KAISER

TWENTY-FOURTH CANADIAN SYMPOSIUM ON WATER POLLUTION RESEARCH

ABSTRACTS

WATER POLLUTION
CONTROL TECHNOLOGY

IMPACT OF POLLUTANTS
ON AQUATIC ECOSYSTEMS

FEBRUARY 16, 1989

CANADA CENTRE FOR INLAND WATERS
BURLINGTON, ONTARIO

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CANADIAN ASSOCIATION ON
WATER POLLUTION RESEARCH
AND CONTROL

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TWENTY-FOURTH CANADIAN SYMPOSIUM
ON
WATER POLLUTION RESEARCH

POSTER SESSION PRESENTATIONS

February 16, 1989

1. **The Effect of Kraft Pulp Mill Effluent on the Sediment Quality of Jackfish Bay, Lake Superior**
   - K. Sherman
   Ontario Ministry of the Environment

2. **Hybrid Growth Systems for Biological Wastewater Treatment**
   - Pr. Senthilnathan and J.J. Ganczarczyk
   University of Toronto

3. **Assessment of Two Activated Carbon Adsorption Systems Treating Wood Preservation Wastewaters**
   - S.A. Zaidi[1], J.P. Jones[2] and C.E. Ross[1]
   Wastewater Technology Centre[1]
   University of Sherbrooke[2]

4. **The Adaptation of Anaerobic Granulated Bed to Changes in Loading Rate and Liquid Upflow Velocity in UASB Reactors**
   - N. Kosaric[1], R. Blaszczyk[2] and L. Orphan[1]
   The University of Western Ontario[1]
   Lodz Technical University[2]

5. **Groundwater Treatment Pilot Work at Ville Mercier**
   - R.M. Booth, L. Simovic and D. Vachon
   Wastewater Technology Centre

6. **Considerations in Calibration and Analysis for Volatile Organic Compounds in Air Emissions from Wastewater Treatment Processes**
   - B.A. MacGillivray and P.J.A. Fowlie
   Wastewater Technology Centre

7. **The Persistence of Organic Contaminants in Soils Treated with Municipal Sludge**
   - J.D. Goodin and M.D. Webber
   Wastewater Technology Centre

8. **The Benefits of Conservation Tillage Practices in Southwestern Ontario**
   - E.J. Dickson and G.C. Fox
   University of Guelph

9. **A Cost Model for Optimizing Polymer Addition**
   - B.W. Baetz and J.H. Barajas
   McMaster University

10. **Treatment of Firefighting Training Waste**
    - P.J. Connell and R.P. Canning
    Zenon Environmental Inc.

11. **Onsite Anaerobic Treatment of Combined Pea and Potato Processing Wastewaters Using a Mobile Microprocessor Controlled, Three Reactor Pilot Plant Facility**
    - R.E. St. Jean and A.R. Stickney
    Canviro Consultants

12. **Fate of Selected Volatile Organic Substances in an Aqueous Environment**
    - G.R. Chadola, N. Biswas, J.K. Bewtra, C.C. St. Pierre and R. Zytner
    University of Windsor

TWENTY-FOURTH CANADIAN SYMPOSIUM ON WATER POLLUTION RESEARCH

THURSDAY, FEBRUARY 16, 1989

CANADA CENTRE FOR INLAND WATERS

BURLINGTON, ONTARIO

WATER POLLUTION CONTROL TECHNOLOGY

IMPACT OF POLLUTANTS ON AQUATIC ECOSYSTEMS

SPONSORED BY:

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SESSION I - AUDITORIUM
WATER POLLUTION CONTROL TECHNOLOGY

PRESIDER: S. NUTT
CANVIRO CONSULTANTS

"TREATMENT TECHNOLOGIES"

DEMONSTRATION PROJECTS

1:30 - 2:00	Design and Operation of a Pilot Plant for the Evaluation of Disinfection Reaction Products in Drinking Water - D.I. Harris, G.D. Milne, G.A. Irvine, D. Kellendonk and P.M. Huck University of Alberta
2:00 - 2:30	Treatment Process Technology for Arsenic Removal from the Gold Mine Tailings Pond Water - S. Domvile[1], L. Desjarlais[1], R. Hiltunen[2] and H.Suan[2] Nerco Con Mine Ltd.[1] Stanley Associates Engineering Ltd.[2]
2:30 - 3:00	A Low Cost Nitrification-Denitrification System for the Control of Ammonia and Hydrogen Sulphide in Lagoon Effluents - W. Lewandowski Ontario Ministry of the Environment
3:00 - 3:30	**Poster Session/Coffee Break** **Main Mall Area - CCIW**

LABORATORY STUDIES

3:30 - 4:00	Sulfides in Anaerobic Treatment; Inhibition & Mechanism of Process Adaptation - D.M. McCartney and J.A. Oleszkiewicz University of Manitoba
4:00 - 4:30	Improved Bacterial Leaching of Metals from Municipal Sludge (Reactor Studies) - R.D. Tyagi, F.T. Tran and B. Boulanger INRS-Eau
4:30 - 5:00	Reactions of Hydroxyl Radicals with Chlorobenzenes: Comparison to TiO_2 Photocatalyst Reactions - G. Lepore and C.H. Langford Concordia University
5:00 - 7:00	**Reception** **Main Mall Area - CCIW Cafeteria**

SESSION II - SEMINAR ROOM
IMPACT OF POLLUTANTS ON AQUATIC ECOSYSTEMS

PRESIDER: R.J. DALEY
NATIONAL WATER RESEARCH INSTITUTE

"POLLUTION EFFECTS AT THE ECOSYSTEM LEVEL"

1:30 - 2:00	Impact and Recovery of an Acid Spill on the York River - R. Prairie, K. Schiefer, L.J. Moulins and V. Chapados Centre de Technologie Noranda
2:00 - 2:30	Planktonic Model Ecosystems for Studying Pollution Effects at the Ecosystem Level - U. Borgmann, E.S. Millard and W. Norwood Great Lakes Laboratory for Fisheries and Aquatic Sciences
2:30 - 3:00	A Comparison of PCB Congener Distributions in two Contaminated Lakes in Ontario - C.R. Macdonald and C.D. Metcalfe Trent University
3:00 - 3:30	**Poster Session/Coffee Break** **Main Mall Area - CCIW**

"BIOLOGICAL ASPECTS OF TOXIC CONTAMINATION"

3:30 - 4:00	Ecological Partitioning of Organochlorinated Contaminants in Forage Fish Species - C.E. Hebert and G.D. Haffner University of Windsor
4:00 - 4:30	The Use of Young-of-the-Year Fish as Bioindicators of Toxic Chemicals in the St. Lawrence River - J. Bureau and H.H., Sloterdijk St. Lawrence Center
4:30 - 5:00	Evidence of Genotoxins in the Sediments of the Welland and Buffalo Rivers as Inferred from the Frequency of Chironomid Labial Plate Deformities - M. Dickman, Q. Lan and B. Matthews Brock University
5:00 - 7:00	**Reception** **Main Mall Area - CCIW Cafeteria**

PLEASE DIRECT ALL INQUIRIES AND MAIL YOUR REGISTRATION FORM TO:

JEAN STAFFORD,
CONFERENCE MANAGER,
CANADIAN ASSOCIATION ON WATER POLLUTION RESEARCH AND CONTROL
WASTEWATER TECHNOLOGY CENTRE,
867 LAKESHORE ROAD, BURLINGTON, ONTARIO.
CANADA L7R 4A6
Telephone No. (416) 336-4598
Fax No. (416) 336-4765

PROGRAM

7:30 - 8:45 REGISTRATION (CCIW FOYER)

8:45 - 9:00 OPENING REMARKS (AUDITORIUM)
K.L. MURPHY, PRESIDENT CAWPRC
McMASTER UNIVERSITY

SESSION I - AUDITORIUM
WATER POLLUTION CONTROL TECHNOLOGY

PRESIDER: P. DOLD
MCMASTER UNIVERSITY

"MODELLING FOR ENVIRONMENTAL CONTROL"

9:00 - 9:30 Economic Analysis of Electroplating Discharges to Sewage Treatment Plants
- N.D.H. Looker, E.A. McBean and G.J. Farquhar
University of Waterloo

9:30 - 10:00 Dynamic Modelling of the Humber Sewer System and Sewage Treatment Plant
- H.G. Fraser and C.J. Edmonds
UMA Engineering Ltd.

10:00 - 10:30 A General Purpose Simulator for Dynamic Modelling of Wastewater Treatment Processes
- G.G. Patry, I. Takacs and J. Yong
McMaster University

10:30 - 11:00 **Poster Session/Coffee Break**
Main Mall Area - CCIW

11:00 - 11:30 Design Methodology for n-Stage Step-Feed Activated Sludge/Sedimentation Systems
- R. Leduc, O. Moreno and R. Gehr
McGill University

11:30 - 12:00 Development of an Expert System for the Assessment of Solid Waste Disposal in Landfills
- D. N. Young[1], A. Moriera[1] and T. Constable[2]
Dearborn Environmental Consulting Group[1]
Wastewater Technology Centre[2]

12:00 - 12:30 An Expert System to Rank Toxic Contaminants According to Environmental Hazard
- E. Halfon
National Water Research Institute

12:30 - 1:30 **Poster Session/Buffet Luncheon**
Main Mall Area - CCIW

SESSION I - SEMINAR ROOM
WATER POLLUTION CONTROL TECHNOLOGY

PRESIDER: H. EISENHAUER
ENVIRONMENT CANADA

"ENVIRONMENTAL MONITORING"

ANALYTICAL PROCEDURES

9:00 - 9:30 The Application of Chemically Modified Fused Silica Fibers in the Extraction of Organics from Water Matrix Samples & Their Rapid Transfer to Capillary Columns
- R.P. Belardi and J.B. Pawliszyn
University of Waterloo

9:30 - 10:00 Supercritical Fluid Extractions of Organics from Water Matrix Samples
- C.S. Burchat and J.B. Pawliszyn
University of Waterloo

10:00 - 10:30 A Continuous Monitor Based on the Dynamic Headspace Technique
- R.G. Denning[1], G.H. Thomas [2] and R.G. Westendorf[3]
Lambton Industrial Society[1],
Ortech International[2]
Tekmar Company[3]

10:30 - 11:00 **Poster Session/Coffee Break**
Main Mall Area - CCIW

ENVIRONMENTAL IMPACT ASSESSMENT

11:00 - 11:30 Determination of Chlorinated Phenolics in Pulp and Paper Effluents
- H.-B. Lee[1], B.L. Hong-You[2] and P.J.A. Fowlie[2]
National Water Research Institute[1]
Wastewater Technology Centre[2]

11:30 - 12:00 Degradation Pathways of Halogenated Ethanes and Ethenes in Anoxic Groundwater
- S. Lesage and R.E. Jackson
National Water Research Institute

12:00 - 12:30 Analysis of Adsorbable Organic Halogens in Pulp & Paper Plant Streams
- J. L. Fraser and M. Foroutan
Wastewater Technology Centre

12:30 - 1:30 **Poster Session/Buffet Luncheon**
Main Mall Area - CCIW

GENERAL INFORMATION

The Twenty-fourth Canadian Symposium on Water Pollution Research will focus on Water Pollution Control Technology and the Impact of Pollutants on Aquatic Ecosystems. This is a one day symposium with two simultaneous sessions.

SUBMISSION OF PAPERS TO THE WATER POLLUTION RESEARCH JOURNAL OF CANADA

Papers being presented at this Symposium will be considered for publication in a future issue of the Water Pollution Research Journal of Canada provided they have undergone two peer reviews and acceptance has been given by the Editor-in-Chief.

POSTER SESSION

A POSTER SESSION will be featured in the Main Mall area at CCIW during the morning and afternoon Coffee Breaks and during the Buffet Luncheon. There will also be ample time for discussion with the participants during the Wine and Cheese Reception beginning at 5:00 p.m.

REGISTRATION INFORMATION

CAWPRC Members	$ 40.00
CAWPRC Student Members	$ 5.00
Non CAWPRC Members	$ 90.00
Non CAWPRC Student Members	$ 20.00

The Non CAWPRC Members fee will include a 1989 Individual CAWPRC or Student membership in the Canadian Association on Water Pollution Research and Control along with a subscription to the Water Pollution Research Journal of Canada. Registration Fees will also include the Buffet Luncheon and the Wine and Cheese Reception.

SESSION CHAIRMEN

B.E. JANK (I)
Wastewater Technology Centre,
867 Lakeshore Road,
Burlington, Ontario.
Canada L7R 4A6

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REGISTRATION FORM

TWENTY-FOURTH CANADIAN SYMPOSIUM ON WATER POLLUTION RESEARCH

Name ____________ Cheque Enclosed ______

Affiliation ____________ Pay on Arrival ______

Address ____________ All Cheques should be made payable to CAWPRC.

____

Postal Code ______ Fax ______ **Advance Registration Would Be Appreciated.**

Telephone ____________

TWENTY-FOURTH CANADIAN SYMPOSIUM
ON
WATER POLLUTION RESEARCH

ABSTRACTS

THURSDAY, FEBRUARY 16, 1989

CANADA CENTRE FOR INLAND WATERS
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CANADIAN ASSOCIATION ON WATER POLLUTION
RESEARCH AND CONTROL

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SESSION I (a.m. Auditorium)
MODELLING FOR ENVIRONMENTAL CONTROL

TWENTY-FOURTH CANADIAN SYMPOSIUM
ON WATER POLLUTION RESEARCH

SESSION I
9:00 - 9:30

ECONOMIC ANALYSIS OF ELECTROPLATING DISCHARGES TO SEWAGE TREATMENT PLANTS

N.D.H. Looker[1]*, E.A. McBean[1] and G.J. Farquhar[1]
University of Waterloo, Waterloo, Ontario[1]
Canviro Consultants Ltd., Waterloo, Ontario* (Present Location)

The growing concern with heavy metals in the environment has given rise to the formulation of regulations in Ontario governing the disposal of sewage sludge to agricultural land. Since many sewage treatment plants (STPs) accept industrial discharges in their influent, metal concentrations in their sludge may exceed the limits imposed by the regulations. Consequently these plants must dispose of their sludge to landfill sites.

Since landfill disposal of sludge is much more expensive than disposal on agricultural land, the financial burden to STPs is important. In these concerns, major contributors of metals are electroplating companies. Further, cadmium is the electroplating metal that is the most important since it is frequently responsible for eliminating STP sludges from possible use on agricultural land (Webber, 1974; Environment Canada, 1984). The problem related to cadmium is widespread; a survey in 1984 indicated that there were over thirty (32) electroplating plants in Ontario with cadmium-plating operations (Envir. Can., 1984).

The focus of the paper is the development of a Lotus spreadsheet analysis to compare the costs of implementing an advanced wastewater treatment system for a cadmium plating plant (i.e. pretreatment at the source), with sludge disposal costs of the sewage treatment plant to which the plating plant is discharging its effluent. Specifically a methodology is described to determine the incremental costs of implementing an evaporative recovery system to eliminate cadmium in the plating plant's effluent and the associated benefits of the STP sludge being disposed to agricultural land.

A case study application is used to demonstrate the principles. In the case study, the costs foregone by disposing of the sludge to agricultural land and not to a landfill, far outweighed the incremental costs of installing the evaporative recovery system. The overall net benefits were approximately five million dollars for a 10 year design life, for a city of 70,000 people. Sensitivity of the findings to design variables are demonstrated, including drag-out rates, sludge production rates and economic variables such as interest rates.

TWENTY-FOURTH CANADIAN SYMPOSIUM
ON WATER POLLUTION RESEARCH

SESSION 1
9:30 - 10:00

DYNAMIC MODELLING OF THE HUMBER SEWER SYSTEM AND SEWAGE TREATMENT PLANT

H.G. Fraser and C.J. Edmonds
UMA Engineering Ltd., Mississauga, Ontario

This paper summarizes the results of a study of the Humber trunk sanitary sewer system and sewage treatment plant in Metropolitan Toronto. About 9% of the catchment area is served by combined sewers.

The influence of various flow components on the sewage treatment plant was analyzed with sewer system and treatment plant models. With the sewer system modelling it was possible to distinguish the various flow components of dry weather flow, infiltration/inflow and combined sewer flow. The dynamic sewage treatment plant (STP) model had the capability of simulating the operation of primary clarification and secondary treatment, and predicting trends in the final effluent quality.

By operating the sewer system and sewage treatment plant model in series the effect of flow control measures on the sewer system and STP operation could be evaluated. The effect of measures such as inlet control, infiltration/inflow reduction, local storage, and in system storage were considered to relieve basement flooding. To solve the combined sewer overflow problem, the impact of techniques such as sewer separation, adjustment of flow regulators, and storage for combined sewer overflows were considered.

This state of the art analytical approach was found to be extremely useful in analyzing different system configurations. For example the study found that resolving basement flooding in local systems, through the use of storage or inlet controls had a negligible impact on the treatment plant operation. It was also found that about 40% of the flow to the STP during a rain event exceeding 10mm, comes from inflow/infiltration. Subsequently recommendations were made to increase efforts to reduce I/I.

One option considered for the control of combined sewer overflows was sewer separation. It was predicted that the impact on flows to the sewage treatment plant during wet weather periods would not be altered significantly. On the other hand the effect of storing combined sewer overflows and then treating the flow was predicted to have a significant impact on the plant operation. Additional treatment plant capacity would be required in order to meet the Ministry of Environment quality criteria.

An important finding of the investigation related to plant ratings which are usually conducted on the basis of some function of dry weather flow estimates. The study found that a more meaningful plant rating should be based on the hydrograph shape, including the magnitude of the peak flow and the duration of the flows (width of the hydrograph), especially under wet weather conditions.

TWENTY-FOURTH CANADIAN SYMPOSIUM
ON WATER POLLUTION RESEARCH

SESSION I
10:00 - 10:30

A GENERAL PURPOSE SIMULATOR FOR DYNAMIC MODELLING OF WASTEWATER TREATMENT PROCESS

G.G. Patry, I. Takacs and J. Young
McMaster University, Hamilton, Ontario

The purpose of this paper is to describe the development and application of simulation-based technologies in the field of wastewater treatment engineering, in general, and dynamic modelling of treatment processes, in particular. **Simulators** make use of simulation models to provide an interactive graphics-based environment to allow the user to control and interact with the simulation as it proceeds. While simulators are particularly useful for operator training purposes, their benefits extend to all phases of the wastewater engineering, including, planning, design and operation/control of wastewater treatment plants.

Developed on a SUN3/160 workstation, the simulator is being adapted to other hardware/software platforms, including the Mac II and eventually the IBM-PS2.

The wastewater treatment plant simulator consists of two-independent modules: a) a screen-oriented modelling interface (SOMI) used to specify (graphically) the characteristics of the wastewater treatment plant, i.e., process models, connectivity, initial conditions, kinetic parameters, etc.; and b) a general-purpose simulator (GPS) allowing the user to interact with the simulation as it proceeds. Both modules make extensive use of object-based modelling concepts as well as on-line graphics and windowing techniques.

A number of models have already been incorporated in the simulator library, including:

- **primary settling:** Busby, Stenstrom, and Lessard/Beck;
- **activated sludge process:** Marsili-Libelli, Olsson, IAWPRC, and the VITUKI (VNP) model;
- **secondary clarifier/thickener:** Vitasovic, Stefhest, Hill;
- **anaerobic digestion:** Andrews, Pavlosthatis, Moletta, and the VITUKI(VANAM) model.

The models were coded in ACSL (Advanced Continuous Simulation Language) and evaluated using already published field and laboratory data. For the purpose of this paper a subset of models were used to provide a description of an actual wastewater treatment plant under realistic inflow conditions, including steady-state and diurnal flow variations. The paper illustrates the benefits of the simulator for **model calibration, model verfication,** and to simulate innovative **control strategies.**

Based on a comparative evaluation of dynamic models, the paper emphasizes the need for hierarchical model development in order to address the various needs of the profession at the planning, design, and operational levels. It has become apparent, based on our investigations, that no single model structure is applicable to all levels. While complex mechanistic models might seem to provide a more realistic description of the time-varying performance of a wastewater treatment facility, there is some concern about the suitability (and transferability) of many of these models to the field conditions. The paper concludes with thoughts on the development of operational/problem-specific models.

DESIGN METHODOLOGY FOR n-STAGE STEP-FEED ACTIVATED SLUDGE/SEDIMENTATION SYSTEMS

R. Leduc[1], O. Moreno[2], and R. Gehr[1]
McGill University, Montreal, Quebec[1]
Caura Ingenieros Consultores C.A., Caracas, Venezuela[2]

The step-feed (also known as step-aeration) activated sludge process is considered by many as having the best operational flexibility among the modifications that have been proposed to the original process. Other advantages include better equalization of the waste load and a more uniform oxygen demand along the aeration tank, with lower peak demands. Also, it allows operational control of the sludge age and hydraulic retention time and can be used in preventing gross process failure due to hydraulic overloading or sludge bulking.

The design engineer faces the problem of having to consider the sizing of a certain number of stages in the aeration tank and the effect of secondary clarifier operation on the overall process. Because of a lack of available software, the engineer is at present limited in the design procedure because of the cumbersome calculations that the design involves. A new computerized methodology is proposed here to assist the engineer in comparing the effects of designing for various numbers of stages on the overall performance of the activated sludge process, including secondary sedimentation. The solution methodology is based on an algorithm, which is further explained below.

The method considers two models: a biodegradation model for the biological processes occurring in the aeration tank, and a clarifier model. The mathematical model for biodegradation is developed from fundamental theory. It considers any number (n) of stages and is an extension of an existing 3-stage model proposed by Benefield and Randall (1980). For each stage, steady-state substrate and biomass balances are considered, based on the complete-mix assumption in each stage, to yield a system of $2n$ nonlinear equations. These, combined with an equation for the total volume of the tank and one for the biological solids retention time, amount to a system of $2n+2$ nonlinear equations. An algorithm was developed to solve this system of equations, which were coupled with a model used for simulating the thickening process in the final settling tank. The thickening/clarification equations, which are based on the limiting flux theory model, are those proposed by Riddel et al. (1983).

The results obtained using this methodology compared very favourably with data found in the literature. The algorithm was found to be adequate for design and for analysis of existing systems, and the convergence of the computational method was satisfactory.

In addition, the method was designed to be flexible. It allows the user to specify the number of stages and the flow fraction directed to each stage. It can be used in a *design*, or in an *analysis* mode. Wastewater and sludge treatment cost functions are included in order to provide the design engineer with a cost comparison of the various possible design options.

The computerized algorithm represents an improved methodology for the design of the step-feed activated sludge system and should prove to be a valuable tool for designers who wish to consider any number of stages and their respective impact on operational variables as well as on cost.

DEVELOPMENT OF AN EXPERT SYSTEM FOR THE ASSESSMENT OF SOLID WASTE DISPOSAL IN LANDFILLS

D.N. Young[1], A. Moriera[1] and T. Constable[2]
Dearborn Environmental Consulting Group, Mississauga, Ontario
Wastewater Technology Centre, Burlington, Ontario[2]

Landfilling is the main disposal method employed for solid wastes generated by industry and municipalities. Bench-scale tests and/or computer models are used to assess potential adverse impacts of solid waste disposal. These estimation procedures are, however, limited to relatively simple disposal conditions and well-defined waste types. More thorough assessments using these techniques are very costly. Environment Canada and Supply and Services Canada are supporting a two and one half year project to develop a comprehensive software package to assist first-time and expert users in developing more in-depth and long-term assessments of environmental impact of solid waste disposal in landfills at a reasonable cost. The modularized package consists of a graphical user interface, hydrogeological model (to define leachate flow through landfill), solid waste characterization and leaching database (to allow storage and retrieval of historical results) and an expert system (to provide specification of leaching test(s), analyses of all results generated and conclusions/recommendations).

The purpose of this paper is to present a summary of progress to date on software development. Following a brief overview of the project scope and objectives, a presentation of the hydrogeological model and leaching database will be given. Photographs of the user interfaces for each program along with a brief explanation of data input and manipulation will be presented. A bata-test version of the database software will be made available on an as-requested basis.

AN EXPERT SYSTEM TO RANK TOXIC CONTAMINANTS ACCORDING TO ENVIRONMENTAL HAZARD

E. Halfon
National Water Research Institute, Burlington, Ontario

The expert system analyzes any number of toxicity tests, physico-chemical properties, concentrations and other criteria to rank toxic contaminants according to their environmental hazard. The expert system has been developed on a mainframe computer. Plans are now in progress to transfer the software to personal computers for distribution to any government department interested in ranking, in priority setting and in decision making. This expert system is not restricted to toxic contaminants but it can rank any data set (provided by the user) organized in matrix or spreadsheet form.

For ranking toxic contaminants, each spreadsheet row represents a chemical and each column contains the values of the criteria, tests or attributes to be used for ranking. The ranking analysis can be done in fully automated form or the user can use his/her expertise to decide which criteria to use and which analysis to perform. In the future, two or three years depending on funding, the expert system should be able to fill gaps in the spreadsheet, either with results from fate models or from QSAR relationships. The ranking method is 100% compatible with the Vector Scoring System (VSS) proposed by the Ontario Ministry of the Environment. If VSS is implemented by Environment Canada and Health and Welfare, this ranking expert system can analyze all the relevant information without any changes in the software.

The software performs several functions: (1) it ranks toxic contaminants according to many criteria, tests or attributes either in their original form, divided into classes or with assigned weights (The expert system can also attribute weights to the criteria if the user so desires). The ranking is displayed with Hasse diagrams, a useful tool adapted from lattice theory. Toxic contaminants are ranked in hazard groups.

(2) It identifies contradictions in the ranking according to each criterium. For example, if only one criterium were used, the ranking would be unique (for example chemical A is worse than chemicals B and C). If a second, different, criterium is used, tha ranking of the same chemicals might be different (for example chemical B is worse than chemicals A and C) and also unique. When both criteria are used together, the new ranking includes contradictory results (both A and B are worse than C, but is A worse than B or viceversa?).

If we use many criteria, the number of contradictions increases. The ranking method analyzes all criteria and it shows graphically, with Hasse diagrams, the presence of contradictions (Contaminants A and B are more hazardous than C and the expert system identifies the tests that rank A and B in a contradictory manner). The user can now analyze the raw data to understand how the ranking is obtained and why contradictions in the criteria exist. This contradictory evidence is usually lost in large spreadsheets with thousands of numbers. This evidence is also lost if a single index of hazard, i.e. all criteria are combined into one, is used to rank chemicals.

(3) The expert system identifies which criteria are the most critical for ranking purposes. This information is important when some criteria contain redundant information, information that is expensive to collect in terms of dollars, time and manpower.

WATER POLLUTION CONTROL TECHNOLOGY

SESSION I (a.m. Seminar Room)
ENVIRONMENTAL MODELLING

"Analytical Procedures"

THE APPLICATION OF CHEMICALLY MODIFIED FUSED SILICA FIBERS IN THE EXTRACTION OF ORGANICS FROM WATER MATRIX SAMPLES & THEIR RAPID TRANSFER TO CAPILLARY COLUMNS

R.P. Belardi and J.B. Pawliszyn
University of Waterloo, Waterloo, Ontario

The ability to analyze water matrix samples in the shortest period of time and in the most cost efficient manner allows the scientist to collect and study more data, which results in a more thorough analysis and rapid warning against dangerous pollutants. In this report a unique and more efficient procedure for preparing and transferring samples to capillary columns for analysis by GC or GCMS is described.

Currently there are several methods that are employed for sample preparation for GC or GCMS analysis of organics in water samples, such as solvent extraction and solid phase extraction. However all these procedures are multi-step and involve the use of solvents and syringes, all possible sources of error. The technique presented here involves a modified version of solid phase extraction. It employs an immobilized organic layer which is chemically attached to fused silica fibers, similar to those used as optical guides. The unique feature of these fibers is, due to their small size, the ability to place them directly into the capillary column. Thus the need for solvents and syringes is eliminated as well as the various steps which are required for these techniques. The result is increased time and cost efficiency.

The fused silica fibers are modified by either chemically bonding or polymerizing an organic layer to the tip of the fiber. This causes the non-polar organics to be extracted from the polar aqueous solution and absorbed into the less polar layer. However, contrary to standard solid phase extraction methods this technique does not extract all of the organic compound. Instead it is based on the equilibrium that is formed between the concentration of the compound in the organic layer and the concentration of the compound in the aqueous medium. Therefore, the analysis results are independent of the sample size and it can be a selective by using appropriate stationary phases.

In this study four different organic layers were used to explore the properties and limitations of this new and unique technique. They were: 1) Carbowax, 2) Octadecyletrichlorosilane (ODS), 3) Polymethylvinylchlorosilane (PMVCS), 4) Liquid Crystalline Polyacrylate (LCPA).

The tips of the fused silica fibers (100 µm o.d.) were all etched with concentrated HF (except the PMVCS fiber) and then rinsed with methylene chloride, acetone and methanol. Once the fibers were rinsed and air dried, they were ready to be coated. The coating conditions varied for each type of layer, however, they all followed the general procedure of immersing the tips of the fibers in a dilute solution of the specific organic layer and statically coating them under the flow of an inert gas such as N_2 or He. Once coated the fibers were conditioned at elevated temperatures.

Water samples containing various concentrations of 2-naphthol were analyzed by immersing the modified fiber in the sample for a specified time. It was then directly transferred to the capillary column of the GC via the on-column injector and a temperature programmed analysis followed.

It was observed that three out of the four fibers performed well with little bleeding up to temperatures of 200 °C. These were the carbowax, PMVCS, and the LCPA fiber. However, their extraction efficiency of 2-naphthol differed considerably. The carbowax fiber had the lowest efficiency with approximately 1/5 of that of the LCPA fiber, which had the highest. While, the PMVCS fiber's efficiency was 1/2 of that of the LCPA fiber's. This provides evidence that the hypothesis of the formation of an equilibrium of the organic concentration between the fiber and the aqueous solution exists.

A study of the extraction performance of the fibre with respect to varying sampling time was conducted in order to provide the optimum (minimum) sample time without sacrificing its performance. In the study the carbowax and LCPA fiber were used. In both cases it was observed that the degree of extraction was initially proportional to the sample time. As the sampling time was increased it was observed that a state of equilibrium had been reached. The optimum sampling time (the equilibrium point) for the LCPA fiber was 15 seconds, while that of the carbowax fiber's was approximately 5 minutes.

A series of identical water samples containing 100 ppm of 2-naphthol were analyzed using the MFSF technique (in this case the LCPA fiber was used) in order to determine its reproducibility. The result was a standard deviation of 18.1 %.

A concentration curve ranging from 20 ppb to 100 ppm of 2-naphthol was plotted, which produced a linear relationship between the 2-naphthol extracted and the sample concentration. The detection limit in the determination of 2-naphthol was found to be 5 ppm.

The variations observed in the reproducibility test revealed that much more work is needed to make this techinique a ready to use and reliable method for the analysis of water samples. However, these preliminary findings support the belief that this unique method of extraction and rapid transfer to capillary columns can be a viable and practical technique which would drastically improve the efficiency in analyzing water matrix samples for the environmental chemist.

SESSION I
9:30-10:00

SUPERCRITICAL FLUID EXTRACTIONS OF ORGANICS FROM WATER MATRIX SAMPLES

C. S. Burchat and J. B. Pawliszyn
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Environmental contaminants such as pesticides and hydrocarbons are increasingly present in groundwater supplies and are of a growing concern to populations. It is necessary to develop rapid and accurate methods for monitoring water pollutants to protect the environment and the public.

Current methods used to analyze organic contaminants in water involve liquid-liquid extractions. These methods generally are labour-intensive and time consuming. Also, they often involve the use of hazardous solvents such as benzene and dichloromethane. With the growing concern with occupational health and safety, an alternative to use of such organic solvents is desirable. Liquid-liquid extractions usually require a relatively large volume of sample, and for trace analysis, preconcentration is necessary. A further disadvantage of these traditional methods of extraction is that they do not readily lend themselves to automation.

A new approach to the problem of extracting contaminants from water is currently being developed using supercritical carbon dioxide. The process involves passing a given volume of the aqueous sample through a guard column containing an adsorbant. The water is forced through the tubing and column by a back pressure of dry nitrogen gas. pH of the water may be varied to increase adsorption. After the sample vial has been emptied, the nitrogen flow is continued, passing through and drying the adsorbant before extraction with supercritical fluid.

Supercritical carbon dioxide is passed through the adsorbant to extract the contaminants. Selectivity may be obtained by varying pressure of the supercritical fluid, or temperature of the adsorbant column. Various adsorbants such as activated charcoal, C18, or Florisil may be used. Our lab is currently working on the development of selective adsorbants. Another way to selectively extract organics is to use different supercritical fluids. Also, modifiers such as methanol or benzene may be added to change polarity and thereby selectively extract the contaminants from the adsorbant.

The supercritical carbon dioxide, with contaminants, is passed through a fused silica capillary. The end of the capillary may be placed in a vial containing solvent to dissolve the organics when the supercritical fluid expands at the opening. The solvent is brought to a given volume and the sample analyzed. This method has been shown to be useful for extracting the herbicide Atrazine, which has been found to be present in some well, river and ground waters.

An alternative method of analysis is to deposit the organics extracted directly on a gas chromatograph (GC) capillary column. A micro-orifice may be used to ensure rapid expansion of the supercritical fluid to deposit the contaminant in a small 'plug' and reduce peak broadening. This is useful for trace analysis since the entire sample is deposited directly on the GC column for analysis. This reduces loss and errors introduced with transfer and injection of the sample. This could lead to lower detection limits of the organics in water.

Other advantages of this method also include a reduced amount of water sample required to do the analysis. Also, this method involves limited use of hazardous and expensive organic solvents. The carbon dioxide used is relatively inexpensive and non-toxic. The major advantage of this system is that the procedure could easily be automated. Several columns may be used in parallel. Once the water is run through the adsorbant, and the adsorbant dried by nitrogen, a valve could switch that would allow the supercritical carbon dioxide to pass through each column, and deposit any extracted organics into a solvent vial. This method would simplify the extraction procedure compared to the liquid-liquid extractions currently in use, and also reduce total analysis time.

A CONTINUOUS MONITOR BASED ON THE DYNAMIC HEADSPACE TECHNIQUE

R.G. Denning[1], G.H. Thomas[2] and R.G. Westendorf[3]
Lambton Industrial Society, Sarnia, Ontario[1]
ORTECH International, Mississauga, Ontario[2]
Tekmar Company, Cincinnati, Ohio[3]

Sampling methods for emergency response purposes i.e. spills into waterways, should be essentially continuous and the analysis immediate so that remedial actions can be implemented without delay.

This paper will discuss the development of a prototype automated water sampling and analysis system which is capable of providing frequent, prompt and quantitative monitoring results for selected target volatile organic compounds at the low PPB level in river water.

The development involved the adaptation of the dynamic headspace analysis technique to automated use at a remote sampling site e.g. river bank.

The prototype system consists of four main components

1. An automated process stream sampler (Tekmar Model 6000) which is used to automatically initiate river water sampling, as well as blank and calibration determinations at predetermined intervals.

2. An automated Purge and Trap (P&T) sample concentrator (Tekmar Model LSC-2) which contains the adsorbent trap (tenax) and electronics that controls the parameters associated with the P&T functions i.e. purge time, desorb time and temperature etc. which determine the conditions necessary for removal of the organics from the water sample and transfer them to the Gas chromatograph (GC) for subsequent chromatographic separation.

3. Microprocessor controlled programmable GC with parallel detectors (ECD and FID) designed for ruggedness and reliability using a packed column system for GC separation of target compounds with a column effluent splitter that permits a portion of the effluent to be directed to the two detectors.

4. Data acquisition module consisting of a Megasys RTU (remote telemetry unit) which accepts an output signal from the GC ranging from 0-1 Volts in amplitude, digitizes it and transmits the value via a data line to a host computer. There are two sample and hold channels, each with eight window capability that are dedicated to the two detectors. At the host computer the data is arranged into a form that is compatible with the existing system and a report on the concentration of each target compound is presented each hour.

A detailed description of the integration of the system components and successful operation of the prototype system will be presented. The major achievements accomplished include; design and fabrication of a suitable blank/calibration system; successful interfacing both mechanically and electronically of the Tekmar units and the GC; interfacing of GC output with the existing host computer system. The eventual successful continuous unattended operation of the system over a six month period and data relating to typical monitoring results of the target compounds will be discussed.

Refinements of the system still under investigation include the calibration system and method detection limits for the target chemical compounds.

This new approach to ambient water quality monitoring will prove a valuable component of water quality assessment programs. It will ensure a prompt awareness and response to any major spills that may occur as well as complement the more normal intermittent sampling programs.

WATER POLLUTION CONTROL TECHNOLOGY

SESSION I (a.m. Seminar Room)
ENVIRONMENTAL MODELLING

"Environmental Impact Assessment"

DETERMINATION OF CHLORINATED PHENOLICS IN PULP AND PAPER EFFLUENTS

H.B. Lee[1], R.L. Hong-You[2] and P.J.A. Fowlie[2]
National Water Research Institute, Burlington, Ontario[1]
Wastewater Technology Centre, Burlington, Ontario[2]

Based on the in-situ acetylation procedure, a method for the determination of 31 chlorinated phenolics in pulp and paper effluent samples has been developed. Except for 4-chlorocatechol, this procedure provided satisfactory recovery for all phenols at three levels of fortification, namely, 400, 40, and 4 ug/L. Analysis of the acetyl derivatives was performed by gas chromatography using a 30 m DB-5 capillary column interfaced to an electron-capture detector. Mass spectral abundance data for the characteristic ions of the acetyl derivatives was acquired and used for the confirmation of compound identities. By operating a mass selective detector in the selected ion monitoring mode, application of this procedure was further extended to the mono chlorinated phenolics. Using a 50 mL effluent sample, the method detection limit was 0.5 ug/L for all except the monochlorinated compounds, which had a detection limit of 1 ug/L.

TWENTY-FOURTH CANADIAN SYMPOSIUM
ON WATER POLLUTION RESEARCH

SESSION 1
11:30-12:00

DEGRADATION PATHWAYS OF HALOGENATED ETHANES AND ETHENES IN ANOXIC GROUND WATER

S. Lesage and R.E. Jackson
National Water Research Institute, Burlington, Ontario

Contamination of the glacial outwash aquifer beneath the Gloucester landfill by a mixture of chlorinated solvents has created an ideal subsurface environment for the study of the degradation pathways of chlorinated alkanes and alkenes.

The production of the carcinogen vinyl chloride from perchloroethylene has been demonstrated by several groups in microcosms and by others in field situations. The pathways have been recognised as including a series of reductive dehalogenation and some elimination reactions. For the first time, the fate of perchloroethylene and trichloroethane and of their intermediate degradation products has been followed over a period of seven years. More importantly, the universality of application of these pathways is being investigated. The formation of chloropropene from dichloropropane provided some evidence that substrates other than chloroethanes may be degraded via the same mechanism. Also, compounds possibly arising through the reductive dehalogenation and elimination of the chlorofluorocarbon 1, 1, 2-trichloro-1, 2, 2-trifluoroethane (F-113) were observed. A proposed degradation sequence is shown in Figure 1. Chlorofluorocarbons have been generally regarded as extremely volatile, non-toxic and stable. This new evidence may require us to revise our views regarding their status as possible groundwater contaminants and the implications in their usage as laboratory solvents and industrial degreasing agents.

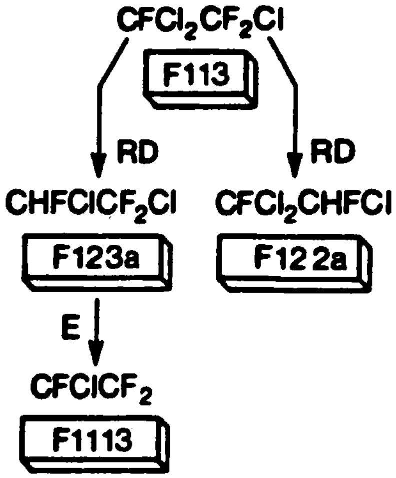

Figure 1.

ANALYSIS OF ADSORBABLE ORGANIC HALOGENS IN PULP & PAPER PLANT STREAMS

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Halogenated organic compounds are among the most prevalent as well as most toxic anthropogenic pollutants known. In the kraft mill processes the bleaching of wood pulp by means of some degree of chlorination is a common and important step in the production of fine papers. This process then, has the potential of being a source of this family of compounds.

AOX (adsorbable organic hologen) has been proposed as a control parameter both in assessing treatability and evironmental impact of these species. A major factor in addressing these edicts is the requirement of meaningful analytical techniques that are capable of quantitating these parameters on a constant monitoring basis.

There are well established methods using gas chromatography and mass spectrometry that can identify and quantify specific halogenated compounds but these methods are time consuming and expensive and are therefore not likely candidates for monitoring processes at frequent intervals.

AOX is considered a gross parameter and is defined as the concentration of halogens (chlorine, bromine an iodine) associated with dissolved or suspended organic matter that are capable of adsorption onto granulated activated carbon under specified conditions.

Two methods have been developed and assessed and are now considered meaningful for measuring AOX as defined in the above paragraph. The first is the commonly used method which involves adsorption under pressure on two columns in series each containing 40mg of GAC followed by combustion-microcoulometry (automated-instrumentation). The second method involves contact adsorption on GAC by way of mixing followed by irradiation and neutron activation. The second method is halogen specific whereas the first method is not.

This report is meant to describe and discuss the two methods in detail with regard to how they compare and the advantages or disadvantages inherent in both.

WATER POLLUTION CONTROL TECHNOLOGY

SESSION I (p.m. Auditorium)
TREATMENT TECHNOLOGIES

"Demonstration Projects"

TWENTY-FOURTH CANADIAN SYMPOSIUM
ON WATER POLLUTION RESEARCH

SESSION I
1:30 - 2:00

DESIGN AND OPERATION OF A PILOT PLANT FOR THE EVALUATION OF DISINFECTION REACTION BY-PRODUCTS IN DRINKING WATER

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University of Alberta, Edmonton, Alberta

Throughout the water treatment industry, a significant amount of research has recently focused on evaluating the effects of trace levels of contaminants on drinking water quality. To study reaction by-products at trace levels, and to provide a better understanding of the mechanisms by which they are formed and removed in the treatment process, drinking water treatment pilot plants should be designed to allow flexibility in process configuration and sampling capabilities. In contrast to batch experimentation, results obtained from pilot scale experiments more closely simulate actual full scale treatment processes. A pilot plant was built at the Rossdale Water Treatment Plant in Edmonton, Alberta, for a study which evaluated, through chemical and biological testing, the potential of the disinfectants chlorine, chloramines, chlorine dioxide, and ozone to form mutagenic compounds. The pilot plant has subsequently been modified to study the effects of ozonation and biological activity in anthracite-sand and granular activated carbon (GAC) filters on the formation and removal of easily biodegradable or assimilable organic carbon (AOC). This paper describes the design of the pilot plant, and indicates typical capabilities and performance levels of the plant.

In order to avoid the possibility of in-plant contamination, all water contacting surfaces within the pilot plant were constructed of inert materials (stainless steel, glass, or fluorocarbons). Increased construction costs associated with the use of these materials were justified, as the possibility of contamination resulting from leaching or reactions with construction materials was minimized.

The pilot plant consists of a common initial treatment sequence of presedimentation, coagulation, flocculation and settling in a parallel plate settler (Figure 1). Effluent from the settler is discharged through submerged effluent launders into a settled water storage tank which serves as a constant head tank and as a splitter box. To allow for the study of various disinfectants, flow from the settled water storage tank is then isolated into four independent parallel streams. The water undergoes addition of a disinfectant, and is passed through a dual-media anthracite-sand filter, a granular activated carbon contactor and into either a post-disinfection contact tank or a backwash storage tank. The process scheme was designed to simulate typical North American water treatment practice. Processes not in common use in North America, such as ozonation and GAC adsorption, were based upon typical westen European practice.

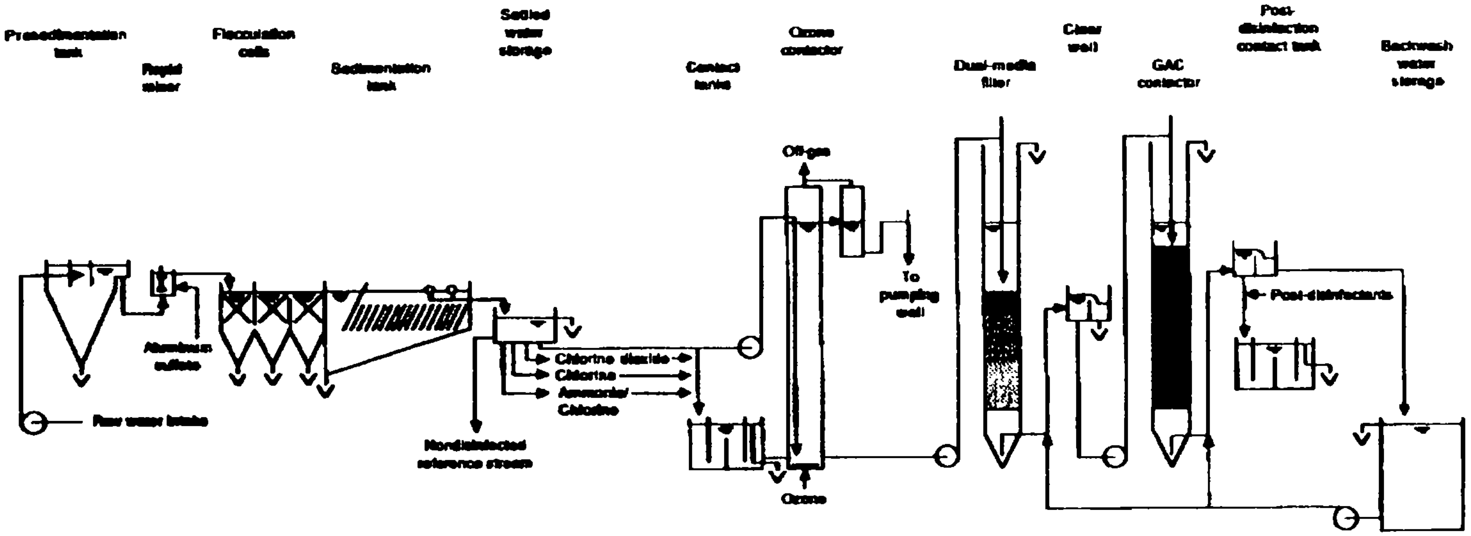

Figure 1. Pilot Plant Schematic

Total daily flow into the plant was approximately $45m^3$/day. To reduce construction costs, each successive treatment step was designed to handle a lower flow as a portion was removed from the previous step for sampling, sludge removal, or from overflow designed to maintain a constant head. At the end of the process sequence, a flow of approximately 2L /min remained. This was either collected for use as filter backwash water, or was run to waste.

Initially, the pilot plant was used to evaluate the reaction by-products formed when chlorine, chloramines, chlorine dioxide and ozone were used as disinfectants. Samples were collected after selected treatment steps and were concentrated on XAD-2® resin without pH adjustment. The resin extracts were then subjected to mutagenicity assays for biological screening. Gas chromatography / mass spectometry analysis of the extracts was also emloyed in an attempt to identify the products present. Other water quality parameters such as TOC, TOX, THM's, THMFP, UV absorbance, turbidity, pH and colour were routinely monitored. Values for a typical daily run during this phase of operation are summarized in Table 1.

Subsequent modifications to the plant and a change in the coagulant used have resulted in improved process performance and the consistent achievement of turbidity levels of 0.1-0.2 NTU following dual-media filtration. These modifications were conducted to permit examination of the process conditions affecting the formation and removal of assimilable organic carbon. Ozone is the sole disinfectant in use, and biological growth on anthracite-sand filter media and granular activated carbon is being promoted. The effects of ozone dose, dual-media filter loading rates and GAC bed contact time on the formation and removal of AOC are being investigated.

This paper outlines the design approach, provides a detailed process description and discusses experimental methods, costs, operating criteria and typical process performance achieved with this pilot plant. Factors found to be important in the design and operation, and problems associated with individual treatment steps are also addressed.

TABLE 1.
Typical Pilot Plant Run Operating Data
(March 30-31, 1987)

Stream	Raw Water	Settled Water	Disinfection Contact Tanks				Post Dual-Media Filtration				Post-GAC Contactors*			
	0	0	1	2	3	4	1	2	3	4	1	2	3	4
Flow (L/min)	40	23	3.7	4.0	4.1	4.0	3.5	3.5	3.5	3.5	2.5	2.5	2.5	2.5
Alum dose (mg/L)	38	-	-	-	-	-	-	-	-	-	-	-	-	-
Turbidity (NTU)+	4.5	3.1	3.1	3.0	2.7	2.8	0.55	0.52	0.55	0.55	0.08	0.09	0.08	0.06
pH	8.0	7.3	7.3	7.3	7.3	7.3	7.3	7.3	7.3	7.4	7.4	7.4	7.4	7.4
Temperature (°C)	6.5	6.5	6.5	6.5	6.7	7.5	7.2	7.2	7.2	8.0	8.2	8.2	8.2	9.2
Colour (TCU)	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Dissolved O_2 (mg/L)	-	10.9	-	-	-	-	10.6	10.8	10.8	13.5	10.2	10.1	10.3	11.6
Dosages:														
mg/L N	-	-	0.50	-	-	-	-	-	-	-	-	-	-	-
mg/L Cl_2	-	-	1.3	0.46	-	-	-	-	-	-	-	-	-	-
mg/L ClO_2	-	-	-	-	0.83	-	-	-	-	-	-	-	-	-
mg/L O_3 (inj.)	-	-	-	-	-	1.1	-	-	-	-	-	-	-	-
mg/L O_3 (abs.)	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Residuals:														
mg/L Cl_2 (free)	-	-	0.01	0.21	0.08‡	-	0.02	0.12	0.05‡	-	-	-	-	-
mg/L NH_2Cl	-	-	0.95	0.04	-	-	0.85	0.05	-	-	-	-	-	-
mg/L $NHCl_2$	-	-	0.12	0.09	-	-	0.11	0.09	-	-	-	-	-	-
mg/L ClO_2	-	-	-	-	0.24	-	-	-	0.13	-	-	-	-	-
mg/L ClO_2^-	-	-	-	-	0.16	-	-	-	0.22	-	-	-	-	-
mg/L O_3	-	-	-	-	-	0.24	-	-	-	LDL	-	-	-	-
Total flow (L/24 hrs)	-	1170§	-	-	-	-	1200	1190	1190	1230	-	1230	-	-

0 = Non-disinfected, 1 = chloramine, 2 = chlorine, 3 = chlorine dioxide, 4 = ozone
LDL = Less than detection limits

* At port 1 (23 cm below top of bed)
\+ At start of run only
‡ Represents total chlorine
§ Represents total flow through XAD-2 cartridge on nondisinfected reference stream line

TREATMENT OF FIREFIGHTING TRAINING WASTE

P.J. Connell and R.P. Canning
ZENON Environmental Inc., Burlington, Ontario

A four month firefighting waste treatment pilot programme at a major Canadian airport was completed. The pilot treatment equipment used in the programme resulted in the processing of approximately 18,000 litres of firefighting waste through 18 batch runs. The three stage treatment approach, entailing gravity settling, ultrafiltration (UF), and reverse osmosis (RO), lead to the removal of impurities in the stream to a degree suitable for storm sewer discharge along with the recovery of unburnt fuel and aquenous film forming foam (AFFF) for reuse. The major objectives of the pilot programme were to assess the capabilities of the treatment solution and to develop capital and operating costs from the data collected.

Shortly after a firefighting training exercise, residues, which pooled around the airplane mockup, were pumped to the gravity settling tank to begin the treatment process. The gravity settler provided the means for unburnt fuel and solids in the waste to separate from the aqueous phase. The solids were disposed of and the unburnt fuel was recovered and stored for later reuse. The bulk aqueous phase of the waste was transferred to the UF system for further processing.

The UF membrane separation system was designed to reject suspended solids in the waste stream and to accept the majority of all the other components (e.g. AFFF in the form of total organic carbon, TOC). The UF system provided a waste volume reduction of 90%, rejecting an average of 100% of total suspended solids and 12% of TOC. The average membrane flux rate for the system was 75 L/m^2/h. Each batch of UF permeate was further processed through an RO system.

The RO membrane separation system was designed to reduce the impurities of the waste stream to a level suitable for storm sewer discharge and at the same time retain and concentrate the AFFF components. The RO system also provided a waste volume reduction of 90%, rejecting an average of 98% of the TOC in the RO feed stream and thus concentrated the active components of AFFF to approximately 8 fold the concentration of that in the RO feed. The RO system produced a permeate clean enough to surpass guidelines for discharge to storm sewer (based on the most recent Ontario "MOE Model By-law to Control Waste Discharge to Municipal Sewers", Aug. 1988). The average membrane flux rate for the system was 15 L/m^2/h.

The reclaimed AFFF from the RO concentrate was approximately 10% of the concentration of virgin AFFF. The reclaimed product could potentially be reused as a diluent with virgin AFFF as a 6% aqueous AFFF solution is suitable for firefighting training exercises. Firefighting tests using reclaimed AFFF mixed with a portion of virgin AFFF (as little as 30%) were conducted by an AFFF supplier, and the results demonstrated that the composite AFFF material had comparable firefighting characteristics to virgin AFFF alone.

The economic feasibility of operating a firefighting waste treatment plant at various airport categories has been determined. Several cost options are presented comparing recycle to disposal of firefighting waste. As a comparison, the treatment cost of hauling firefighting training waste from a Category 9 airport (e.g. Pearson International) is approximately $1.25/L compared to a treatment cost of approximately $0.12/L if the waste is treated by the proposed process and the byproducts are recycled.

A LOW COST NITRIFICATION-DENITRIFICATION SYSTEM FOR THE CONTROL OF AMMONIA AND HYDROGEN SULPHIDE IN LAGOON EFFLUENTS

W. Lewandowski
Ontario Ministry of the Environment, Toronto, Ontario

In Ontario, anaerobic conditions in waste stabilization ponds during periods of ice cover favor microbial transformations that generate ammonia and hydrogen sulphide. As a result, the pond effluent quality may exceed levels acceptable for discharge to a receiving water, particularly where annual retention cannot be provided, or may give rise to odour problems during the Spring ice breakup.

To control ammonia and hydrogen sulphide in pond effluents, the Ministry of the Environment conducted pilot studies utilizing a pre-treatment unit which produces a highly nitrified effluent to create an optimal nitrification-denitrification system. The studies indicated that increased sludge age and controlled release of sludge from the clarifier to the lagoon (rather than the conventional practice of sludge haulage to waste disposal sites) improved system performance. Following testing at a full-scale facility, the new procedures were implemented at several sites in Ontario where they have yielded substantial benefits, namely, high effluent quality in terms of BOD_5, suspended solids, phosphorus, ammonia, nitrates, hydrogen sulphide and bacteria, and reduced operating costs, as no sludge digestion haulage of externally supplied carbon source for denitrification, is required.

The pre-treatment unit consists of a complete-mix aeration cell followed by clarification and sludge return. Ammonium conversion to nitrate in the aeration cell followed by denitrification in the pond and the release of nitrogen gas from the pond surface. The continual presence of nitrates in the pond prevents the conversion of sulphate to hydrogen sulphide, as nitrates are preferrentially utilized by heterotrophic bacteria. High sludge age in the pre-treatment unit contributes to high year-round nitrification. Controlled release of the waste activated sludge to the pond acts as a carbon source for the bacteria and, thus, enhances denitrification.

The presentation will include a description of this new process, as well as plant design, operation and maintenance procedures and pond effluent quality at the Colborne and Sutton Water Pollution Control Plants.

WATER POLLUTION CONTROL TECHNOLOGY

SESSION I (p.m. Auditorium)
TREATMENT TECHNOLOGIES

"Laboratory Studies"

TWENTY-FOURTH CANADIAN SYMPOSIUM
ON WATER POLLUTION RESEARCH

SESSION I
3:30 - 4:00

THE ADAPTATION OF ANAEROBIC GRANULATED BED TO CHANGES IN LOADING RATE AND LIQUID UPFLOW VELOCITY IN UASB REACTORS

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The University of Western Ontario, London, Ontario[1]
Lodz Technical University, Poland[2]

Four 20L UASB reactors. R1. R2, R3 and R4 were operated at different upflow velocities of 0.25, 1.0, 1.5 and 0.5 mh^{-1}, respectively. Higher loading rates were achieved by increasing the feed rate at different times and by removing the parts of granules from the bed at a constant volumetric feed of 6.2 g. COD L^{-1} day^{-1}.

It was found that the granulated bed may adapt to the increased organic loading rate up to about 1.6 kg COD $(kg\ VSS)^{-1}$ day^{-1} and achieve a 100% conversion of the COD (composed of volatile fatty acids). Increasing the loading rate over the above value can bring about a decreased COD conversion. At the organic loading rate of 1.6 kg COD $(kg\ VSS)^{-1}$ day^{-1}, the accumulation of granules in reactors R1 and R4 was observed (from 77 g VSS to 143 g VSS in 40 days and from 79 g VSS to 94 g VSS in 26 days, respectively). At the same loading rate no accumulation of granules was observed in reactor R2 (within 40 days) and in reactor R3 (within 55 days).

It was also found that a number of large granules was washed out from reactors R1 and R4 when the loading rate of about 0.7 kg COD $(kg\ VSS)^{-1}$ day^{-1} was maintained for about 70 days.

IMPROVED BACTERIAL LEACHING OF METALS FROM MUNICIPAL SLUDGE (REACTOR STUDIES)

R.D. Tyagi, F.T. Tran and B. Boulanger
INRS-Eau, Sainte-Foy, Quebec

Heavy metals removal from municipal sludge was studied in different bioreactor schemes (batch, continuous stirred tank with and without cell recycle, airlift) in search of lower bioreaction time. The efficiency of metal solubilization was found to be higher in airlift reactor. Required metal solubilization was achieved in 0.75 days residence time.

REACTIONS OF HYDROXYL RADICALS WITH CHLOROBENZENES: COMPARISON TO TiO_2PHOTOCATALYST REACTIONS

G. Lepore and C.H. Langford
Concordia University, Montreal, Quebec

The presence of chlorinated aromatic compounds in natural and drinking water has become a serious problem in many parts of the world, including North America. The major concerns are the toxicity and persistance of the species in the environment.

Substantial interest has gone into the development of an efficient and inexpensive system for water purification. Photocatalysis can be an effective method (1,2,3,4). The concept involves illumination of an oxide semiconductor in the presence of polluted water. Light absorption of energy greater than that of its optical band-gap leads to the generation of electron-hole pairs. Under the influence of the electric field these separate via the conduction and valence bands, respectively. The resulting distribution of electrons and holes gives rise to powerful reduction or oxidation agents towards adsorbed species, surface groups, or the semiconductor itself. Evidence seems to indicate a significant involvement of surface produced hydroxyl radical reactions in degrading chlorinated aromatic compounds (5,6,7,8).

The purpose of this study is to contrast the behavior of surface and solution generated hydroxyl radical reactions, which seem to occur in photocatalysis. This was accomplished by acquiring information on the reactivity and selectivity pertaining to both generating systems towards model contaminants. The photocatalyst was a TiO_2 (anatase) dispersion.

Solution generation of hydroxyl radicals was achieved by a non-photochemical process employing Fenton's Reagent (9,10,11). The process involved the addition of hydrogen peroxide to an aqueous solution containing an organic substrate and excess ferrous ions at low pH (less than 3). The hydroxyl radicals generated attack on the substrate. The subsequent course of the reaction depends upon the fate of the organic radicals so produced. The test substrates were the comparatively refractory chlorobenzenes; o, m, p, dichlorobenzenes (DCB) and 1,2,4-trichlorobenzene (TCB).

The photocatalytic dechlorination (wavelengths $\geq$ 350 nm) of 20 ppm DCB isomers and TCB over TiO_2 (anatase) dispersions, followed first order kinetics. Dechlorination increased accordingly;
p-DCB < 1,2,4-TB < o-DCB < m-DCB.

The use of Fenton's reagent towards similar water contaminants exhibited approximate first-order kinetics. Dechlorination increased as follows: 1,2,4-TCB < p-DCB ~ o-DCB ~ m-DCB. Furthermore, successive addition of acetone (hydroxyl radical trap) to both systems, showed a decrease of dechlorination for each compound. However, only 1,2,4-TCB exhibited a substantial decrease compared to DCB's in the non-photo chemical system. In the photocatalysis, system effects were non-selective.

Results indicate that although solution generated hydroxyl radicals are highly reactive species, they are not as selective towards the isomers compared to surface generated radicals. Therefore, it is unlikely that surface generated hydroxyl radicals desorb from the catalyst into the solution to subsequently react with water contaminants.

Evidence put forward would suggest dechlorination occurs via surface adsorption of chlorinated aromatics onto the illuminated catalyst. This means the oxidant may be better described as a "surface trapped hole". The selectivity order is difficult to explain on the grounds of electronic effects and may indicate an important role for adsorption site and surface orientations of the adsorbed molecules.

IMPACT OF POLLUTANTS ON AQUATIC ECOSYSTEMS

SESSION II (p.m. Seminar Room)
POLLUTION EFFECTS AT THE ECOSYSTEM LEVEL

IMPACT AND RECOVERY OF AN ACID SPILL ON THE YORK RIVER

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Beak Consultants Ltd., Brampton, Ontario[2]
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As the result of a sulphuric acid spill in June, 1982 at the Mines Gaspe operation in Murdochville, Quebec, water quality of effluents being discharged to the headwaters of the York River was temporarily impaired. It rapidly became apparent that the aquatic fauna of this important Atlantic salmon river had been affected in some areas. This paper provides a technical overview of the results obtained in extensive biological studies (salmon and benthos) carried out by Beak Consultants Ltd. and Noranda Research Centre annually, 1982 to 1985.

The biological and water chemistry surveys carried out during this four-year period indicated a short duration event of high dissolved metals levels, primarily copper, shortly after the spill followed by a rapid improvement in water quality. Both the aquatic macroinvertebrate benthos and fish life in the river were negatively impacted. The nature and degree of this impact as well as the subsequent recolonization of aquatic habitats by both groups was observed and documented.

The most affected aquatic groups in 1982 were the youngest salmon age classes (0+ and 1+) along with the intermediate and sensitive benthic communities. This impact was mainly observed in the upper and middle river section. The maintenance of suitable water quality during the following years has permitted excellent survival rates for juvenile salmon and recolonization of benthic habitats by sensitive species. This has contributed to the gradual re-establishment of a natural aquatic fauna in the York River.

More recent surveys carried out since 1985 confirm that the quality of the York River ecosystem has been maintained and suggest that the survival rates observed for juvenile salmon are higher than the theoretical values usually used in salmon production models.

PLANKTONIC MODEL ECOSYSTEMS FOR STUDYING POLLUTION EFFECTS AT THE ECOSYSTEM LEVEL

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Large volume (3400 L) model ecosystems in our laboratory can contain stable populations of zooplankton and phytoplankton for at least several months. These systems are unique among both field and laboratory experiments because they allow us to investigate the interaction between nutrient loading rates, zooplankton harvesting rates (i.e. fish "predation") and toxic substances at the ecosystem level under controlled environmental conditions. Using Daphnia magna as the sole zooplankton species in initial experiments has demonstrated that these ecosystems are ecologically stable. Daphnia and phytoplankton exhibited damped oscillations and a return to steady-state conditions after perturbation. Population biomasses of both trophic levels followed relationships correctly predicted by mathematical models. The combination of nutrient loading and zooplankton harvesting rates which lead to unstable conditions were also correctly predicted. Addition of cadmium to the model ecosytems resulted in a much more dramatic ecosystem response than expected based on observations from benchtop toxicity tests, although the minimum cadmium concentration required to produce an effect was similar in both the ecosystems and the benchtop tests. The addition of cadmium resulted in a drop in Daphnia biomass and an increase in phytoplankton biomass. These effects were then enhanced by the inhibition of Daphnia population growth rates caused by the higher algal concentrations.

Current experiments using natural plankton collected from the Burlington Canal suggest that Daphnia, Bosmina, Calanoid copepods, Cyclopoid copepods, rotifers, and several algal species can coexist for at least several months in these experimental systems. Whether all these species can maintain truly stable populations is not yet certain. After preliminary experiments in which nutrient addition and zooplankton harvesting rates are varied, these ecosystems will be used to test the effect of toxic substances on species composition and abundance of the natural plankton of Lake Ontario. These data should allow us to better predict the effect toxicants have on fish production in the lake through alterations in the food chain.

A COMPARISON OF PCB CONGENER DISTRIBUTIONS IN TWO CONTAMINATED LAKES IN ONTARIO

C.R. Macdonald and C.D. Metcalfe
Trent University, Peterborough, Ontario

High concentrations of polychlorinated biphenyls (PCBs) have led to restrictions on the consumption of sport fish in two lakes in eastern central Ontario. Lake Clear was contaminated in the mid-1970's by road oiling along the western rim of the lake and, in 1981 and 1982, lake trout, smallmouth bass and northern pike were shown to contain 6, 1.2 and 0.6 ppm PCB wet weight, respectively. Rice Lake was subjected to a range of PCBs for several years and has been shown to have high concentrations of PCBs in all sport fish. Smallmouth bass and yellow perch in Rice Lake have been shown to contain approximately 0.5 µg PCB g^{-1} wet weight, considerably higher than other lakes in the Kawartha region. Lake Scugog, a highly productive lake also in central Ontario has detectable but very low levels of PCBs in fish and, in addition, has a food web structure to Rice Lake. It is the purpose of this study to compare the concentrations of 19 PCB congeners in several groups of biota, including 4 fish species, and sediments in the three lakes, to determine the differences in distribution of the PCB congeners between the lakes. The data will be used to estimate the movement of the PBCs and to estimate the pathways of the congeners to the upper trophic levels.

Samples of clams, crayfish, zooplankton and four species of fish were collected in 1986 and 1987 in all three study lakes and analysed by high resolution gas chromatography. The samples were analysed for nineteen PCB congeners which ranged from tri- to decachlorobiphenyl.

Total PCB congeners in the biota in Lake Clear ranged from 23.6 ng g^{-1} (SD = 15.5-36.0, n = 5) in clams to a maximum of 153 ng g^{-1}(SD-125-186, n = 5) PCB (wet weight) in smallmouth bass. No significant difference was observed in PCB concentration on a wet weight or lipid weight basis between groups of biota. The distribution of congeners was virtually identical throughout all biota amd sediments, with high proportions of all penta- and hexachlorobiphenyls. This pattern was similar to the original contamination and indicates that the lower chlorinated PCB congeners are not decreasing in the lake, and that PCBs are being transported into the sediments as a group. Hence the higher trophic levels will continue to accumulate PCBs until the levels in their diet and in the water decrease. Total congener concentrations in Rice Lake ranged from 26 ng g^{-1}in clam whole body samples to 153 ng g^{-1} in smallmouth bass. The distribution of congeners in the smallmouth bass in Rice Lake was considerably different from the lower trophic levels, such as zooplankton and young-of-the-year perch, indicating preferential accumulation of penta- and hexa-chlorobiphenyls.

The same phenomenon was observed in Lake Scugog where the concentrations of PCBs were considerably lower but a shift of congeners towards the higher chlorinated congeners was observed. In contrast to Lake Clear, this indicates that the congeners are either being preferentially accumulated by the upper trophic levels or are being metabolized. Computer modelling suggests that the majority of the body burden in the fish of the upper trophic levels has been transported through the diet rather than from the water.

IMPACT OF POLLUTANTS ON AQUATIC ECOSYSTEMS

SESSION II (p.m. Seminar Room)
BIOLOGICAL ASPECTS OF TOXIC CONTAMINATION

ECOLOGICAL PARTITIONING OF ORGANOCHLORINATED CONTAMINANTS IN FORAGE FISH SPECIES.

C.E. Herbert and G.D. Haffner
University of Windsor, Windsor, Ontario

Four species of forage fish: *Labidesthes sicculus* (brook silverside), *Notropis atherinoides* (emerald shiner), *Notropis hudsonius* (spottail shiner), and *Pimephales notatus* (bluntnose minnow) were collected during August and September, 1988 from a site in the St. Clair River immediately south of Sarnia's Chemical Valley. The fish were caught in nearshore waters using a 0.6 cm mesh bagseine. They were measured (total length) and immediately wrapped in hexane-rinsed aluminum foil. Samples were kept frozen at -20 degrees Celsius until they were analyzed.

The four species are morphologically distinct and it is these physical differences that separate them ecologically (Keast 1966). *L. sicculus* is an obligate surface feeder, *N. atherinoides* is a facultative surface feeder, *N. hudsonius* is a facultative benthivore, and *P. notatus* feeds on benthic organisms. Therefore, there was an integration of benthic and pelagic food webs by organisms of the same size and age.

Whole fish extracts were prepared according to the protocol developed by the Canadian Wildlife Service (1982) and were analyzed by GC-ECD techniques. Pentachlorobenzene ($\log K_{ow} = 5.0$), hexachlorobenzene ($\log K_{ow} = 5.5$), octachlorostyrene ($\log K_{ow} = 6.2$) and various PCB congeners ($\log K_{ow} = 5.8$-7.0) were examined. *P. notatus* had the highest mean contaminant levels followed by *N. hudsonius*, *N. atherinoides*, and then *L. sicculus*. These interspecific differences became more apparent with increasing $\log K_{ow}$ of the compounds.

There were no significant interspecific differences in size or lipid content among the species examined (Anova,$p>0.1$). Lipid normalized HCB and OCS levels showed significant interspecific differences (one-way Anova, $p<0.05$ and $p<0.01$ respectively) but QCB did not (one-way Anova,$p<0.1$). The PCB congeners varied similarly but reflected the input of these compounds from atmospheric sources.

The lipid normalized interspecific differences in contaminant burdens indicated that bioaccumulation was a major factor regulating contaminant levels in forage fish. Due to their relatively high K_{ow} and low aqueous solubility, compounds such as HCB and OCS partition more readily into sediments. As a result, the benthic feeding species were subjected to higher levels of these contaminants. This was reflected in the bioaccumulation factors calculated for each species for a range of compounds. BAF's were estimated by examining the ratio of lipid normalized contaminant concentration in the fish to organic carbon normalized contaminant levels in the sediment. The benthivores exhibited higher BAF's than the surface feeding species. For all species, however, a significant correlation was observed between log K_{ow} and BAF (Anova, $p<0.05$).

Ratios of contaminants (QCB:OCS and HCB:OCS) were also examined to measure food web interactions (Flint, 1988). Significant interspecific differences confirmed (one-way Anova, $p<0.05$) that benthivores had greater proportions of the higher K_{ow} compounds. If contaminant levels in these forage fish species were regulated by food, then habitat utilization and food selection are important factors in determining species specific contaminant burdens.

Previous studies have produced conflicting results as to the prediction of contaminant levels in fish from sediment levels (Connor, 1985; Oliver and Niimi, 1988). This study illustrates the importance of sediment in regulating contaminant levels in forage fish species. However, exposure to these contaminated sediments is regulated by species specific vertical habitat partitioning.

TWENTY-FOURTH CANADIAN SYMPOSIUM
ON WATER POLLUTION RESEARCH

SESSION II
4:00 - 4:30

THE USE OF YOUNG-OF-THE-YEAR FISH AS BIOINDICATORS OF TOXIC CHEMICALS IN THE ST. LAWRENCE RIVER

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The analysis of water samples for contaminants often gives unsatisfactory results since concentrations are usually close or below detection limits and large temporal fluctuations prevent a meaningful statistical interpretation of the data.

Adult fish have been used as bioindicators with limitations. Within-station variations due to mobility, food chain effects, change in diet, reproductive cycle and the general-life history of the species including size, age and sex, curtail the use of the adult in spatial and temporal trend analysis.

In view of these problems, a pilot study was initiated in 1984 on the use of young-of-the-year fish (Notropis hudsonius, Spottail Shiner, as target species, and Perca flavescens, Yellow Perch, as replacement species) as bioindicators. The results of this study showed that these young-of-the-year are good indicators of certain contaminants such as PCB's, DDE, HCB and Hg. Following the recommendations of this study, further exploratory work was carried out to improve the use of these indicator-fish and to establish the limits of this biomonitoring tool.

In 1986, a second study was carried out to investigate interspecies correlations and length-concentration relationships. The analysis of the results showed that a significant correlation exists between species for contaminants such as PCB's, HCB, DDE and Hg. This allowed us to develop a predictive model which unables the estimation of contaminant concentrations in the target species from concentrations in the replacement species. In 1987, the scope of the study was broadened to include less persistent contaminants such as triazine herbicides, organophosphates, and PAH's. The results showed that these compounds did not accumulate to detectable levels. It seems, therefore, that the use of young-of-the-year is limited to persistent lipophilic contaminants and non-essential metals.

At some stations, neither the target species nor the original replacement species were present. Therefore, during the same study, the use of a second replacement species was introduced (Notropis atherinoides, Emerald Shiner). It was found that this new species accumulated PCB's at levels of up to 5 times as high than that of the target species. This may be explained by higher lipid contents of Emerald Shiner as compared to Spottail Shiner.

In addition to these above mentioned points, the site-specific nature of this biomonitoring tool will be discussed in terms of spatial trend along the St. Lawrence River.

Mercury levels are relatively uniform along the River from Cornwall to Quebec City, harbouring concentrations of around 35-45 ng/g with the exception of the southern part of Lake St. Louis where mercury levels are higher, around 180 ng/g, due to the presence of a chlor-alkali plant and highly contaminated sediments. PCB concentrations showed maxima of around 200ng/g in Lake St. Francis source: Lake Ontario and Massena and downstream from Montreal (source sewage outfall and general industry). Massena seems to be a significant point source of PCB pollution. Downstream from Lake St. Pierre, levels stabilize around 80 ng/g.

We shall also touch upon some recent developments oriented toward the use of these species as bioindicators of general or specific stress. A particular emphasis will be given to ATP measurements related to general stress, mixed function oxydase systems in relation to organic aggression (particularly PAH) and metalothionein determination in relation with metal contamination.

EVIDENCE OF GENOTOXINS IN THE SEDIMENTS OF THE WELLAND AND BUFFALO RIVERS AS INFERRED FROM THE FREQUENCY OF CHIRONOMID LABIAL PLATE DEFORMITIES

M. Dickman, Q. Lan and B. Matthews
Brock University, St. Catherines, Ontario

The highest frequency of chironomid labial plate deformities occurred immediately downstream of the B.F. Goodrich Company's point source discharge to the Welland River. In 1986, B.F. Goodrich released 33 kg of vinyl chloride, (C_2H_3Cl), into the Welland River at this site (MOE 1987). Vinyl chloride is an extremely powerful mutagen and human carcinogen and is suspected of inducing the high frequency (47%) of chironomid labial plate deformities which we observed at this site.

The next highest frequency of chironomid labial plate deformities occurred in the heavily industrialized section of the Buffalo River in Buffalo, New York. Thirty-five percent of the chironomids which possessed labial plates at this site displayed gross deformities such as fused teeth, crossed teeth, extra teeth, numerous missing teeth and/or teeth of extremely bizarre shape.

Study sites in the Niagara River watershed where there was no record of genotoxic substances displayed chironomid deformity frequencies which ranged between 6 and 9%.

These differences (6-9% vs. 35-47%) were statistically significant ($P<0.05$) using the Mann Whitney U Test. A similar conclusion was reached when the Wilcoxon two-sample nonparametric test was employed.

In conclusion, it is believed that the frequency of chironomid labial plate deformities is a useful tool for detecting areas which are contaminated by persistent genotoxins.

SESSION III (a.m. and p.m. Main Mall Area)
POSTER

THE EFFECT OF KRAFT PULP MILL EFFLUENT ON THE SEDIMENT QUALITY OF JACKFISH BAY, LAKE SUPERIOR

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During 1987 and 1988 a sediment survey was conducted in Jackfish Bay to determine, in part, the effects of a Kraft pulpmill effluent. Surficial sediment samples were collected from 37 sites located largely within the deposition areas of the Bay. Analyses of bulk chemistry included trace metals and organic contaminants. Although sediment grain size was similar through all of the deposition areas within the Bay, elevated contaminant concentrations were noted in sediments of the area near the Kraft mill effluent source. Contaminant distribution suggested that rather than a direct relationship between proximity to the source and sediment concentration, a secondary redistribution of contaminants was occurring in response to physical factors active in the Bay.

HYBRID GROWTH SYSTEMS FOR BIOLOGICAL WASTEWATER TREATMENT

PR. Senthilnathan and J.J. Ganczarczyk
University of Toronto, Toronto, Ontario

The microorganisms retained in biological wastewater treatment systems are usually either in suspended growth form as in the activated sludge process, or in attached growth form as in trickling filters and rotating biological contactors. A new class of treatment systems such as fluidized bed systems and activated sludge systems appended with biomass carriers can be classified as hybrid growth systems. The hybridization of suspended and attached growth systems derives the advantages of both the systems and overcomes some of the disadvantages associated with these systems. By means of biomass carriers it is possible to maintain a large inventory of (5000 to 30,000 mg MLVSS/L) microorganisms in the aeration basins. The increased concentration of biomass will lead to reduced volume of the reactor, increased treatment system stability and its improved performance.

Currently, there are many hybrid growth systems available for commercial applications. These systems can be further classified as 1) immersed media systems, 2) porous media systems, and 3) carrier activated sludge systems. These modifications are especially attractive for upgrading existing overloaded activated sludge plants and may require relatively minor changes to the existing process installations.

In the immersed media systems, various stationary solid surfaces are immersed in the activated sludge reactor. These solid surfaces can be modular plastic media, or synthetic fiber media such as "RING LACE". In the porous media systems, the biomass carriers are small, highly porous, reticulated polyurethane foam pads suspended in the aeration basin. At present, there are two patented processes using porous foam pads: the "CAPTOR" process and the "LINPOR" process. In the carrier activated sludge systems, large quantities of micro-carriers are added to the aeration basin to provide a very high surface area for passive immobilization.

This paper traces the history of the application of hybrid growth systems in biological wastewater treatment, and systematically describes various hybrid growth systems which are currently available. The advantages, disadvantages and operating characteristics of these systems are analyzed. The characteristics of biomass in these systems are discussed.

ASSESSMENT OF TWO ACTIVATED CARBON ADSORPTION SYSTEMS TREATING WOOD PRESERVATION WASTEWATERS

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Phenols. chlorophenols and some of the other toxic organics (eg. polyaromatic hydrocarbons) can be removed from aqueous solutions by adsortion on activated carbon. Therefore, the activated carbon adsorption process is recognized as one of the technologies that may be used cost-effectively for treating some of the industrial wastewaters which contain phenols and/or chlorophenols. One industry which produces wastewaters containing elevated levels of these chemicals is the wood preservation industry. However, published data from the application of activated carbon adsorption to wood preservation wastewaters are limited.

In Canada, there are several wood preservation plants which use activated carbon adsorption for treating their wastewaters. During the study covered by this paper, the performance of two of these plants was evaluated to determine their effectiveness with respect to the removal of TOC. phenolics, pentachlorophenol, tetrachlorophenol and some of the other specific organics. One of these plants was located in Delson, Quebec and the other was in Trenton, Ontario.

The Delson facility treats process wastewater, whereas at Trenton the system is less typical in that it is used to treat surface run-off that contains suspended particulates. Both facilities use two carbon adsorbers in series with a pretreatment stage prior to the adsorbers. The pretreatment stage at Delson is more elaborate than that at Trenton. The two treatment systems will be discussed in detail in the paper and a discussion of the modifications made to the systems since the study will also be included in the paper.

During this study, samples were taken of the feed to the activated carbon system, the effluent from the first column and the effluent from the second column, and analyzed for total organic carbon (TOC), phenolics, pentachlorophenol (PCP) and tetrachlorophenol (TTCP). Selected samples were also analyzed for specific priority pollutants.

The ranges for the influent concentrations, the loadings on the activated carbon and the ranges for the effluent concentrations for phenolics, TOC, PCP and TTCP are shown in Table 1 and will be discussed in detail in the paper.

TABLE 1. Influent Concentrations, Loadings, and Effluent Concentrations for Delson and Trenton

	DELSON	TRENTON
INFLUENT CONCENTRATION		
phenolics	241-474 mg/L	0.1-3.4 mg/L
TOC	639-1029 mg/L	17-488 mg/L
PCP	1.9-5.9 mg/L	0.4-2.1 mg/L
TTCP	1.6-8.4 mg/L	0.1-1.8 mg/L
LOADING		
phenolics	157.6 mg/g	0.14 mg/g
TOC	217.0 mg/g	133.3 mg/g
PCP	0.57 mg/g	2.39 mg/g
TTCP	0.59 mg/g	0.58 mg/g
EFFLUENT CONCENTRATION		
phenolics	0.1-3.8 mg/L	0.1-1.3 mg/L
TOC	24-345 mg/L	0.25-402 mg/L
PCP	n/d*	n/d-19 µg/L
TTCP	n/d	n/d-10 µg/L

* n/d means not detected

The concentration of priority pollutants, except polyaromatic hydrocarbons (PAH's) and chlorophenols, in the final effluent at both facilities was found to be lower than the detection limit of the method and instruments used in this study. At Delson, PAH's were found to be near or below the detection limit (0.3-1.0 µg/L depending upon the specific PAH) in the effluent from the first column and consistently below the detection limit in the second column effluent. The concentrations in the final effluent from Trenton were slightly higher but were still only in the low µg/L range.

TWENTY-FOURTH CANADIAN SYMPOSIUM
ON WATER POLLUTION RESEARCH

SESSION III
POSTER

TREATMENT OF CONTAMINATED GROUNDWATER AT VILLE MERCIER, QUEBEC

R.M. Booth, D.T. Vachon, L. Simovic and J. Schmidt
Wastewater Technology Centre, Burlington Ontario

From 1968 to 1972 approximately 40,000 cubic meters of industrial liquid waste, predominately from the petroleum and petrochemical industry, were dumped into lagoons in an abandoned gravel pit near Ville Mercier causing widespread contamination of the ground water. By 1971 the local drinking water wells were impacted.

Based on a feasibility study undertaken by the Quebec Government a full-scale treatment plant was built including air stripping, alum and polymer addition, sedimentation, rapid sand filtration and activated carbon adsorption. The treated water is discharged into a stream in the Chateauguay river basin. Treatment objectives were set on the basis of drinking water quality at the time of designing the plant.

To date, the main problems during the plant operation have been the plugging of unit processes by bacterial growth, incomplete removal of iron and 1,2-dichloroethane, loss of activated carbon by backwashing, and silting up of the wells.

In July 1988 the Department of Supply and Services awarded a contract to a consortium of Laval University, SNC and the University of Sherbrooke. The objectives of the contract were to monitor and report on the aquifer conditions, to optimize the full-scale treatment plant performance and to develop a successful pilot treatment train for the removal/oxidation of toxic organics.

The pilot plant was designed in conjunction with the contractors and constructed by the Wastewater Technology Centre's staff. The plant was installed on site in October, and preliminary tests have been completed. The experimental program is underway and will be completed by July, 1989.

CONSIDERATIONS IN CALIBRATION AND ANALYSIS FOR VOLATILE ORGANIC COMPOUNDS IN AIR EMISSIONS FROM WASTE TREATMENT PROCESSES

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Chemical analysis of air samples for volatile organic compounds requires validation of calibration procedures. The difficulty and cost of obtaining commercial gas standard mixtures for large parameter lists has generally precluded their use. Alternatively, vapour phase standards can be prepared in the laboratory.

Factors to be considered when preparing a gas standard mixture are: 1) efficiency of vapourization of components; 2) possible interactions between organics and container walls; and 3) accuracy in the transfer of gas aliquots to the analytical system.

This study employed a 3.0 litre glass dilution flask to which measured amounts of 38 volatile organics of interest were spiked. Aliquots were withdrawn from a septum port by syringe and analyzed by GC/MSD to generate calibration data. The instrument responses of 11 volatile compounds were measured at four flask temperatures between 26 - 164° C and compared to commercial standard mixtures which contained these same 11 volatile organics in two pressurized cylinders.

An attempt was made to determine whether the degree of volatilization for individual compounds was dependent on flask temperature within the working temperature and concentration ranges. The flask temperature at which the laboratory standard showed best agreement with commercial mixtures was 26° C.

The analytical procedure has been used to analyze gaseous emissions from municipal wastewater treatment plant aeration tanks, pulp and paper industry aerated lagoons, and oil refinery landfarms.

THE PERSISTENCE OF ORGANIC CONTAMINANTS IN SOILS TREATED WITH MUNICIPAL SLUDGE

J.D. Goodin and M.D. Webber
Wastewater Techology Centre, Burlington, Ontario

Studies have been conducted to determine: (a) the persistence and (b) plant uptake of industrial organic contaminants in soils treated with municipal sludge.

An aerated incubation technique was developed to study the persistence of four volatile organic contaminants (VOC) in soil systems. The compounds selected for study were toluene, ethylbenzene, 1,1-dichloroethane and trichloroethylene. The incubation apparatus consisted of a 250 mL Erlenmeyer flask with a screw-on lid, connected to a compressed air cylinder on the air inlet side and to one or more methanol traps on the air outlet side. All connections were made with Viton tubing. Samples spiked with a known amount of contaminant were aerated for a specified time and the volatilized contaminant recovered in methanol. Virtually 100% of the toluene and ethylbenzene and approximately 90% of the chlorinated contaminants were recovered from an empty flask. This indicated that there were no leaks in the system. The recovery of contaminants from sludge treated soils was dependent on equilibration time and temperature. Samples were spiked and equilibrated for 0 h, 1.0 h and 18 h. The recovery of contaminants after 1.0 h and 18 h was similar and somewhat lower than for 0 h. Several experiments indicated that VOC recoveries increased with temperature. The maximum recoveries of toluene, ethylbenzene 1,1-dichloroethane and trichloroethylene were achieved in samples heated to 95°C and purged for 4 hours. Based on these results, subsequent experiments involved a 1.0 h equilibration of contaminants with sludge treated soils, followed by purging at 22°C for a specified period of time and then purging at 95°C for 4 hours.

The persistence of the volatile organic contaminants in sludge treated loamy sand and loam soils was investigated. The results of several tests indicate that toluene and ethylbenzene were completely volatilized at 22°C over a 12 day period. However, only 60% of the 1,1-dichloroethane and trichloroethylene were volatilized. Purging at 95°C did not increase the contaminant recovery after 12 days. Experiments with ^{14}C-labelled contaminants are in progress to determine the fate of the remaining 40% of the chlorinated contaminants.

Plant uptake of ^{14}C-labelled industrial organic contaminants was investigated with ryegrass grown in microcosms in a greenhouse. Microcosms isolate the soil from the above ground plant material. An initial study with 1,2,4-trichlorobenzene indicated that there was no uptake of this contaminant into the ryegrass. All of the contaminant volatilized over a seven week period and was recovered on Tenax traps. Currently a study to investigate the uptake of anthracene, pentachlorophenol, 2, 2', 5, 5'-tetrachlorobiphenyl and benz(a)pyrene is in progress.

AN ECONOMIC ASSESSMENT OF BENEFITS ARISING FROM ADOPTION OF CONSERVATION TILLAGE PRACTICES IN SOUTHWESTERN ONTARIO

E.J. Dickson and G.C. Fox
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Displaced sediment and chemicals carried by runoff from cropland is one of the most important sources of water pollution in Ontario (Coote, 1980). The purpose of this study is to compare the costs incurred by farmers in the adoption of conservation tillage with the downstream benefits of improved water quality. Data from three watersheds in Ontario; the Big Creek watershed in Essex County, the Newbiggen Creek watershed in Middlesex County, and the Stratford/Avon watershed in Perth County, is used in two simulation models.

Much of what is considered erosion on cultivated land is simply the movement of soil and nutrients on the soil surface. Only a portion of this transported soil will make its way to streams and lakes. The Guelph model for evaluating the effects of Agricultural Management Systems on Erosion and Sedimentation (GAMES) developed by Cook et al., (1985) was used to estimate on-farm sediment movement and the proportion of transported sediment that is delivered to the stream.

The Soil Conservation Economics (SOILEC) model was used to study the on-farm economics of alternative tillage practices. The SOILEC model utilizes a topsoil depth - yield relationship to simulate erosion-induced changes in soil productivity. The model also utilizes a topsoil depth - cost relationship to simulate changes in the variable costs of production, such as increases in fertilizer costs, which may increase as erosion occurs. The model was used to calculate the present value of net returns for 50 years of erosion and the change in net returns resulting from the adoption of selected conservation tillage practices.

The off-farm costs of soil erosion occur as sediment and other erosion-related contaminants enter streams and lakes. This disrupts fish reproduction and feeding, reduces the value of water recreation activities, reduces the capacity of water-storage facilities and navigation channels, affects preservation values of concerned individuals, increases the frequency and volume of floods, increases water-treatment costs and maintenance costs of water-using machinery and appliances and clogs water-conveyance systems, such as drainage ditches and irrigation canals. Recent research in the United States has indicated that the off-farm costs of soil erosion are substantial and may in fact be larger than the on-farm costs. This result implies that society, rather than farmers, may be the major beneficiary of efforts to reduce the rate of soil erosion and sediment delivery from cropland.

A number of off-farm costs in the study area were estimated. Costs of sedimentation to recreational fishing, water treatment, and water conveyance were estimated for the Thames River Basin in Ontario. The GAMES model was used to estimate changes in sediment delivery resulting from the adoption of alternative tillage practices. The sediment - water user relationships enabled estimation of the off-farm benefits (reduced off-farm costs) arising from the adoption of conservation tillage practices on cropland in southwestern Ontario. Many of the off-farm damages associated with erosion could not be included so the estimates can be considered conservative.

Using the conventional tillage practice in each watershed, fall moldboard ploughing, as a base for comparison, conservation tillage practices are found to be financially unattractive to the average farmer. The annual off-farm benefits of adopting conservation tillage, which accrue to society as a whole, range from $9.55 to $69.23 per hectare and outweigh the on-farm costs of adoption in all watersheds. Thus, when the off-farm benefits are considered the adoption of conservation tillage becomes very attractive from a social point of view.

This is a classic example of a production externality. Farmers have little incentive to adopt the socially efficient production system since they are not held accountable for the costs they impose on others. Adoption of an environmental and economy-wide perception of the consequences of soil erosion would produce a new perspective for soil conservation policy in Canada.

OPTIMIZING POLYMER ADDITION: A COST MODEL FOR THE DEWATERING, TRANSPORT, AND INCINERATION OF WASTEWATER SLUDGE

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This paper deals with a wastewater process stream where sludge is produced, dewatered, transported, and incinerated. Polymers may be added to the sludge before the dewatering process to increase dewaterability. The enhanced dewatering will reduce the volume of sludge requiring transport to the incineration facility, and will also reduce the amount of auxiliary fuel that is required to maintain the sludge incineration process. These reduced transportation and fuel costs must be traded off against the cost of polymer addition.

Considerable research effort has been expended in the area of polymer addition to enhance sludge dewaterability, but the existing literature does not include a systems approach to the potential process elements after polymer addition, nor a consideration of the effect of incremental polymer addition on the operating costs of these downstream elements. The objective of the research summarized in this paper is the development of a comprehensive cost model which is capable of generating optimal polymer dosages for given operating/design conditions (polymer/sludge characteristics, dewatering process constraints, haul distances, incineration requirements). The scope of the paper is limited to wastewater treatment sludges, but the general methodology is also applicable to other types of sludges (e.g., industrial process residuals) which have similar dewatering/transport/incineration requirements.

The paper summarizes information relating to the individual process components. These include:

* functional relationship between polymer dosage and sludge dewaterability for various dewatering options and polymer types;

* unit costs for a number of polymer types;

* transportation costs for sludge transport;

* functional relationship between sludge moisture content and auxiliary fuel requirement for sludge incineration;

* unit costs for auxiliary fuel used for sludge incineration.

This information is developed into a general analytical cost model, with the decision variable established as the moisture content of the dewatered sludge. Through simple differentiation, and backcalculation using the polymer dosage-dewatered moisture content function, the optimal polymer dosage is obtained in terms of dewatering, transport, and incineration variables. Representative costs for a number of polymer/dewatering/transport scenarios are used to determine the associated optimal polymer additions, and conclusions are drawn with respect to preferred polymer dosing strategies for a variety of conditions.

ONSITE ANAEROBIC TREATMENT OF COMBINED PEA AND POTATO PROCESSING WASTEWATERS USING A MOBILE MICROPROCESSOR CONTROLLED, THREE REACTOR PILOT PLANT FACILITY

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The presentation describes a 9 month onsite anaerobic treatability study conducted using a unique, three reactor, microprocessor controlled anaerobic pilot plant facility treating combined pea and potato processing wastewaters. The presentation includes a description of the pilot plant facilities, a description of the reactor configurations and control strategies used during the study, and a summary of the wastewater characterization and reactor operating and performance data acquired during the study.

Three 0.9 m^3 pilot scale reactors housed in a mobile facility were used to carry out the onsite treatability study. One reactor was configured as a hybrid reactor using Biopod random packed media, one reactor was configured as a hybrid reactor using Munters oriented media and one reactor was configured as an upflow anaerobic sludge blanket reactor (USB). All three reactors were operated in parallel.

Treatment levels varied significantly for the three anaerobic technologies demonstrated. Filtered COD removals ranging from 75% - 85% were achieved with the hybrid ramdom media reactor at loading rates ranging between 8.5 kg and 11 kg total COD/m^3 reactor volume/day and an 8 hour hydraulic retention time. Treatment levels achieved with the hybrid oriented media and upflow anaerobic sludge blanket reactors were significantly lower.

FATE OF SELECTED VOLATILE ORGANIC SUBSTANCES IN AN AQUEOUS ENVIRONMENT

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Laboratory studies were conducted to evaluate the influence of several processes on the behaviour and fate of synthetic volatile organic chemicals in an aqueous environment. Five organic priority pollutants: benzene, methylene chloride tetrachloroethylene, toluene and trichloroethylene, were investigated to determine their susceptibility to the transformation processes of direct photolysis and/or hydrolysis under various pH, temperatures and concentrations. In addition, tetrachloroethylene, benzene, methylene chloride and toluene were examined for volatilization from the water surface as well as mass flux movement by diffusion into water.

The experimental findings for direct photolysis indicated that the susceptibility was negligible for all the selected organic compounds. Also, all the organics were found to be hydrolytically stable over the range of initial concentrations employed in both acidic and basic environments.

Tetrachloroethylene, benzene. methylene chloride and toluene exhibited relatively rapid rates of volatilization and these rates were significantly influenced by the area to volume ratio, A/V. The overall liquid film coefficients, K_{OLW}, at the water-air interface for tetrachloroethylene. benzene, methylene chloride and toluene were observed to be 0.006, 0.029, 0.003 and 0.027 m/h, respectively, under the specified conditions. It was observed that the overall liquid film coefficients determined under quiescent conditions are at least an order of magnitude lower than those reported by others under stirred conditions.

The mass flux experiments indicated that under quiescent conditions, the mass transfer occurring at the water-chemical interface of a submerged pool of tetrachloroethylene and methylene chloride was low, thus providing an opportunity for clean up. For benzene and toluene, which floated to the surface, the mass transfer into the water column occurred in the early stage of the experiments while these floating chemicals were volatilizing into the atmosphere. The results from these experiments were used to determine the overall liquid film coefficient at the chemical-water interface. Also, mathematical equations have been developed to predict mass flux of such substances under given conditions.

AUTOMATION AND OPTIMISATION OF CENTRIFUGE SLUDGE DEWATERING

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The dehydration of sewage treatment plant sludges has become one of the major problems in the treatment of waste water. Very high costs, especially those of flocculation, additives, increasingly call for optimisation of this phase of the process. Taking the dewatering of sludge by centrifugation as an example, two different approaches can be considered: mechanical excess sludge thickening without the use of additives and the dehydration of sewage sludge with use of chemical additives. A prerequisite of any automation is the reliable acquisition of data of the parameters required for control. Continuous measurement of the concentration of suspended solids in the sludge that is to be dewatered, of sludge flow and of the turbidity of the clear phase (centrate) leaving the centrifuge, makes it possible to design several methods of effective control.

THE CLARITEK SUSPENDED SOLIDS MONITOR - TRANSDUCER - AN EXAMINATION OF TAKING INSTRUMENT TECHNOLOGY FROM THE UNIVERSITY TO PRACTICE

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The instrument now referred to as the Claritek Suspended Solids Monitor originated from a need to make insitu measurements in a laboratory model clarifier. Attempts to convert the monitor into a commercial instrument in a university environment produced disappointing progress from lack of development funds and uncertainty as to requirements for field use. Success came only after a unique fusion of University, potential user, manufacturer and sales expertise. Design of the monitor will be reviewed in brief with specific reference to performance objectives. Actual performance in mining, chemical manufacturing and waste treatment environments will be examined and short comings of the design and the reasons therefore will be analyzed. Failure of the University system in Canada to deliver new technology seems to relate to the lack of interface with the most likely exploiters of the technology -- the entrepreneurial sector of Canada's manufacturers.

BIOCHEMICAL AND PHYSIOLOGICAL RESPONSES OF GREAT LAKES FISH AS AN INDICATOR OF CHEMICAL EXPOSURE AND EFFECT

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Despite abundant evidence of chemical contamination of the Great lakes ecosystem, and the closure of numerous fisheries to protect human health, there is little evidence that chemical contamination has harmed fish. While there appears to be reproductive failure of lake trout in Lakes Michigan and Ontario and the prevalence of tumours in benthic species increases near heavy industries, the chemical etiology is not clear. Based on the assumption that all toxic effects must begin with an interaction between a toxic chemical and some biological substrate of individual fish, we measured biochemical and physiological responses of lake trout and white sucker that would reflect chemical exposure and toxicity.

Fish were sampled offshore in each of the Great Lakes, and in three harbours of Lake Ontario; fish from Lake Siskiwit on Isle Royale and from several inland Ontario lakes were sampled as a reference. The fish were captured by netting or electroshocking and sampled live; tissues were immediately preserved in liquid nitrogen or dry ice to preserve biochemical activities. Chemical residues were also measured in whole-fish homogenates to compare chemical exposure and responses.

The most notable response was the induction of hepatic mixed function oxidase (MFO) activity. The MFO system oxidizes multi-ringed compounds such as the polynuclear aromatic hydrocarbons (PAHs) to facilitate excretion, and activity increased with proximity to industrial and urban development or to known sources of carcinogenic compounds. While absolute levels of activity varied from year to year, the pattern of activity remained the same: levels were highest in locations such as Hamilton Harbour, Toronto Harbour, Lake Ontario and Lake Michigan and much lower in areas with less chemical contamination. Elevated activities were associated with tissue residues of polynuclear aromatic hydrocarbons (PAHs) and with reports of tumours in other fish species.

No major changes were observed in fin-ray asymmetry (chemical stress indicator), and analyses of metallothionein (metal exposure), serum chemistry (stress indicator) and histopathology are still under way.

The results collected to date suggest that chemicals taken up by fish in the Great Lakes are biologically active and that effects are widespread and in proportion to chemical exposure. The enhanced activity of the MFO system suggests that the first stages in carcinogenesis are occurring in fish and that there may be a chemical basis for some tumours.

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