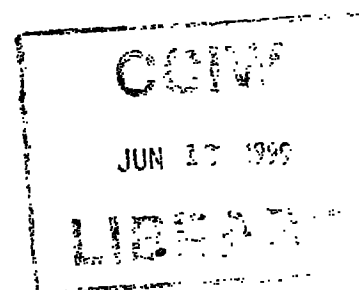**Thirty-Third**
Central Canadian
Symposium on Water
Pollution Research

February 9 and 10, 1998
Canada Centre for Inland Waters
Burlington, Ontario

ABSTRACTS

Themes
Advances in Water Pollution Control Technologies
Assessment and Remediation of Water Pollution Impacts

Sponsors
Canadian Association on Water Quality
National Water Research Institute

THIRTY THIRD CENTRAL CANADIAN SYMPOSIUM ON WATER POLLUTION RESEARCH
February 9, 1998, Canada Centre for Inland Waters
867 Lakeshore Road, Burlington, Ontario

● FINAL PROGRAM ●

FEBRUARY 9, 1998

8:00-8:45	Registration
8:45-9:00	Opening Remarks, South Seminar Room P. Jones, President - CAWQ

Session 1: Advances In Water Pollution Control Methodologies
South Seminar Room, Chair: J. Stephenson

9:00-9:30	**R. Jones, J. Stephenson and G. Wheeler** Application of Process Simulation in the Design of Upgrades and Expansion of the Burlington Skyway WWTP
9:30-10:00	**M. Boivin, P. Lessard and J. de la Noüe (S)** Modelling Removal of Nitrogen and Phosphorus in a Microalgae Wastewater Treatment System
10:00-10:30	**Éric Giroux and M. Newbigging** Modeling and Simulation of the Gabal El Asfar Wastewater Treatment Plant
10:30-11:00	**COFFEE BREAK - MAIN MALL AREA**
11:00-11:30	**Jan A. Oleszkiewicz** Feasibility of Nitrification in Oxygen Activated Sludge
11:30-12:00	**C. Cousin and J. Ganczarczyk (S)** Effects of Salinity on the Physical Characteristics of Activated Sludge Flocs
12:00-12:30	**B. G. Brenner, W. Jesien, L. J. Schneider and R. Gehr (S)** An Appraisal of Fouling During UV Disinfection for Physiochemical and Biological Wastewater Treatment Plants
12:30-1:15	**LUNCH - MAIN MALL AREA**
1:15-1:45	**J. B. Copp and P. L. Dold (S)** Influence of Influent Phosphorus Concentration on the Anaerobic COD Uptake to Phosphorus Release Ratio in a Biological Excess Phosphorus Removal System

1:45-2:15	**S. Kok, J. Shaw and P. Seto** Environment Canada's Great Lakes 2000 Cleanup Fund Sewage Treatment Program
2:15-2:45	**J. A. Nicell** Developments in Odour Impact Assessment
2:45-3:15	**D. Liu, G. J. Pacepavicius, R. J. Maguire, Y. L. Lau, H. Okamua and I. Aoyama** Review of Cyclone Fermentor Test For Assessing The Biodegradability
3:15-3:45	**COFFEE BREAK - MAIN MALL AREA**
3:45-4:15	**K. L. E. Kaiser** Review of Biodegradability Tests for the Purpose of Developing Regulations
4:15-4:45	**Efraim Halfon** CD-ROM Demonstration - Canada's State of the Environment Report - This Covers The Great Lakes
5:00-5:45	**CAWQ Annual General Meeting - South Seminar Room** **Announcement of Winner of Student Presentation**
6:00-7:00	**Wine & Cheese Reception - Cafeteria**

Session 2: Advances In Water Treatment Methodologies
North Seminar Room, Chair: K. Roberts

9:00-9:30	**P. T. Srinivasan, T. Viraraghavan and J. Bergmann (S)** Aluminum Speciation During Drinking Water Treatment
9:30-10:00	**B. Gorczyca and J. Ganczarczyk** Porosity of Alum Coagulation Flocs
10:00-10:30	**Sh. Bahrami and J. J. Ganczarczyk (S)** External Surface and Porosity of Ferric Flocs
10:30-11:00	**COFFEE BREAK - MAIN MALL AREA**
11:00-11:30	**S. Jasim** Particle Count Evaluation of Polyaluminum Chloride Performance in Water Treatment
11:30-12:00	**C. Baxter and S. J. Stanley (S)** Development of a Full-Scale Artificial Neural Network Model for the Removal of Natural Organic Matter
12:00-12:30	**M. J. Conboy and Mike Goss (S)** Bacterial Contamination of Rural Drinking Water Wells
12:30-1:15	**LUNCH - MAIN MALL AREA**

Session 3:Assessment and Remediation
of Water Pollution Impacts
North Seminar Room, Chair: I. Brindle

1:15-1:45	**N. Gagné and Rosa Galvez-Cloutier (S)** Effet de la distribution géochimique du Pb, du Zn et du Cr et sur la biodisponibilité pour trois plantes: Le taraxacum officinal, le paturin du Canada et le trifolium repens
1:45-2:15	**M. Elektorowicz and G. Hatim (S)** Scale-up of the Electrokinetic Surfactant Supply to the Hydrocarbon Contaminated Soil
2:15-2:45	**S. Ghoshal** Biodegradation of Polycyclic Aromatic Hydrocarbons From Nonaqueous Phase Liquids
2:45-3:15	**S. Burland and E. Edwards (S)** Enrichment and Characterization of Anaerobic Benzene-Degrading Cultures
3:15-3:45	**COFFEE BREAK - MAIN MALL AREA**
3:45-4:15	**P. Patel, J. G. Henry and D. Prasad (S)** Plant Material as Substrate for Sulphate Reduction for Acid Mine Drainage Treatment
4:15-4:45	**G. Ruygrok** Diamond Exploration in Angola Using Onshore Digital Seismic Imaging
5:00-5:45	**CAWQ Annual General Meeting - South Seminar Room** **Announcement of Winner of Student Presentation**
6:00-7:00	**Wine & Cheese Reception - Cafeteria**

Poster Session Displays
Main Mall Area

Kealy Dedman
Monitoring of a Constructed Wetland

A. Smoczynska and M. Elektorowicz
Efficacity of Phytoremediation Related to a Synergistic Behaviour of Heavy Metals in Soil

A. Smoczynska, I. Bojanowska and H. Bartnicka
Ecological Concerns About the Phytoremediation of Cadmium Contaminated Soils

APPLICATION OF PROCESS SIMULATION IN THE DESIGN OF UPGRADES AND EXPANSION OF THE BURLINGTON SKYWAY WWTP

Dr. Richard Jones

Water Technology International Corporation, 867 Lakeshore Rd. Burlington, Ont., L7R 4L7

John Stephenson

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Gerry Wheeler

Regional Municipality of Halton, 1151 Bronte Rd., Oakville, Ont., L6M 3L1

The Skyway Wastewater Treatment Plant in Burlington, Ontario, is presently designed to treat 93 MLD before discharging to the Hamilton Harbour. To accommodate growth in the community for the next 10 years, a project is currently underway to expand the plant capacity to 116 MLD by the year 2001. Because the Hamilton Harbor has been designated as an Area of Concern (AOC) by the International Joint Commission (IJC), the Hamilton Harbour Remedial Action Plan (RAP) has developed strict loading based targets for both ammonia and phosphorus which the plant will be required to meet if it continues to discharge to the Harbour. Relocation of the plant outfall to Lake Ontario is also being considered as part of the expansion project. However, ammonia and phosphorus limits are also likely with a lake outfall.

Over the past year, an optimization program has been in progress and operations staff have reduced phosphorus loadings to the Harbour substantially. The effluent now meets initial RAP targets most of the time. However, ammonia levels are still above RAP targets. Establishing nitrification at the plant will require an increase in aeration tank sludge mass which may result in an increase in effluent phosphorus.

In order to establish the requirements for nitrification at the plant, a number of analyses and tests were conducted to develop data to be used to calibrate a dynamic process model of the plant. Composite sampling of raw sewage, degritted sewage, primary effluent, mixed liquor and final effluent allowed certain stoichiometric ratios to be established, thereby allowing calculation of wastewater COD and TKN fraction-based wastewater characteristics for modelling from the historical data base of BOD_5, TSS, TKN and TP. A bench scale sequencing batch reactor (SBR) was operated with Skyway degritted sewage at 15 °C for about two months to establish nitrification rates and further characterize the wastewater for modelling.

A dynamic process model was configured for the Skyway WWTP using the GPS-X simulation software. The issues explored with the model include:

- the design and operating requirements for nitrification at both 93 MLD and 116 MLD;
- the impact on nitrification requirements of reducing aeration tank organic loading through optimization of the primary clarifiers;
- the impact on nitrification requirements of reconfiguring the aeration tank flow pattern to create more plug flow conditions and installing anoxic zones;
- the potential benefits of step feed; and,
- the impact on nitrification of nitrogen-rich sidestreams such as digester supernatant and sludge storage tank farm supernatant.

This paper will describe the tests conducted to calibrate and configure the model and the results of the simulation studies.

MODELLING REMOVAL OF NITROGEN AND PHOSPHORUS IN A MICROALGAE WASTEWATER TREATMENT SYSTEM

M. Boivin[1], P. Lessard[1] et J. de la Noüe[2]

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It is well known that phosphorous and nitrogen compounds in municipal wastewater are harmful to environment. Biological nitrogen removal coupled with chemical precipitation by addition of a coagulant are widely used to tackle this problem. However, these processes have some disadvantages such as high operating costs and increased sludge handling. Solar technology using algal biomass is a biological process which may be a good alternative for nutrient removal for small flow treatment plants. A photobioreactor has been developped for the treatment of secondary effluent[1]. In order to predict the photobioreactor behaviour and to control the operation under different conditions, a mathematical model simulating the inorganic nitrogen and phosphorus removal has been developed. The purpose of the paper is to present the model, to show the implementation made with GPS-X and to discuss the validation procedure used.

The model is composed of four state variables. Two are used to express the total nitrogen pool in the system; one for the nitrate (NO_3^-) concentration and one for the ammonia (NH_4^+) concentration. The two other variables express the inorganic phosphorus (PO_4^{3-}) and the algal biomass concentrations. In addition to kinetics and stoechiometric parameters and initial concentrations, the model needs some input data like pH, temperature and light intensity; data that are easily monitored.

The photobioreactor works like a batch reactor and the implementation on GPS-X uses this treatment unit. A new library, called "biolib", has been created, and the CSTR (Completely Stirred-Tank Reactor) equations were copied in it. The equations in the CSTR model have been changed to include all of the photobioreactor processes. During this step, new parameters and variables, mostly needed to simulate the algae growth and nutrients uptake in the reactor as well as to reproduce the ammonia stripping and the phosphorus precipitation phenomena, were added in the GPS-X's ".con" and ".var" files.

The model's validation has been done with the results of four experiments conducted wih the cyanobacterium *Phormidium bohneri*[2]. The model was first validated with data obtained from experiments done with an artificial substrate and secondly with data from other experiments using real wastewater from secondary effluent. The model behaved well when compared to the data.

[1]   Théberge A., Lessard P. et de la Noue J. 1997. Épuration d'effluents de petites municipalités par lagunage : utilisation d'une biomasse algale pour l'enlèvement du phosphore. dans Comptes Rendus du 20ᵉ Symposium sur le Traitement des Eaux Usées, Montréal, Qc, Canada (Novembre, 1997)), pp: 193-204

[2]   Sylvestre S., Lessard P. et de la Noue J. 1996. Performance d'un photobioréacteur utilisant la cyanobactérie *Phormidium bohneri* pour l'enlèvement de l'azote et du phosphore. Env. Technol., 17 (7) : 697-706.

MODELING AND SIMULATION OF THE GABAL EL ASFAR WASTEWATER TREATMENT PLANT

Éric Giroux, Michael Newbigging

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The principal objective of this work was to simulate and review the capacity and predicted performance of the first stage of the Gabal El Asfar wastewater treatment plant, serving the greater Cairo area in Egypt. The first stage was already under construction, and prior to construction of the second stage, the owner wished to re-evaluate its design compared to the first stage. The design of the first stage was completed many years ago, and a second review of design conditions with modern design and review guides was required.

The plant is of the conventional activated sludge type, and includes screening and grit removal, primary sedimentation, surface aeration, final clarification and chlorination facilities. The sludge treatment facilities comprise thickening in two stages: anaerobic digestion and mechanical dewatering. Sludge gas in excess of demand for digester heating will be used for power generation with surplus automatically wasted to a flare stack. The plant will discharge to the Belbeis drain and ultimately to a lake on the Mediterranean coast.

We have reviewed the capacity of the current design using GPS-X. The use of this simulation and modeling tool was critical since no actual operating data were available. Based on design data and data from nearby treatment plants, we used the simulator to evaluate different operating scenarios with key operating variables and parameters. We have examined the expected performance based on key parameter ranges. The review included an assessment of the steady state and dynamic performance of the plant.

We found that the plant will operate within its effluent requirements, and the capacity of the liquid train is greater than the design capacity. However, the following items are of concern:

- The ability to inhibit nitrification during the summer
- The ability to handle maximum loading, especially through the solids handling processes
- The capacity of the solids handling process is not as high as expected
- Pumping capacity may be limited in the solids handling processes during maximum loading periods

The following recommendations were made as a result of this work:

- The plant should plan for nitrification, at least in the summer, and operate to handle this condition
- Investigate the final clarifier inlet structures and baffling should be investigated to enhance solids separation in these tanks
- Investigate options for solids thickening including pumping thicker primary sludge to the gravity thickener to provide enhanced separation, reduce hydraulic loading to downstream processes and to provide for temporary storage in the settlers during maximum loading periods
- For the future plant expansion, evaluate one-step WAS thickening processes and thicken raw sludge in the primary clarifiers

FEASIBILITY OF NITRIFICATION IN OXYGEN ACTIVATED SLUDGE

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Feasibility of implementing the one-step nitrogen removal process in a pure oxygen activated sludge process (OAS) was tested in full scale by the City of Winnipeg at the 300 ML/d North End Water Pollution Control Center (NEWPCC) and in pilot scale by the University of Manitoba. Results indicated a need for a much more detailed bench-scale simulation of the OAS process to assess the reasons for erratic performance of nitrification and to quantify the effects of alkalinity and pH depression as well as determine if denitrification could help restore some of the lost alkalinity.

This presentation will cover that bench scale study which had three objectives: 1. What is the potential for nitrification of the NEWPCC effluent in the existing reactors? 2. What are the effects of temperature on nitrification? 3. What is the potential for pre-denitrification to alleviate the alkalinity destruction and the resulting pH drop?

The reactors were maintained either in room temperature (23°C) or a walk-in temperature- controlled room set at 12°C±1. Two configurations were used: straight nitrification and pre-denitrification—>nitrification.

The hydraulic residence time - HRT in the NEWPCC full scale reactors is usually 2.5 h and the SRT (based on the mass of solids in the reactor) is 2±1 day. In the initial phase of the bench-scale study (which preceded this study and was reported elsewhere) we have simulated two hydraulic retention times: 2.5 h and 4 h and concluded that a better control of biomass is necessary as significant portion resided in the clarifier. It was decided to test the most unfavorable nitrification conditions: one stage carbon and ammonia removal: short 2.5 h HRT, such as exists in the full scale and at 12°C - typical winter wastewater temperature.

After establishment of TKN removal at or above 80%, at 20 d SRT, the reactors were adjusted to a range of SRT equal to 10, 20 and 30 days. The removals were less differentiated than expected and there was no correlation between SRT and performance. The SRT was based on the total mass in the system (system SRT - SSRT) and the mixed liquor solids were quite high in the reactor. The differentiation in the mass of sludge came after the mass in the clarifier was added up in calculation. At higher SRT more mass resided in the clarifier than in the reactor. Similar observation was independently made during the full scale studies in NEWPCC, where at SRT>15 d sometimes more than 50% of the biomass resided in the clarifier.

In conclusion, the increased SRT is necessary to keep the SRTmin above the 7d limit for this temperature and to maintain a pool of nitrifiers to compensate for high flows and larger C/N ratios. The effective benefit of the extended SRT is, however, somewhat obscured by the fact that a large portion of the biomass resides in the final clarifier. Sedimentation then becomes the limiting process in the ultra-short-HRT activated sludge process such as the pure oxygen OAS systems.

After defining the role of SRT and the fate of solids in the system, the main question remaining was: is the HRT=2.5 hours long enough - or is longer hydraulic residence necessary? Inadequate HRT would be evidenced by resulting effect of the incoming carbon to nitrogen ratio (C/N) which would affect performance, regardless of the SRT.

In order to test the effect of denitrification on nitrification efficiiency two parallel process trains A and B were operated at system SRT=20 d, at 23°, degradable SOC/TKN ratio of 0.7-0.8 and alkalinity of 300-350 mg/L CaCO3. The resulting specific nitrification rate SNR = 2.1-2.7 mg N/g VSS·h based on filterable (soluble) TKN removal.

Specific denitrification rate for train B was SDNR = 4.3 mg/g VSS·h for the period of combined recycle R=1.5 Qraw;, while the averaged TN removal efficiency across the whole system was 65% TN. For the period of R=2.5 Qraw the SDNR = 2.25 mg/g·h and the TN removal efficiency across the system dropped to 40% TN. Effluent alkalinity dropped to 200 mg/L and the pH to 6.5.

In conclusion:

1. Long term 80% nitrification was accomplished at 12°C in one stage carbonaceous/nitrifying reactors having HRT=2.5, at a wide range of SRT from 10 to 30 days. The nitrification rates were strongly correlated to the incoming ratio of carbon/nitrogen - C/N and varied from 2.3-2.6 mg NH4-N/g VSS·h.

2. Sedimentation was one of the limiting factors in the ultra-short-HRT activated sludge process such as the pure oxygen OAS systems often more than 50% of biomass resided in the clarifier.

3. Pre-denitrification in an anoxic reactor at HRT=1.5 h eliminated the pH and alkalinity depression.

4. Fluctuations of C/N affected the specific denitrification rate which varied at 2.25-4.3 mgN/g·VSS·h.

5. TN removal across the whole system was limited by the amount of recycle to a maximum of 65% TN. The optimum recycle was 180% of the raw waste flow. Above that recycle level the amount of oxygen fed into the anoxic reactor was too high to maintain negative redox potential and denitrification suffered. Low C/N ratio in the raw influent contributed to the problem of low TN removal.

EFFECTS OF SALINITY ON THE PHYSICAL CHARACTERISTICS OF ACTIVATED SLUDGE FLOCS

Chris Cousin and Jerzy Ganczarczyk
Department of Civil Engineering
University of Toronto

The effect of increased salinity on the physical characteristics of activated sludge flocs was studied. Waste activated sludge, obtained from the Main Treatment Plant, Toronto, Canada, was exposed to incremental increases of NaCl and then the physical structure of the individual flocs was measured. The experimental setup was a series of small scale batch reactors with mixing of $G \approx 22 \ s^{-1}$. The sludge was exposed to 0, 10, 20, 30, and 45 g NaCl/L for 15 minutes each. A portion of the sample was then fixed in either agar or resin. The size distributions of the area, equivalent diameter, perimeter, longest dimension, and shape factor of the flocs were determined from the agar embedded samples. The porosity, boundary fractal dimension, and Sierpinski fractal dimensions were determined from the resin embedded samples. A time profile of the experiment, using 30 g NaCl/L and time points of 0, 1, 5, 10, 15, and 30 minutes, was also done to understand floc development. The characteristics were measured using light microscopy and image analysis.

Two separate series of tests were run and it was determined that, for both tests, as the NaCl concentration was increased the mean floc area, equivalent diameter, perimeter, and longest dimension all increased, with linear regression analysis resulting in r^2 values ranging from 59% for floc area, test #1, up to 97% for perimeter, test #2. It was also determined that the flocs were becoming more elongated with decreasing shape factor with the increasing NaCl concentration. The mechanism involved in the increase of the floc sizes is considered to be that described by the DLVO theory, where the electrical double layer of charges surrounding the particles is compressed by the change in ionic concentration and so the particles are able to approach one another more closely, resulting in larger aggregates.

From the first series of porosities measured it was found that the mean porosity increased linearly ($r^2 = 86\%$). No correlation was found between NaCl and the boundary fractal dimension, which is a measure of the ruggedness of the surface profile of the floc. The flocs exhibited two separate Sierpinski fractal dimensions, thereby indicating the presence of two populations of pore spaces. The Sierpinski fractal dimension for smaller pores was found to be higher and of a more consistent value as the NaCl concentration was increased. This indicates that the distribution of pore sizes is more uniform, and also that the effect of the NaCl addition was less on the smaller pores than on the larger pores.

Examination of the size distributions revealed that the data were best fitted by a log normal distribution and that for both tests, as the NaCl concentration was increased, the distribution of the characteristic tended to shift towards a higher proportion of larger values. The opposite was true for the shape factor results as the trend was shifted to a higher proportion of smaller shape factors with the increased NaCl. Finally, the time profile experiment revealed that the flocs undergo a development stage of about 15 minutes prior to achieving maximum, or equilibrium, size, validating the use of a 15 minute sampling time for the treatment experiments.

An appraisal of fouling during UV disinfection for physicochemical and biological wastewater treatment plants

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The development of fouling of UV lamps during the course of wastewater treatment is a serious nuisance and disinfection problem. While fouling is a universal problem in UV disinfection plants, it is particularly evident when dealing with effluents from physicochemical treatment, and especially those employing iron coagulants. However in one case reported below, fouling has also been a problem with a biologically treated effluent.

This study was designed to examine fouling phenomena from two treatment plants. The Montreal Urban Community Wastewater Treatment Plant (MUCWTP) is a physicochemical system which uses ferric chloride as the primary coagulant. A low-pressure lamp pilot plant was installed and operated there during the 1997 summer disinfection period. An assessment was made of the iron balance in the influent and the foulant, as well as the fecal coliforms, foulant mass, UV_{254} transmission, and other parameters in an attempt to correlate influent quality with fouling extent and rate. In addition, the foulant material was extracted in a number of buffers and protein fingerprints were run on SDS polyacrylamide gel electrophoresis to monitor for differential protein adhesion to the UV lamp sheaths. These fingerprints were contrasted to upstream and downstream material. The second plant studied was a full-scale treatment facility in the Quebec Urban Community (QUC), which uses biofilters upstream of UV disinfection. Here, the foulant forms rapidly (within a few days) but is very thin, hence the analysis focussed on metals in the influent as well as in the phosphoric acid solution used to clean the lamps.

Preliminary assessment of the MUCWTP results shows that the influent iron concentration to the UV system ranged from 1.8 - 3.6 mg/L, but the percentage of iron in the foulant solids grew from approximately 1% after 6 days to 8.75 % after 28 days. Physicochemical and protein analyses are still ongoing, but indications are that the combination of organics and iron in the influent lead to the rapid accumulation of foulant which may contain a biomass.

Analysis of data from the QUC tests are also continuing. Interesting features include significantly higher concentrations of Al, Ca, Fe, and Mg in the cleaning solution than in the influent. Thus even though Fe is rather low in the UV system influent (less than 1.0 mg/L and often approaching 0.4 mg/L or less), nevertheless it features prominently in the foulant material. Furthermore, Ti (a strong UV absorber) is close to 1 mg/L in the fresh acid solution and 0.45 mg/L in the foulant itself, whereas its concentration in the influent is only 0.1 mg/L.

These results show, first, that although "high" iron concentrations in the influent clearly lead to fouling problems, the foulant itself can concentrate iron as well as other metals which may only be present in "medium" concentrations. Second, cleaning solutions should be assessed for their role in exacerbating the problem. Finally, the interaction between organic chemicals, metals and secondary substances such as proteins needs to be further evaluated regarding their role in the fouling process.

Developments in Odour Impact Assessment

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Of the various categories of air pollutants, odours are ranked as the major generators of public complaints to regulatory agencies in North American communities. Many of the sources of such odorous emissions are publically and privately owned and operated facilities for the treatment of wastewaters, sludges and solid wastes. While regulatory agencies and facility personnel are often expected to deal routinely with community odour problems, they have no truly objective strategies for assessing the impacts of odorous emissions on communities affected by stationary sources. Consequently, the lack of such methods prevents the development of strategies which would be used to eliminate, or at least minimize, community odour nuisances.

The Odour Impact Model (OIM) is an extension of the currently methodology for the measurement of detection thresholds of odorous gases. The extension involves the use of olfactometry to establish dose-response relationships for the odour rather than a single threshold. The OIM includes measures of the probability-of-response and degree-of-annoyance as a function of a range of odour concentrations or dilutions. The OIM may be used in conjunction with dispersion modelling which, based on local geographic and meteorological conditions and source parameters, provides predictions of odor concentrations in the surrounding community.

The Industrial Source Complex Short Term Dispersion Model Version 3 (ISCST) was chosen for this study. The capabilities of ISCST were verified using data collected during a year-round study of the impacts of the odorous emissions from a major industry located in Ontario, Canada. ISCST was successfully applied to the industrial complex in order to predict the zone of its impact on the surrounding community under a variety of meteorological and operating conditions. A natural extension of this work was to use the ISCST model to predict the dilutions that an odour would undergo in a neighbourhood upon release and dispersion into the surrounding atmosphere. By combining the dose-response relationships from the OIM with dispersion modeling, this strategy allows for variables such as odour concentration, gas flowrate and local geographic and meteorological conditions to be considered in an odour impact assessment. Dispersion modelling can then be used in conjunction with the OIM to provide measures of the probability-of-response and the corresponding degree of annoyance of the surrounding population. The combination of the OIM with dispersion modelling (not necessarily ISCST3) provides a basis for significantly improving current regulations by incorporating the effects of odour hedonics into estimates of the impact of odorous emissions on surrounding communities. Through the use of a complete set of meteorological data for a typical year, the dispersion model can be used to identify the meteorological conditions under which the greatest impact would occur. Consequently, the severity of the impacts from different sources in a neighbourhood can be assessed and ranked. Subsequent analyses of the model output and the location of the neighbourhood impact can provide regulatory agencies and plant management with a basis for prioritizing their approach to resolving impacts which originate from odorous sources.

Review of cyclone fermentor test for assessing the biodegradability

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Abstract

This review was attempted to demonstrate the use of the cyclone fermentor test in determining the biodegradability of organic and organometallic compounds under controlled laboratory conditions. The persistence of many priority chemicals including herbicides, insectcides, lampricide, chlorophenols, PAHs, and organotins has been satisfactorily assessed by the fermentor test, and the results were compared with other biodegradability tests. In addition, the application of the fermentor test in the development of structure-biodegradability relationship will be discussed.

REVIEW OF BIODEGRADABILITY TESTS FOR THE PURPOSE OF DEVELOPING REGULATIONS

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This review was undertaken with the goal to propose acceptable testing method(s) to be used for the measurement of a chemical's biodegradability under both waste treatment and typical environmental conditions, particularly those relevant to Canada. A multi-tier biodegradability test system is recommended for the protection of the environment and human health. The tiers are comprised of International Organization for Standardization (ISO) standard tests for rapid biodegradability (*Headspace Carbon Dioxide Evolution Test*, ISO #9439), for inherent *biodegradability (Activated Sludge Simulation Test*, ISO #11733) under oxidative conditions, and for biodegradability under anaerobic conditions (*Ultimate Anaerobic Biodegradability Test*, ISO #11734).

POROSITY OF ALUM COAGULATION FLOCS

B. Gorczyca and J. Ganczarczyk

Porosity of alum floc is an important characteristic of an aggregate. Still, very little is known about the porosity of particle aggregates formed in the water coagulation process. Hypothetically, floc grow according to the following model: primary particles form compact flocculi, and these group themselves into microflocs. Microflocs together form floc aggregates. If this model of floc formation is correct, then flocculi, microflocs and floc aggregates would vary in size, resistance to shear, and porosity. The main difference between flocculi, microflocs and floc aggregates is their structure. Porosity can be used to indicate difference in this structure.

In this study, alum coagulation flocs were broken-up with increasing amounts of mixing energy. The objective of the experiment was to establish whether alum flocs disperse into floc components that represent different structure, indicated by porosity. Porosity of alum flocs determined in this study was compared with the data available in literature.

Alum coagulation flocs were formed in jar test . After the flocs were well developed they were dispersed by increasing the mixing speed. After every mixing period, a sample of flocs was withdrawn. A portion of this sample was embedded in agar and the size of flocs was measured (Diameter 2). Another portion of the same sample was embedded in resin. Thin sections were cut from the resin sample. The size of alum flocs and on these sections was determined again (Diameter 1) . The porosity of flocs was determined as the ratio of total area of pores within the floc section to the cross-sectional area of the aggregate.

It was found that the size and porosity of alum flocs decreased with the increase of mixing energy (Figure 1). This means that large flocs had low resistance to shear and high porosity and small flocs showed high resistance to shear and low porosity. This experimentally confirmed the hypothetical model of floc formation.

So far, the porosity of alum coagulation flocs have been measured on microtome sections of aggregates [1] as well as calculated from the settling rates of the flocs [2] (Table 1). Porosity of alum flocs can vary from 6 - 81 % depending on the method for its determination. Clearly, the absolute value for the porosity of alum flocs is still unknown. However, both methods for porosity determination show very similar relationships between the size and porosity of alum flocs. Therefore, the porosity of alum floc is a function of floc size and the form of this relationship was experimentally confirmed.

Table 1 Porosity of Alum Coagulation Flocs - Summary

Average Porosity of Alum Coagulation Flocs [%]	Porosity (P) vs. Equivalent Diameter of floc (D)	Method for Porosity Determination
6	$P = 0.4 * D^{0.680}$	direct microscopic observations [1]
81	$P = 9.7 * D\ 0.408$	on the basis of settling tests 2

FIG.1. SIZE AND POROSITY OF FLOCS VS. MIXING ENERGY
ALUM COAGULATION FLOCS
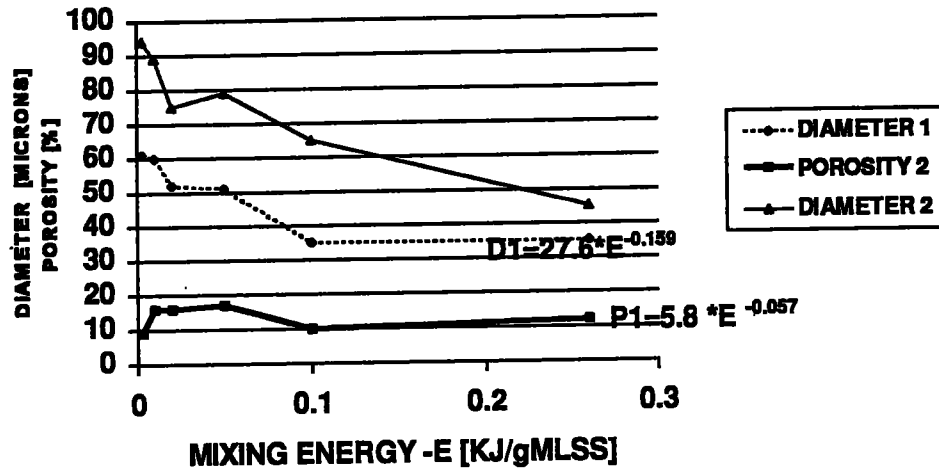
Particle Count Evaluation of Polyaluminum Chloride Performance in Water Treatment

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The drinking water treatment industry is facing increasing demands for improvement of finished water quality and optimization of removal of pathogens such as *Giardia* and *Cryptosporidium*.

Particle counting is an accepted method for monitoring and evaluating filter performance in many industries. The water treatment industry has identified particle counting as an effective method for measuring the performance of the water filtration process. Filtration is an important step in drinking water treatment process to make water safe for human use. In drinking water treatment, coagulation and sedimentation is usually required prior to filtration. The use of a chemical coagulant is a common practice in the water industry.

Polyaluminum chloride coagulants are widely used in the drinking water treatment industry. There are some advantages in using such coagulants compared to using alum (aluminum sulfate), such as that coagulant aid can often be reduced or eliminated, extended filter run times, reduced sludge generation, and lower coagulant dosages. Polyaluminum chloride performs better in cold water, coagulation and flocculation occur very rapidly in cold temperatures.

The Windsor Utilities Commission, Windsor, Ontario, conducted a pilot scale study to evaluate the performance of polyaluminum chloride and to investigate any improvement in finished water quality. The pilot plant used in this study had two identical process trains constructed of organically inert materials. Each side of the pilot plant shared identical physical characteristics which allowed for direct comparison between the two sides of the pilot plant with common raw water quality.

Alum was used as the primary coagulant on side 1 of the pilot plant, a cationic coagulant aid was also added to side 1 (Percol LT 24), while polyaluminum chloride (SternPac) was used on side 2. Three particle counters were used in this study to monitor raw water quality and filtered water quality on both sides of the pilot plant. Particles were measured in eight particle size channels (2-5 μm, 5-10 μm, 10-15μm, 15-25 μm, 50-80 μm, and >100 μm). Differential particle counts (particle counts in different size ranges) and particle size distribution data can be used to track particle counts in specific pathogen size ranges (e.g. *Giardia* and *Cryptosporidium*). Filtered water rarely contains particles greater than 20 μm, therefore, size ranges below 20 μm provide the necessary data for evaluating process performance in the drinking water industry. The particle size distribution reported in this study was; (2-5 μm, 5-10 μm, 10-15 μm, and 15-25 μm).

It was noticed that pH on side 1 where alum was used, was lower than pH on side 2 where polyaluminum chloride was added (7.1 vs. 7.6 respectively).

Preliminary findings indicated improved particles removal was achieved using polyaluminum chloride compared to using alum. Improved log removal was achieved on side 2 of the pilot plant compared to side 1 where alum was used.

At the present time, an experiment is being conducted by using alum versus polyaluminum chloride as primary coagulant where Carbon dioxide is added to depress pH. Carbon dioxide addition to reduce pH represents an alternative to the use of acid or acid-containing products for pH control.

The study provided useful information to assist in considering alternative coagulants to alum to be used in the full scale plant.

"Development of a Full-Scale Artificial Neural Network Model for the Removal of Natural Organic Matter by Enhanced Coagulation"

by

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As water treatment regulations for the removal of disinfection-by-products (DBPs) become more stringent, water utilities must actively search out new technologies that improve the removal of DBP precursors, namely natural organic matter (NOM). Enhanced coagulation has been identified as the best available technology for the removal NOM. Few attempts have been made to develop a full-scale model of the enhanced coagulation process. Models derived from bench-scale and pilot scale experiments often fail when applied to full-scale systems

This report describes the development of a full-scale artificial neural network (ANN) model for the removal of NOM by enhanced coagulation at the Rossdale Water Treatment Plant in Edmonton, Alberta. The ANN modelling technique is an artificial intelligence technique that simulates the human brain's problem solving processes. ANN models are trained to recognize patterns in historical input data in order to correctly predict a desired output in new data. The ANN modelling process can be divided into three stages: source data analysis, preliminary model development, and model optimization. The primary objectives of the source data analysis are to gain a familiarity with the study domain and to examine the applicability of available data to model development. In the preliminary model development stage, the model input and output parameters are selected, the relevant data is organized, and potential network architectures are evaluated. Finally, in the model optimization stage, candidate architectures are optimized and evaluated for use.

At this stage in the research, which is being funded by the American Water Works Association Research Foundation, both the source data analysis and preliminary model development stages have been completed. With respect to the former, a literature review was completed in order to determine which physical, chemical, and operational parameters are likely to impact the removal of NOM by enhanced coagulation. In addition, five years of water quality and operational data was obtained from the utility and was subjected to a comprehensive statistical analysis in order to identify seasonal and daily trends and to ascertain its applicability to the modelling process. With respect to the preliminary model development stage, twelve input parameters were selected to model the desired output, clarifier effluent colour. The output parameter was selected based on the availability of colour data. Recent studies suggest that colour can be used as a surrogate for NOM provided that site-specific correlations are made. Using a series of factorial design experiments, 160 potential architectures were evaluated and 9 candidate architectures were selected for further optimization. The best candidate architecture, when applied to previously unseen data, yielded an R^2 of 0.7 and an average absolute error of 0.36 TCU.

In the next few months, the primary objective will be to optimize the candidate architectures and select the candidate that is best able to model the removal of NOM by enhanced coagulation. The completed model can then be used as a virtual full-scale laboratory to provide insight into the enhanced coagulation process. The effects of simultaneously changing multiple input parameters on the removal of NOM can be assessed without the added costs and scale-up concerns associated with bench-scale and pilot-scale experimentation.

BACTERIAL CONTAMINATION OF RURAL DRINKING WATER WELLS

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In rural areas, drinking water is often supplied by wells which are fed directly by groundwater. In 1992, a Survey of 1200 wells in Ontario (the Ontario Groundwater Quality Survey -- OGWQS), revealed that over one-third of these wells were contaminated with bacteria indicative of fecal contamination. This represents a health risk for people and animals drinking the water. In an epidemiology study of farm families, the incidence of gastro-intestinal illnesses correlated with *E. coli* in wells. These bacteria likely originate from manure. This study was undertaken to determine which factors lead to infiltration of bacteria to groundwater.

A study was conducted to identify indicator organisms that would reliably indicate if samples contained bacteria of manure origin. Total coliforms, fecal coliforms, fecal streptococci and *Clostridia perifringens* were selected. Over three hundred rural wells were then sampled throughout Southern Ontario. All of these wells were part of the original 1992 survey and many had been resampled several times prior to this study. This provided a look at the frequency with which wells were contaminated. All of the wells were tested in the spring, just after the snow had melted and when the fields were saturated, and resampled in August. All the well water was analyzed for the four indicator organisms. In the spring survey just under 50 % of the wells exceeded the Maximum Acceptable Concentration (MAC)in drinking water. This was reduced to 37 % in the summer. Wells that tested positive for bacteria in the summer sampling generally had a history of contamination and regularly exceeded the MAC. Other wells never exceeded the MAC. In this case it is believed that some aspect of the soil characteristics or geological profile, may have provided protection from contamination. Understanding the factors which offer protection from bacterial contamination, and those which lead to bacterial infiltration, will provide a firm basis to investigate possible measures which can be taken to decrease a site's susceptibility.

A similar well survey was conducted in Zimbabwe. The wells in Zimbabwe offer a comparison in geology and soil type, but there are also differences in well construction and management practices.. Approximately 150 wells were sampled and tested for the four indicator bacteria. This survey was conducted during the dry season. 95 % of the wells had bacteria in excess of drinking water standards, and 59% of the wells tested positive for *Clostridia perifringens* which is an indicator of animal origin contamination.

Some of the sites in Ontario that have tested in excess of the drinking water standard on several occasions have been used to try to understand the manner in which bacteria are being transported into the well water. The results of the previous surveys are used to try to locate the most likely source of contamination. The sites were innoculated with a biotracer, *Escherichia coli* NAR. Using this strain, movement of bacteria was traced from the likely sources on the farms. The well water was monitored regularly for 96 hours post innoculation. Where the biotracer appeared in the well, it was clear that the direction of groundwater movement was towards the well and the location of one potential source of well water contamination is confirmed. This allows more detailed planning of remedial action to improve water quality on the farm.

Effet de la distribution géochimique du Pb, du Zn et du Cr et sur la biodisponibilité pour trois plantes: Le taraxacum officinal, le paturin du Canada et le trifolium repens.

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Les sols contaminés par les métaux lourds présentent un danger potentiel pour l'environnement dû à la toxicité de plusieurs d'entre eux et leur persistance. (.. du à la toxicité et persistance). Les micro-nutriments essentiels à la croissance des plantes (Cr, Zn, Co, Cu, Mo, Ni, Se) sont assimilés au même titre que les éléments toxiques traces (Pb, Cd, Hg, As) et s'insinuent à l'intérieur de la chaîne alimentaire (Mench, 1997). La mobilité, ou encore le transfert des métaux lourds vers la plante (i.e. trasnfert) des métaux , découle d'un processus physico-chimique complexe qui résulte d'un (desequilibre et reequilibre) équilibre thermodynamique entre les phases liquide et solide du milieu. Il est régi par le pH, le potentiel d'oxydoréduction, la capacité d'échange cationique, la teneur en carbonates, la présence des hydroxydes de fer ou de manganèse ainsi que du type de minéraux argileux contenu dans le sol (Kabata-Pendias et Pendias, 1992). Depuis les dernières décennies, une acidification progressive des sols est remarquée dans plusieurs régions industrialisées, où la combustion des matières fossiles est plus importante (Ahokas, 1997; Solberg et Torseth, 1997 ; Buysse et coll., 1996 ; Droyan et Sharpe, 1997). L'équilibre du milieu étant géré par le pH, nous pouvons supposer qu'une modification des liens géochimiques peut survenir.

Les plantes peuvent être comparées à des réservoirs passifs de métaux traces. À pH plus faible, 1) la distribution géochimique des métaux varie : solubles, matière organique, carbonates, oxydes/hydroxydes, 2) les métaux peuvent adopter une forme deviennent plus facilement assimilable pour les plantes (Kabata-Pendias et Pendias, 1990). Dans le but de faire la lumière sur cette problématique, De facon à faire la lumière dans cette problématique..., Le but de ce projet de recherche vise àest de déterminer la relation existant entre l'augmentation de la disponibilité des métaux dans les sols contaminés suite à l'acidification du milieu et au relargage des métaux sous d'autres formes géochimiques et l'assimilation du Pb, du Cr et du Zn par trois différentes plantes répandues : taraxacum officinal, paturin du Canada et le trifolium repens.

Trois sols naturels couramment rencontrés au Québec (typiques de la zone de rusticité 6? Au Québec) furent contaminés artificiellement avec du carbonate de plomb (1500 ppm), de l'oxyde de chrome (800 ppm) et de l'oxyde de zinc (1000 ppm). La terre végétale (principalement composé de matière organique)(sol humique?),, l'argile naturelle et les sédiments (sol limoneux/argileux) ont été acidifiés selon leur courbe de titration spécifique à quatre valeurs de pH.

(différentes),

L'acidification du sol a entraîné le relargage des métaux et de cette façon, ces derniers ont été réadsorbés dans les sols sous différentes formes, les rendant plus ou moins biodisponibles selon le cas. L'extraction séquentielle sélective nous a permis de connaître de quelle façon les métaux traces se sont liés aux différentes composantes du sol(composants du) sols et ainsi nous a renseigné sur quelle forme la plante les a ingéèrése. La concentration de métaux biodisponibles dans les sols devant augmenter due à l'acidification du milieu, l'assimilation s'est fait croissante, du sol le moins acide au sol le plus acide. Nous avons remarqué que seule la fraction des métaux liés aux composantes solubles, échangeables et la matière organique des trois sols exerçait une influence nette sur la biodisponibilité des métaux, et ce, pour les trois plantes. Effectivement, dans la terre végétale, plus la concentration augmente dans ces fractions, plus les plantes en absorbent, contrairement à ce que nous observons lorsque nous comparons la biodisponibilité des métaux avec les autres fractions métalliques restantes. Pour les fractions de métaux liées aux carbonates, aux oxydes et hydroxydes et la fraction résiduelle, plus la concentration a augmenté dans la terre végétale, moins les métaux sont devenus biodisponibles. Dans l'argile, cette même tendance a été observée pour le Pb et le Zn. Quant au Cr, il ne semble pas devenir plus biodisponible (pour aucune des trois plantes) lorsqu'il est présent sous la forme oxyde (Cr_2O_3). Contrairement à ce qui ce passe dans la terre végétale, lorsque le Zn est lié aux oxydes et hydroxydes, il devient plus disponible pour les plante lorsque la concentration augmente dans le sol.

Ces résultats démontrent que la distribution géochimique a un rôle très important dans la biodisponibilité des métaux pour ces trois plantes et que ce type d'analyse est plus pertinent dans la gestion des sols contaminés que les mesures en vrac (quantité totale des métaux dans les sols).

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SCALE-UP OF THE ELECTROKINETIC SURFACTANT SUPPLY
TO THE HYDROCARBON CONTAMINATED SOIL

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ABSTRACT

The presence of hydrophobic organic compounds (HOC) creates an important impact on groundwater and surface water quality. Consequently, 80% of remedial actions in Quebec are related to the biodegradation of HOC. The bioavailability of HOC, eg. PAH's, is related to the degree of their partitioning to the liquid phase in the soil matrix. The degree can be increased by introduction of surfactants. The surfactants decrease the surface tension and due to their binary (hydrophobic and hydrophillic) structure, form micelles and remove the HOC from solid to liquid phase. Several studies demonstrated the effectiveness of the applied method to the washing of contaminated soils ex-situ. However, the application of surfactants in-situ, especially in presence of fine soil material is in an experimental phase. The supply of any materials to fine granulated soil is a difficult challenge. The specific porosity, low permeability, high sorption capacity discourage the approach to clay materials.

The electrokinetic method which enhanced the movement of ionic substances, fine particles and water in the electrical field, seems to be a panaceum for these above mentioned constrains. Electrokinetic method consists of the introducing of series of anodes and cathodes to enhanced the movement of species in soil. Several electro-chemical processes on electrodes appear on electrodes and in soil when DC current is applied. Experiments showed pH rising, oxidation, corrosion, ferrous hydrous oxides formations, etc close to electrode area. These processes can be controlled through a compatible surfactant, an accurate electrode material and a optimal system for the claude of electrons formed around electrodes. Research related to these subject were performed.

Research was carry out in three phases: in batch sorption/desorption test, in small electrolytic cells in laboratory scale and in the natural scale. The results demonstrated the possibility of the removal of HOC (diesel fuel, phenanthrene) through the application of amphoteric surfactants supplied by electrokinetic system. The system was subjected to extensive changes to modify the electrochemical processes. The correlation between these processes are evaluated in the each phase of research. The results from each phase permitted the describe the scale-up process regarding the placement of a new technology in the in-situ with full consideration the microscale phenomena.

The methodology can be applied to several methods which have necessity to be scale-up to the natural conditions.

BIODEGRADATION OF POLYCYCLIC AROMATIC HYDROCARBONS FROM NONAQUEOUS PHASE LIQUIDS

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Subsurface contamination by nonaqueous phase liquids (NAPLs) such as fuel oil, creosote and coal tar are widespread across North America at sites where prolonged industrial activities related to petroleum refining, coal coking, coal gasification and wood processing have occurred. These NAPLs are often sparingly soluble, and are composed of various polycyclic aromatic hydrocarbons (PAHs). The slow dissolution of PAHs from these NAPLs may result in continued contamination of groundwater. Biotreatment of NAPL-contaminated media may be a feasible technology for elimination of the relatively soluble PAH NAPL components such as naphthalene. However, not much is currently known about the physicochemical mechanisms that may control the rate of bioremediation. The presentation will discuss some important biological and physicochemical phenomena that have been identified in laboratory experiments as potential rate controlling factors in the biodegradation of PAHs in NAPL-water systems.

In this study fundamental relationships between the composition of multicomponent NAPLs, the aqueous concentration of solutes and the rates of solute biodegradation have been evaluated. These relationships have been investigated for coal tar, a multicomponent, aromatic, dense nonaqueous phase liquid, and for a two-component NAPL simpler in composition than coal tar. The rates and extents of microbial degradation of naphthalene from coal tar, and from the two-component NAPL comprised of heptamethylnonane and naphthalene, have been evaluated in gently mixed batch reactors. Laboratory experiments demonstrated for the first time substantial depletion of naphthalene from coal tar by microbial degradation. The rate of degradation of naphthalene, the principal constituent in coal tar, was found to be significantly influenced by the rate of external surface mass transfer from the coal tar. This suggests that the rates of biodegradation of PAH compounds may be strongly influenced by the patterns in which the NAPL is distributed in the subsurface media. The results with gently-mixed batch reactors under favorable conditions provide an indication of the maximum potential rates of microbial degradation of naphthalene from coal tar. A dissolution-degradation model that incorporates dependence of the microbial degradation process on the NAPL composition, and the naphthalene mass transfer rate between the NAPL and the aqueous phases was developed. Parameters in the model were determined from independent experiments and by nonlinear least squares regression of experimentally obtained mineralization profiles. Model predictions for different initial conditions compared favorably to results from experiments using coal tar and the two-component NAPL in terms of capturing general trends. This model provided a framework for evaluating effects of system composition, NAPL-water mass transfer and microbial growth kinetics on the biodegradation of naphthalene. The efficacy of biotreatment in remediation of contaminated groundwater and residual NAPL mass will be discussed. The presentation will conclude with a brief discussion of the effects of 'aging' of NAPL-water interfaces on the mass transfer of solutes from the NAPL.

Enrichment and Characterization of Anaerobic Benzene-Degrading Cultures

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Gasoline is a common groundwater contaminant as a result of leaking underground storage tanks, spills and improper disposal. Of all the constituents of gasoline, the aromatic compounds benzene, toluene, ethylbenzene and the three xylene isomers (BTEX compounds) are of particular concern because they are the most soluble components and can therefore travel with the groundwater flow to contaminate drinking water wells far removed from the source of contamination. Benzene is of most concern because it is a human carcinogen and the most toxic BTEX compound.

Aerobic bacteria readily degrade benzene, and the processes and degradation pathways are well understood. However, anaerobic conditions often develop at contaminated sites as bacteria deplete available oxygen. The low solubility of oxygen in water and poor diffusion of atmospheric oxygen into the subsurface result in very slow groundwater reaeration rates. Bioremediation schemes designed to promote degradation by aerobic bacteria are sometimes prohibitively expensive due to the difficulties associated with injecting oxygen into the subsurface and biofouling caused by rapid growth of aerobic bacteria. In situ anaerobic biodegradation offers an attractive alternative, especially for passive or intrinsic bioremediation. Toluene, xylene and ethylbenzene are readily degraded under a variety of anaerobic conditions. In contrast, benzene has proven to be much more difficult to degrade under anaerobic conditions. Anaerobic benzene degradation has only recently been confirmed and very little is known about the process. The overall objective of this study is to improve our understanding of anaerobic benzene degradation to more effectively predict the fate of this compound in the environment. The specific objectives of this study are to optimize growth conditions and to characterize the terminal electron accepting processes in existing anaerobic benzene-degrading cultures.

In a previous study, batch microcosms were constructed with soil and groundwater from six sites located in North America. These microcosms were incubated anaerobically with benzene and a variety of electron acceptors to determine anaerobic benzene biodegradation potential. Sustained benzene biodegradation was observed in microcosms from four of the six sites examined. Active microcosms were used to generate enrichment cultures for this research. The effects of different electron acceptors and varying benzene concentrations were evaluated in these enrichment cultures. Benzene, nitrate, sulphate, iron (II) and methane concentrations were monitored over time in the enrichment cultures. Mole and electron balances were conducted to establish the electron-accepting processes.

Enrichment of anaerobic benzene-degrading organisms has been successful as indicated by increased rates of benzene degradation over time. Benzene biodegradation in enrichment cultures has been linked to sulfate reduction, nitrate reduction and iron reduction. Studies to maximize the rates of degradation are on-going. The results have shown that more than one population of anaerobic benzene-degrading bacteria can be enriched from the same sediment, and that anaerobic benzene biodegradation potential may be much more widespread than previously thought.

Plant Material as Substrate for Sulphate Reduction for Acid Mine Drainage Treatment

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Acid Mine Drainage (AMD) contains high concentrations of sulphate and heavy metals at a low pH. Of the many treatment methods available, biological treatment using sulphate reducing bacteria (SRB) is a promising alternative. The viability of this process depends upon the availability of a low cost organic carbon source in the vicinity of the treatment site. A previous study has shown that plant material is a poor source of organic material for the SRB. It was suspected that the poor sulphate reduction could have been a reflection of high carbon : nitrogen (C:N) ratio and the complexity of the available organic substrate. The objective of this research was to study the effect of C:N ratio on the volatile fatty acid (VFA) production from plant material and the sulphate reduction using the VFA as a carbon source. A series of anaerobic batch reactors was set up in both phases at 35 C in a buffered medium. In Phase 1 (acid production phase) rabbit pellet were used as a surrogate for plant material; three carbon : nitrogen (C:N) ratios 41.5, 29.4, and 19.5 were used. In phase 2 (sulphate reduction phase), with propionic acid as a carbon source and ferrous sulphate as a sulphate source, four reactors were set up at C:N ratios of 59.5, 31.2, 14.3 and one control. Ammonium chloride was used as nitrogen source for both phases.

The results from Phase 1 indicated that additional nitrogen is required to increase the rate of production of the volatile fatty acids (VFA) from plant material. At the lowest C:N ratio of 19.5, about 1078 mg VFA as acetic acid/L were produced compared to about 800 mg VFA as acetic acid/L at the C:N ratio of 41.5.

For the sulphate reduction phase, addition of nitrogen increased the efficiency of the SRB. At the C:N ratio of 14.3, maximum sulphate reduction of 40% was observed as compared to the C:N ratio of 59.5. The results indicate that plant material can provide a suitable source of organic carbon for sulphate reduction when supplemented by nitrogen.