = yield of organisms (mg biomass COD/mg substrate COD), X_F = concentration of organisms (mg biomass COD/L), S_F = concentration of glucose (mg COD/L), K_{SF} = half velocity concentration (mg COD/L), and k_{GL} = rate constant (inverse time)

The rate constants (k_i) for these expressions are critical model parameters. Values of these constants reported in the literature vary in source, sludge age, culture purity, reactor configuration, biomass present, temperature, pH, alkalinity and mixing conditions. Choosing appropriate values for these constants is a critical step in using the numerical model for anSBR simulations. The objective of this work was to determine which of the k_i values required to model glucose degradation, most significantly affected the predictive capability of the anSBR model.

To achieve the objective, a 2 level factorial experiment was used to examine each k_i at 2 possible values. The response variable examined was the time required by an unacclimated system to achieve 90 % removal of influent COD. The anSBR operation was simulated under the following conditions: 12 L total reactor volume, 6 L fill/decant volume; 8 h total cycle time –5 h fill, 2 h react, 0.5 h settle, 0.5 h decant The factorial experiment was repeated at organic loading rates of 1.5, 5, 10, 15, and 20 kg COD/m^3/d

The glucose degradation model considers 6 microbial populations including hydrogenotrophic and acetoclastic methanogens, 1 fermentative population, and 3 syntrophic populations. Results for a loading rate of 1.5 kg COD/m^3/d indicate that the k_i's associated with hydrogenotrophic and acetoclastic methanogens most significantly affect the time required to achieve 90 % COD removal after startup. The k_i for butyrate consuming acetogenesis and the interaction between the k_i's for glucose fermentation and propionate acetogenesis were also observed to exert significant effects.

When using the anSBR model, the use of literature values may be appropriate for several of the k_i's. However, experimental efforts should be focused toward measuring k_i values for hydrogenotrophic and acetoclastic methanogenesis for the particular anSBR of interest. This will ensure that the model predictions will be more indicative of actual anSBR performance.

Reference

Bagley, D.M. and T.S. Brodkorb. 1998. Modelling the Microbial Kinetics in an Anaerobic Sequencing Batch Reactor – Model Development and Experimental Validation. Submitted to Wat. Env. Res.

SESSION 4

South Seminar Room

UV Disinfection of Waters and Wastewaters: New Technologies and Research to Address Problems of Particulates, Fouling, and Energy Efficiency

Session Chair: J. Stephenson

Validation of a Numerical Model of a UV Disinfection Reactor

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Ultraviolet light (UV) is an established and increasingly popular alternative to chemicals for the disinfection of drinking water, waste water and industrial waters of various qualities. The use of UV for disinfection processes has many desirable attributes, however the technology is limited by the current status of reactor theory. Recent advances in Computational Fluid Dynamics (CFD) software and computer processing speeds have provided the numerical modelling tools necessary to overcome some of the limitations regarding reactor design and performance modelling. As with all numerical models, comparison with experimental data is essential to establish the validity of the model and its limitations. This research focuses on the validation efforts applied to a simple annular UV reactor model.

Experimentally, overall reactor performance can be determined as follows. A marker organism (microbe) is introduced into the flow upstream of the reactor. Samples of water are collected downstream of the reactor and appropriate biological assays are performed to determine the inactivation of the organism. By changing the volume flow rates and lamp intensities, different average reactor doses can be plotted versus the microbial inactivation to produce a dose response curve for the reactor. A second dose response curve can be produced by measuring the inactivation of the microbial samples which are exposed to known UV doses in a laboratory setting. A reactor with good performance will exhibit a dose response curve which closely follows the curve generated in the laboratory. Deviation from the laboratory curve represents reactor short circuiting and inefficiency. The task of identifying the cause of the poor performance requires further trial and error experimental testing of a redesigned reactor.

CFD can be used overcome the experimental deficiencies. Reactor hydrodynamics can be modelled numerically to produce average fluid velocity components, and turbulence intensities and length scales at discrete points throughout the reactor flow domain. This information can be used to predict the trajectories of particles by using a sophisticated Lagrangian tracking model. The particle trajectories can then be integrated with an intensity field representation within the reactor to determine the dose received by each particle as it travels through the reactor. Thus a distribution of the dose delivered to the particles can be computed. The benefits of such a numerical tool are clearly beneficial. Not only can short-circuiting and over-dosing be detected but the advanced graphical visualisation tools of CFD help to identify problematic regions. Another benefit of CFD is that expensive experimental testing can be reduced during the reactor design phase.

As mentioned above, to use models effectively, it is important to validate them. This work compares the results obtained from microbe inactivation in a simple annular reactor to the inactivation predicted by the numerical models. The initial results show good qualitative agreement, but, quantitatively, the numerical models under-predict the microbial inactivation at high dose for low UV transmitance water.

FIELD CASE STUDIES ON THE DISINFECTION OF WASTEWATER USING HIGH POWERED MEDIUM PRESSURE UV LAMPS.

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High intensity, medium pressure UV disinfection systems are becoming widely accepted as an alternative to conventional low pressure UV technology, especially for high flow rate applications where the lower installation and maintenance costs outweigh the higher electrical cost.

Typical medium pressure designs for secondary effluent treatment employ approx. 8 to 12 kW per mgd. While the power requirement is higher than that of low pressure systems, the number of lamps required is greatly reduced, with the Aurora UV™ Medium Pressure Disinfection Systems using two lamps per mgd or less. This UV Disinfection System incorporates novel design solutions to the problem of passing this large water volume close to the lamps without excessive pressure drop. The system is based on the use of two banks of 5 kW lamps in series. The lamps are enclosed in 100 mm (4") diameter quartz sleeves with a 240 mm (9.5") center to center square configuration. Treatment is enhanced by the use of delta wings to create vortex mixing along the length of the lamps and box spacers to prevent flow in the areas of lowest UV intensity.

A 10 kW pilot unit was tested in the winter of 1997/98 at the Lindsay WWTP. In several tests, three logs removal of fecal coliform was achieved using 6 to 8 kW per mgd.

More extensive field testing of a 60 kW prototype disinfection system was conducted at the Dundas WWTP over a two month period in the spring of 1998. Effluent flow through the unit varied from 7.6 - 20 ML/d (2 - 5.4 mgd) during the test period. The effluent transmittance ranged from 64 to 76% at 254 nm and the TSS levels were typically less than 5 ppm. By varying the lamp power, tests could be conducted with UV doses ranging from 2 to 20 kW per mgd. Treatment results demonstrated that discharge levels less than 200 fecal coliform counts/100 ml could be achieved by operating in the range of 4 to 8 kW per mgd. Headloss across the UV system at 8 kW per mgd is less than 330 mm (13").

A full scale 200 kW system was installed in the summer of 1998 for treatment of a peak flow of 68 ML/d (18 mgd) secondary effluent. In recent performance testing, operation at down to 6 kW per mgd resulted in effluent fecal coliform counts less than 100/100 ml.

Case study data from pilot, prototype and full scale Calgon Carbon Aurora UV™ Medium Pressure Disinfection Systems are presented showing that effective treatment can be obtained with high power 5 kW UV lamps without suffering an unacceptably high pressure drop. The key design parameters that are necessary to obtain high efficiency are discussed.

New UV technology applied in treating municipal wastewater with high iron (Fe) content

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The applicability of a high intensity, low pressure UV system to disinfecting a wastewater with a high iron content was evaluated at Toronto's Humber municipal wastewater treatment plant. This plant provides secondary treatment (activated sludge) but no filtration. It uses low-cost iron from the local steel industry. Either ferrous (Fe^{2+}) is injected at the inlet to the aeration basins and is oxidized to ferric (Fe^{3+}), where it then becomes available for phosphorus removal, or Fe^{3+} is injected at the aeration basin outlet directly. The iron concentrations ranged from 0.2 - 3.2 ppm in the plant effluent which was fed into the pilot UV reactor.

The effects of varying iron concentrations on the quality of the effluent from the UV system, and its impact on the cleaning of the disinfection equipment, are outlined. Using a collimated beam system which incorporated the same high intensity UV lamp as used in the pilot system, and based on *E. coli* counts, the applied dose in the pilot UV system was calculated as ranging between 7 - 12 mW-s/cm^2, depending on the flow rate, which ranged between 12.6 - 37.8 L/s (200 - 600 gpm). The *E. coli* reduction achieved was 2 - 3 logs.

The operation and maintenance (O&M) costs of the high intensity, low pressure UV system will be compared to the present costs of chemical disinfection. The presentation will also discuss some of the major factors affecting disinfection performance for wastewaters containing high iron concentrations.

Inactivation of *Cryptosporidium parvum* by ultraviolet light: dose response curves for low- and medium-pressure mercury lamps and pilot scale demonstration studies.

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Both low-pressure and pulsed UV light have been shown to provide high (>3 log) inactivation of *Cryptosporidium* oocysts in treated drinking water. Few reliable data exist in the literature as to how these organisms respond to ultraviolet light. Neither the mechanisms of inactivation with UV light, which may be different for continuous vs pulsed, or the effective UV dose are known.

This study was designed to determine the effective dose for *Cryptosporidium* inactivation for low-pressure (which emit primarily at 254 nm) and medium-pressure (which emit a broad band of radiation from 200-300 nm) mercury lamps. The *in vitro* surrogates (DAPI/PI and excystation) and animal infectivity studies using the CD-1 neonatal mouse model were used to assess inactivation and develop and determine the UV dose-response curves [log (percent viability) versus UV dose (mW.s cm^{-2})] for *C. parvum* oocysts under various conditions. The water matrix causes both a decrease in the irradiance reaching a given cell and a change in the spectral distribution of the UV within the water. This study compares the UV dose-response curves for deionized water and finished waters to examine matrix effects. Two different oocyst strains were used to examine possible strain differences.

The results of this study show that UV will inactivate oocysts at doses lower than previously shown using the advanced UV system (Clancy *et al,* 1998 a, b), and that UV treatment of drinking water can provide high levels of inactivation in a cost effective manner.

The *in vitro* surrogate data show that differences exist between low- and medium-pressure UV light for inactivation of *Cryptosporidium parvum* oocysts. Equivalent total UV doses do not show similar inactivation levels. Experiments to date with two different strains (the Harley Moon isolate passaged in calves and a UK isolate from deer which has been passaged in lambs from the Moredun Research Institute) indicate that there may be differences in strain susceptibility. Results from a UV dose response trial using a collimated beam in bench scale studies with mouse as the indicator of inactivation were used to establish the lethal UV dose for the demonstration study. This trial was conducted in June 1998 at the Regional Municipality of Waterloo Water Treatment Plant in Kitchener, Ontario, which experienced a cryptosporidiosis outbreak in 1993. The demonstration study was done on a 760 ML/d (200 gpm) system fed from the effluent of the water treatment plant. A series of trials was conducted using animal infectivity as the inactivation indicator. Results show that >4-log inactivation of *Cryptosporidium parvum* oocysts was achievable under demonstration-scale conditions.

The trial was designed to meet the requirements of the joint United States Environmental Protection Agency/National Sanitation Foundation Environmental Technology Verification (NSF-ETV) program for testing innovative technologies for small water treatment systems. This UV technology was the first system tested and verified under this program.

Clancy, J.L., T.H. Hargy, M.M. Marshall, and J.E. Dyksen. (1998a). Inactivation of *Cryptosporidium parvum* Oocysts in Water Using Ultraviolet Light. *J. American Water Works Assoc.* 90: 92-102. (1998).

Clancy, J.L., T.H. Hargy, M.M. Marshall, and J.E. Dyksen. (1998b). Innovative Electrotechnologies for Inactivation of *Cryptosporidium parvum.* Final Report. AWWARF (in press). AWWA, Denver, CO.

Laboratory-Scale Tests on Inorganic Fouling of Ultraviolet Mercury Lamps used in Wastewater Disinfection.

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Ultraviolet (UV) irradiation has emerged as the most common alternative to chlorination in the disinfection practice of wastewater in North America. Preference for the former has been attributed to the absence of effluent toxicity and ease of operation.

However, UV disinfection has been associated with a major drawback, fouling of the quartz lamp sleeves, which acts to reduce intensity and therefore affects disinfection performance. This fouling, the undesired deposition of mainly inorganic constituents on the quartz sleeves, also necessitates frequent cleaning of the lamps. Iron, aluminium and calcium have been shown to be dominant components of fouling material and, to a lesser extent, magnesium, inactivated and active microorganisms. Fouling is mostly predominant in waste trains employing physico-chemical treatment. It is believed to be caused by a combination of hydraulic, chemical and biological factors, the kinetics and mechanisms of which are not fully understood.

The focus of this project is to establish a mechanism for inorganic fouling in UV lamps by studying the effects of heat and UV energy on inorganic aqueous species. It is hypothesized that thermally and/or UV induced precipitation of inorganic salts on the quartz sleeve is one of the dominant mechanisms of fouling. Heat, generated from UV production, diffuses out and is absorbed by water passing along the quartz surfaces. Sparingly-soluble inorganic salts (such as $FePO_4$ and $CaCO_3$) are induced to precipitate. This experimentally observed precipitation is compared with a theoretical solubility model based on solution equilibria, considering concentration, temperature dependence and presence of heterogeneous ions in solution.

Laboratory-scale tests using recirculating aqueous solutions of ferric salts with one module of two low-pressure mercury lamps were conducted to assess fouling potential. The lamps were suspended in a plexiglass channel parallel to the flow. An hydraulic loading of 0.9 L/s-lamp was employed for the first two experiments but reduced to 0.3 L/s-lamp for subsequent experiments. UV intensity measurements (to monitor fouling) were made with a radiometer through two quartz windows inserted in the plexiglass.

The experiments consisted in studying the effects of UV light (and the associated heat output) on the precipitation of inorganic salts (Fe, Ca, PO_4, CO_3), as well as inorganic salts with organics (whey powder). With the lamps under continuous operation, daily measurements of UV intensity, total and dissolved metal ion concentration, bulk aqueous temperature as well as pH were taken.

Results obtained using only inorganic species (initial iron concentrations of 1 and 3 mg/L) have indicated virtual absence of fouling of the UV lamps. UV intensity measurements initially showed increasing levels which tended to level off or decrease slightly after 12 days. The initial increase could be attributed to increased transmissivity of the bulk solution (due to precipitation and settling of solids in the pipeline). Current experiments are investigating fouling potential of inorganic salts in the presence of organics.

Pilot plant tests at a full-scale wastewater treatment plant with ferric chloride addition

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A pilot plant study is being performed at the St. Eustache municipal wastewater treatment plant. This plant provides biological treatment via biofilters prior to disinfection with ultraviolet (UV) lamps. The Trojan UV 3000 pilot plant consists of 3 modules with 2 low pressure mercury lamps each. The modules are separated by baffles enabling each channel to work independently of the others. Only one module irradiates UV light ("UV"), while the other two serve as controls, one being off ("lamps off"), and the other irradiating only heat and visible light ("NUV"). The influent to the pilot plant reactor is pumped from the full scale facility basin just upstream of its own disinfection process and flows through the pilot reactor at 5 L/s. The primary objectives of this study are to qualify and quantify the composition of foulant material formed on the UV lamps of the pilot reactor in terms of organic, inorganic and biological material, to qualitatively describe the distribution of foulant along the lamps, and to compare foulants formed from biologically treated versus physico-chemically treated wastewaters. This last objective is possible through the addition of ferric chloride to the influent to the UV pilot plant. Furthermore, several parameters such as COD, fecal coliforms, metal concentrations, pH, particle size distribution (PSD), suspended solids (SS), temperature, UV transmittance, and turbidity are measured regularly to monitor the quality of the wastewater influent to the pilot plant and to assess any correlation between the influent quality and the foulant composition. The lamp foulant was initially examined with the biologically treated wastewater. A four week old foulant was sampled from each lamp. The "lamps-off" had a brown sludge-like foulant matter which was composed mainly of alum. The NUV lamps' foulant was green (algae), which also contained some alum, calcium, and iron. The UV lamps' foulant consisted of a thin transparent inorganic film. No change in UV disinfection efficiency was observed following the four-week period, where coliform counts in the effluent were still virtually zero. This indicated that fouling was not a principal operational problem in this facility with this quality of wastewater. Hence the second phase of the project began which involves the pumping of ferric chloride into the influent to simulate effluent coming from a physico-chemically treated wastewater. Jar tests were performed to simulate the quality of effluent expected from a coagulation/sedimentation process, and a 2,500 litre tank was installed upstream of the pilot UV unit where ferric chloride is pumped into the influent. Based on the results of the jar tests, ferric chloride dosages were varied between 0.5 and 2 mg Fe^{3+}/L. The corresponding foulant composition and rates of foulant formation are being investigated.

SESSION 5

South Seminar Room

Water Quality as Affected by Agricultural Practice

Session Chair: Mary Jane Conboy

Reducing Environmental Contamination by improving N-use efficiency on farms: Measurement and Estimation of Nitrogen Fluxes for a Dairy Farm

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Farmers are constantly being encouraged to reduce environmental contamination. Specific farm management practices influence the magnitude and form of N inputs and the partitioning of N losses into the groundwater and the atmosphere. The needs of farmers and the environment may best be met by improving the N-use efficiency on farms, but there is no easy way for this to be evaluated. A detailed nitrogen balance for a single farm has been established. Nitrogen inputs (gaseous deposits, biological fixation from the atmosphere, purchases of animals, fertilizer, manure and other N containing materials), fluxes internal to the farm (mineralization and immobilization as well as transfers between barns and fields), and outputs (drainage losses, gaseous losses, crop and animal sales) have been measured or estimated. The budget is being used to develop a technical support package that will assist farmers in identifying and selecting best management practices for nitrogen that are most appropriate for their operation.

Sampling of soils and crops was along transects established in each field. Spatial variability was accounted for by working at marked locations at toe, mid and upper slope positions. However, repeated sampling at the same locations over time gave more reliable information on seasonal trends. In association with the samples collected from the field, feed, manure and milk samples were collected to monitor the transfer of N within the barn. To determine each major flux of N, either a direct measurement was obtained, or it was estimated from the partial balance of the components.

A nitrogen balance was also calculated for each field. Results from this part of the budget indicated that the greatest amount of NO_3^- leaching took place under conditions having a large positive N balance. Nonetheless, NO_3^-leaching also occurred under fields having a negative N balance in the year of measurement, and was associated with the cultivation of short seasoned crops. When these crops were harvested in August, water use effectively stopped, so precipitation readily resulted in a soil moisture regime having a greater potential to allow leaching, and NO_3^- mineralization increased the amount of solute available.

Transport of faecal bacteria from manure through the vadose zone

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Results of a long-term, ongoing study on the ground-water quality under a farm with a history of manure application indicated that contamination of groundwater with faecal coliforms could occur after field application of livestock manure.

The objective of the present study was to evaluate the potential for ground water contamination after field application of animal manure.

The movement of faecal bacteria through the vadose zone following application of animal manure with contrasting water contents, on two soil profiles at contrasting initial soil water contents was researched.

Faecal coliforms, specifically Escherichia coli, were used as indicators to estimate the transport of faecal bacteria through the soil. Bacteria present in the soil solution were collected using ceramic-porous-cup samplers with an air entry value of 1bar. The development of a protocol for the calibration of these samplers is described. Analysis of the soil solution samples for bacterial contamination was carried using standard agar incubation and plate counts.

Results from the ceramic porous cup samplers indicated that no diffusion of the bacteria through the cups' walls occurred. Hence bacteria entered the porous cups only through advection with water. Despite their limitations the ceramic porous cup samplers could be used for the assessment of differences in bacterial transport through vadose for contrasting conditions. Estimated bacterial migration velocities were consistent with the hypothesis that bacterial transport occurs mostly through soil's macropores, faster than the average pore water velocity.

Macropore transport was more likely to occur in wet soils, but it was not necessarily restricted by the initial soil water content. As the soil's clay content increased and the total porosity decreased, the saturated hydraulic conductivity of the soil matrix decreased. For such conditions the water, and therefore the suspended bacteria, was more likely to be funnelled at greater velocities through soil's macropores increasing the potential depth for bacterial contamination. The continuity of the soil's macropores was more important for the deep transport of faecal bacteria than the total porosity of the soil.

The potential for deep contamination with faecal bacteria was greater for the application of manure with higher water content for both soil profiles considered.

An important conclusion of this study was that field application of animal manure can readily lead to ground water contamination with faecal bacteria.

Transport of Nitrate and Chloride applied to Turfgrass: Observations and LEACHM (within EXPRES) Predictions

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The leaching of surface-applied solutes, such as nitrate, to groundwater is an environmental concern. Computer simulation models are useful in designing management practices to address this problem and to further our understanding of solute transport processes. The objectives of this study were (i) to measure the leaching of nitrate and chloride applied to turfgrass, and (ii) to test the ability of the model LEACHM (within EXPRES) to simulate the transport of nitrate and chloride below turfgrass, considering both as inert, conservative tracers. Twelve lysimeters were packed with a three-horizon profile of a sandy loam soil, topped with Kentucky bluegrass (*Poa pratensis*) sod and monitored for 2 years in the field. Leaching of both nitrate and chloride occurred mainly in late autumn and winter, coinciding with lysimeter drainage patterns. Based on soil water samples taken from suction samplers placed at depths of 10, 17, 29, 43, 54, 64 and 85 cm, part of the solute from spring/summer applications remained in the soil during the very dry summers, and was later transported downward with the ensuing infiltration front in autumn. Observed variability between lysimeters may be linked to summer irrigation and/or the effects of past fertilization on turf rooting. For the most part, predictions by LEACHM of solute concentration profile were similar to field measurements. However, predicted and measured solute concentration values often differed significantly. Predictions of mass leached in drainage were too high. The predictions were affected by various solute sinks we did not attempt to include (eg. denitrification), and water flow inaccuracies, including summer evapotranspiration rates and the difference between the model and actual bottom boundary condition. There were also a few indications of preferential flow with sharp peaks in solute concentration measured at depths much sooner than predicted.

PREDICTION OF SOIL EROSION IN A SEMI-ARID ZONE OF IRAN BY THE INTEGRATION OF MUSLE AND SPANS-GIS

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The dynamic nature of erosion and associated processes and their dependence on climatic, pedologic, land cover, land use, and agriculture management factors can cause spatial and temporal variability. Computing and mapping this variability will produce important information that is essential for designing dams, reservoirs, stable channels, and evaluation of transport of pollutants and water quality.

This article presents the promising tool for the prediction of water erosion and sediment yield in the areas where availability of hydrological data is limited. The modeling includes the integration of MUSLE with SPANS-GIS for semi-arid zones particularly Syahrood one of the sub basins of Damavand watershed in Iran where soil erosion by water is one of the land-related problems. Runoff erosivity, soil erodibility, slope length, slope steepness, agriculture management, and erosion control practice factors were computed and included in the digitized and computed Thiessen polygon, land component, slope and land use maps of the watershed. The amount of sediment yield in each land use was computed by overlaying these maps with the appropriate models in the SPANS-GIS. The result shows higher erosion rates are related to drylands that usually belong to steep slopes and are cultivated in rows parallel to the slope direction. The average sediment yield for the entire study area was 745 with the higher and lower rates of 978 and 221 in the drylands and gardens, respectively. This sub basin is characterized with the lack of recorded rain gauge data, which limited the application of commonly used erosion models. Results demonstrated that interfacing MUSLE with a GIS is an effective method for the prediction of soil erosion in small watersheds with limited data sets. A GIS simplifies the extracting of necessary factors from databases. SPANS-GIS uses quadtree data model that provides compact raster representation by using a variable sized grid cell, useful for having least file size when the data are relatively homogeneous and do not require frequent updating. "SPANS-GIS" and "PC-TIN of PC-ARC/INFO" were weak in preparing a slope map from the digital elevation database for mountainous areas.

DEVELOPMENT OF CONCEPTUAL MODEL FOR THE TRANSPORT OF CRYPTOSPORIDIUM OOCYSTS IN WATERSHEDS

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A conceptual model is being developed to estimate *Cryptosporidim parvum* oocyst transport from source to water treatment plant intakes. The source terms are a function of activities within the watershed and the transport is related to watershed characteristics and events.

The modeling approach is carried out as follows: to identify transport mechanisms, the physical properties of *Cryptosporidium* oocysts are first investigated to provide insights into their adsorption or desorption tendency; next, the two broad mechanisms (overland transport caused by runoff and water channel transport) are investigated. This conceptual modeling is focused on overland transport of oocysts from wastes to a watercourse. Subsurface transport is neglected because there is likely little oocyst transport through the porous medium of the subsurface, since there is little transport of bacteria, which are of similar size.

This paper describes the initial development of a conceptual model for *Cryptosporidium* transport from the source to a drinking water treatment plant intake. An oocyst detachment function is derived from bacterial detachment to describe oocyst transfer form the solid phase to runoff water. Based on the physical properties of oocysts, an initial assumption was made that "free" oocysts (i.e. those not attached to other particulate matter) would be much more readily transported by overland flow. The transport of oocysts incorporated in organic or inorganic floc would be hampered by settling and the shallow depth of overland flow. Water channel transport is basically governed by the advection-dispersion equation.

DEVELOPMENT OF A CONCEPTUAL MODEL FOR DEFINING SOURCE TERMS OF *CRYPTOSPORIDIUM* OOCYSTS IN WATERSHEDS

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Due to the increasing awareness of outbreaks of cryptosporidiosis in public water supplies throughout the world recently, water utilities are trying to better understand the occurrence and density of *Cryptosporidium* in their watersheds. The research reported in this paper represents the initial steps in a long-term project to establish a framework to define the source terms of *Cryptosporidium* in watersheds.

Farms, wildlife, wastewater treatment plant effluents, and combined sewer overflows are all potential contributors of oocysts in source waters. However, all these source terms are watershed-specific. The oocyst production rate from cattle farms, for example, is a function of the specific farm operations and watershed characteristics (e.g. topography). Watershed characteristics and the degree of watershed protection can be judged important controllers of oocyst levels in source waters.

A framework for defining source terms is a very complex decision problem involving analysis of source terms, watershed characteristics and their inter-relationships. The approach used here is to first decompose the complex problem into two sub-problems - source terms and watershed characteristics, then understand the main effects of each sub-problem, and finally come up with the overall framework through studying the inter-relationships. In this paper, application of the model is illustrated using the examples of cattle farms and wastewater treatment plant (WWTP) effluents.

Preliminary work showed that young calves make most contribution to oocyst production from cattle farms due to their high infection rate and high shedding rate. Oocyst contributions from different WWTPs depend on the operation practices, capacities, sources of wastewater, etc. Data from the literature are used to estimate the order of magnitude of oocyst production for different categories of WWTP, such as domestic wastewater, domestic and industrial wastewater, and domestic and slaughterhouse wastewater treatment plants. The exact value may not be accurate due to the need to make assumptions and use of data from the literature. However, the results give the order of magnitude of oocyst contribution, which is the information of interest.

A sensitivity analysis of the proposed model is also performed. It is anticipated that through this analysis, we can gain a better understanding of the factors which affect oocyst production from a given source and determine the most sensitive factors which need to be manipulated carefully to reduce oocysts release into a watershed. Sensitive factors also need to be determined more accurately to refine the framework.

SESSION 6

North Seminar Room

Groundwater/Subsurface Remediation

Session Chair: S. Ghoshal

Efficiency of PAHs removal from clayey soil using supercritical fluid extraction

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The clay soil has specific properties that cause difficulty in the contaminated site assessment and the remediation process. The difficulty in extraction of HOC (hydrophobic organic compounds) from clay material was reported. Therefore, the SFE (supercritical fluid extraction) has a potential to substitute classical methods. The efficiency of the use the SFE (ISCO 200 model) for clay soil (illite) was investigated.

SFE tests were performed on various compositions of clayey soils. Phenanthrene was used to examine the extraction efficiency of PAHs from clayey soil. Phenanthrene concentration in soil specimen was determined by UV. Carbon dioxide was chosen as the supercritical fluid and 5% (mol) methanol was used as a modifier. The highest recovery (72%) from clay was obtained at a pressure of 55 kPa (8000 psi) and temperature of 150 °C with modifier when dynamic time of 30 min was applied. The impact of pressure (5000 to 8000 psi), temperature (50 to 150 °C) and time (static and dynamic) were discussed.

The extraction efficiency of phenanthrene from soil was modeled. The model accounts for effective diffusion of the phenanthrene in the solid pores, axial dispersion in the fluid phase and external mass transfer to the fluid phase from the particle surface. This model, involving partial differential equations, was solved using the finite difference. The model showed the relationship between diffusivity, mass transfer coefficient and properties of porous media (clay texture). The porous media analysis was reported by an electron microscopy and an image analysis. The developed model, being useful in a prediction, can be applied for more precise analysis necessary for contaminated site assessment as well as for evaluation of the remediation technology efficiency.

CYCLODEXTRINS FOR DESORPTION OF 2,4,6-TRINITROTOLUENE AND METABOLITES FROM SOIL

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Contamination of soil by energetic chemicals such as 2,4,6-trinitrotoluene (TNT) and its metabolites is a worldwide environmental problem. These compounds are considered to be toxic and mutagenic and are persistent in the environment. Remediation of soil contaminated with TNT requires an understanding of the processes of adsorption and desorption since these processes control the mobility as well as the bioavailability of contaminants. Many studies have demonstrated that TNT is not completely mineralized in soil but rather biostransformed to metabolites. Some of the initial products of TNT biodegradation have been identified as 4-amino-2,6-dinitrotoluene (4-ADNT), 2-amino-4,6-dinitrotoluene (2-ADNT), 2,4-diamino-6-nitrotoluene (2,4-DANT), and 2,6-diamino-4-nitrotoluene (2,6-DANT). Therefore, the complete mineralization of TNT will also depend on the adsorption-desorption characteristics of these metabolites. The objective of the present study was to characterize the adsorption-desorption characteristics of TNT, 4-ADNT, and 2,4-DANT in the laboratory using an agricultural topsoil, a sandy aquifer material, and a pure illite clay mineral saturated with potassium. In addition, the effects of two cyclodextrins (*i.e.* hydroxypropyl-β-cyclodextrin (HPβCD) and heptakis (2,6-di-O-methyl-β-cyclodextrin (DIMβCD)) were studied to determine their ability to enhance the desorption of these compounds as an attempt to increase their bioavailability for subsequent mineralization. Cyclodextrins are cyclic oligosaccharides produced by the microbial breakdown of starch. Their "donut" shape allows them to form inclusion complexes with a number of compounds. Cyclodextrins have been used in the pharmaceutical industry for a number of years in drug preparations to enhance the water solubility of highly polar compounds. Cyclodextrins are only just beginning to be examined for their suitability as solubility enhancers in the field of bioremediation. Their candidacy for this purpose stems from the fact that they are considered to be less toxic than surfactants. Results of the present study indicate that adsorption and desorption isotherms of TNT, 4-ADNT, and 2,4-DANT for the three soils tested were best described by the nonlinear Freundlich isotherm. This implies that the three soils examined possess specific binding sites for the contaminants tested, and that once filled, the remaining sites are less attractive for the remaining molecules in solution. For the case of topsoil, the Freundlich sorption capacity constants (*i.e.* K_d) of the three compounds increased slightly with the number of amino groups (*i.e.* 2,4-DANT > 4-ADNT > TNT). Desorption of 2,4-DANT from topsoil, the strongest sorbing compound, was not achieved with distilled water by successive dilutions. However, the use of HPβCD slightly enhanced desorption of 2,4-DANT from topsoil. In contrast, DIMβCD was more effective than HPβCD for desorption of 4-ADNT from the topsoil. For the sandy aquifer material, TNT was adsorbed only slightly, and neither metabolite was adsorbed. For the case of illite, the sorption capacity constant increased significantly with the number of nitro groups (*i.e.* TNT > 4-ADNT > 2,4-DANT). The DIMβCD was more effective than HPβ CD in facilitating desorption of TNT from the illite. Hence, there appears to be some merit in the use of cyclodextrins for enhancing the solubility of TNT and some of its metabolites in soil systems. However, the benefits of such treatments will depend on the structure of the compound as well as the soil type. Further research is underway to determine whether such solubility enhancements will result in an increase in TNT mineralization.

Surfactant Solubilization of Polycyclic Aromatic Hydrocarbon Compounds from Nonaqueous Phase Liquids

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Subsurface contamination by non-aqueous phase liquids (NAPLs) such as creosote, petroleum products and coal tar, is widespread at sites where prolonged industrial activities related to petroleum refining, coal coking, coal gasification and wood processing have occurred. These NAPLs are sparingly water soluble and often contain various polycyclic aromatic hydrocarbon (PAH) compounds. PAHs are of significant interest because of their potential as carcinogens and because they have negative impacts on soil biota. As PAHs are relatively water insoluble it is difficult to achieve desired remediation endpoints using traditional pump and treat technologies.

Surfactants have been shown to be effective at increasing the solubility of hydrophobic organic compounds and it is believed that *in-situ* surfactant flushing could significantly speed the remediation process at NAPL-contaminated sites. When present at high aqueous concentrations surfactant molecules form aggregates called micelles. The core of these micelles is a hydrophobic environment into which hydrophobic organic hydrocarbons may partition. By partitioning significant quantities of PAHs from sorbed phases or NAPLs into micelles, PAHs may be efficiently extracted from contaminated phases.

Research to date has investigated surfactant aided dissolution of individual solid PAH compounds. However, the rates and extents of partitioning of PAHs from multi-component NAPLs is not well understood and thus it is difficult to determine the feasibility of using surfactants for remediation of NAPL contaminated sites. This research aims to improve the understanding of the role of surfactants in increasing the rate of PAH dissolution from multi-component NAPLs. In order to investigate the dissolution process, multi-component NAPLs have been synthesized using hexadecane as the bulk NAPL and several individual PAH compounds as components. These NAPLs are contacted with aqueous non-ionic surfactant solutions in a batch reactor and the relative partitioning behavior of individual PAH compounds between the NAPL phase, the aqueous bulk phase and the aqueous micellar phase is being studied. It is our hypothesis that PAH partitioning between the three phases should follow Raoult's law which states that the concentrations of a given compound in the aqueous and micellar phases should be a function of the compound's mole fraction in the NAPL phase. The experiments and analysis of the data will yield the relationships between several important system parameters: the molar solubilization ratio, the surfactants' hydrophilic-lipophilic balance, NAPL component mole fractions and the NAPL-phase activity coefficients. Such information is essential for predicting the relative rates of PAH dissolution from a multi-component NAPL into surfactant-water solutions.

BIOREMEDIATION OF HYDROCARBONS UNDER OXYGEN-LIMITED CONDITIONS

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A packed-bed biobarrier system inoculated with a soil-indigenous microbial consortium continuously removed gasoline under limited supply of molecular oxygen. The removal mechanisms included adsorption as well as biological degradation. This study was part of an effort to develop an alternative technology for the *in situ* bioremediation of hydrocarbons at low concentrations of dissolved oxygen.

The operating conditions of the biobarrier were similar to the *in situ* condition, including gasoline concentration of 22 mg/L, linear liquid velocity of 12.5 cm/day and temperature of 10 °C. The inlet dissolved oxygen concentration (DO) changed from 11.3 to 0.5 mg/L. The supplied oxygen was quickly consumed, establishing a microaerophilic condition along the length of the biobarrier as evidenced by the near zero concentration of DO in the system. Under these conditions, the removal efficiency of gasoline ranged from 97.0% to 98.9% while its elimination rate changed from 5.2 to 6.4 mg/L.d.

Independent batch studies investigated the biodegradation of benzene, as the representative hydrocarbon, at initial DO of 0.0, 0.05, 0.1, 0.2, 0.5, 1.0 and 2 mg/L using the microorganisms withdrawn from the biobarrier. A 34% benzene biodegradation was observed even at the low initial DO of 0.05 mg/L, which increased to 80% at initial DO of 0.5 mg/L and to100% at initial DO of 1 mg/L. The degraded benzene was considerably higher than the theoretical predictions for aerobic mineralization. Phenol was produced concomitant with the utilization of benzene and continued to accumulate even after the establishment of anoxic condition in the system. No benzene biodegradation was observed under strictly anaerobic condition.

The results of this study showed the high capacity of the developed biobarrier in removal of hydrocarbons under low availability of molecular oxygen.

SESSION 7

South Seminar Room

Lessons Learned Through Great Lakes 2000 Projects

Session Chair: Sandra Kok

Actions to reduce Phosphorus from Urban Discharges in the Bay of Quinte

Fred Stride

The Bay of Quinte was identified in 1985 as a Great Lakes Area of Concern due to a number of pollution problems including hyper-eutrophication. In 1993, the Bay of Quinte RAP Stage 2 Report: Time to Act was released with 80 cleanup recommendations. Actions were advocated for urban and rural pollution sources. For urban source inputs of phosphorus, the cleanup work targeted two issues: (1) stormwater and (2) point-source discharges. The stormwater program contain many innovative components including a Ano net gain in pollution loadings@ policy and pre-planning technical advice. The point-source actions included sewage treatment plant upgrade and industrial abatement. Between 1993 and 1998, many successful projects were implemented, and loadings of phosphorus were reduced substantially. The various restoration actions will be highlighted and discussed.

SESSION 8

North Seminar Room

Wastewater/Storm Water Treatment

Session Chair: R. Gehr

Using microbial fatty acids to quantify population dynamics for biofilm and suspended microbial communities in wastewater treatment systems.

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Spectra of microbial fatty acid methyl esters were used to assess the influence of contaminant shock loading on biofilm and suspended biomass populations. Microbial consortia were monitored within well-acclimated bench scale moving bed bioreactors treating bleached kraft mill wastewater. The microbial fatty acid spectral data that were reduced by logcontrast canonical component analysis, were used to define a trajectory for the changing microbial community structure as a function of time. The time rate of change along this trajectory was used to evaluate the reactor population dynamics. This evaluation of the population dynamics indicated a shift in the community structure due to a sudden input of resin acids. Resin acids are a group of naturally occurring hydrophobic organic aquatic toxicants that are released during wood pulping. The measured changes in the community structure were considered concurrently with the bioreactor operating characteristics. Although the shock load did not appear to adversely affect overall microbial activity, the data suggested that some members of the consortia must have suffered as a result of the imposed environmental change. Hence, the assessment of population dynamics was helpful for indicating plasticity in the community structure in response to an environmental perturbation. The high growth rate, short SRT fraction of the population was shown to change most rapidly in response to the shock load. It was concluded that the observed changes in the microbial fatty acid profiles were more an indication of a community change than a measure of individual species adaptations. These techniques of microbial community analysis have potential application in treatment plant monitoring and control.

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WASTEWATER CHARACTERIZATION : EVALUATION OF A BIO-CHEMICAL METHOD AND PRELIMINARY RESULTS

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Influent fractionning is a challenging issue in wastewater treatment modelling using ASM1 (Henze et al., 1986). The model distinguishes between 4 to 5 COD and TKN subfractions, according to biodegradability and biodegradation kinetics. As to now, there exist several methods to measure those fractions, but no consent seems to be drawn on that matter. Moreover, the use of fix fractions can be questionned as time and event-linked variability will certainly affect the different COD and TKN ratios in a wastewater. This paper presents some preliminary results on the implementation of a biodegradability batch test to fraction different types of wastewater samples to assess the variability of a WWTP influent composition.

The method is derived from Lesouef et al. (1992), who proposed to draw the inert soluble and particulate COD fractions (Si and Xi) out of the total and filtered COD evolution in 2 aerated batches, one containing crude sewage and the other one filtered sewage. The procedure was adapted to determine also the readily and slowly biodegradable COD (Ss and Xs), and the nitrogen fractions (Sni, Xni, Snd, Xnd, and ammonia Snh). The results of the first 2 tests led to further experimental modifications to improve the reliability and the repeatability of the method. A significant improvement was obtained by seeding the batches with activated sludge. Si, Ss, and Xs can be determined quite reliably, but the precision on Xi remains poor.

A dry weather 24 h composite sample, a dry weather peak sample, a wet weather 24 h composite sample accounting for the diluted stage of a rain event, and a sample of the first hour of a rain event after 2.5 dry days were fractionned. Concerning COD, the results showed that biodegradability was always high (Ss + Xs > 80% of total COD). Xs was always prevailing (50 to 83%). Si was the less important and the most constant fraction (3 to 6%). No significant difference appeared between the dry and wet weather composite samples. In comparison, both dry and wet weather peak samples appeared to be more particulate (Xs + Xi = 86 and 77% of total COD) and more biodegradable (Ss + Xs = 93 and 90%). The additional COD load coming in during those peaks is mostly under Xs form : the COD produced by domestic peak activities as well as the COD of sewer deposits which are resuspended at the beginning of a rain event are mostly slowly biodegradable.

Regarding TKN, the first tests confirmed that the inert fractions of organic nitrogen represent only a few percent of the total incoming nitrogen, at least in the composite samples. Afterwards they were considered as negligible. In both dry weather samples, ammonia was prevailing (about 75% of TKN), and decreased around 50% in the wet weather peak sample. The additional load was mostly brought by the Xnd fraction (sewer deposits). During the dry weather peak however, the additional nitrogen load was both produced as ammonia and Xnd. Xnd and Snd vary roughly as their COD counterparts, whereas ammonia follows its own variations.

Those characterization experiments conducted with a global method requiring simple equipment showed that influent fractionation varies over the day at a few hours time scale. There is probably a daily periodic pattern, overlapped by other events such as rain. We have now to assess through simulation how much these variations affect the activated sludge behaviour.

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DEVELOPMENT OF TECHNOLOGY FOR LEACHATE TREATMENT

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Landfill leachate is usually characterized by high content of organic matter (expressed as COD, BOD_5 and TOC), high concentration of ammonia, metals and high alkalinity. Leachate quality can fluctuate over both short and long term and is related to the number of physical, chemical and biological processes in the landfill as well as weather conditions. Therefore a treatment system for leachate must be flexible enough to produce the same quality effluent despite the variation in the streanght of the leachate. In order to meet this criterion, leachate treatment plants utilize a combination of physical, chemical and biological treatment which is often followed by advanced oxidation process (AOP) or chlorination.

In this paper the results of the treatability studies on the high strength leachate (COD = 8000 mg/L, ammmonia = 590 mg/L) are presented. The aim of the treatability studies was to determine an efficient and costs effective technology for leachate treatment that would produce an effluent acceptable for discharge to surface water. During the studies physico-chemical methods, biological treatment and ozonantion were tested. Biodegradability of the leachate was evaluated using aerobic respirometry. Respirometric data were also used for the design of a bench scale biological treatment system for removal of ammonia and COD. It has been found that preaeration of the leachate with phosphoric acid allowes substantially reduce (>35 %) the ammonia load and subsequently reduces the size of biological system. Ozonation of the biological effluent was found effective in removing colour and improving

coagulation/flocculation of suspended solids. Optimization of the treatment using each investigated method was performed. The performance of the whole treatment system was also evaluated.

It has been determined that preaeration of the leachate with 50 mg/L of phosphoric acid, followed by biological treatment (aerobic and anaerobic) and ozonation allowed to remove 99.6 % of ammonia , 98 % of total nitogen and 92 % of COD.
The overall performance of the treatment system was tested for 30 days with leachate collected regularly from the leachate collection system. Leachate and effluent from the treatment system were analyzed for general chemistry parameters, ammonia, phosphorus, phenols, calcium, iron, magnesium and manganese. It has been confirmed that tested technology would produce a high quality effluent, which can be discharged to the surface water.

Effect of Chloride and Temperature on Metal Partitioning in an Urban Stormwater Detention Pond

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The use of constructed wetlands and detention ponds as an inexpensive and efficient way to chemically 'treat' urban runoff has been gaining support. However there is some concern with respect to the seasonal and long-term mobility and bioavailability of toxic metals in these systems as well as the total storage capacity of these ponds and wetlands. The current research involves a laboratory study to investigate the partitioning of Cd, Cu, Pb and Zn between the water and sediment of a detention pond receiving urban runoff. The effects of chloride concentration and temperature on the sorption and desorption of these metals is being investigated. Sediment and pond water were collected from a stormwater detention pond in Richmond Hill. Sediment-water jar experiments were set up in 4 L glass jars. For the sorption experiments jars were spiked with a mixture of Cd, Cu, Pb and Zn and routine sampling of the overlying water was conducted over a four week period. The remaining water was then siphoned from each jar and fresh pond water was added in order to conduct a four week long desorption experiment. Sorption and desorption experiments were run at three different chloride concentrations (0, 500 and 2500 ppm added Cl^-) and at two different temperatures (approximately 4 and 25°C) and sampling occurred ten times over the four week period. Samples were analyzed for dissolved and total metals, chloride, pH, oxidation-reduction potential (ORP), total phosphorous (TP), total organic carbon (TOC) and turbidity. Preliminary results indicate that metal concentrations in the overlying water rapidly decrease within 24 hours and Pb within 8 hours. Sorption at 4°C is slower than at 25°C, however this may be due to either reduced benthic activity or to slower diffusion or sorption kinetics. We are presently investigating this. There was very little metal desorption after the four week period, indicating that all the metals may be tightly bound to sediment surfaces.

POSTER SESSIONS

A Comparison of Six Techniques to Measure Nitrogen Flux Below the Root Zone

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Results from a recent study of 2000 rural Ontario wells indicates that approximately 1/3 of the wells exceeded the provincial objectives for nitrate and/or bacteria. Of the wells tested, 15% surpassed the objectives of 10 ppm set for nitrate-NO_3^-. Nitrate contamination of these rural wells is believed to be a direct consequence of conventional agricultural practices. The extent of nitrogen contamination of groundwater resources is of concern to municipalities reliant on groundwater.

Through the Partners in Nitrogen Use Efficiency (PINUE) project, a number of farms in Ontario are being investigated for nitrogen use efficiency prior to the implementation of best management practices (BMPs). Currently, a budgetary approach is being used to monitor inputs, outputs and surpluses of nitrogen at each of these farms. Investigation of nitrogen is divided into an analysis of the sources of nitrate for leaching, and the transport of nitrate from the rooting zone towards the groundwater.

For the past 1½ years a comprehensive monitoring program of nitrogen leaching below the root zone (established at 80 cm below the soil surface) has occurred on one of the five farms, a 150-acre dairy farm. This initial time period has allowed for the monitoring of both temporal and spatial trends in nitrogen leaching characteristics. Instrumentation on the farm includes 44 solution samplers, 44 tensiometers, 30 groundwater monitoring wells, 7 zero tension funnel lysimeters, 2 tile outlet weirs/sampling stations, and a meteorological station.

The goal of this study is to monitor nitrogen leaching using different techniques and to deduce which technique best represents nitrogen flux values below the root zone by comparison to the farm nitrogen budget results.

Six techniques are currently being used to measure the nitrogen fluxes below the root zone prior to the implementation of the BMPs. These techniques include:

(1) Surplus water from a farm water balance (precipitation-evapotranspiration), multiplied by the nitrogen concentration from solution samplers;
(2) Nitrogen concentration from solution samplers multiplied by the Darcy Flux from the tensiometer measurements
(3) Nitrogen concentration multiplied by the water volume measured in the zero tension Guelph lysimeters
(4) Nitrogen concentration at the water table multiplied by the rise in height of water table and specific yield;
(5) Loss of nitrogen in 90 cm soil cores taken after harvest in the fall and before planting in the spring, and;
(6) Nitrogen concentration of tile outflow multiplied by the tile water discharge rate.

Each of these sampling techniques has advantages and disadvantages, which will be presented in more detail.

METHODOLOGY OF INVESTIGATIONS ON THE STRUCTURE OF PARTICLE AGGREGATES

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For practical and theoretical reasons, information on the structure of various particle aggregates is important even in such different fields as gravity separation and mass transfer in water and wastewater treatment technologies. Specifically, the size and size distribution, and porosity/permaebility of the aggregates are of special interest. There are a few measurements techniques which allow to generate data describing directly or indirectly some structure features of such aggregates. Among these techniques, relatively simple are measurements of free settling velocity of the aggregates, and measurements of some geometric characteristics of the stabilized or the solidified and segmented aggregates. They have been the subject of extensive experimentation in this laboratory for about 15 years. The achieved developments in these techniques and their critical evaluation are presented in this paper.

Basically, the measurements of free settling velocities of the particle aggregates should lead to the determination of the mass porosity of the aggregates, but several additional factors affecting the aggregates' drag force have to be taken under consideration. They are, above all, the permeability and the surface development of the aggregates. The first factor is a function of the resulting settling velocity and itself increases it; the second factor decreases the settling velocity. The role of both of these factors increases with the size of the aggregates, but cannot be measured independently in the free settling experiments. To effectively utilize the observed free settling velocity data, a simultaneous measurement of the size of the aggregates have to be made. This can be achieved by an application of a proper experimental setup . In practice, for the particle aggregates no Stokes' relationship between free settling velocity and aggregates' size were observed. Often it was found to be close to a linear dependence. Perhaps, it is more proper for a characterization of the structure of the particle aggregates to use rather an index value based on this relationship, than to try to calculate from the settling measurements the uncertain values of aggregates "mass porosity" or "density".

Stabilization of the samples of particle aggregates by solidifying them in agar is insufficient for segmenting the aggregates, but it can allow to measure size, size distribution, and geometric properties of the aggregates. Depending on the quality of agar used, some aggregates' size limitation may apply. A similar agar stabilization may be also applied before embedding the aggregates in resin for the purpose of segmenting (slicing with a microtome knife) to minimize possible distortions of the aggregates during the sample processing. Microscopic examination of the aggregates' thin, transparent segments allow to evaluate the geometric porosity of the aggregates. This porosity for most of the aggregates will differ from the mass porosity. It will also not provide conclusive information on aggregates' permeability. However, it may reveal some important structural features of the aggregates, specifically, it may help identify the size of primary particles and the mechanism of aggregation. The roughness of the aggregates' external surface may be estimated on the basis of measurements of the segments' perimeter.

Porosity Structure of Alum and Activated Sludge Flocs

Beata Gorczyca and Jerzy Ganczarczyk

Hypothetically, flocs grow according to the following model: primary particles form compact flocculi, and these group themselves into microflocs. Microflocs together form floc aggregates. The main difference between flocculi, microflocs and floc aggregates is their structure. Porosity can be used to indicate difference in this structure.

Earlier studies reported that population of pores within a floc consists of two groups of voids:

Small voids usually of cross-sectional area smaller than 10 □m2 and
Large voids of cross-sectional areas larger than 10 □m2.

According to the hypothetical model, small voids would be associated with flocculi and microflocs whereas large pores would mainly be present in floc aggregates.

In this study, alum and activated sludge flocs were broken-up with increasing amounts of mixing energy. The objective of the experiment was to establish the effect of mixing intensity on porosity of aggregates. Increasing the mixing speed dispersed alum and activated sludge flocs. After every mixing period, a sample of flocs was withdrawn and embedded in resin. Thin sections were cut and porosity of flocs was measured on these sections. The total porosity of the aggregate was divided into two components:

- Small voids porosity – calculated as ratio of the total area of small voids within the floc section to the cross-sectional area of the aggregate and
- Large voids porosity, calculated in the same way but including large voids only.

With increasing mixing intensity the number of small voids decreased in activated sludge flocs. Quite opposite was observed for alum flocs, here mixing had a significant effect on the number of large pores (Table 1).

Table 1 Effects of Mixing Intensity on Small and Large voids Porosity of Flocs – Results of Analysis of Variance

Flocs Type	Small Voids Porosity	Large Voids Porosity
Alum	Effect statistically non-significant	Effect statistically significant
Activated Sludge	Effect statistically significant	Effect statistically non-significant

During floc breakup "large" voids, interconnecting microflocs are affected first.

The reason why "large" voids were not affected in activated sludge flocs is that the size of these "large" is much smaller than 10 □m2. It follows then that microflocs and flocculi must also be smaller in activated sludge floc than they are in alum floc.

To further analyze the structure of alum and activated sludge flocs Sierpinski fractal dimensions were calculated for each floc. Sierpinski dimension indicates the rate at which solid fraction of the floc disappears on the section viewed at increasing magnifications. The higher the dimension the slower is that rate of solid background disappearance. Two different rates are reported, for population of small voids (Dimension 1) and for population of large voids (Dimension2).

Table 2 Sierpinski Fractal Dimensions for Alum and Activated Sludge Flocs

Flocs Type	Sierpinski Dimension 1	Sierpinski Dimension 2
Alum Flocs	1.960	1.920
Activated Sludge Flocs	1.998	1.980

Clearly the rate at which solid background disappears is always slower for activated sludge flocs (Table 2). This confirms that the structural components flocculi and microflocs are much smaller in activated sludge floc than they are in alum floc.

Method Development for Drinking Water Aluminum Measurement Using Graphite Furnace Atomic Absorption Spectrophotometer

By P. T. Srinivasan[1] and T. Viraraghavan[2]

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Determination of trace levels of aluminum present in drinking water is becoming important due to two reasons. One is that the aluminum (Al) present in drinking water because of its increased bioavailability compared to aluminum from other sources, may contribute to possible many neurological disorders. The other reason is that many regulatory bodies across the world like Health Canada, USEPA and WHO are trying to establish a health based guideline value for Al in drinking water, making it imperative for many water treatment plants to accurately and reliably determine Al in their finished water. While there is a variety of analytical techniques available to measure Al such as X-ray fluorescence, spectrofluorimetric analysis, neutron activation analysis and inductively coupled plasma – mass spectrometry (ICP-MS), graphite furnace atomic absorption spectrophotometer (GFAAS) is currently the method of choice for many laboratories measuring Aluminum. Even though GFAAS gives high analytical sensitivity, accurate and reproducible measurement for an analyte (here Al) is difficult without a proper method development and testing for matrix interferences if any by analyzing a reference sample containing a known amount of analyte. In method development for Al, considerable amount of differences exist (in literature) in developing a suitable temperature program (furnace optimization), use of modifiers and the way (mechanisms) by which ground state Al atoms are formed during atomization. In this connection, the objectives of the present study are i) to explore the different furnace programs by changing temperature and time during drying, charring and atomization of samples; ii) use of different matrix modifiers (calcium, magnesium nitrate) in enhancing sensitivity of the analytical signals of the analyte namely Al and iii) verify the method developed by measuring a reference sample containing known amount of analyte. The instrument used in this study was Varian type SpectrAA – 600 Zeeman GFAAS equipped with GTA 100 – graphite tube atomizer and PSD –100 programmable sample dispenser. During this study thirteen different furnace programs were developed and out of that one furnace program was found to be successful. Details are to be explained in full paper. The experiments showed that i) sample drying time was proportional to the sample volume, and a uniform sample drying without spattering of samples in graphite tubes was essential to get reproducible results ii) aluminum present in the sample should not be lost during charring iii) a high atomization temperature (2850) helps in getting a good signal and iv) a 0.1% magnesium nitrate proved to be the best modifier without which a proper signal was not possible during this method development.

The observation made in this study is in agreement with some of the studies mentioned in the literature. The optimized furnace program was verified for matrix interference if any by running reference standard obtained from National Water Research Institute (NWRI) of Canada. The true value of aluminum present in the standard was 95 ±20.8°µg/L (mean ±2SD) and the measured value was 84 µg/L which falls within the mean ± 2SD of the reference standard. Experiments are currently in progress to investigate the degree to which the proposed method is susceptible to interference from common interfering elements namely Mg, Fe, K, Cu, and Ca that are present in water in the determination of aluminum by GFASS.

Sewage treatment by a vertical flow constructed wetland - a success story

L.R. Rozema [1], T. Braybrook [2], E.R. Lemon [2]

Since the Fall of 1994 an experimental constructed wetland has treated sewage on a year round basis in a cold climate at Niagara-On-The-Lake, Ontario. This was the third and final experimental system constructed at this site. Treatment relies on sub-surface, vertically pulsed fluid flow through cattail beds. One cubic metre cells containing various root-bed media were tested. These cells were operated in series, with each series containing two cells. One years worth of data is presented here, collected after 19 months of continuous operation. The series containing either a Queenston Shale or a Fonthill Sand media provided the best treatment. The Queenston Shale series reduced BOD_5 by 96.81%, suspended solids by 94.24 %, total phosphorus by 56,74 % and total nitrogen by 52.66 %. This series would easily meet most MOEE requirements for discharge, save for total phosphorus. Ammonia and ammonium concentrations were consistently below 2.5 mg/L. The series containing Fonthill Sand reduced BOD_5 by 95.68 %, suspended solids by 92.83 %, total nitrogen by 37.11 % and total phosphorus by 91.60 %. Ammonia and ammonium concentrations were consistently below 2.5 mg/L. This series would easily meet most MOEE requirements for discharge, as total phosphorus concentrations never exceeded 1.0 mg/L.

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RECLAIMATION AND RECYCLING OF CHROMIUM (VI) AS A METHOD FOR WATER PROTECTION AND RAW MATERIALS REUSE

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The treatment of industrial wastewater containing Cr (VI) is one of the major concerns nowadays due to the high toxicity of chromium ionic form and the prevalence of the chromium in a wide variety of industrial processes. The concentration of chromium compounds commonly used in the chromate dips varies in the range from 0.56 g/L for clear bright baths to 25 g/L for olive-drab dips.

In Poland, about 5 million tons of hazardous sludge, containing chromium is deposited.

The great volume of water used during the rising processes generating the main problem to metal-finishing industries. As a general consideration, it can be said that rinse water presents a concentration between 50-500 mg/L of chromium (VI), being necessary to treat them before discharge to surface water.

Several methods are available to remove heavy metals produced in metal finishing industries from wastewater streams. Although, standard technologies employed for the treatment of these effluents, such as reduction and precipitation, ion exchange, electrodialysis, and reverse osmosis, reduces the chromium concentration in the waste effluents to a low level; these techniques create an additional sludge and they are costly.

Extraction of chromium (VI) from sulphuric acid solutions was carried out by means of 0.05M Triisooctyl amine (TIOA) in methyl isobutyl ketone (MIBK) and chloroform. Re-extraction was conducted with 2M solution NaOH. Chromium (III) is not extracted with TIOA sulphate solutions. Oxidation of chromium (III) to chromium (VI) was carried out by means of ammonium persiflage.

The removal of cadmium from aqueous solutions. I. The application of biopolymers for cadmium uptake.

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The discharge of cadmium into the environment by electroplating industry, manufacturing of pigments, nickel-cadmium batteries production plants or other industries constitute one of the major reasons for the increasing amounts of water pollution due to this metal.

Therefore there is a necessity to develop new technologies of wastewater treatment. Polymers of biological origin are known to bind metals and may be used to recover or to remove metals from industrial wastewater. These techniques may be the alternative to ineffective or uneconomical conventional chemical methods.

Cadmium adsorption by biopolymers was analyzed. The polymers included 2% alginate and alginate with the addition of polyvinyl alcohol (APV) in the proportions of 1.5% : 0.5% and 2% : 5%. Sorption isotherms and diffusion coefficients were determined. It was shown that sorption was the main limiting process.

Here are some results of the research:

- mass transfer coefficient (k) for 2% alginate and 1.5% of alginate with 0.5% APV were 5.66 and 5.6×10^{-4} $m \cdot s^{-1}$, respectively and a bit lower for 2% alginate with 5% APV and equal 4.55×10^{-4} $m \cdot s^{-1}$,
- internal diffusion coefficient (D_{eff}) for 2% alginate and 1.5% of alginate with 0.5% APV were 2.87 and 3.00×10^{-10} $m \cdot s^{-1}$, respectively, whereas for 2% alginate with 5% APV was 1.91×10^{-10} $m^2 \cdot s^{-1}$,
- constants K_C and q_{max} of Langmuir equation for 2% alginate equaled 0.038 $(mg \cdot dm^{-3})^{-1}$ and 163 $mg \cdot (gsm)^{-1}$, respectively, for 1.5% of alginate with 0.5% APV were 0.02 $(mg \cdot dm^{-3})^{-1}$ and 182 $mg \cdot (gsm)^{-1}$, whereas for 2% alginate with 5% APV equaled 0.054 $(mg \cdot dm^{-3})^{-1}$ and 46.5 $mg \cdot (gsm)^{-1}$.

The completed study shows that the addition of polyvinyl alcohol in low concentrations (0.5%) increases the polymer mechanical resistance and the effectiveness of cadmium removal from aqueous solutions remains unchanged. The addition of 5% APV to alginate reduced the effectiveness of all individual processes such as external and internal diffusions well as constants K_C and q_{max} determined from the Langmuir equation.

The removal of cadmium from aqueous solutions. II. Uptake and release of cadmium by biopolymers in sorption-desorption cycles.

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Practical polymer utilization in metal removal from industrial wastewater prior to their discharge into surface water depends on polymer sorption and ease of metal recovery through desorption. The possibility of polymer recycling is also essential.

Cadmium uptake and release from aqueous solutions by polymer in sorption and desorption cycle was studied in this paper. The following polymers were used in the research: 2% alginate and alginate with polyvinyl alcohol (APV) in the proportions of 1.5% : 0.5% and 2% : 5%.

At the beginning of the experiment and after each cycle of desorption, cadmium solution was introduced containing 50 $mgCd^{2+} \cdot dm^{-3}$. The following mineral acids were used: 1M HNO_3, 1M H_2SO_4, and 1M HCl.

It was shown that the amount of the removed cadmium was the lowest in the first cycle. In the following cycles cadmium sorption was almost complete. The lowest amounts of cadmium were desorbed in the 3 and 4 cycles and the most cadmium was desorbed in the final cycles.

Based on the completed experiments it has been found:

- the largest and comparable effectiveness of desorption was achieved for 2% alginate and nitric acid for 1.5% alginate and 0.5% APV with sulfuric acid,
- the lowest desorption effectiveness was found for 2% alginate with 5% APV which could be concluded that the increase of APV concentration to 5% causes desorption effectiveness decrease,
- among the tested desorbents, hydrochloric acid was the least effective in most cases,
- the number of cycles was the smallest for alginate and equaled 7 and increases up to 11 with the APV addition.

The removal of cadmium from aqueous solutions. III. Extraction of cadmium from sewage sludge.

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Currently sewage sludge is utilized with the use of the following techniques: landfilling incineration, oceanic dumping and agricultural fertilizers. If sludge contains heavy metals then most of the above methods stand the risk of metal migration to surface and ground water. Therefore an effective technique of metal removal from sludge is essential.

This paper evaluates the utilization of 1M of sulfuric acid (pH=2.2) and 0.05M EDTA (pH=6.7) as absorbents. Activated sludge from anaerobic culture is a SBR sequence reactor multiplied on domestic wastewater with cadmium. The cadmium concentration in activated sludge was 1.8 $mg.(gsm)^{-1}$. The rates of cadmium desorption from activated sludge and dehydrogenases activity over time was studied.

The almost total activity decrease of dehydrogenases was found when desorption was done with sulfuric acid from 0.05 to 0.005 $\mu mol.mg^{-1}$). A higher efficiency of desorption around 99% was achieved for EDTA. The desorption efficiency of sulfuric acid equaled 91%.

TREATMENT OF PULP AND PAPER INDUSTRY WASTEWATER IN AN AEROBIC MOVING BED BIOFILM REACTOR.

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In the past, untreated wastewater from the pulp and paper industry caused great pollution of water in lakes and rivers. New production process technologies and introduction of wastewater treatment, has drastically reduced the discharge of pollutants over the last couple of decades.The number of mills investing in biological wastewater treatment plants has grown rapidly.

The wastewater from pulp and paper mills consists of lignin, organic acids, organic derivatives of sulfur, resin soap – very difficult biodegradable substances. Thus the conventional processes of biological treatment effluents from pulp and paper mills have not good results. For example the mill in Swiccie in Poland discharged 2.3 tonns COD and 7,7 tonnes BOD_5 per day in 1997.

The wastewater from pulp and paper mill in Ostrolcka was biologically treated in a two-stage activated sludge system. In 1995 the mill decided to build a full-scale moving bed biofilm reactor as a pre-treatment of wastewater. The moving bed biofilm process was chosen because of the following reasons: the process is compact, has flexible design and low investment cost, pilot-scale result show high level of COD- removal efficiency at high volumetric loads.

Based on experience from Ostrolcka mill where pre-treatment of wastewater in the moving bed biofilm reactor had a good results, other Polish pulp and paper mill in Swiccie has decided to build moving bed biofilm reactor.

The moving bed biofilm process is a joint system of a conventional biofilm process and an activated sludge process. The process is based on the biofilm principle and the biofilm is attached to a small plastic element that moves freely along with the water in the reactor. The biofilm surface area in the reactor is controlled by the quantity of plastic elements filling the reactor.

The objective of the pilot plant study was to obtain the pre-removal efficiency COD from the pulp and paper industry wastewater from Swiccie. The process was tested on the moving bed process in different hydraulic times of retention and with the addition of the biological preparation DBC Plus. The pilot plant was operated continuously for 3 months. Soluble COD reduction through the pilot plant was about 30%. Results show that at the highly volumetric organic load, it is advantageous to help the biological process by adding the biological preparation.

Date Due

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