TWENTY-FIFTH CANADIAN SYMPOSIUM ON WATER POLLUTION RESEARCH

FEBRUARY 15, 1990

ABSTRACTS

WATER POLLUTION CONTROL TECHNOLOGY

IMPACT OF POLLUTANTS ON AQUATIC ECOSYSTEMS

CANADA CENTRE FOR INLAND WATERS
BURLINGTON, ONTARIO

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ENVIRONMENT CANADA

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TWENTY-FIFTH CANADIAN SYMPOSIUM ON WATER POLLUTION RESEARCH

Thursday, February 15, 1990

Canada Centre for Inland Waters
Burlington, Ontario

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CANADIAN ASSOCIATION ON WATER POLLUTION RESEARCH AND CONTROL

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TWENTY-FIFTH CANADIAN SYMPOSIUM
ON WATER POLLUTION RESEARCH

PLENARY
9:00 - 9:30

EVALUATION OF CANADIAN AND AMERICAN BIOLOGICAL TESTING PROCEDURES USED IN THE ASSESSMENT OF WASTEWATER DISCHARGES

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Eco-Research Canada Inc[5], Pointe Claire, Quebec; SAI, McLean, Virginia

This joint Canada/United States project was initiated in January 1987 by parties from both countries who were interested in the effective application of biological test procedures for assessment and control of treated wastewater discharges. The project has two main objectives: 1) assess the sensitivity and ruggedness of acute toxicity, chronic toxicity and genotoxicity procedures through industrial wastewater and reference toxicant testing, and 2) evaluate the effectiveness of the Environment Canada, Quebec Region multi-tiered wastewater hazard assessment scheme. With the assistance of a number of Canadian and American testing laboratories, the toxicity and genotoxicity potential of wastewater samples collected from eight different industrial sector facilities (five Canadian/three American) and five reference toxicants were evaluated using a battery of biological tests.

Each wastewater sample collected was split on-site into allotments for each participating laboratory. Strict control was maintained over wastewater sample collection, transport and testing (i.e. all testing was initiated on the same date, common dilution water used by all testing laboratories, etc.) to ensure comparability of test results between laboratories. Acute toxicity test procedures used in the wastewater assessment included rainbow trout/fathead lethality, Daphnia pulex/Ceriodaphnia dubia lethality and bacterial bioluminescence inhibition (i.e. Microtox TM). Chronic toxicity test procedures included rainbow trout ATP stress in muscle tissue, fathead minnow larval growth/survival, fathead minnow embryo-larval hatchability/survival/ teratogenicity, Ceriodaphnia dubia reproduction inhibition/survival and algal growth inhibition using both flask and microplate techniques. Genotoxicity/mutagenicity testing included the SOS Chromotest, Ames and Sister Chromatid Exchange procedures. In addition, the performance of the above procedures was assessed using five different reference toxicant compounds. Results of the wastewater/reference toxicant testing will be discussed.

EFFECTS OF BIO-TREATED BLEACHED KRAFT MILL EFFLUENT ON JUVENILE CHINOOK SALMON

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I. Rogers[3] and J. McBride[3]
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Freshwater Institute, Winnipeg, Manitoba[2]
West Vancouver Laboratory, West Vancouver, B.C.[3]

Four bleached kraft pulp mills discharge bio-treated effluents to the upper Fraser River. Calculated effluent concentrations are in the range 1.5 to 3.0 percent during typical winter low flow periods assuming bank to bank dispersion. In dilution zones, effluent concentrations exceed these values. The effluents usually meet acute detoxification criteria specified by Federal Regulations and Provincial Objectives. Although unproven, it has been presumed that these criteria would provide a safe environment for aquatic life, especially the large numbers of Pacific salmon common to the Fraser River. However, chemical assays reveal residual chloro-organics, including dibenzo furans and dibenzo dioxins, in these effluents. Total organic chlorine (TOCl) levels averaged 3.3 kg/ADT in bio-treated effluents. Furthermore, juvenile chinook collected from the Fraser River contained chloro-organics of bleached kraft mill origin (chloroguaiacols, chlorophenols and dioxins), while extractable organic chlorine (EOCl) and mixed function oxidase (MFO) enzymes were elevated.

The biological implications of the above findings for chinook salmon are unknown. Although declining returns of chinook salmon to the Fraser River are believed related primarily to increased harvest, data are insufficient to determine whether kraft mill effluents exacerbate this decline. There is concern that contaminant residues and elevated MFO levels indicate chinook survival is being compromised. Accordingly, a laboratory study was conducted in the period January-August 1989. This paper reports results of the study.

Following acclimation to test apparatus and temperatures, juvenile chinook were exposed to bio-treated BKME in the laboratory at concentrations and temperatures representative of the upper Fraser River in winter and spring. When a control group indicated smoltification had occurred, the fish were transferred to seawater free of bio-treated BKME.

At the time zero and throughout the study fish were evaluated for length, weight, proximate analysis, EOCl, chloro-organic contaminants, liver MFO, serum sorbitol dehydrogenase, haematocrit, tolerance to hypoxia, liver somatic index and histopathology.

Exposure to non-lethal bio-treated BKME at environmental concentrations and temperatures led to contaminant burdens accompanied by biochemical and

histological responses. However, exposures did not comprise freshwater growth, seawater acclimation or subsequent growth in seawater. There was evidence of Bacterial Kidney Disease among fish exposed to effluent in freshwater and this raises the possibility that immune competence may have been affected.

ZERO EFFLUENT DISCHARGE AND NUTRIENT RECYCLING THROUGH A FAST GROWING TREE PLANTATION

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The paper reports the design and operational experience acquired from the recycling of secondary treated effluent through sprinkler irrigation in an actively growing poplar and willow plantation, serving a Community College situated in King City, Ontario, Canada. Due to restrictive regulations related to a stream discharge, the design adopted a zero effluent discharge strategy which was initially achieved through natural grass evapotranspiration. Subsequent additions to the system lead to augmented evapotranspiration via actively growing poplar and willow forest, utilizing fast growing (2 m per year) clones.

The secondary treated effluent produced by a small wastewater treatment facility is stored over the winter period for 265 days and distributed to the plantation in the summer through an automated sprinkler system fed by pressurized underground pipes. The daily application rate was calculated based on information from an automatic weather station collecting data about air temperature, relative humidity, solar radiation, wind and rain. Data handling, calculation of atmospheric demand for evapotranspiration and graphics for application control were performed with custom developed software for an IBM-AT computer. The software has provision for a number of potential evapotranspiration models although the actual system was run with a modified Penman approach.

Recycling of effluent through plantation appears to be very successful up to the current age of seven, both for the hydraulic and nutrient load, especially nitrogen. Significant growth rhythm differences were found amongst the poplar clones. The influence of effluent irrigation on growth is positive but barely significant. Due to larger leaf area index, higher ratio of direct evaporation and advection, results to date would indicate that the actual evapotranspiration of plantation is about three to four times greater as compared to grass in a sub-humid climate similar to those of King City, Ontario, Canada. The foliage of both poplar and willow shows an increased nitrogen content, thus being an effective nutrient sink. On the basis of current data, it is envisaged that further increases of evapotranspiration can be achieved even in a sub-humid climate through plantation structure manipulation. Additional increases of the recycling rate can be obtained through selection of clones having: a) large foliage, b) high foliar nitrogen content, and c) long duration of foliage.

When fully parametrized, the concept can be practiced in various geographic areas, employing locally adapted fast growing species. Software developments now in progress will allow for complete automation of the effluent recycling.

AMMONIA NITROGEN OXIDATION IN RAPID GRAVITY SAND FILTERS RECIRCULATING FISH HATCHERY WATER

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The water recirculating fish rearing section at the Fraser Valley Trout Hatchery comprises of a preliminary aeration tower, eleven circular self-cleaning rearing ponds and a water reconditioning unit. Water is reconditioned by rapid settlement to remove fish faeces and waste food followed by microbiological oxidation of ammonia nitrogen on three rapid gravity sand filters. The water is re-aerated on a cascade tower, then returned to the fish ponds. Design parameters for this system were generated in pilot studies and the full scale system has performed well for several years.

To investigate the nitrifying capability of the bio-filters, fish loads and water quality in the recirculating water were monitored over a three month period. Fish loading on the system increased steadily from 3,357 kg at the start to 7,858 kg. During the first month, when the fish load was approximately 4,000 kg, water was recirculated through the three-filter system. Hydraulic loading was 0.42 L/m2/sec and ammonia levels were very low. The filters completely oxidized the ammonia nitrogen to nitrate and nitrite levels were below levels of detection.

During the remainder of the study the recirculation system was operated with two filters only, resulting in a hydraulic loading in the range of 1.12 to 1.16 $L/m^2/sec$. In a final test, one filter was shut down for a 4 1/2 h period so that 8,800 l/min was passing through one filter and hydraulic loading was about 2.0 $L/m^2/sec$.

The nitrification reaction was not inhibited to any great extent during the test period. However, dissolved oxygen levels dropped below 6 mg/L at a fish load of 7,564 kg and water temperature of 16°C. The test results confirmed observations made during the pilot scale test work showing that, within the range of hydraulic flows tested, the limiting function for ammonia oxidation is the oxygen carrying capacity of the recycling water, not the nitrifying organisms in the filter media.

A low cost expansion of the hatchery to obtain full utilization of the existing filters would be feasible.

CHARACTERIZATION OF MUNICIPAL SOLID WASTE LEACHATE OVER TIME

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Landfilling has been the most common method of municipal solid waste (MSW) disposal. However, the production of leachate from MSW landfills is recognized as a significant environmental concern. This concern has progressed to the point where the control of leachate through collection systems and treatment has become a fundamental component of landfill operation and management.

With the requirements for leachate treatment and control came the need for a predictive capability to characterize the change in leachate quality during the operation and eventual closure of the landfill. The focus of the paper is the characterization of leachate strength and its variation with time. Through the use of past lysimeter studies, leachate strength was characterized by the examination of a series of contaminants, namely; chloride (Cl), chemical oxygen demand (COD), total phosphates ($T.PO_4$), ammonia (NH_3-N), iron (Fe), cadmium (Cd), and lead (Pb).

The paper presents the development of the leachate contaminant curves including: the selection of the lysimeter studies, the smoothing of the data sets and the final regression equations. The time scale was normalized by leachate production and refuse mass and has been developed as cumulative litres of leachate per kilogram of MSW.

The purpose of developing leachate characterization curves has been to provide a management tool to allow the forecasting of the leachate treatment and groundwater monitoring requirements during the active phase of the landfill. By characterizing the change in leachate quality over time, the time required for landfill stabilization can be estimated and the operational and monitoring costs more accurately predicted.

TREATMENT OF LANDFILL LEACHATE BY SULPHATE REDUCTION

M. O'Shaughnessy, D. Prasad and J.G. Henry
University of Toronto, Toronto, Ontario

Although the importance of sulphate reducing bacteria for the direct reduction of sulfate to sulphide was pointed out as long ago as 1904 by Beijerinck, environmental engineers have only recently begun to appreciate the application of these bacteria in biological waste treatment. In the past the significance of species like Desulfovibrio was viewed in a negative manner by their inclusion among the "nuisance organisms" (odour problems, corrosion of steel, cast iron and concrete pipes).

The present study, which is a continuation of earlier work on leachate treatment, was conducted to demonstrate the effectiveness of sulfate-reducing bacteria in anaerobic treatment of landfill leachate. The effects of several COD/SO_4 ratios on anaerobic filters were studied and compared with the results from filters operated in the conventional manner, via the methanogenic pathway.

Results indicated that the treatability of landfill leachate by sulphate-reducing bacteria was dependent upon the strength of the leachate. With high strength leachate (COD = 15,000 mg/L), it was found that at lower COD/SO_4 ratios (<10) the sulphide generated could become inhibitory to both the sulphate-reducing bacteria and the methanogenic bacteria. As the COD/SO_4 ratio increased, methanogenesis predominated. No predominance of sulphate-reduction was observed at any COD/SO_4 ratios with high strength leachate. However, using batch tests with low strength leachate (COD = 2,000 mg/L) and low COD/SO_4 ratios, sulphate reducers could become predominant. Sulphide inhibition was not observed at any COD/SO_4 ratios with low strength leachate.

ANALYSIS OF SHOCK LOAD CONDITIONS - A CASE STUDY

I. Takács, G.G. Patry and W.J. Snodgrass
McMaster University, Hamilton, Ontario

The Hamilton Water Pollution Control Plant is a 280,000 m^3/d (75 MGD) activated sludge plant servicing the combined sewer system of the City of Hamilton. The purpose of this investigation was to examine the behaviour of the plant under steady-state and dynamic conditions, in order to assist in the development of appropriate control strategies during storm flow conditions. Particular attention was focussed on solids control in the secondary clarifier.

Nine months of average daily data were collected at a number of strategic locations in the plant, including: influent, primary settler, biological reactor, and final clarifier. In addition, hourly flow samples were collected during five storm flow conditions, each lasting between 10 to 12 hours. Finally, extensive discussions were conducted with plant personnel to assess the existing behaviour of the plant along with current control strategies.

The plant was modelled using the General Purpose Simulator (Patry and Takács, 1989), a modular/multi-purpose library of dynamic models developed at McMaster University for the simulation of wastewater treatment plants. The simplified flowsheets of the plant consists of a primary clarifier, three biological reactors, three secondary settlers, two hydraulic units (wet well and detritor), and 15 flow handling units (splitters, combiners). The IAWPRC Task Group Model was used to simulate the behaviour of the activated sludge process, while the clarifiers were simulated using a multi-layered solid flux model. The process flowsheet was translated into ACSL (Advanced Continuous Simulation Language; Mitchell and Gauthier, 1986) by the General Purpose Simulator and simulations conducted on a Unix workstation (SUN 3/160).

The model was first calibrated to a number of steady-state conditions, including winter and summer operation conditions. The model was then calibrated to the set of dynamic events recorded during the summer of 1989, in an attempt to identify a consistent set of model parameters. The calibrated model was then used to develop a number of operational control strategies designed to keep the effluent loads within acceptable limits during storm flow conditions. Recommendations concerning the "optimal" steady-state operation of the plant and possible control strategies under storm flow conditions are presented in the paper. To address the solids management problem during storm flow conditions, the simulations and resulting control strategies emphasize the utilization of existing facilities, as well as a number of low-cost modifications to the existing process.

NUMERICAL MODELLING OF CIRCULAR SECONDARY CLARIFIERS

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The simulation of the performance of a clarifier involves the computation of the hydrodynamic field (velocity and turbulence) in conjunction with a solids transport equation. In secondary clarifiers the solution to the concentration field affects the hydrodynamic solution because of the appearance of the density term in the momentum equations. The concentration related density gradients have two important effect on the physical processes in the tank, namely, a) the occurrence of density currents and stratification, and b) the damping of the vertical turbulent momentum and mass transfer coefficients in the settling zone.

This paper uses a calibrated numerical model to investigate the significance of these phenomena on clarifier performance under transient operating conditions. The transient cases will include impulse loadings during start-up and diurnal validations in solids and hydraulic loading.

A numerical model that was developed in cooperation with CH2M Hill Ltd, the Municipality of Metropolitan Seattle and the University of Windsor, is used as a tool to simulate clarifier performance under steady and unsteady flow and loading conditions. The presentation will include a brief discussion of the physical processes that were incorporated in the model. The calibration and verification of the computer model against physical model and field data will also be discussed. The present model has been designed to simulate center feed circular clarifiers with user defined geometry, sludge and effluent withdrawal arrangements. The model was developed to run ona microcomputer with a 386 processor and 387 coprocessor although the model will run on a 286/287 system. On a 386 25 Mhz microcomputer, the model computation is typically 50 times faster than the real time for prototype tanks. The model is interactive with respect to input and the display of output.

The model accounts for the radial and vertical components of the velocity in a radial flow clarifier with a skirt. Either a peripheral weir or an in-board launder can be simulated. The model can simulate central, peripheral or uniform radial sludge withdrawal. The model hydrodynamics include the effects of the density gradients caused by the suspended solids. The turbulent mixing is represented by a simplified mixing length model with a correction for the damping effect of the density induced stratification. The settling characteristics of the floc were modelled by fitting a double exponential relationship to the settling column data.

EVALUATION OF EXCESS ACTIVATED SLUDGE PREDICTIVE MODELS

H.R. Jakubiec and J.J. Ganczarczyk
University of Toronto, Toronto, Ontario

Knowledge of the quantity of sludge produced is important to both designers and operators of activated sludge plants. However, there is little information on the adequacy of existing predictive models.

Excess sludge production (ESP) data from nine different municipal activated sludge treatment plants were collected for a period of one year and statistically processed. These data were then compared with the predictions of sludge generation resulting from the use of five separate models developed for this purpose by: Heukelekian, Eckenfelder, von der Emde and Kayser, Barnard, and the one used in the CAPDET program.

The simple Heukelekian model was evaluated. This model does not account specifically for the effect of influent suspended solids. It was found that, with two exceptions (+46.2%, +14.6%), excess sludge production was underestimated by this model (-119.2% to -5.4%).

Eckenfelder's first modification of the Heukelekian model also was evaluated. This model does account for influent suspended solids. With this model, good agreement with the data from one plant was realized (+1.2%). The ESP from six plants was underestimated (-117.0% to -11.0%) and the ESP from two plants was overestimated (+7.7% to +45.8%). It is noteworthy that one of these two plants was oxygen activated (+45.8%).

The von der Emde-Kayser model was evaluated. This model accounts for influent suspended solids, as well as for the temperature effect, and incorporates the concept of active fraction of the MLSS. The von der Emde-Kayser model exhibited good agreement at two plants (-5.2%, +3.1%), overestimated ESP at the oxygen activated plant (+26.5%) and underestimated ESP at all remaining plants (-62.9% to -21.5%).

Barnard's modification of the Heukelekian model was evaluated. This model accounts for influent suspended solids and incorporates the concept of degradable fraction of the MLVSS. This model yielded a prediction of good agreement in only two cases (+3.1%, +4.0%). For three plants, there was over-prediction (+21.4% to +76.5%), two of which were substantial (+30.1%, +76.5%). One of the substantial overestimates was for the oxygen activated plant (+76.5%). For the remaining plants, ESP was substantially underestimated (-35.5%, -57.9%).

The CAPDET set of models was evaluated. CAPDET is unique in that specific

estimation equations are suggested for various activated sludge modifications. Over-estimation of ESP at two plants was observed (+19.4%, +41.0%); there was good agreement at one plant (+4.8%) and underestimation was observed at the remaining plants (-88.1% to -12.6%).

All the predictions were erratic and most of them underestimated the observed sludge production. Certainly, there is need for the development of a more reliable sludge production model.

PERFORMANCE OF A SECOND GENERATION ENHANCED OXIDATION SYSTEM

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Solarchem Environmental Systems, Richmond Hill, Ontario

Some recent results are presented from the application of the Rayox second generation enhanced oxidation system to treat water contaminated with toxic chlorinated and other organic material. Enhanced oxidation is described, as well as the general characteristics of Rayox, e.g. no secondary disposal required. The Rayox process generates reactive species such as the hydroxyl radical. In essence, this is a very powerful version of the sunlight-induced photochemical processes that occur in surface waters.

Examples are given from the treatment of real streams, both in our lab and in field demonstrations of pilot scale Rayox equipment. Depending on the rate of flow and the degree of contamination, the most cost effective treatment will be obtained by minimizing either capital cost or operating cost or a combination of these two. These issues will be discussed as they relate to industrial process effluent on creosote plant wastewater and to groundwater on PCB and TCE removal. Our laboratory test programs, using the actual subject water, are done on a relatively large scale. A typical batch size is 100-150 L. Flow through simulations on real and artificial water use up to 50 GPM. It will be shown that this type of lab result is directly transferable to the field environment, as seen on-site with Rayox systems. In this paper there is also a discussion of by-products and the treatment results with compounds like TCE and chloroform. These are compared to a newly developed computer model.

THE PERFORMANCE OF FULL-SCALE HYDROGEN PEROXIDE SYSTEMS FOR CYANIDE REMOVAL FROM GOLD MILL EFFLUENTS

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WASTART Ltd[2], Guelph, Ontario

Wastewaters produced by gold mines commonly contain elevated levels of cyanide which needs to be removed/destroyed before these wastewaters can be discharged to the receiving environment. Chemical oxidation of cyanide to less toxic cyanate is a technique commonly used by Canadian gold mines to remove cyanide from their effluents. Hydrogen peroxide is one of the oxidants which is increasingly being used for achieving the required cyanide removal. However, published data on the effectiveness of this process for treating actual wastewaters from gold mining and milling operations are sparse. Particularly, the data on the performance of full-scale hydrogen peroxide systems operating at Canadian gold mills are very limited.

Environment Canada's Wastewater Technology Centre (WTC) recently conducted a study to evaluate the status of the application of the hydrogen peroxide process for the treatment of gold mill effluents. As a part of this study, a survey of Canadian and international gold mines was conducted to identify the mines which have tested or used the process on their effluents. Also, three major suppliers of hydrogen peroxide in Europe and North America were contacted to obtain the information collected by them on the theory and application of the process to gold mill effluents. In addition, an evaluation of operating full-scale hydrogen peroxide systems at two Canadian gold mines was conducted. During the field work, samples of wastewater were collected at various locations in the effluent treatment plant and analyzed for several parameters including cyanide and heavy metals. Process variables such as temperature, pH, hydrogen peroxide dosage, retention time in the reactor, etc, were also monitored during the study.

This paper will present a summary of the information collected on the theory of the hydrogen peroxide process and the status of its application to gold mill effluent treatment. Also, the data collected during the field work will be presented along with a discussion of the costs and the recommendations concerning the areas of process research and development that would be of value to the Canadian gold mining industry and the relevant regulatory agencies.

REMOVAL OF ORGANOCHLORINE FROM KRAFT PULP MILL EFFLUENT BY AN AERATED LAGOON

D.G. Allen, P. Tomar, A. Hossain and T. Collins
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The environmental persistence, toxicity and mutagenicity of some chlorinated organic compounds has led to considerable concern over the broad spectrum of chlorinated organic compounds that are discharged from bleached kraft pulp mills. This has resulted in recommendations from several governments, including the Ontario Ministry of the Environment, that steps be taken to regulate the discharge of this class of compounds.

One long term solution to reducing or eliminating organochlorine discharges could involve the replacement of chlorine containing compounds (e.g. chlorine, chlorine dioxide) as oxidizing agents in the bleached kraft pulping process. However, several recent studies on organochlorine removal by biological treatment suggests that the addition of optimized treatment facilities could provide a simpler solution that can be readily adapted to existing pulp mills. Although the relative importance of the major mechanisms of organochlorine removal in these treatment systems (e.g. biodegradation, precipitation, biotransformation, adsorption, air stripping) are unclear, it has been suggested that the settling of these compounds to anaerobic regions of the lagoon is an important process in dechlorination and subsequent mineralization of these compounds.

We have recently initiated a study on this subject with Canadian Pacific Forest Products Ltd. in Dryden, Ontario, with the following objectives: 1) to study the seasonal performance of an operating aerated lagoon used for effluent treatment of a kraft pulp mill with emphasis on the fate of chlorinated organic compounds; and, 2) to develop lab scale experiments on anaerobic/aerobic systems to elucidate the mechanisms of chlorinated organic removal. In this presentation, we plan to give a brief overview of the problem, describe our approach and discuss the results that we have obtained since we began our field study (i.e., objective 1) in February of 1989.

The kraft mill being studied has a pulp production rate of approximately 1,000 tonnes/day and has a typical monthly production schedule of 27 days softwood pulp production followed by three days of hardwood pulp production. Combined wastewater from the acid, alkaline and neutral sewers goes through a clarifier and then flows to the lagoon at a rate of about 100,000 m^3/day. The residence time in the aerated basin is about seven days, followed by a two day residence time in a settling pond.

Weekly, monthly and 24 hour composite samples were collected from the aerated stabilization inlet, outlet and settling pond outlet. In addition, grab liquid and sludge samples were taken at various locations in the lagoon towards the end of a softwood run. Our analysis has focussed on the concentration of organically bound chlorine by measurement of the adsorbable organic halide (AOX) in the samples using a Mitsubishi Total Halogen Analyzer. Liquid samples were acidified with nitric acid to a pH of two to preserve the samples subsequent to analysis. The total AOX for a sample was measured along with the AOX for a filtered (<1.2 um) and ultrafiltered (Amicon <1,000 daltons molecular weight) sample. Filtering the samples provided more uniform results and the ultrafiltered samples are intended to try and assess the concentration of the more "biologically active" low molecular weight chlorinated compounds. Sludge samples are presently being analyzed using neutron activation analysis. Additional measurements include: total organic carbon, biochemical oxygen demand, purgable organic halide (POX), total suspended solids and solvent extractable organic chlorine (EOX).

Our preliminary results indicate that the overall removal of AOX (filtered samples) is about 30 % across the lagoon and settling basin combined. Of that total AOX removal, 50 to 60 % of the AOX removal occurs in the aerated stabilization basin. For the ultrafiltered (<1 000 dalton) AOX fraction, the overall removal rate is approxiamtely 45 to 50 % and about 80 % of this occurs in the aerated stabilization basin. In addition, hardwood bleaching produces about one-half the organochlorine discharge in comparison with softwoods. Further analysis will be available for presentation at the conference and future directions of the research will be discussed.

THE BIOLOGICAL IMPACT OF AGRICULTURAL RUNOFF FROM CONSERVATION VS CONVENTIONAL TILLAGE: EFFECTS ON PRIMARY AND SECONDARY PRODUCTION IN STREAM ECOSYSTEMS

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In recent years, reduced tillage and no-till practices in Canadian and U.S. agriculture have been on the increase (i.e., any method that leaves 20-30% of the soil surface protected by crop residue). The advantages of conservation tillage are control of soil erosion, reduced nutrient loadings to watersheds, increased efficiency of water use by crops and decreased labour and energy costs. However, it has been suggested that conservation tillage may require increased usage of pesticides, particularly herbicides, and this may result in increased concentrations of such chemicals in agricultural runoff. Since 1983, the province of Ontario (Upper Thames River Conservation Authority, MNR and MOE) has been working with farmers in the Kintore Creek Watershed near London, Ontario in a demonstration study to monitor the effects of reduced tillage practices on nutrient and sediment loadings to the watershed. The West branch of Kintore Creek (633 ha) has 12/15 farms involved in a conservation program which includes mulch-tilling of row crops, some no-till practices, construction of waterway diversions and stream bank revetment. The East branch (628 ha) has 13 farms practicing conventional tillage which leaves zero to 15% crop surface residue. Both subbranches in the watershed are otherwise similar in their physical, chemical and biological attributes and consist of rolling cropland with silt, silt loam and sandy loam soils.

In 1988, scientists from NWRI and WQB, Burlington, Ontario became involved in this study with the specific objectives of 1) to monitor the concentrations of pesticides and nutrients in agricultural runoff from the two subwatersheds and 2) to compare the effects of this runoff on the productivity of stream ecosystems by measuring differences in the density, growth and biomass of both attached algal communities (periphyton) and benthic invertebrates (caddisflies).

Results from this study indicate that levels of atrazine were lower in the subwatershed practicing conservation tillage (West branch; <0.8 ug/L vs 1-2 ug/L) on a bimonthly basis but higher in storm runoff events (5-15 ug/L vs <5 ug/L). However, such events were more frequent in the watershed practicing conventional tillage (East branch) during the 1988 growing season. Concentrations of metolachlor were low or non-detectable in most samples in both branches. Primary production of periphyton measured as ash-free dry weight (AFDW) on artificial substrates was reduced in the East branch and may be related to the higher level of

herbicides and lower nutrients in the water. Other studies have indicated that exposure of attached algae to levels of atrazine as low as 1-134 ug/L may significantly reduce algal photosynthesis and growth. In 1989, this trend was reversed i.e., growth of periphyton was lower in the West branch; however, concentrations of atrazine were higher in storm runoff in this branch than during the 1988 growing season. Secondary production of benthic invertebrates measured from May 1988 - May 1989 was lower in the East branch and may be indirectly related to a decrease in the primary production. Herbicides such as atrazine and metolachlor are not known to be toxic to invetebrates at the concentrations found in this study and therefore it is unlikely that agricultural chemicals are directly responsible for the differences noted. Net-spinning caddisflies inhabit the periphyton found on the surfaces of rocks in riffle environments and are filter-feeders, consuming small detrital particles in the stream flow. Higher levels of nutrients in the West branch and greater primary production may provide a more extensive habitat and source of food for these organisms in the West branch (at least during 1988) and thus explain their greater productivity.

THE PROBLEM OF NEW CHEMICALS IN THE ENVIRONMENT: TRIBUTYLTIN AS AN EXAMPLE

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Tributyltin (TBT) is an example of a chemical brought into new uses (in anti-foulant paints for boat, ship and fish-farm netpens) with unpredicted environmental consequences. Since the 1970s its new use in the marine environment has harmed bivalve mollusc fisheries and farms (oysters and mussels) particularly in Europe, and has contaminated some farmed salmon. Controls are currently implemented by banning TBT-based paints on small boats, but even this control is not yet applied in Canada.

The risk of TBT impact can be demonstrated by a simple biological index, imposex (male genitalia imposed on females) in shoreline whelks (neogastropod molluscs). Described here is a regional survey protocol developed in British Columbia and S.E. Asia for measuring the frequency and intensity of imposex in neogastropod molluscs. It is based on measures of penis length in males and females, using binocular microscope, supported by gonad smears for some species. We provide new data from the Canadian and U.S. Pacific coast, and Southeast Asia, demonstrating the occurrence of high imposex level, hence TBT risk, even in remote areas. For example all of over several hundred specimens collected throughout the inner waterway of the Straits of Juan de Fuca, Straits of Geogia, and Puget Sound showed imposex. Substantial numbers of specimens collected on the exposed west coast of Vancouver Island and Washington state were affected. At only two sites isolated in remote northern Vancouver Island did sampled whelk populations not show imposex. In S.E. Asia all specimens collected at 3 sites around the shores of the island-state of Singapore, and 6 sites in the isolated Indonesian harbour of Ambon were affected.

The development of simple biological indicators can facilitate risk assessments of new chemicals in the environment, especially where their chemical analysis requires time-consuming skilled use of sophisticated chemical analytical equipment working close to levels of sensitivity. The initial biological surveys can provide guides to directed chemical testing. Our results indicate that TBT environmental surveys to find sources of contamination and ways of control should be directed to remote small-boat marinas and harbours supporting high-seas ship traffic, in coastal regions with bivalve mollusc mariculture.

THE IMPACT OF ALGAL FIBRILS ON THE TOXICITY OF FENVALERATE TO DAPHNIA MAGNA STRAUS

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Toxicity tests were conducted using fenvalerate, a synthetic pyrethroid insecticide, and Daphnia magna Straus. Adults of D. magna were reared in the laboratory under controlled environmental conditions (16:8 hr light/dark, 19°C +/- 2 and fed a diet of Chlamydomonas reinhardii). One day old offspring were removed from breeding colonies prior to tests and then exposed to a range of fenvalerate concentrations (0, 0.1, 0.5, 0.8, 1.0 and 5.0 ug/L), in well water, in the presence and absence of algal fibrils. A minimum of 25 daphnids were used per treatment in a single test. In early tests, daphnids $\leq$48 hours old were also used.

Three fibril sources were used in the study. A fibril rich sample of DOM (lake fibrils) collected from Lake St. George, Ontario during an algal bloom in July, 1981, was generously donated by Dr. Kent Burnison, National Water Research Institute, Canada Centre for Inland Waters, Burlington, Ontario. Two relevant-type fibril products were obtained from a commercial source, pectin from apple (Sigma P-2157) and polygalacturonic acid (pga) from orange (Sigma P-3889). Fibrils were added to test solutions to a final concentration of 4 mg/L, a level found naturally in lakes.

After a 48 hour test period, D. magna was observed for immobility. A significant adhesion reaction occurred between D. magna ($\leq$24 hr and $\leq$48 hr old) and the fibrils in the presence of the insecticide. Adhesion was greatest in the presence of lake fibrils. D. magna experienced reduced mobility as fibrils clumped on swimming appendages as well as the dorsal spine. Organisms also clumped to each other during the tests as well as to glassware.

Both commercial fibril products produced similar results. Adhesion was greater with pectin than with pga, but less pronounced than with lake fibrils. Controls consisted of a fenvalerate blank plus fibrils or fibrils alone in well water. Controls showed no adhesion reaction.

This interaction affected the results of the tests because the criteria for recording a response was the inability of D. magna to swim in the test beaker in a 10 second period after gently swirling the solution. Under natural conditions this could mean "death" to the organism and could have important effects on the aquatic food chain.

A range of EC50 values was generated for each set of treatments. EC50 values for D. magna <24 hr exposed to fenvalerate plus pectin, plus fenvalerate pga and fenvalerate alone were 3.44 to 3.88, 1.67 to 3.45, and 0.30 to 1.80 ug/L respectively. There was a significant difference ($p < 0.05$) between treatments including the fibrils and the fenvalerate only treatment. This would indicate that the fibrils were affecting the availability of the insecticide, and hence its toxicity, to D. magna. EC50 ranges for D. magna <48 hr treated with fenvalerate alone, fenvalerate plus pectin and fenvalerate plus lake fibrils were 0.34 to 1.72, 0.65 to 0.97, and 0.15 to 0.81 ug/L respectively. There were no significant differences between any of these ranges. There was a significant difference between 48 and 24 hr old daphnids exposed to fenvalerate plus pectin that could not be explained. Results from treatments including pga were variable because pga does not readily dissolve in water so stock solutions may not have been homogeneous between or within tests.

Immobility and bioavailability of contaminants are being tested in this system and both are of great importance in studying the effects of pollutants in aquatic ecosystems.

RESPONSE OF ZEBRA MUSSELS TO SODIUM HYPOCHLORITE TREATMENT AT NANTICOKE TGS

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In August 1989, veliger forms of the zebra mussel were identified in plankton samples taken outside Nanticoke Thermal Generating Station. As their arrival was anticipated, experimental treatment of station service water piping was started within eight weeks. Veligers were no longer observed in the plankton at that time.

Through the use of "bioboxes", the infestation of different systems was observed and the effect of the subsequent treatment monitored. These observations were verified by inspection of some of the service water piping.

To treat the piping, solution of 12% sodium hypochlorite was injected just before the low pressure service water pumps. The amount injected was gradually increased over several days and than maintained at 2 - 3.5 ppm until all mussels placed in the biobox receiving this treatment were dead.

Animals were observed after exposure to various levels of residual chlorine and their responses were charted. Laboratory study was conducted in parallel to these experiments to corroborate field results and to test the treatment regime on different size classes of zebra mussels.

The combination of field and laboratory study allowed us to develop the most effective and least environmentally disruptive short term treatment regime possible.

ARCTIC ECOTOXICOLOGY EVOLVING: SOME THEORETICAL AND PRACTICAL ASPECTS

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Ecotoxicology evolved over the past 20 years, essentially in response to ecological problems in temperate, industrially and agriculturally developed areas of the planet. High latitude regions, with low densities of residents and industrial activities and absence of agriculture, attracted much less attention. Polar regions were widely thought of as being pristine. Awareness is spreading that they are not. Three significant sources of chemical and physical perturbation are located in the Arctic: human settlements, oil and gas related activities, and metal mining. Long-range transport mechanisms acting through air and water carry contaminants from low to high latitudes. Water, soil, and organisms in the Arctic already contain and continue to accumulate chemicals emanating from agricultural and industrial practices in the south. Some ecological processes set in motion by man's activities are expected to lead to global climate changes. Ecotoxicology deals with fate and effects of contaminants in the environment. Little is known about processes determining the fate of contaminants in the Arctic, and less about the normal functioning and the vulnerability of Arctic organisms and ecosystems, their sensitivity or tolerance when exposed to anthropogenic changes and stresses.

This paper deals with some aspects of an evolving Arctic ecotoxicology, particularly in relation to aquatic environments and points listed above. Theoretical considerations include current concepts pertaining to the environmental behaviour and fate of contaminants under high-latitude conditions, to species responses at various levels of biological integration, and to fragility or resilience of Arctic ecosystems. It is proposed that a foreseeable increase in Arctic ecotoxicology efforts be accompanied by an increased level of and coordination with basic Arctic ecology research. Practical aspects include technical requirements, costs, and logistics of Arctic field research and monitoring. It is proposed that field projects be supplemented to a greater extent by year-round experimental work on Arctic species in suitably equipped southern laboratories. Existing field stations and research vessels should be upgraded and possibly expanded, but also optimally utilised by a well-coordinated, long-term national Arctic research and monitoring programme, comprising elements of projects presently undertaken by several Canadian government departments and universities. Preferably, such a Canadian effort should be part of a long-term international programme, with contributions from nations bordering the Arctic, as well as others that have the scientific and technological capacity or potential for Arctic research and monitoring.

A PHYTOTOXICITY BIOSENSOR USING IMMOBILISED THYLAKOID MEMBRANES

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In the chloroplast thylakoid membranes, light energy is transduced into chemical energy. At this level, light is absorbed by the photosynthetic pigments embedded in chlorophyll-protein complexes and its energy is transferred to the reaction centres of photosystems I and II, where a charge separation takes place. These processes lead to the formation of negatively charged species. In a photoelectrochemical cell, thylakoid membranes can be used to produce photocurrents. The reduced species formed by the photosynthetic light reactions are oxidised by a working electrode.

We have used a very small (80 uL), one compartment electrochemical cell which works under potentiostatic conditions. The presence of inhibitors of photosynthetic electron transport in the electrolytic medium strongly inhibits photocurrent generation. Several herbicides like diuron and atrazine, sulfate and nitrate compounds, as well as heavy metals ($Cd^{2}+$, $Zn^{2}+$, $Cu^{2}+$, $Hg^{2}+$, $Pb^{2}+$) are all photosynthetic inhibitors and can be detected by the electrochemical cell. When these inhibitors are present, they can be detected at very low concentrations in our system. The cell sensitivity can be controlled by varying the chlorophyll concentration in the photosynthetic samples used.

The photoactivity of the electrochemical cell was enhanced by a factor of four when the artificial acceptor potassium ferricyanide was added. The system could also be stabilised with the use of thylakoid membranes immobilised in an albumin-glutaraldehyde cross-linked matrix. This matrix constitutes a porous network in which the proper electrolytic solution can be introduced by aspiration of the medium. Using this procedure, the photocurrent produced by immobilised membranes could also be enhanced by potassium ferricyanide or inhibited by herbicides.

When water aliquotes are used with thylakoid membranes in the electrochemical cell, the system is a sensitive biosensor for the detection of water toxicity for phytoplankton or other aquatic plants. The short time involved for each measurements (~5 min) and the small volume of the cell (80 uL) will allow adequate screening of large water areas.

TOXINS AND GENOTOXINS IN THE NIAGARA RIVER WATERSHED AS REFLECTED BY CHIRONOMID (DIPTERA: CHIRONOMIDAE) DIVERSITY AND THE FREQUENCY OF LABIAL PLATE

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Chironomids from five locations in the Niagara River Watershed were sampled and classified as either normal (no deformities in their labial plates), slightly deformed (slight asymmetries due to teeth which were missing or chipped), or grossly deformed (those with extra teeth, fused teeth, crossed teeth or large gaps between their teeth). Among the 495 chironomids taken from the 125 Ekman grab samples 9.9 % (48) possessed deformed labial plates with gross deformities. The highest frequency of chironomid labial plate deformities occurred at a polyvinyl chloride company's discharge pipe (20 %). In 1986, 33 kg of vinyl chloride, (C_2H_3Cl), was released into the Welland River at this site (MOE 1987). Vinyl chloride is an extremely powerful mutagen and human carcinogen and is suspected of causing the high frequency of gross chironomid labial plate deformities observed at this site.

IN-STREAM WATER QUALITY MODELLING SENSITIVITY ANALYSIS OF WQRRS WHEN APPLIED TO THE BOW RIVER

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The in-stream water quality model, "Water Quality for River-Reservoir Systems", (WQRRS), was applied to a 68 kilometre section of the Bow River through the City of Calgary. A sensitivity analysis was performed on the stream quality module for unsteady water quality conditions using both unsteady and steady flow hydraulic computations. To simulate unsteady water quality conditions the concentration of a conservative substance (total dissolved solids) was linearly increased to a maximum concentration both gradually over a period of several hours and rapidly over one hour before being decreased to its initial concentration.

Steady flow hydraulics were computed using the backwater and stage flow methods and unsteady flow hydraulics were computed using the finite element solution of the St. Venant equations and the kinematic wave method.

The sensitivity of TDS concentrations for various time step and geometric channel cross-sectional cases is investigated and the TDS concentrations predicted with steady and with unsteady hydraulics are compared.

It was determined that except for high TDS concentrations, the determination of water quality constituent values is insensitive to the number of cross-sections used in the stream hydraulics package because the hydraulic properties do not vary significantly as the number of cross-sections used is changed. Also, the selection of time step is more important for rapidly changing water quality conditions because constituent concentrations may change rapidly and by significant amounts.

ASSESSING THE MIGRATION AND TRANSFORMATION OF PESTICIDES IN THE SUBSURFACE: THE ROLE OF EXPERT SYSTEMS

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Studies focusing upon the fate of pesticides within the subsurface provide strong evidence that pesticides have the potential to cause serious contamination of shallow aquifers even if the recommended application procedures are followed. All pesticides used in Canada undergo extensive testing to ensure that they and their degradation products present minimal risks to the environment before being registered for public use. Numerous models currently exist for predicting the distribution and concentration of a pesticide and its degradation products in the subsurface. However, the application of these models in a regulatory framework is limited because, first, the theoretical framework upon which the models are based are generally complex and typically they can only be operated by a trained modeller, and second, the models require a specialised set of physical and chemical field data. Therefore, these models can not readily be used by regulatory personnel who are assigned the task of assessing the effects of the pesticide on the quality of the groundwater.

A recent development that transfers the decision making requirements associated with computer modelling technology from a complex science to a practical tool for the non-specialist is the expert system. Thus, expert systems can assist the user in solving a complex problem that is beyond the user's present level of knowledge in either the field of interest or in computing ability. This paper describes the framework of an expert system which is designed to provide regulatory personnel with a tool that will aid in their evaluation of the transport and transformation of pesticides in the subsurface environment in order to identify potential groundwater problems. Specifically, it is designed to (1) provide regulatory personnel with a method of obtaining the geological, hydrogeological and computing modelling expertise required for their assessments (2) predict migration rates and concentrations of pesticides in the unsaturated zone and reaching the water table with time and depth, and (3) be easy to use by staff not trained in the use pesticide transport models.

This expert system is designed as a management tool to be used as an aid in making policy decisions and is not intended for use as a research tool. Thus, the application of the expert system is not to provide insight into the process that control the transport and fate of pesticides in porous media, but to provide an assessment of the potential hazards to the shallow groundwater regime associated with a particular pesticide and to identify if further study (e.g. field testing) is warranted. The primary use of the model is as an aid in making policy decisions regarding balancing important criteria used in the design and construction of the

expert system and its data bases, and the required biological, chemical and physical processes that the model should incorporate is discussed in this paper.

The transport and transformation of pesticides in the subsurface must be based on the accepted scientific principles that describe the important biological, chemical and physical processes within a mathematical framework in order to accurately predict pesticide migration. The expert system actually contains two existing mass transport and reaction models for predicting pesticide migration and concentrations in the subsurface, coupled with a knowledge-based system that guides the user through the choice of parameters for a simulation. The inclusion of two models, a mathematical-research model (LEACHM) and a mathematical-management model (PRZM) model, allows different simulations to be run, depending on the objective of the simulation and the availability of data.

The expert system contains a user-system interface module which is an interactive program that will guide the user through the entry of data required by the transport model through the use of production rules and explanations. Production rules basically consist of encoded expertise or knowledge that guide a user in the choice of parameters for a simulation. Explanations consists of a data base of encoded information that clarifies the meaning of the information being requested by the user, recommends values of parameters for a simulation and evaluates the plausibility of values and relationships among the chosen parameters. The interface module provides a link between the user and the expert's information and knowledge, and guides the user through the choice of parameters and options necessary to perform a pesticide transport and degradation simulation.

All data characterising the physical, climatic, hydrogeological and agricultural setting of typical agricultural zones across Canada are contained within a data base that can be recalled by the user to test the environmental effects of applying the pesticide in these agricultural zones. The characterisation of these typical agricultural zones is hypothetical to the extent that the basic model parameters are not derived from a particular field or orchard. The choice of parameters used to define the typical agricultural zones are guided, however, by experience from a variety of field studies undertaken within a particular zone. Because there is considerable variation in the physical, hydrogeological, climatic and agricultural settings on a local scale, the parameters comprising a typical agricultural zone can easily be modified by the user for a particular simulation.

A second data base, containing the chemical characteristics of pesticides, can be accessed by the user when information for a new pesticide is required by the model but does not exist. The user is able to approximate the required data for the new pesticide. An important feature in the design of this data base is that it must allow values contained in the data base to be easily be modified, new data to be included as it becomes available and new pesticides to be added to the data base.

A REVIEW AND SENSITIVITY STUDY OF UNSATURATED ZONE SOLUTE TRANSPORT MODELS

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A review has been conducted to identify pesticide transport and transformation models that are capable of aiding in the assessment of the potential risk that pesticides pose to the contamination of ground water supplies. This review identified 15 existing pesticide models from two general categories of models. Five of the models are classified as screening models while the remaining ten are mathematical models. Screening models simply assess the potential for the contamination of ground water supplies by pesticides on a relative basis by comparing a few chemical characteristics of the pesticide, and/or hydrogeological parameters of the application site, with similar pesticides and situations where contamination of the ground water was known to have occurred. The models do not actually attempt to simulate the processes involved and do not quantify the amount or rate of pesticide leaching to the ground water table.

In assessing the potential for ground water contamination by pesticides, mathematical solute transport models attempt to simulate the processes that are involved in the migration and transformation of pesticides in the unsaturated zone of a soil. The models represent these processes with mathematical approximations that quantify the amount and rate of pesticide leaching through the soil profile. Mathematical models can be further subdivided into three groupings, these being educational, management, or research models. The categories are distinguished from each other based on (1) the extent to which they describe the basic processes involved, (2) the sensitivity and accuracy of the simulations, and (3) on the amount of input characterization data required. The number of processes included in the models, as well as the level of complexity of the description, increases as you move from educational to research models and is accompanied by a corresponding increase in the accuracy of the model results.

The limitations and assumptions inherent in each of the models must be considered in the application of models to different situations. Screening models are best suited for situations where only a general indication of the potential for ground water contamination is desired. As an example, screening models can be used to map general areas that are susceptible to ground water contamination problems.

Because mathematical models actually attempt to simulate condition and processes existing in the field they are more useful in situations where the amount and rate of pesticide leaching is required. However, the simple educational models are generally applicable to only a limited number of near ideal situations and are more applicable as teaching aids. Management models are designed to be simple and quick to use and are intended for use as an aid in making day to day operational decisions. Management models are also useful in making initial, general assessments of field situations. Research models provide more quantitatively accurate results and are most useful in determining which of the processes involved are most influential in determining the transport and transformation of the pesticides in the natural environment. Mathematical models may also be applicable in making assessments of field situations. However, because of the complexity and the amount of data required by the research models, they generally have received little use beyond the initial development and testing of the model.

Two mathematical models were chosen to assess the sensitivity of model results to the physical and chemical parameters affecting pesticide transport and transformation in the unsaturated zone. The first model, LEACHMP (Leaching Estimation And CHemistry Model - Pesticides), provides the most detailed description of the processes involved and is classified as a research model. The second model PRZM (Pesticide Root Zone Model), is the most widely used of the models identified and is representative of the models in the management classification.

Sensitivity studies are useful in identifying the model parameters that are most influential in determining the amount and rate of pesticide leaching to the water table. Particular attention can then be given to the measurement of these parameters in field and/or laboratory studies with the aim of increasing the accuracy of the model simulations. For example, the models were found to be most sensitive to the chemical degradation rate constants and partition coefficients in the soil, and to the dispersivity values assigned to the model simulation.

WASTEWATER DATA ACQUISITION FOR REMOTE NATIVE COMMUNITIES IN BRITISH COLUMBIA, CANADA

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There is very little reliable information available in the literature regarding sewage collection, treatment and disposal data for small remote rural communities. Generally wastewater system designs are based on data obtained from larger urban communities, which are easier to monitor. Practical experience has shown that the application of this type of data obtained can result in poor system designs and operations and maintenance difficulties. furthermore, small communities often do not have skilled operation staff, making it difficult to trouble-shoot equipment problems, particularly when the cause is an intermittent flow event.

Under contract to Public Works Canada, a microprocessor based data acquisition (D/A) device was developed for use in-house to collect flow and operations data from remote native Indian communities in British Columbia. Specific problems were identified during the early stages of the development program, the more significant of which include, 1) site access difficulties resulting in infrequent data collection; 2) multiple data sources at each site with different signal characteristics; 3) absence of wastewater flow measurement devices; 4) harsh environmental conditions; and 5) a limited program budget. To overcome the restricted site access, the D/A device had to have a large memory storage capacity (up to 1.5 megabytes) and the capability to use available telecommunications equipment. Data can be retrieved remotely through a built-in modem via the telephone, downloading directly into a computer in the field, or by removing the unit and transporting it to the office. As it was necessary to be able to monitor analog signals, digital signals, intermittent pulsed DC currents, and equipment operating times, a multiplexer was incorporated capable of monitoring up to 30 channels. Although most of the communities do not have flow measurement devices on their waste streams, many utilize sewage lift stations. By incorporating the capability to monitor 110 and 220 volt events, the D/A device can be used to measure sewage flows in a non-intrusive and reliable manner. Wastewater flow rates can be measured knowing the wastewater storage volume within the wet well between the pump stop and start levels, and the time of operation of the pumps. Furthermore, valuable information can be obtained regarding the operating characteristics of the pumps, including the deterioration of pumping rates with time, and the frequency of pump maintenance. In the event of a pump station failure, the D/A devices can

serve as a status recorder, documenting the pump and flow conditions leading to the failure. As these devices often have to operate in harsh environments, the miocroprocessor is capable of operating within a temperature range of -40°C to +40°C, and can operate on either AC or DC power sources. The RAM memory has a battery back-up in the event of power failure. To keep the operation of the unit simple, data is downloaded in either an ASCII format or with an XMODEM protocol using a number of commercially available computer communications software programs. The data can then be directly manipulated, analyzed and plotted using software such as LOTUS 1-2-3.

In addition to a detailed description of the D/A device, two case studies are presented which demonstrate the usefulness of using such devices for monitoring in small remote communities. The first case reviews a data monitoring program carried out in the community of Stoney Creek, British Columbia, Canada. The data illustrates the use of D/A devices to measure and record wastewater flows, evaluate pump efficiencies and to monitor pump maintenance and emergency servicing characteristics. The second case study reviews data collected from the community of Alert Bay, British Columbia, intended to investigate frequent sewage lift station failures, believed to be due to intermittent infiltration events.

Key to the utility of these D/A units is their low cost and the large memory storage capacity, which is of particular use in collecting data from remote and difficult to access areas. The information obtained has application not only for hydraulic design but also for assessing the service requirements and operating characteristics.

FLUORIDE ADDITION TO MONTREAL'S DRINKING WATER: PREDICTED AND ACTUAL RAW SEWAGE CONCENTRATIONS AND REMOVAL DURING SEWAGE TREATMENT

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In order to assess the potential risks to the aquatic ecosystem of the St. Lawrence River as a result of the proposed fluoridation of Montreal's drinking water, it was necessary to determine the expected fluoride concentrations in the raw sewage, as well as removal of fluoride which might occur during physicochemical treatment at the Montreal Urban Community's wastewater treatment plant. Calculations of fluoride concentrations in the raw sewage had to take into account the existence of mostly combined storm and sanitary sewers, the fact that two small communities on the Island of Montreal (Dorval and Pointe Claire) were already fluoridating their drinking water, unknown discharges from industrial and other sources, and the only partial completion of the interceptor at the time of the study.

A monitoring program was instituted between February and April, 1989, to assess hourly and daily fluctuations of fluoride in the raw sewage entering the treatment plant. Average daily fluoride concentrations yield a range of 0.22-0.58 mg/L (mean 0.34 mg/L), however discrete samples showed a much higher fluctuation, i.e. from 0.20-1.11 mg/L. This indicates that point discharges from industries or other unnatural sources are not a rare occurrence in the Montreal sewer system.

To assess removals during physicochemical treatment, jar tests were first conducted using the same chemicals as those being applied at the full-scale plant (i.e. ferric chloride and anionic polyelectrolyte), but over a three-fold range of fluoride concentrations to cover extreme conditions. These tests indicated that no removal of fluoride would occur. Full-scale tests were subsequently conducted by applying a fluoride dose to the plant influent at a concentration approximately twice as high as would be expected as a result of drinking water fluoridation. Again, no removal occurred as a result of the treatment process. However, during the experiment an additional plug of fluoride was monitored in the raw sewage and this was damped out somewhat due to non plug-flow conditions in the full-scale plant.

Taking into account background fluoride concentrations from infiltration, natural fluoride concentrations in the raw sewage, and fluoride addition to the drinking water to a final level of 1.2 mg/L, the average fluoride concentration in the raw sewage is expected to be 0.83 mg/L.

This may change slightly when the interceptor is completed in 1992. Based on a mass balance analysis, unidentified sources (industrial and others) in the actual sewer system were estimated to be 132 kg/d. Since none of this is removed during physicochemical sewage treatment, the same fluoride concentration as in the raw sewage (i.e. 0.83 mg/L) would be discharged into the St. Lawrence River, increasing its average fluoride mass flux by 1.2 %.

TREATMENT AND DISPOSAL OPTIONS FOR THE METAL FABRICATING INDUSTRY

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British Columbia Research Corporation scientists and engineers have worked with several metal fabricating industries to solve waste production problems. Often the work requires assessment and classification of wastes under the various regulations imposed by all levels of government. In the process of completing this work, process development and plant modification work to effect treatment of special (hazardous) waste streams has been completed to enable non-secure disposal. This paper reviews some of the options available to industries in the metal processing (secondary smelting, pipe and wire processing, etc.) to effect treatment of streams such that they are suitable for non-secure disposal.

As environmental regulations become more strict under the pressure of public awareness, knowledge and concern for the environment, the disposal of non-hazardous, non-municipal wastes is becoming more and more difficult. Landfill operators and sewer system managers who have accepted these materials for years are becoming hesitant to accept or are totally rejecting non-municipal waste material. This is creating a problem and a new unofficial classification of waste called nuisance wastes. The authors will discuss such wastes and the problems encountered in disposal.

PURIFICATION AND DETOXIFICATION OF TEXTILE DYEBATH EFFLUENT BY ELECTROCHEMICAL TREATMENT

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The large quantity of aqueous waste produced by the textile industry constitutes a significant environmental hazard. Dyebath effluents, specifically, are not only aesthetic pollutants by virtue of their colour, but may impede light penetration in the receiving body of water, thereby interfering with biological processes. Dye effluents may also pose the problem of potentially toxic or carcinogenic chemicals entering sewage treatment plants not specifically designed for them.

Several physical and chemical treatments have been used to treat dye wastewater with varying degrees of success. The effectiveness of each of these methods is dependent upon the type of dyestuff and the chemical assistants used. An electrochemical method, based on the use of sacrificial iron electrodes, was developed (by Andco Environmental Processes, Amherst, N.Y.) to remove heavy metals from waste generated by the electroplating industry. Attempts are now being made to adapt this method to the removal of colour from a wide range of textile dyestuffs.

The Andco electrochemical process was applied, on a laboratory scale, to three of the most commonly used disperse (polyester) dyes in Canada. The dyes were first applied individually to pieces of polyester fabric using different chemical systems which are representative of those currently used in Ontario. Effluent from each of the dyeings was electrochemically treated and tested for toxicity to Daphnia magna before and after that treatment. Treated effluent was also used as the liquor in subsequent dyeings to demonstrate its suitability for reuse.

The electrochemical treatment involved circulating wastewater between two iron electrodes with simultaneous passage of an electric current between the electrodes. The iron hydroxide which was produced caused adsorption of the dye from the effluent. Subsequently flocculation, precipitation and filtration resulted in the separation of dye-containing sludge from purified waste liquor.

Preliminary results with a single chemical system indicate that the treatment is highly effective in colour removal as shown by spectral

analysis. Dye peaks which appear in the spectra of untreated effluents are absent in those after treatment, indicating total colour removal. Toxicity to D. magna is substantially reduced following electrochemical

treatment. Reuse of the effluent from a single dye cycle yields uniform dyeings with no dyespots, suggesting that recycling liquor from used disperse dyebaths is potentially viable. The colour differences between the initial dyeings and those using treated effluent as though it were water were greater than desirable. It is likely that this difference can be minimized substantially by use of a computerized colourmatching system.

Additional research with other dyes and chemicals is required before the laboratory model will be subjected to industrial-scale dyeing operations.

IRRADIATION-PASTEURIZED SLUDGE: EFFECTS ON MICROORGANISMS, NUTRIENTS, AND HEAVY METALS

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Digested sewage sludges have been used for crop production for many years and can provide an excellent source of organic matter, nitrogen, phosphorus and micronutrients, chiefly zinc and copper. For home garden use or for use near buildings, water courses, or wells, digested sewage sludges require further pathogen reduction. In January, 1989, a research and testing program to determine the effects of irradiation on pathogens and other components of municipal sewage sludge was begun.

Sludge irriadiated at three different doses, together with control samples, were studied for types and levels of pathogenic and non-pathogenic microorganisms, nutrient values, and regulated heavy metals. In addition, more specific testing involving inoculation of known quantities of selected test strains of pathogenic organisms, their irradiation at three doses, and examination for survivability/recovery, is planned to be carried out this year.

Greenhouse studies examined crops of grasses, lettuce and beans grown in unirradiated and irradiated sludges, irradiated sludge compost, and manure compost, for differences in plant growth, uptake of metals, etc. The objective of this study was to evaluate irradiated composted sewage sludge for the production of garden crops.

Field experiments will be conducted at the Cambridge Research Station of the Ontario Ministry of Agriculture and Food. These will start in April, 1990 and continue through the 1991 growing season. The same mix of soil amendments as for the greenhouse study, will be used.

THE INFLUENCE OF INLET STREAM PORTS ON MAINTENANCE OF GRANULES IN UASBR

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Pilot plant UASB reactors (20 L each) were used to study hydrodynamic influences on granule maintenance and stability. Within this overall program, the effect of influent port configurations in terms of the number of inlet ports, their diameter and the direction of influent streams into the reactors were investigated.

The position of influent ports was found to be very important for the maintenance of granules within the reactor. Both the linear liquid velocity and inlet stream directions were found to influence the stability of the granules within the reactors, as evaluated by their change in size, settling velocity and the wash-out/accumulation from the reactors.

DETOXIFICATION OF PHENOLIC COMPOUNDS WITH ALGAE

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An upflow flocculated algae photo bioreactor was investigated for removal of toxic phenolic compounds, 2,4-dichlorophenol and 2,4-dimenthylphenol. Biodegradation was evaluated by monitoring substrate disappearance, and concurrent generation of artifacts. 2,4-dichlorophenol disappeared faster than the 2,4-dimenthylphenol and relative rates of removal were greater by the live than by the dead algae biomass. In this study, centrifuged and alum flocculated cultures of Chlorella and Scenedesmus species were used, in a continuous up-flow photobioreactor to treat wastewaters containing 1000 mg/L each of 2,4-dichlorophenol and 2,4-dimenthylphenol applied to the bioreactors individually and as a mixture. The system was found to be efficient, versatile, adaptable and easy to operate for removal and biodegradation of these phenolic compounds.

BIODEGRADATION AND BIOACCUMULATION INTERACTIONS AFFECTING THE FATE OF PRIORITY POLLUTANTS

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The kinetics of biosorption and desorption of lindane by live activated sludge and the fungus R.arrhizus was studied. The results from the use of live activated sludge suggest that besides biosorption, other lindane removal mechanisms acted in parallel. Most probably, biodegradation. A relationship between biodegradation and biosorption-desorption was established. Mass spectroscopy and gas chromatography studies suggested a possible series of lindane biodegradation by products. Lindane accumulated by the live activated sludge could be desorbed while being biodegraded at the same time. Biosorption of lindane by live R.arrhizus is a rapid and reversible process. Specific biodegradation rates were estimated.

WASTE TREATMENT IN THE METAL FINISHING INDUSTRY

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Proctor & Redfern Limited conducted a study of the metal finishing industry in Ontario in 1989. the study identified the types, quantities and disposal methods for wastes generated by the industry. It also identified the various methods used to treat waste streams to prevent water and soil pollution. The paper presents a summary of the results of the study.

SELECTIVITY OF WITHDRAWAL AS THE KEY TO MODELLING THE EFFICIENCY OF A GRAVITY CLARIFIER

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A new clarifier design using downstream flow contractions was developed at the University of Waterloo ten years ago. Since then, numerous tests in pilot scale have demonstrated the superiority of this design in terms of removal efficiency. The next step is now to develop a mathematical model to predict the removal increase to be expected from flow contractions. For that purpose, a better understanding of stratified fluid dynamics inside the sedimentation tank is necessary.

In this study, the concentration of sediment particles was measured continuously inside a rectangular laboratory scale clarifier and in the effluent using a photoextinction method. The concentration profile as a function of depth demonstrated that the clarifier is composed of three layers. In the upper layer, the concentration gradient is strong, the flow is quiescent and powerful internal waves were detected. In the middle and lower layers, the concentration gradient is almost zero, the flow is turbulent and no internal waves were recorded.

The use of downstream flow contractions could increase the removal by 10 %. A corresponding increase in the power of internal waves in the effluent was observed. It is suggested that the effect of flow contractions is to decrease the selectivity of withdrawal by allowing a larger fraction of the upper layer to flow out with the effluent. (Complete selective withdrawal occurs when only the lower layer formed by the density current flows out of the tank, the other layers remaining stagnant).

A mathematical model for removal was developed using the selectivity of withdrawal as a parameter. This model is based on a combination of limiting settling models introduced by Hazen in 1904. Comparison with experimental results showed good agreement.

NEW INSTRUMENT FOR FLOC-BLANKET DETECTION AND CONTROL IN WATER TREATMENT PLANTS

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At the 4th IAWPRC Workshop in Houston and Denver, U.S.A., April 27 to May 4, 1985, Solmon and Slipper's paper illustrated a new instrument for Floc-Blanket monitoring in water treatment plants which contained six sensors spaced vertically one above the other. Markland at that time were manufacturing a Sludge Depth Meter for wastewater sludges which had 64 sensors plus an advanced algorithm which had improved resolutions plus intelligent interpretation of conditions at the sludge/liquid inteface. When the Markland Model 600 was tested by the Water Research Centre at the ECCUP facility in Leeds, England, the through transmission infrared beam proved to be too penetrating and the light floc blanket did not cause sufficient attenuation to enable the Meter to differentiate between the floc and the overlying clear water. Subsequently, Markland redesigned the probe to detect instead the backscattered light, and this instrument (designated the Markland Model 600-LF) is being successfully used to continuously m onitor and control the floc-blanket at the Hanna, Alberta, Water Treatment Plant.

EMERGENCY RESPONSE SPILL CLEANUP OF WOOD TREATING WASTE

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The use of copper, chromium, arsenate (CCA) solution for pressure treating wood is an accepted and useful method for extending the useful life of wood. In the unimpregnated form however, the wood treating solution can be hazardous to the environment if spilled or improperly handled.

In the spring of 1989 a fire at a wood treating plant in western Canada resulted in the accidental spill of a large amount of treating solution containing 3 % CCA, along with a spill of an organic based wood dye. These two solutions combined with firefighting effluents and rain water to produce well over 100,000 US gallons of wastewater. The waste was contained on-site in ditches, portable pools, and tanker trucks. The British Columbia Ministry of the Environment ordered the treatment of the waste prior to discharge to a nearby water course.

A skid mounted reverse osmosis-ion exchange treatment system, designed and built by Zenon, was employed for the cleanup. The treatment system processed 90,000 US gallons of wood treating waste over a three week period. The system was operated in a 70% recovery mode; where 70% of the feed wastewater was treated for discharge and the remaining 30% of concentrate was recovered for reuse in the wood treating plant. The quality of the treated effluent was confirmed by the British Columbia Ministry of the Environment as suitable for discharge. The CCA level in the feed wastewater was reduced from approximately 65 ppm to <0.01 ppm following treatment. Wood dye was not visibly detected in the treated effluent. The productivity of the system decreased over the first two weeks of the operation, as the reverse osmosis membranes conditioned to the wastewater, and eventually attained a stable performance during the last week of operation, as foul/clean cycles became controlled.

The good results of this cleanup operation offer significant potential for the use of reverse osmosis-ion exchange treatment in spills of this nature, as well as other wastewater streams containing low concentrations of organic and inorganic contaminants.

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