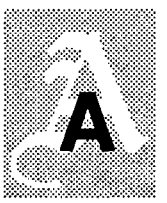
Twenty - Seventh

Central Canadian Symposium on Water Pollution Research



Abstracts

February 12, 1992

Canada Centre for Inland Waters
Burlington, Ontario

Management of Urban Lakes

Impact of Pollutants on Aquatic Ecosystems

Water Pollution Control Technology

Sponsored by

The Canadian Association on
Water Pollution Research and Control

TWENTY-SEVENTH

CENTRAL CANADIAN SYMPOSIUM ON WATER POLLUTION RESEARCH

INSERT FOR ABSTRACTS

SESSION I

PARTICLE CHARACTERIZATION FOR BETTER UNDERSTANDING OF EFFLUENT FILTRATION

A.Adin[1]

Granular, deep bed filtration plays a major role in the protection of system components vulnerable to clogging in disposal systems, including water reuse projects. It is also used to prevent organic particles from polluting rivers and lakes. Filter design in this area is yet more of an art lacking a sound scientific basis.

The understanding of filtration mechanisms and of effluent reuse problems associated with particulate matter has been promoted through particle characterization studies. The work includes introduction of particle size distribution into deep-bed filtration models, investigation of differences in particle retention mechanisms between water and wastewater filtration; development and selection of filter media based on grain characteristics - e.g. surface structure and shape; physical, chemical and physical-chemical characterization of particulates in wastewater effluents for better design of filters and definition of deposition mechanisms for the prevention of clogging of drip irrigation systems, such as interactions between biofilm and organic and inorganic particles. The work has also wide application to various topics of great interest including transport of pollutants in porous media (soil), particle characterization methods, and coagulation and a variety of filtration processes.

The application of particle size analysis is one example of using particle characterization for better understanding and improved design of the direct filtration process (no chemical pretreatment) of secondary municipal effluents. Particle size analyses were performed for various secondary effluents, particle counts decreased from thousands per ml to few per ml for 2-300 μm range. Effluents coming out of seasonal reservoirs exhibit lower cumulative frequency curves than common secondary effluents. Least square analysis shows that in some cases an exponential function describes particle size distribution (PSD) somewhat better than power-law function, the difference, however, is not radical enough to rule out the generality of the latter.

Particle volume distribution (PVD) calculated from PSD data resembles a bell-shape curve. Although most of the particles are smaller than 10 μm, the PVD curves demonstrate that the largest volume of clogging material is contributed by the 10-80 μm size range, implying that filter design should aim at the removal of particles of that size range.

Comparison of filter removal efficiency as a function of particle size for different filtration rates shows a lower efficiency for the smaller particles, with a tendency of the removal curve toward a minimal efficiency in the 1-2 μm range, thus supporting the minimum particle transport efficiency theory. However, it is also observed that relatively large grain sizes remove particles more effectively and retain larger volume of suspended material than small grain sizes for some types of effluents tested, contradicting general water filtration theories. This phenomenon can be related to several factors: pore geometry, grain surface roughness, diffusion and gravity deposition mechanisms and interstitial hydraulic gradients.

[1]The Hebrew University of Jerusalem, Israel

Experimental results corresponded well to the power-law distribution function for both filters influent and filtrates. While dealing with such suspensions it seems to be an obvious conclusion that particle size should not be represented in the filtration models by only one representative diameter. Linear correlations established between the filter influent and effluent PSD function parameters, enable to use a predictive model for run terminal head loss by feeding the computer with influent PSD along.

PROGRAM

Wednesday, February 12, 1992

8:00 - 8:45 Annual General Meeting, L205
8:45 - 9:00 Opening Remarks: Dr. J. Norman, Auditorium

Session I - CCIW Auditorium
Industrial Wastewater Treatment

PRESIDER: N.W. Schmidtke, N.W. Schmidtke & Associates Ltd.

9:15 - 9:45 **J.A. Oleszkiewicz, University of Manitoba**
Upgrading of the Performance of Aerated Lagoons by Managing Solids Residence Time

9:45 - 10:15 **D. Thirumurthi, Technical University of Nova Scotia**
Investigation of Aerobic Biological Treatability of a Diary Process Waste

10:15 - 10:45 **A.R. Keen, Altech Environmental Consulting Ltd.**
Total Wastewater Treatment and Reuse by Closed Looping

10:45 - 11:15 *COFFEE BREAK - Main Mall Area*

11:15 - 11:45 **H. Buisson, Wastewater Technology Centre**
Potential for Ultrafiltration and Nanofiltration Processes in the Treatment of Selected Pulp and Paper Effluents

11:45 - 12:15 **W.N. Wheeler, Boojum Research Ltd.**
Biopolishing of Zinc and Other Metals by Periphyton Communities Around a Base Metal Mine

12:15 - 1:15 *LUNCH - Main Mall Area*

Session II - CCIW Auditorium
Municipal Wastewater Treatment

PRESIDER: R. Corsi, University of Guelph

1:15 - 1:45 **T.D. Vassos, Novatec Consultants Inc.**
Evaluation of ORP and NADH Sensors for Use in Biological Nutrient Removal Process Audits and Monitoring

1:45 - 2:15 **J.J. Ganczarczyk, University of Toronto**
Multi-Dimensional Evaluation of Full-Scale Aeration Systems

2:15 - 2:45 **P. Dold, McMaster University**
Ontario Survey of Filamentous Bulking and Foaming in Municipal Activated Sludge Plants

2:45 - 3:15 *COFFEE BREAK - Main Mall Area*

3:15 - 3:45 **K.L. Murphy, McMaster University**
Investigations into Excess Activated Sludge Accumulation at Low Temperatures

3:45 - 4:15 **F. Poulin, University of Sherbrooke**
A New Technique for Evaluating the Dewatering Potential of Sewage Sludge

4:15 - 4:45 **D. Moore, Technical University of Nova Scotia**
Potential Solutions to Scaling Problems in Anaerobic Reactors Treating Landfill Leachate

5:15 **RECEPTION - CCIW Cafeteria**

Session III, Section I
North/South Seminar Rooms
Management of Urban Lakes

PRESIDER: J. Barica, National Water Research Institute

9:15 - 9:40 **W. Ripl, Technical University, Berlin**
Management of the Watercycle - An Approach to Urban Ecology

9:40 - 10:05 **G.K. Rodgers, National Water Research Institute**
Watershed Planning and Pollution Control Technology for Restoring Hamilton Harbour

10:05 - 10:30 **W. Edgar Watt, Queen's University**
Retrofitting Stormwater Ponds for Water Quality Control

10:30 - 10:50 *COFFEE BREAK - Main Mall Area*

10:50 - 11:15 **G. Klein, Federal Health Office, Berlin**
Recovery of Urban Lakes During Ten Years of Phosphate Removal

11:15 - 11:40 **A. Pulvermuller, Institut fur Physische Geographie (Germany)**
Ecological State of the Gravel Ponds within the City Limits of Freibuig (Germany)

11:40 - 12:05 **D. Kudelska, Institute for Environmental Protection, Poland**
Situation of Urban Lakes in Poland

12:05 - 12:30 **I.G. Altafin, Companhia de Agua e Esgotos de Brasfila, Brazil**
Lake Paranoa, Brasilia, Brazil: Integrated Management Plan for its Restoration

12:30 - 1:30 *LUNCH - Main Mall Area*

1:30 - 1:55 **G. Vincent, Montreal Botanical Garden, City of Montreal**
Artificial Marshes to Maintain Water Quality: The Beach Park of Ile Notre Dame, Montreal

1:55 - 2:20 **R. Leduc, University of Sherbrooke**
Eutrophication, Microphyte Growth and Sedimentation in Shallow Lakes Receiving Urban Runoff

2:20 - 2:45 **T.G. Northcote, University of British Columbia**
Water Quality Problems and Management in Deer Lake, Burnaby, B.C.

2:45 - 3:05 *COFFEE BREAK - Main Mall Area*

3:05 - 3:30 **J. Babin, University of Alberta**
Application of Lime and Alum to Stormwater Retention Lakes to Improve Water Quality

3:30 - 3:55 **M.E. Fox, National Water Research Institute**
An Investigation of Long-Term Intermittent High Discharges of Lindane into Hamilton Harbour, its Correlation with Chlorobenzenes and Chloroanisoles and a Comparison with Geographically Diffuse Sources of Lindane

Session III, Section II
North/South Seminar Rooms
Management of Urban Lakes

PRESIDER: C. Gray, National Water Research Institute

3:55 - 4:20 **M. Elektorowicz, McGill University**
Vulnerability of Inland Waters to Leachate from Animal Wastes

4:20 - 4:45 **S. Kirby, Natural Water Research Institute**
Evaluation of Sediment Manipulations on Chronic Sediment Bioassays Using Four Species of Benthic Invertebrates

4:45 - 5:10 **E. Halfon, National Water Research Institute**
Visualization of Scientific Data: Hamilton Harbour

5:15 **RECEPTION - CCIW Cafeteria**

Poster Session - Main Mall Area

Poster 1 **N. Kosaric, University of Western Ontario**
Response and Recovery of Anaerobic Granules from Shock Loading

Poster 2 **Z.J. Risko, University of Guelph**
Residential Stormwater Quality in Guelph

Poster 3 **S. Ricard, Université du Québec à Trois-Rivières**
Tadpoles Blood Parameters as Indicators of Cadmium Water Pollution

Poster 4 **M. Halevy, Wastewater Technology Centre**
Iron and Manganese Removal and Sequestration from Groundwaters: Drinking Water and Site Remediation Applications

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Session I - Industrial Wastewater Treatment

UPGRADING OF THE PERFORMANCE OF AERATED LAGOONS BY MANAGING SOLIDS RESIDENCE TIME

J.A. Oleszkiewicz[1]

Wastewater from an integrated bleached kraft pulp and paper mill was treated in seven parallel treatment trains. Each train consisted of three reactors in series, with primary reactor (denoted L1) simulating an aerated equalization/stabilization lagoon with hydraulic residence time (HRT) equal to 1.5d. The secondary (middle) reactor was different in each train. Three reactors (R1, R2, R3) were operated at HRT = 4.5d and the solids residence time (SRT) equal to, respectively 10d, 20d, and 40d. The next three secondary reactors (R4, R5, R6) were operated at HRT = 1.5d and SRT equal to 10, 20 and 40d respectively. The secondary reactor in the seventh train (R7) was operated at an HRT equal to SRT set at 1.5d - i.e. effectively operating as an aerated lagoon. The last, third or secondary reactor in each of the series was operated as a settling lagoon with all reactors (denoted E1 to E7) having identical HRT = 1.5d. The objectives were to compare the effects of varying the solids residence time and hydraulic residence time in the secondary reactors R1 to R7 on the removal of AOX, to compare the performance of the most effective full system containing SBR to that of the "pure lagoon" system L1 -> R7 -> E7 with a total residence time of 4.5d, to assess the phenomenon of biosorption of organics.

The primary aerated lagoon (L1) at 1.5d HRT removed 65% of (settleable) BOD_5, 33% SOC and up to 19% of adsorbable halide AOX. The secondary sequenting batch reactors (R1 to R6) have removed virtually all of the remaining (settleable) BOD_5, while the lagoon R7 removed 90%. The removals of SOC and AOX in all secondary reactors were directly proportional to the increasing biomass concentration and to the increase SRT. For the sequencing batch reactors R1 to R6 the AOX and SOC removals at equal SRT values were higher in the reactors having shorter HRT and consequently higher F/M and volumetric organic load. This was attributed to the mechanism of biosorption and export of adsorbed poorly degradable organics with the waste activated sludge (WAS). Fig. 1 shows the AOX removal across only the secondary reactors R1 to R7. The removal is in proportion to the biomass (MLVSS) concentration which at equilibrium was (mg/l) R1 - 380, R2 - 790, R3 - 1360, R4 - 840, R5 - 1650, R6 - 2780, R7 - 210. These findings, which suggest the smaller-HRT, higher-SRT reactors are superior are somewhat in contrast to the current design practise in this industry which calls for larger lagoons to achieve better removals.

The final polishing facultative lagoons E1 to E6 served only as solids removal units following the SBR reactors R1 to R6. The E7 lagoon served a biological removal purpose when preceded by an aerated lagoon in the sequence L1 -> R7 -> E7. The most efficient system of basins : L1 -> R6 -> E6 removed on the average 30% AOX. The comparable (i.e having the same volume corresponding to HRT = 4.5d) system of "pure" lagoons L1 -> R7 -> E7 removed only 21% AOX.

[1]Environmental Engineering Division, Department of Civil Engineering, University of Manitoba, Winnipeg, Manitoba R3T 2N2

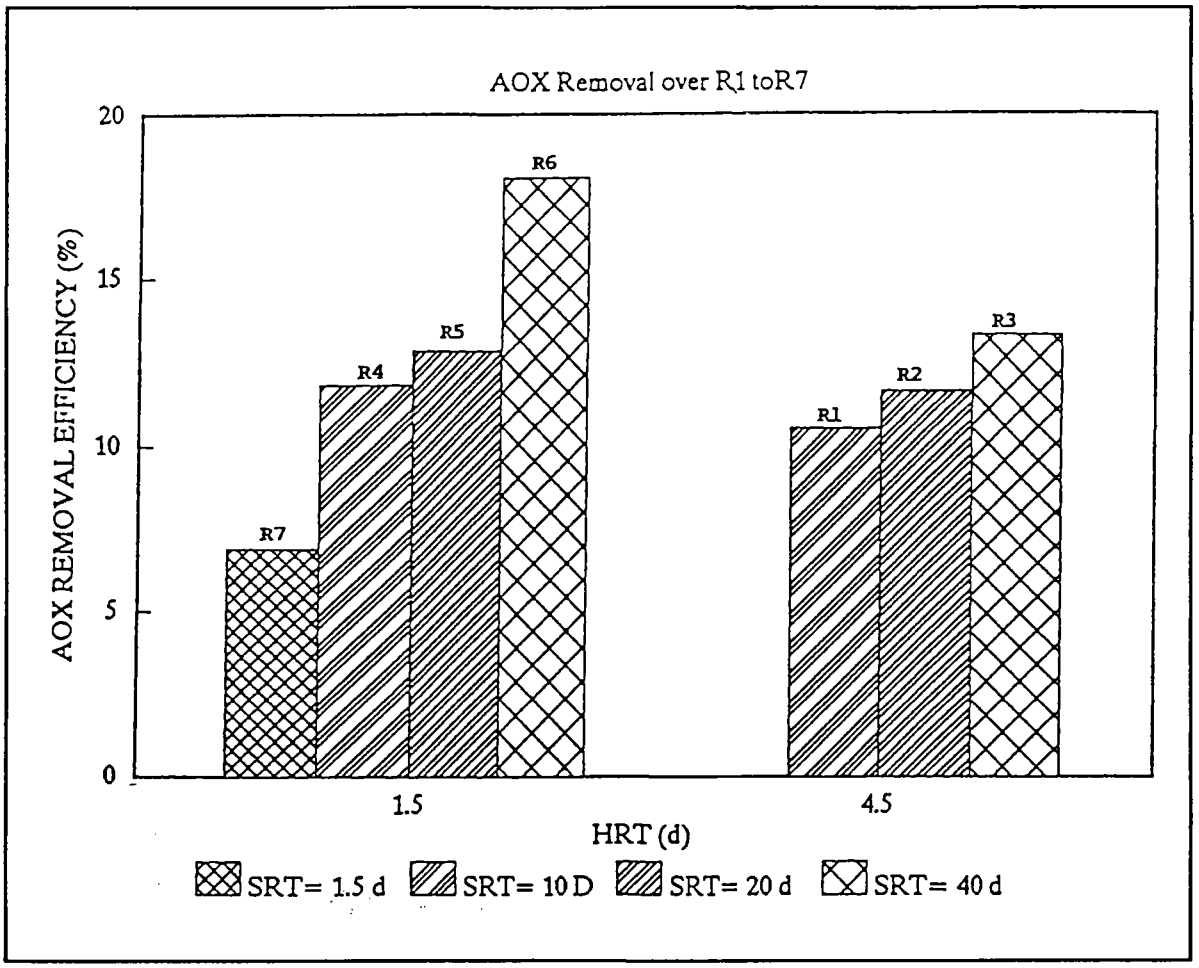

Figure 1. AOX removal across the secondary reactors R1 to R7.

INVESTIGATION OF AEROBIC BIOLOGICAL TREATABILITY OF A DAIRY PROCESS WASTE

D. Thirumurthi[1], S. Thompson[2], J.M. Murphy[3], E. Andavan[3], and A. Bourque[1]

Operating problems have plagued a dairy waste treatment plant since start-up in 1975. The facility consists of an equalization tank and two lagoons, aerated by surface-mount, aspirating type units. Wastewater generated by the dairy enters an equalization tank where load surges are minimized and pH adjustment/nutrient addition can be made. The wastewater is treated via a two-stage aerated lagoon system, from which the effluent discharges into a sewer which feeds a municipal treatment plant for final polishing.

The average effluent BOD_5 from the dairy's treatment plant has typically exceeded the 200 mg/L imposed by the municipality. During the summer months, low dissolved oxygen levels have sometimes resulted in anaerobic conditions. This in turn has led to occasional odour complaints from the homes in the immediate vicinity of the treatment plant.

The inadequate performance by the lagoon system has been attributed to a possible combination of four variables, namely (i) pH fluctuations (ii) nutritional deficiencies (iii) potential sterilizing effects by sanitizers used in the cleaning operations of the dairy and (iv) inadequate aeration capacity. It was strongly felt by the dairy that the ten aspirating-type aerators, amounting to a total capacity of 49 KW (66 horsepower), were one of the significant factors affecting the operation of the treatment plant.

It was decided by the dairy to investigate these variables by way of a laboratory-model study, the objectives being (i) to establish treatability of the actual waste using small aeration tanks (ii) to estimate the BOD_5 removal coefficient (K), and (iii) to determine the minimum aeration capacity required to meet the effluent BOD_5 requirements. An engineering firm was engaged by the dairy to undertake the study which in turn used the expertise of a local university.

The first phase of the study was designed to verify the biodegradability of the waste and the effects of pH on treatability. It was concluded that the waste was biodegradable (the sanitizing chemicals used in the cleaning operations did not seem to affect the biodegradation process). BOD_5 removal rate of 95 percent was achieved with a hydraulic retention time (HRT) of eight days. Though the initial pH of the raw waste ranged from 9.9 to 11.8, the pH of treated waste dropped to a range of 7.7 to 8.8. The K value varied from 2.1 to 2.4/d for completely mixed conditions (20-24°C). Due to the daily addition of urea by dairy personnel to the waste stream, the BOD_5:N ratio in the influent samples averaged 100:5.1. The average BOD:P ratio was 100:4.9 (the source of phosphorous from the dairy is believed to be the detergents used in it's cleaning operations. In view of the fact that BOD_5 decreased in the aeration tanks, from 503 mg/L to 25 mg/L, it was concluded that no nutritional deficiency existed, and pH fluctuations did not seem to constitute a problem.

A literature search revealed that very limited information exist on oxygen transfer rates pertaining to dairy wastewater. Therefore, the second phase of the laboratory-model study involved determining the oxygen

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[1]Technical University of Nova Scotia

[2]Farmers Co-operative Dairy Ltd.

[3]UMA Engineering Ltd.

transfer coefficient (KLa) for water and wastewater, the oxygen transfer ratio (alpha), the ratio of oxygen saturation between water and wastewater (beta), and rates of oxygen dissolution in wastewater (Nww) and tap water (Ntw). The value of alpha ranged from 0.37 to 0.41, beta from 0.52 to 0.71, and the ratio Nww/Ntw from 0.24 to 0.26.

The third phase of the study involved assessing the effects of three different aeration rates on BOD_5 removal and determining the optimum air requirements under laboratory conditions. Tank 1 was aerated at a low rate (166 ml/min) to study the effect of under aeration, Tank 2 was aerated at "near-optimum" conditions (357 ml/min) and Tank 3 was completely mixed (725ml/min). The K values for the three tanks were 0.4/d, 0.7/d and 1.5/d respectively.

Based on this data, it was concluded that for the dairy's average wastewater flow rate of 632 m^3/d (0.167 US mgd) and mean influent BOD_5 of 600 mg/L, the oxygen required to reduce the BOD_5 to 200 mg/L was about 760 kg/d. The minimum required oxygenation capacity of the proposed aeration equipment, under standard temperature and pressure, in tap water environment, was estimated as 122 kg/hr (269 lbs/hr) to achieve the target maximum BOD_5 of 200 mg/L.

New surface-type aeration equipment with a total capacity of 112 KW (150 HP) was installed in July 1991, and subsequent operation resulted in outlet BOD_5 conditions below municipal guidelines and control of odour generation due to improvement in mixing and oxygen input. The dairy is currently investigating the use of variable speed drives controlled by on-line oxygen sensors to adjust the speed of aerator motors to varying load conditions. The ultimate objective is to reduce operating cost for this equipment during the winter season when oxygen demand is considerably lower than the rest of the year.

TOTAL WASTEWATER TREATMENT AND REUSE BY CLOSED LOOPING

A.R. Keen[1] and R.J. Sinukoff[1]

Recent initiatives toward wastewater pollution management in the photographic processing and printing industries have been primarily directed at reducing volumes of washwater used and at removing valuable contaminants such as silver. New chemical formulations and chemical regeneration packages for processing solutions have also decreased the quantities of regulated materials being discharged down the sewer. In reality, only regeneration and recycling of processing solutions has had an impact on overall mass loading of contaminants found in sewer effluents from these industries.

ALTECH Environmental Consulting has thoroughly researched the mechanisms of the photographic processes, the function of all chemistry involved, and appropriate technological options to completely close loop and treat all process streams and washwater at the Black Photo Corporation main photographic processing plant in Markham, Ontario. This total system, called *System Crystal*, has been operating since June 1, 1991 to provide total water reuse and a dry process sewer.

Before System Crystal was installed, up to 70,000 USGPD of wastewater was discharged from the facility. The closed loop process treats and recycles water, resulting in a final system byproduct of up to 200 USGPD mixed photochemistry concentrate, which is sent for incineration. Black's has now achieved a 97% reduction in process water usage.

Detailed studies were conducted to delineate the composition of each in-house process stream which was previously discharged to the sanitary sewer. An extensive literature survey was done to establish baseline information, and where information was unavailable or unknown, bench-scale and pilot-scale tests were conducted to determine feasibility of theories and design.

During the initial study, analysis of key parameters such as BOD, TOC, iron, silver, and halogens at source and at end of pipe determined that over 95% of mass contaminant loading originated from the 2% of the total wastewater volume attributed to high strength process solutions. From this, the treatment system was designed to handle process chemistry and washwater separately. Typical BOD values for photographic solutions and non-recycled washwater are 1500 ppm and 10 ppm respectively.

For depleted photographic solutions which cannot be regenerated or reused due to technology, quality, or economic restrictions, the water portion of the solution (typically above 90%) is extracted by vacuum distillation, operated at ambient temperature and 685 mm Hg of vacuum. A mixture of these solutions can contain components such as benzyl alcohol, ethylene glycol, EDTA, ammonia, carbonate, sulphate, thiosulphate, halides, and iron, in up to percent concentrations.

Depending on the feed composition, the aqueous distillate contains impurities of up to 0.4% ammonia, 0.2% benzyl alcohol, 0.04% ethylene glycol, and trace aromatic derivatives. The concentrate contains approximately 25% precipitated organic and inorganic salts of glycol, EDTA, amine, halide, carbonate, and sulphate nature. The remaining concentrate liquid is approximately 40% water, 55% paraphenylene diamine derivatives (from photographic developers), 3% ethylene glycol, 1% benzyl alcohol, and remainder trace organics. This stream represents the 200 USGPD residual which is ultimately taken for incineration.

[1]ALTECH Environmental Consulting Ltd., 225 Sheppard Ave. W., Willowdale, Ontario M2N 1N2

The distillate is treated by activated carbon to remove organics and by ion exchange to remove ammonia. This enables this water to be reused as makeup for washwater and process solutions.

Rinsewaters generated by the photographic processes are more dilute than the corresponding high strength solutions and are thus handled separately. All fixer washes contain silver thiosulphate complexes and are treated by nanofiltration at 5000 GPD to concentrate silver for subsequent electrochemical removal. The remaining washwaters are recirculated at source to increase contaminant loading before separate treatment by nanofiltration at 2400 GPD. All nanofiltration permeate is combined and treated by reverse osmosis to remove remaining ammonia, chloride, bromide, sodium and calcium. Total dissolved solids content in the final treated water is typically 280 ppm as compared to Markham city water at 370 ppm. All water is recirculated to source wash baths after treatment.

Evaporative and system losses are replenished with city water makeup and treated vacuum distillate. The city makeup stream constitutes approximately 8% of the daily volume of water treated, and depends primarily on the volume of water lost to the atmosphere as a result of drying the photographic paper product.

A comprehensive economic and performance evaluation of the entire system is currently underway.

POTENTIAL FOR ULTRAFILTRATION AND NANOFILTRATION PROCESSES IN THE TREATMENT OF SELECTED PULP AND PAPER EFFLUENTS

H. Buisson[1], A. Zaidi[1], L. Beaudoin[2], H.-C. Lavallée[2], and M.C. Barbe[3]

The pulp and paper industry is currently faced with the challenge of substantially reducing its discharge of conventional and toxic pollutants to the receiving environment without compromising its competitiveness. Researchers interested in developing schemes for meeting this challenge are focusing on two areas: (i) pollution prevention through the implementation of internal measures to minimize water usage and reduce the generation of toxic contaminants, and (ii) end-of-pipe treatment through the use of innovative and optimized effluent treatment schemes for the removal of undesirable components from process waste streams. In this context, the use of innovative separation and destruction processes is expected to reduce the water usage of both kraft and mechanical mills while minimizing the discharge of toxic contaminants to the environment. Among these processes, ultrafiltration and nanofiltration are attracting significant attention.

The Wastewater Technology Centre (WTC), the Centre de Recherche en Pâtes et Papiers (CRPP) and HYMAC have been active in evaluating, developing and demonstrating cost-effective effluent treatment technologies for the pulp and a paper industry. Recently new activities were undertaken under to evaluate the technical and economic feasibility of integrating ultrafiltration (UF) and nanofiltration (NF) into kraft and CTMP mills. Those programs involve the following steps: (i) selection of the most appropriate membranes and systems, (ii) simulation the UF and pulping processes, (iii) study of downstream options for the handling of the permeate and concentrate, (iv) cost-estimation and full-scale demonstration of the system.

The work conducted to date had the following specific objectives: (i) selection of the most suitable membranes through a review of the pertinent literature and discussions with the researchers active in this area, (ii) experimental evaluation of the rejection and flux behaviour of the selected membranes using bench-scale apparatus and synthetic solutions of selected toxic organics most commonly found in pulp mill effluents, (iii) experimental evaluation of the flux behaviour and Colour, COD and AOX rejections of the membranes using selected bench-scale systems and bleach plant effluents from a kraft mill pulping softwood and (iv) experimental evaluation of the flux behaviour and TOC, Dissolved Solids and COD rejections of the membranes using selected bench-scale systems and segregated BCTMP effluents.

This presentation will review internal options and end-of-pipe measures available for both types of mills. The emphasis will be put on the use of UF and NF for the recycling of process waters, at source containment of toxic organics and the recovery of valuable by-products. Also included in the presentation are the data generated from the WTC and CRPP experimental works completed to date on: (i) the characterization of the selected effluents, (ii) the fluxes and rejections of the membranes/systems used to date and (iii) a study of the effects of the operating conditions on the performances of such systems.

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[1]Wastewater Technology Centre (WTC), Operated by RockCliffe Research Management, 867 Lakeshore Road, P.O. Box 5068, Burlington, Ontario L7R 4L7

[2]Centre de Recherche en Pâtes et Papiers (CRPP), Université du Québec à Trois-Rivières, Trois-Rivières, Québec

[3]Hymac Itée, Laval, Québec

BIOPOLISHING OF ZINC AND OTHER METALS BY PERIPHYTON COMMUNITIES AROUND A BASE METAL MINE

W.N. Wheeler[1] and M. Kalin[1]

Biological polishing of zinc and other heavy metals was measured in populations of periphyton at a polymetallic mine in Buchans, NFLD. This work was part of a feasibility study to measure the capacity of periphyton populations to remove contaminant metals from waste water on a pilot-scale. The algal populations have been studied for two growing seasons in the effluent from an abandoned gloryhole.

Six polishing ponds, in series, were constructed near the effluent creek. The surface area for algal colonization was increased using brush cuttings. Flow rates through the ponds were variable and low, resulting in residence times ranging between 10 and 180 hours.

Accumulation of algal-precipitate biomass was monitored by collecting branches over two growing seasons in 1989 and 1990. The algal-precipitate mass was quantified by separating branch and algal-precipitate and drying both (60° C for 24 h).

Biomass of periphytic communities growing in seepages in the meadow was also collected. Multi-elemental analysis was carried out on water and algal material using Inductively Coupled Plasma Spectrophotometry (ICP) by a certified laboratory (Assayers Ontario, Ltd.).

The periphyton population growing on the branches in the polishing ponds was dominated by the green alga *Microspora* spp. and the diatom, *Achnanthes linearis*. The algae in the seeps were dominated by a population of *Ulothrix* spp. Reproductive structures have not been seen in the green algae, inhibiting species identification.

Bio-accumulation of metals by the two periphytic communities is described by calculated concentration factors based on a wet to dry weight ratio of 10. The *Ulothrix* population in the meadow contained 1.8% zinc, a concentration factor of only 104 (Table I). In contrast, at the same ambient dissolved zinc concentration, the polishing pond community contained 500 x the concentration of zinc (Table II). Barium in *Ulothrix* community was about 12,000 times over ambient water levels as compared to 22,900 times in the *Microspora-Achnanthes* community.

The zinc concentration differences in the periphyton communities are related to the presence of zinc and iron hydroxide precipitates. The polishing pond community acts as a biosieve, accumulating precipitate as well dissolved zinc. This results in concentrations as high as 8% zinc on a dry weight basis (Table I).

Water sampled from the first and last (sixth) pond showed evidence of dissolved zinc removal, which appeared to be related to environmental factors and biomass density. Increases in algal-precipitate mass per unit branch in the second year appeared to be related to the increased biopolishing of zinc. Differences between incoming and outgoing dissolved zinc concentrations reached a maximum during the late summer of the second year, corresponding with the period of greatest biomass per branch.

The ability of these algae to concentrate dissolved cations, and the sieving capability of the algal community in the polishing ponds, indicate that periphytic algal populations with the proper scale-up may provide substantial polishing capacity in waste water from active and decommissioned base-metal mines.

[1]Boojum Research Limited, 468 Queen St. E., Suite 400, Toronto, Ontario M5A 1T7

ELEMENT	WATER (mg/L)	ALGAE (μg/gdw)	CONC.
Ba	0.02	2331	11,655
Cd	0.01<	10	>100
Co	0.01<	70	>700
Cr	0.01<	36	>360
Cu	0.01<	62	>620
Ni	0.01<	26	>260
Pb	0.01<	122	>1,220
Sr	3.6	120	3
Zn	18	18800	104

Table 1. Concentrations of metals in *Ulothrix* community in the meadow.

ELEMENT	WATER (mg/L)	ALGAE (μg/gdw)	CONC.
Ba	0.01<	2287	>22,900
Cd	0.01<	40	>400
Co	0.01<	43	>430
Cr	0.01<	39	>390
Cu	0.01<	210	>210
Ni	0.01<	50	>500
Pb	0.01<	638	>640
Sr	2.4	125	4
Zn	16	81000	500

Table 2. Concentrations of metals in the *Microspora-Achnanthes* community.

Session II - Municipal Wastewater Treatment

EVALUATION OF ORP AND NADH SENSORS FOR USE IN BIOLOGICAL NUTRIENT REMOVAL PROCESS AUDITS AND MONITORING

T.D. Vassos[1]

This paper describes the comparative use of Oxidation Reduction Potential (ORP) and NADH sensors as a means of monitoring relative biological activity and reduction state in a biological nutrient removal (BNR) treatment facility. The work was carried out as a part of a research program, with the financial assistance from the Science Council of British Columbia, to develop process audit techniques for use in optimizing BNR systems and in upgrading activated sludge systems for BNR. The research was conducted at a 3.0 MGD Advanced Wastewater Treatment Plant (AWWTP) located in Penticton, British Columbia.

ORP sensors have been previously used in BNR research to monitor denitrification in batch processes and to determine the relative anoxic or anaerobic condition in specific mixing tanks. The ORP levels within a BNR facility will vary depending upon the presence of electron acceptors such as dissolved oxygen or NO_x. Once the supply of dissolved oxygen (DO) to the mixed liquor in an "aerobic" zone is shut off, the ORP level gradually diminishes until all of the DO is consumed. At this stage the mixed liquor is defined as "anoxic" and the principle electron acceptor becomes NO_x. The ORP continues to diminish until all of the NO_x is consumed, which can be identified by a sudden drop in the ORP level as the mixed liquor becomes "anaerobic". Optimal BNR performance can only be achieved if specific aerobic, anoxic and anaerobic zone sequences within the plant can be controlled and maintained. As the ORP level in each of the three zones is different, it has been suggested as a potential on-line control mechanism.

There are three key factors which interfere with the successful application of ORP as a control mechanism within BNR facilities: (1) ORP sensors are difficult to calibrate; (2) ORP ranges in anoxic and anaerobic zones are different in each plant; (3) ORP levels reflect the "environmental" reduction state rather that the biological activity within the activated sludge. NADH sensors have been recently promoted as an alternative to ORP sensors as they assess the reduction state within the cells. In a BNR process the reduction state [NADH/(NAD+NADH)] of the activated sludge depends on the relative anaerobic, anoxic or aerobic condition to which the sludge is exposed and the duration of the exposure. This intracellular reduction state can be monitored using the principle that NADH within the biomass fluoresces at 460 nm when irradiated with light at 360 nm (Rao, 1989). Changes in biological activity, or differences in biological activity between reactor zones, can be determined by constantly monitoring the fluctuations in fluorescence within each zone. These sensors have been used to monitor biological activity at the Oaks, Pennsylvania, BNR plant (Armstrong, 1990) and at the University of British Columbia BNR pilot plant (Armstrong et al., 1991).

Four on-line ORP sensors and seven NADH sensors were installed specific reactor zones in one of the two Penticton AWWTP modules, in addition to eight solids and DO probes. Data was collected for a period of three months, during which time the plant experienced a number of process upsets which were tracked by the on-line equipment, permitting a comparison of the performance and maintenance characteristics of the NADH and ORP sensors. The on-line data was analyzed in conjunction with data collected during the routine plant operations including flow and laboratory analyses results.

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Both sensors effectively delineated specific biomass reduction states (i.e. anaerobic versus anoxic) and the relative changes in those states due to diurnal fluctuations and process changes. Specific advantages and disadvantages of each sensor were noted during the study. For example, the ORP sensors reacted more quickly to process changes which altered specific reactor conditions (i.e. changes in the aerobic zone size), and were less sensitive to diurnal fluctuations in biomass due to sludge wasting, than the NADH sensors. Alternatively, the ORP sensors required more maintenance and calibration than the NADH sensors. The data indicates that both sensors can be effectively used to monitor BNR processes, and that the sensors are not mutually exclusive, and require other on-line instrumentation (i.e. solids and DO) for their effective implementation in a BNR control or assessment strategy.

MULTI-DIMENSIONAL EVALUATION OF FULL-SCALE AERATION SYSTEMS

J.J. Ganczarczyk[1] and E.J. Gill[2]

To provide a possibly broad information basis for optimal design of future activated sludge process wastewater treatment plants, eight full-scale aeration systems in Ontario were evaluated with the use of a comprehensive methodology based on the Analytic Hierarchy Process. In addition to the conventional comparisons, this methodology allowed for the examination of relation arising from criteria where measurements did not exist or were not extensive enough. The selected evaluation criteria covered economic, technological, environmental and local factors. High importance was given to the economic criteria, followed by environmental, technological and local factors. Each criterion played an important role in the Analytic Hierarchy Process evaluation.

Various comparison scales were utilized to illustrate the subjectivity of the comparisons and the variations in individual preferences in assigning degrees of importance to evaluation criteria. It was evident that depending upon the selection of the relative importance of the evaluation criteria or the scale of comparison, the overall ranking of an aeration system can be altered.

The found consistency of comparisons, as marked by the consistency ratio, was remarkable. The economic factor was the single most important criterion, followed by environmental, technological and local criteria. It was evident that aeration systems that possessed better economic and environmental performance were likely to show higher composite preferences.

The economic evaluation indicated the strong presence of economies of scale for capital costs and for operation and maintenance costs. The economies of scale were more evident at small sized plants than for large sized plants. The accuracy of the modified EPA equations in estimating capital cost was found questionable. However, the accuracy of the modified EPA equations in estimating operation and maintenance costs was acceptable. The modified Environment Canada equations were only accurate in estimating operation and maintenance costs at small sized plants. Small sized plants also exhibits appreciably low utilization of design capacities in comparison with large sized plants.

The technological evaluation revealed that aeration systems at almost all the studied plants were capable of providing adequate wastewater treatment. However, some distinct technological differences between aeration systems were visible, especially with respect to their operational characteristics. At some plants improper process control caused poor operation of the aeration systems. Some plants failed to utilize the process flexibility of their designed operating modes.

Although air pollution was a problem at some of the studied plants, noise pollution was not a problem at any of the plants. All the large size plants were equipped with expensive air pollution control systems but still showed a high air pollution potential. In general, the adverse effects on the local environment were greater in the case of large size plants than for the small plants.

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ONTARIO SURVEY OF FILAMENTOUS BULKING AND FOAMING IN MUNICIPAL ACTIVATED SLUDGE PLANTS

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International experience indicates that sludge bulking and/or foaming, and the associated poor sludge settleability, often constitutes the major operational problem at municipal and/or industrial activated sludge wastewater treatment plants. A research program has been initiated at the Department of Civil Engineering and Engineering Mechanics, McMaster University to address the following aspects:

a) Identify the severity and extent of the problem in Ontario by conducting a preliminary postal survey;

b) identify the filamentous organism type(s) causing bulking or foaming in municipal wastewater treatment plants;

c) provide advice to plants on strategies for control and remediation of bulking or foaming problems;

d) run laboratory experiments to establish data on the efficacy of selector reactor installation and non-selective (e.g. chlorination) methods for the control of filamentous organism growth.

This paper is concerned with aspects (a) and (b), and presents the results from the Ontario survey on bulking and foaming.

There is a direct relationship between the abundance of filamentous organisms in the mixed liquor and the settling properties of activated sludge. From national surveys conducted in the USA, South Africa, Japan, and in Europe, sludge bulking and/or foaming caused by excessive growth of filamentous organisms has been identified as perhaps the most significant problem in municipal activated sludge plant operation. In addition, by relating the dominant filamentous organism(s) to plant design features and various operational conditions, including reactor configuration, wastewater characteristics, organic load, electron acceptor conditions, etc., a pattern has emerged whereby it is often possible to determine the cause of bulking by identifying the specific filament type(s). For example, the dominance of certain filament types, or groups of filament types have been associated with the following conditions:

1) Low dissolved oxygen concentrations (e.g. *Sphaerotilus natans*);

2) low F/M ratios (e.g. *Nocardia spp.*);

3) septic wastewater or sulfide (e.g. *Thiothrix spp.*);

4) nutrient deficiency (e.g. *Type 021N*);

5) low pH conditions (e.g. *fungi*).

The concept of microscopic identification of the dominant filament type(s) as an indicator of conditions causing activated sludge bulking or foaming is continuing to develop. However, activated sludge

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examination to identify filament types has been recognized as a fundamental step in the diagnosis of the cause of bulking and foaming.

A postal survey has been conducted to assess the extent and severity of the bulking/foaming problem in Ontario. About half of the 214 surveyed plants have responded to the questionnaire. Of the 110 responses, about 50% of the plants have experienced either intermittent or constant bulking or foaming problems; these account for approximately 80% of the wastewater flow treated in activated sludge systems in the Province. The survey results highlight the great extent of the operational problems associated with bulking and foaming in Ontario. In addition, it has become evident that there is limited expertise available on methodologies to identify and remedy the causes of the problem.

Case studies have been conducted on samples collected at a number of treatment plants. Based on preliminary information from microscopic filamentous organism identification the dominant cause of bulking in Ontario appears to be associated with low F/M ratios prevailing in the plants.

INVESTIGATIONS INTO EXCESS ACTIVATED SLUDGE ACCUMULATION AT LOW TEMPERATURES

S. Tian[1], L. Lishman[1], and K.L. Murphy[1]

The yield or increase in mixed liquor solids is fundamental to biological treatment of wastewater. Not only is the activated sludge process predicated on the ability to concentrate microorganisms, but overall waste treatment costs are a direct function of handling and disposal of the excess activated sludge. Low temperature operation has been reported to increase the yield of solids but little quantitative data are available and an explanation of the reported phenomena is lacking.

To study sludge production a laboratory study was initiated using 2 parallel 4 litre Sequencing Batch Reactors operating at a Sludge Retention Time of approximately 10 days and a Hydraulic Retention Time for approximately 1 1/4 days. The experimental design employed two levels of temperatures (8° and 20°C) and two levels of influent volatile solid concentrations (approximately 15 and 70 mg/l). The feed was primary effluent which was either concentrated or filtered and augmented with nutrient broth to provide a consistent concentration of Chemical Oxygen Demand.

The experimental data obtained verified the hypothesis that the observed yield (kg ΔVSS/kg ΔCOD) increased at lower temperatures for both levels of influent suspended solids. This increased yield was reflected in an increased accumulation of activated sludge which would require disposal.

Direct characterization of the sludge produced into viable organisms, endogenous decay products and accumulated particulates is not feasible and thus the IAWPRC activated sludge model was adapted to differentiate the particulate fractions. Simulation of the experimental conditions indicated that the actual concentration of viable organisms apparently decreased from approximately 75 to 90% of the MLVSS at 20°C to 45 to 65% at 8°C. Calculations indicate this estimated decrease in the viable population would explain the requirement of longer sludge ages during cold weather operation to achieve equal removals. In addition, the simulations indicate that waste sludge production at a typical treatment plant would increase by approximately 20% if no change in SRT is implemented.

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A NEW TECHNIQUE FOR EVALUATING THE DEWATERING POTENTIAL OF SEWAGE SLUDGE

F. Poulin[1], J.P. Jones[1], and A. Poulin[1]

The management, treatment and disposal of sludge is the most difficult aspect of wastewater treatment. Many processes and especially transportation and sanitary landfilling are made possible and made economical by effective dewatering. It is however extremely difficult to design and operate dewatering processes based on either first principles or laboratory evaluations. To date many process recommendations have been made based on pilot trials of unusual wastewater sludges. This work and associated projects attempt to find some useful generalizations of laboratory tests to full scale operations. In this context, the specific resistance to filtration on flocculated sludge has been investigated as a possible laboratory test for predicting the potential for dewatering unusual sludges. The work attempts to see if this test can be profitably integrated into a procedure for evaluating dewatering potential.

The project includes both traditional laboratory tests and novel laboratory tests which are then compared to full scale runs. The full scale runs were generally made on the belt filter press of the treatment station of a small municipality.

Laboratory characterization to evaluate the difficulty of dewatering sludges may call upon the following tests:

- Specific resistance to filtration (SRF)
- Capillary suction time (CST)
- Compressibility (S)
- Standard cake formation time (SCFT)

These tests performed on raw sludge however are imperfect and better methods would be a great help to operators. In an effort to improve our understanding of the usefulness of these tests and also to develop other more useful tests, a profile was done on four (4) municipal sludges.

- secondary sludge from conventional aeration basins
- secondary sludge from extended aeration basins
- primary sludge containing alum
- biofiltration sludge

A filter aid-shredded paper was added to various sludges so that a suitable independent parameter would be under our control to evaluate characterization tests. The SRF, S, and the ultimate dryness were performed in a filtration cell constructed according to the AFNOR standard T97-001.

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The results were generally consistent, however several parameters especially the SRT did not predict the wide variations found with different types of sludge on full scale dewater units. Available tests are generally performed on raw sludge while flocculated sludges are fed to the dewatering units.

A series of tests of the specific resistance to filtration were conducted on flocculated sludge (SRF_F) to determine if such tests are more sensitive and more realistic than those conducted on raw sludge. The tests were conducted according to the AFNOR standard T97-001 with the following modifications:

- A piston was used to apply pressure uniformly on the sample
- The sample volume was increased from 100 mL to 150 mL.

The sludge investigated was flocculated with the polyelectrolyte used in the full scale plant. The dose of the polyelectrolyte to be used has not been fully investigated and generally a dose equal to the dose used in the full scale plant was used. It will require more investigation to determine a standard yet appropriate way to flocculate the sludge before performing the SRF_F determination.

The SRF_F was conducted on secondary sludge with conventional aeration. The average value was 2.23×10^{11} m/kg which is 400 times smaller than the average value of 9.24×10^{13} m/kg for the SRF on raw sludge. When aeration time was increased from 5.5 hours to 12 hours, the SRF_F increased from 2.23×10^{11} m/kg to 4.23×10^{11} m/kg. This is thought to be at least a preliminary indication of the sensitivity of the new test.

A comparison of SRF for septic sludge (8.60×10^{13} m/kg) with the SRF for conventional activated sludge (9.24×10^{13} m/kg) showed that they had nearly equal values yet tests conducted during this investigation show their performance in dewatering equipment to be very different. It was possible to attain 35-40% solids for the septic sludge while only 16-18% solids could be attained with the conventional activated sludge. The comparison of flocculated SRF's more nearly predicted the difference in dewatering potential. An SRF_F of 8.82×10^{10} m/kg for the septic sludge was significantly lower than the SRF_F for the conventional activated sludge of 2.23×10^{11} m/kg.

Testing on flocculated sludge gives a more realistic and more sensitive result than the characterization of raw sludge. The reproducibility to date of flocculated RSF has been lower than with raw sludges (standard deviation of 14.4% compared to 8.8% for raw sludge). This technique seems to have considerable potential but there are many obstacles to overcome. The experimental data that has been obtained to this point has shown both the potential and the barriers to a wider application of this technique.

POTENTIAL SOLUTIONS TO SCALING PROBLEMS IN ANAEROBIC REACTORS TREATING LANDFILL LEACHATE

D. Moore[1] and D. Thirumurthi[1]

High-strength leachate (20,000 mg COD/L, 1200 mg Ca/L, 500 mg Fe/L and 200 mg Mg/L) generated at Halifax Sanitary Landfill site is being treated in a plant consisting of physical-chemical treatment (to precipitate the inorganics), two anaerobic reactors in parallel (hybrid upflow type) followed by two aerated lagoons in series. The effluent passes through four holding lagoons, in series, and is discharged into swamps close to Sackville River. The plant has several operational problems due to hydraulic and organic overload, and short-circuiting in a settling tank. Another problem is caused by deposits of Ca, Mg and Fe in the heat exchangers and anaerobic reactors resulting in significant amounts of very hard scale formations which have to be removed once every two years. The scale in the reactors is so thick and strong that, at times, the operators have to remove it by hammer and chisel, sand blasting, axe, or pick and shovel. The pipes are cleaned with sulfamic acid. The physical-chemical treatment (which consists of a rapid mix tank, a flocculation tank and a settling tank) was not precipitating the inorganics effectively because of (i) incomplete pre-design treatability studies, (ii) short-circuiting in the clarifier, (iii) intermittent stoppages of additions of chemicals due to mechanical problems, and (iv) foaming and overflows in the rapid mixing tank.

The objectives of this laboratory-model research were (i) to identify the optimum pH and the chemicals required to precipitate Ca, Mg and Fe, (ii) to explore various options to enhance the efficiencies of the rapid mix, flocculation and settling tanks, and (iii) to recommend chelating, sequestering, or dispersing agents which have the potential to keep the inorganics from precipitating in the anaerobic reactors.

Raw leachate was analyzed for 24 parameters. Twenty five jar tests, using a standard six-position multi-stirrer apparatus, were conducted to optimize the pH and doses of chemicals required to precipitate Ca, Mg and Fe. NaOH, Na_2CO_3, and combinations of NaOH and Na_2CO_3 were tried with and without nine commercial coagulant aids.

The results confirmed the well-known fact that as the pH increases from 7 to 12 the precipitation of the metals increases. However, it was considered unrealistic to increase the pH to values above about 9.5, because anaerobic degradation was expected to decrease at such high pH levels. Therefore more tests were conducted at a pH range of 8.8/9.6, using NaOH with/without the coagulant-aids, Na_2CO_3 with/without the coagulant-aids, and the combinations of the two.

The results indicated the following: (i) Na_2CO_3 was more effective than NaOH in precipitating Ca, Mg and Fe at a pH range of about 9 to 9.6. (ii) To increase the raw leachate pH from 6.3 to 9, a higher dose (14.8 mg/L) of Na_2CO_3 was required than NaOH (2.3 mg/L); similarly, 20 mg/L of Na_2CO_3 was needed to increase the leachate pH from 6.3 to 9.6, whereas, a lower dose of 2.5 mg/L of NaOH was able to achieve the same pH increase. (iii) Eight of the nine polymers (coagulant aids) were not useful in enhancing the precipitation of Ca, Fe and Mg, when used with NaOH and Na_2CO_3 as the primary coagulants. (iv) One mg/L of Dearborn's Lime Floc, however, used along with 1.6 mg/L NaOH (at pH 8.6) resulted in 94% removal of Ca. At the same pH, NaOH alone could remove only 33% Ca. On the other hand, Dearborn's Lime Floc did not significantly enhance the precipitations of Mg and Fe. Nor did the Lime Floc improve the removals of Ca, Mg and Fe, when used in combination with Na_2CO_3. (v) At a pH of about 9.1, 1.4 mg/L of NaOH precipitated 47% of Ca and 95% of Fe. At the same pH and NaOH dose, when both NaOH and Na_2CO_3 were used at various doses (3.6, 7.2, 18 and 36 mg/L)

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of Na_2CO_3, the highest removals of Ca (89%) and Fe (96%) were obtained at a Na_2CO_3 dose of 36 mg/L. (vi) The highest ranges of Ca removal were observed: (a) at pH 12.4, with 3.8 mg/L NaOH (87%), (b) at a much lower pH of 9.1, with 1.4 mg/L NaOH and 36 mg/L Na_2CO_3 (89%), (c) at 9.6 pH, 20 mg/L of Na_2CO_3, 99.7% of Ca was precipitated. (vii) The highest ranges of Fe precipitation were recorded: (a) at pH 11.3, with 3.4 mg/L NaOH (99.9%), (b) at pH 9.6, with 20 mg/L Na_2CO_3 (98%), (c) at pH 9.6, with 2.5 mg/L NaOH (99%). (viii) The highest ranges of Mg removal were possible (a) at pH 12, with 3.8 mg/L of NaOH (99.8%), (b) at pH 10.4, with 3.3 mg/L of NaOH (86%). (ix) "The optimum" flocculation pH could be as high as 12, from the view point of inorganic precipitation. However, because the anaerobic reactors may not function well at pH above 8.5/9.5 range, it is also possible, subsequent to settling, to reduce the pH to "the optimum biological" pH range of 8.5 to 9.5, by adding sulfuric or phosphoric acid. (There is provision in the plumbing system to accomplish this goal).

Penta sodium dithylene triamine penta acetate (DTPA), a chelating agent used in the pulp and paper industry, and/or Dearborn 773, a "crystal modifier" used in cooling-water treatment systems, have potential to be used as dispersing/sequestering agents in the anaerobic reactors so that Ca, Mg and Fe, which are not removed by physical-chemical treatment, can be prevented from depositing and forming scales. In wastewater, DTPA is reported to complex metal cations. Dearborn 773 is quoted to be used in a Sarnia Leachate Treatment Plant.

Temperature measurements in the settling tank showed that, due to improper locations of inlet and outlet, serious short-circuiting was taking place, resulting in lower than expected hydraulic retention time (HRT). The design value of HRT was about 1.5 to 2 hrs. During a tracer test, however, it was observed that within a few minutes a significant portion of the tracer exited through the effluent weir, due to short circuiting. A potential solution to the problem is to build a short circuit-reducing baffle in front of the inlet pipe.

Session III - Management of Urban Lakes

Section I

MANAGEMENT OF THE WATERCYCLE - AN APPROACH TO URBAN ECOLOGY

W. Ripl[1]

In the last century, densely populated urbanized areas have developed, mainly due to centralized water supply, sewerage plants, facilities for hydroelectric power generation or thermal power plants, with vast demand of cooling water.

Considerable areas have been drained or sealed and the short circuited water cycle has been distorted, large rivers have been converted to shipping channels with the permanent risk of accidental pollution.

Hitherto, it was tried to meet the environmental damage by technical means as sewage treatment plants, air filters, imission control, and in a growing number of cases, lake and soil restoration measurers. However, a balance sheet for material losses (mainly base cation charges) from the urbanized areas, including the surrounding landscape to the sea, in an irreversible manner shows increasing trends. These losses are destabilizing ecosystems at highly increased rates.

In this paper management of the water cycle together with the coupled cycling of the matter are discussed.

For the metropolis of Berlin, with a network of shipping channels, it is considered to supply by means of these channels biologically treated wastewater containing base cations and nutrients to the surrounding rural areas to obtain manageable wetlands for the production of raw material and to reestablish fertile soils. At the same time, the natural cooling system close to the urban areas is improved and by providing increasing areas of vegetation by which imission loading is lowered.

For the water supply, an artificial treatment of less polluted surface water is considered in a way that the groundwater table is not involved in the large oscillations induced at present by pumping groundwater. The widely used shoreline infiltration should then be omitted and the prevailing severe damage of the litoral vegetation in the rivers should be stopped.

The aim of all this measures is:

- to close matter cycles between the city and the surroundings,
- to improve the eveness of evapotranspiration and the short circuited water cycle,
- to control emissions and imissions by the distribution of permanent vegetation,
- to release surface waters from high salt and nutrient loadings,
- and to minimize mater losses by the point source (city) and the non-point sources from the surrounding rural areas due to increased groundwater tables and increased wetland areas.

Thereby, oscillations and charge losses from the top soil are minimized covering fassades and roofs with vegetation will finally lead to:

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- reduced emissions of dust from the city,
- a reduced noise level,
- and an improved microclimate due to a reestablished short circuited water cycle.

WATERSHED PLANNING AND POLLUTION CONTROL TECHNOLOGY FOR RESTORING HAMILTON HARBOUR

G.K. Rodgers[1]

Hamilton Harbour is one of 43 Areas of Concern around the Great Lakes Basin for which a Plan is required to bring the area into compliance with Basin-wide objectives under the terms of the Great Lakes Water Quality Agreement Protocol signed by Canada and the United States in 1987.

All wastewater from industries and from a population of about 500,000 is discharged into the Harbour. The Harbour has an area of 2150 ha and a mean depth of 13 m. The combination of run-off, wastewater flow, and a large exchange of water between Lake Ontario and the Harbour result in an hydraulic residence time of about 100 days.

To restore a number of beneficial uses, and the related aquatic biological system of the Harbour, three areas of remediation require more attention. The first is work to undo some of the historical damage. This will require removing, isolating, or detoxifying contaminated bottom sediments and replacing littoral habitat lost through infilling.

The second concern relates to the industrial and sewer effluents, where remedial work to date has brought about improvements to the point where most of the Harbour now meets Ontario Water Quality Objectives. Further work is recommended in the MISA program to move towards virtual elimination of persistent toxic substances. Also, since diversion of wastewater discharges from sewage treatment plants to Lake Ontario has very little public support, major upgrades of sewage treatment plants will be required to achieve, for example, phosphorous concentrations of 0.15 to 0.2 mg/l in the effluent. Modifications will also be required to substantially reduce effluent from combined sewers that overflow to the Harbour during rainstorm or runoff events.

The third area has to address the means to maintain conditions into the future. This will require careful planning in the watershed as a whole, to take account of the limited capacity of the Harbour to absorb nutrients and other contaminants.

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RETROFITTING STORMWATER PONDS FOR WATER QUALITY CONTROL

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Progressing urbanization leads to increasing stresses on the urban ecosystem and its water subsystem in particular. Past practices in urban water management, which focused on provision of water supply, wastewater disposal and drainage, led to serious degradation of the quality and utility of urban waters. Such trends have to be reversed by adopting an ecosystem approach in which the traditional goals of urban water management are expanded for ecological protection and enhancement of the receiving waters. Ecological protection of urban waters is particularly challenging in the existing areas, where many infrastructures are obsolete, in terms of environmental protection they provide, and require rehabilitation.

During the last 15 years, more than 100 stormwater ponds, also referred to as urban lakes, were built in Canada. While these ponds were designed to control runoff flows by peak shaving and thereby prevent flooding resulting from urbanization, they are ineffective in protection of water quality in the receiving waters. Thus, one of the emerging challenges in urban water management is the upgrading of existing stormwater ponds to meet the current environmental concerns. The feasibility of this upgrading is discussed, focusing on such issues as flow, heat and sediment regimes of stormwater ponds; chemical transfers; ecology; downstream impacts; and, maintenance. Wherever feasible, the problems and solutions discussed are documented by field data from existing facilities. Even though the emphasis is placed on man-made ponds, the solutions presented also apply to natural urban lakes which receive urban runoff.

The upgrading of existing stormwater ponds should be planned within the framework of implementation of the best management practices for control of quantity and quality of urban runoff. Implementation of such practices in the catchment feeding the pond would reduce the pollutant loads reaching the pond and make the upgrading task easier. Typical existing stormwater ponds require many retrofit measures to improve their suitability for water quality control. The measures discussed include changes in flow regimes, storage pool volumes and flow velocities, achievable by structural changes in inlet, storage and outlet structures; pretreatment of runoff by sedimentation or filtration; enhancement of biological processes contributing to pollutant removal through longer detentions and introduction of aquatic plants; and, improvement of aquatic life habitat. Among the problems experienced downstream of ponds, the most common one seems to be erosion which could be reduced by improved regulation of flow releases. The quality of pond effluents can be further improved by effluent polishing. Finally, regular maintenance is prerequisite for sustainable operation of ponds.

Even though it is unlikely that all the existing ponds can be upgraded to the high standards proposed in this paper, such standards should be adopted in new designs and the feasibility of retrofitting the existing ponds examined. Where feasible, pond facilities should be combined with other control measures (infiltration facilities, wetlands) to achieve stable ecosystems in the affected areas and thereby to contribute to the sustainable development of urban areas.

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RECOVERY OF URBAN LAKES DURING TEN YEARS OF PHOSPHATE REMOVAL

G. Klein[1]

All lakes in the Berlin area have received excessive phosphorus load during the last century. Following a considerable reduction of the phosphorus input to three of these lakes (from about 0.5 - 2 mg/l down to 0.005 - 0.02 mg/l total P) nutrient budget and biotic reactions show special reaction types varying from lake to lake.

Further activities such as storm water removal and hypolimnetic drainage were exercised. The results of these measures will be presented here.

Even after phosphate precipitation (flocculation, sedimentation and filtration) to the greatest extent worldwide, lakes need four to six years until first signs of recovery will be significant (resilience phenomena).

Urban lakes restoration needs a great variety of techniques for gaining success (the most important are P-removal from main inflow and small contributories, in special cases hypolimnetic drainage).

Every single lake has its own characteristics that need a special restoration strategy (well designed treatment plants, flushing and additional restoration measures).

Urban lake areas will not be restored by conventional sewage treatment and restoration techniques (P-removal from main inflow down to a few µg/l of total P is at least required).

Well suited techniques had to be developed for nutrient removal to an extent, that is in accordance with the present knowledge of eutrophication processes and the special situation of the case studied (dosage of chemicals, removal of algae from treated surface water, filtration techniques).

From the political point of view, it seems to be most important to present some successfully restored lakes all over the world to demonstrate, that even under extreme conditions, we can come to good results. Then we need support from politicians and governmental organizations, and scientists have to convince these politicians that lake restoration is possible within short periods of time and at very low cost. The Berlin lake restoration cost is less than 0.30 DM per m3 of treated water and has demonstrated best results within a few years.

These results are of greatest importance for the further planning of water resources management, recreation and for a safe drinking water supply for the growing urban area of the greater Berlin.

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ECOLOGICAL STATE OF THE GRAVEL PONDS WITHIN THE CITY LIMITS OF FREIBURG (GERMANY)

A. Pulvermüller[1]

From 1987 to 1989, physical and chemical parameters of eight man-made lakes were investigated. In some lakes, the phytoplankton, zooplankton and zoobenthon communities were examined. For several lakes, microbiological and parasitological data are also available. The surface areas vary within 5,000 to 430,000 square meters, the maximum depths of the lakes reaches from 1.6 to 28 meters.

All lakes, except a very shallow one, show oxygen-contents close to zero near the lake bottom. Phosphorus is the limiting nutrient for phytoplankton growth in most of the lakes. In the hypertrophic Waltershofener See, mitrogen is limiting. The Opfinger See, still used to excavate gravel, seems to be limited by both phosphorus and light.

The Schistosomatidae, which are responsible for a skin disease, are found in several snail species, mainly at warm spots of the lake shores. The number of bacteria are high. Measures to maintain the acceptable water quality of these lakes are discussed.

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SITUATION OF URBAN LAKES IN POLAND

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Pollution of water ecosystems caused by anthropgenic multiple uses is especially significant in the case of urban lakes. The extensive exploitation of these lakes results in deterioration of water quality and as such usually causes considerable social and economic costs.

Poland with a total area of 312,683 km2 and population of nearly 40 million people has about 9,000 natural lakes with areas greater than 1 ha. Most of Poland's lakes belong to the eutrophic category. Severely polluted and highly eutrophic are all urban lakes of which about 40 have been investigated in last decades.

Surface of urban lakes in Poland differs greatly. Many of them have a surface area less than 100 ha whereas some are quite large exceeding the surface of 2,000 ha. Irrespectively to the area of urban lakes and sometimes their very favorable natural characteristics, most of them are not suitable to any uses according to Water Law regulations. Due to their bad water quality, urban lakes belong to inferior class III or are located beyond the principle three classes according to Lake Quality Evaluation System implemented in Poland. In many of them massive fish kills were observed as well as coliforms exceeding permissible limits.

The main reason for the alarming situation of urban lakes in Poland is attributed to contamination of the lakes with untreated and/or partly treated sewage and/or wastewater from adjacent municipalities, urban run-off and excessive recreation.

This situation calls for effective urban lakes quality control and management. Restoration of rapidly deteriorating urban lakes requires sound watershed management practices reducing pollutant loads from point and nonpoint sources and in-lake measures with application of different techniques.

Sound watershed management is hardly implemented in Poland due to the high costs of such operations which the government can not afford.

Sometimes there are situations when it is absolutely necessary for a community treatment system to discharge to the lake. Such is the case with Mikolajskie Lake (one of the precious great Masurian Lakes). Mikolajki town community system does discharge directly to the lake, thus accelerating the progress of eutrophication of the other interconnected Masurian lakes. The permit requirements from local authorities concerning the load can not be enforced because the existing treatment plant has no technical capabilities to reduce phosphorus to the desirable level. It would require advance treatment which is expensive and as such not applied yet on a wide scale in Poland. In many cases, due to relatively lower costs prior to the watershed management, in-lake restoration activities are being conducted which deal with the consequences and not the causes of pollution.

The first restoration experiment carried out took place in the middle of sixties when Prof. Olszewski installed a wooden pipeline to remove nutrient rich hypolimnetic waters from Kortowskie lake polluted with municipal sewage from urban settlement and recreational grounds. The pipeline was installed in the southern part of the lake over the bottom with the outlet directed to the natural outflow of the lake.

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In 1976 the decayed wooden pipe was replaced by flexible polyester pipeline longer and larger than the previous one. The results of a permanent monitoring program indicates that the removal of hypolimnetic waters is probably slowing down the process of lake degradation but does not improve it's water quality significantly. The main cause is the permanent pollution of the lake, which is already several times greater than dangerous load according to Vollenweider's criteria.

Another restoration technique applied to several urban lakes in Poland is aeration with and without destratification. For this purpose Miniflox and Ecoflox devices are used which combine high oxygen transfer with very efficient mixing capacity. Those aerators produced and patented in Poland, have a modular construction that enables them to be adjusted to desirable depth of the lake. Ecoflox is used for oxygenation of hypolimnetic waters and Miniflox is installed in the shallow polymictic lakes.

The new development is Microflox, the improved version of Miniflox, which through vibrating action produces very small air bubbles. Such bubbles rise very slowly providing longer air retention time. Consequently, much better oxygenation is achieved and the unit is more efficient and economic. The above mentioned aerators have already been installed in several urban lakes in Poland (Karczemne, Klasztorne, Kiekrz, Jaroszewskie, Lidzbarskie to name a few). The Microflox device was also purchased by a Canadian company in Mississauga, Ontario for testing in ponds.

It is difficult to evaluate the results of the aeration technique applied in the restoration of urban lakes in Poland. Highly variable results from case to case have occurred. In some cases the improvement in lake water quality was obtained. In other cases failure to achieve the desired objective was caused by continuous pollution of the lake from adjacent municipality or by faulty maintenance of the equipment.

Recently, new devices have been designed in Poland and installed in several urban lakes in addition to aerators. So-called Bio-Hydro Structures consist of three dimensional constructions fixed in the lake in such a way that reverse current is induced passing through the structures. Bio-Hydro Structures thus accelerate the sedimentation of suspended solids but most of all, due to the enormous surface per unit, these devices are functioning as an ecological niche for peryphyton community which is acting as a biological filter reducing nutrient concentration in the water. Long food chain developed on the structures contains also large amount of consumers, therefore the biomass turnover in the ecosystem is more effective. The visible effects of Bio-Hydro Structures operation is an increase of water transparency, decrease of nutrient concentration, more efficient water oxygenation and stimulation of self-purification capacities of the ecosystem. Now all the lakes with Bio-Hydro Structures installed are investigated on regular basis. Some promising results have already been obtained. Manufactured and patented in Poland Bio-Hydro Structures and have been also purchased and installed in the Netherlands.

The Institute of Environmental Protection, the largest environmental research establishment in Poland seeks solutions to emerging problems of urban lakes management. All the activities in this field are surveyed and authoritative expertise is transmitted to the Ministry of Environmental Protection.

LAKE PARANOÁ, BRASILIA, BRAZIL: INTEGRATED MANAGEMENT PLAN FOR ITS RESTORATION

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Built in 1959, Lake Paranoá has a drainage basin of 1,015 km^2, which contains a population currently estimated at 650,000. Of this total, 70 percent inhabit the capital of Brazil, Brasilia. Created with multiple objectives (recreation, landscaping, power generation and improvement of the microclimate), the gradual increase in the population density of its basin has been provoking alterations in its water quality, due mainly to the domestic sewage which is inappropriately discharged into the reservoir, compromising its utilization for the purposes initially anticipated.

In 1976, the Water and Sewage Company of Brasilia (CAESB) began monitoring the ecosystem and its tributaries and main punctual sources of pollution (the North and South Sewage Treatment Plants), in order to continually assess the alterations in their characteristics, understand the system dynamics and seek management measures to contain the eutrophication process identified in 1970.

With a surface area of 38 km^2, a volume of ca. 498.62 x 10^6 m^3, a retention time of 299 days and maximum and average depths of 40 m and 13 m, respectively, Lake Paranoá is characterized by a predominance of the filamentose blue algae Cylindrospermopsis raciborskii, with mean readings of 65 µg/l of chlorophyll a, low water transparency (0.65 m) and high nutritional contents (40 µg/l and 1800 µg/l of phosphorus and total nitrogen, respectively). Furthermore, there are records of sporadic occurrences of the Microcystis aeruginosa bloom (which is controlled with the algicide copper sulphate), small scale mortality of fish and proliferation of the aquatic macrophyte Eicchhornia crassipes (which is adequately removed mechanically).

This initial phase of the study, centered around the internal processes of the system, brought the technical staff of this company innumerable items of information, contributing to the development of an holistic approach, which was implemented beginning in the mid-eighties and culminated in the letter of agreement signed in 1987 between CAESB and the United Nations Development Programme. With the development of mathematical models, in which the total phosphorus parameter was considered to be the key variable for containment of primary production (the limiting factor), the principal sources of this variable were identified. Attempts began to be made to implement corrective measures for system management, instead of the palliatives employed up to that time. The expansion and upgrading of the existing Sewage Treatment Plants, with capacity for removal of ca. 95 percent of the principal nutrients produced by the population residing in the Lake Paranoá Basin (phosphorus and nitrogen), should be considered the starting point for restoration of the reservoir.

In order to accelerate the process of restoration of the lake, CAESB has been investing in biomanipulation projects, aeration and interference in the operational control of the reservoir. At the same time, through studies conducted by the Government of the Federal District, regulation of the occupation of the basin is underway, as well as the creation of new conservation units, which already make up ca. 40.9 percent of the area of the Federal District.

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ARTIFICIAL MARSHES TO MAINTAIN WATER QUALITY: THE BEACH OF ILE NOTRE-DAME, MONTREAL

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In June 1990, the City of Montréal opened a beach on an artificial lake in the southern sector of Ile Notre-Dame in the Saint Lawrence river, a man-made island built for Expo '67. This lake is fed from the Saint Lawrence river and the beach stretches some 600 meters with a swimming area of approximately 15 000 m^2. Since the desired environmental character was that of a natural lake, it was decided to avoid the use of conventional methods of water purification such as treatment with chlorine. Instead, a series of technique more compatible with natural systems were chosen in order to maintain water quality. The major component of these techniques is a "filter-lake" complex. Occupying an area of 20 000 m^2, the "filter-lake" complex consists of four ponds of varying depth where 1000 000 aquatic plants of different native species were introduced. Intake pipes draw 28 litres/sec. of water into the first marsh and then, water circulates by gravity through the three remaining marshes. During the last two seasons, several parameters were monitored in order to evaluate the efficiency of the system. The parameters considered were: total phosphorous (TP), ortho-phosphate ($O\text{-}PO_4$), ammonium (NH_4+), nitrates (NO_3-), suspended solids (SS) and fecal coliforms (FC). Although the organic charge of the water is very low compared to normal wastewater, the artificial marshes showed very good performance: for NO_3-, the reduction varied between 60 to 100%; for $O\text{-}PO_4$, 60 to 90%; for NH_4+, 30 to 60%; for TP and SS, 40 to 50% and for FC, 20 to 70%. The filter-lake complex is therefore a very good trap for most of the components considered.

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EUTROPHICATION, MACROPHYTE GROWTH AND SEDIMENTATION IN SHALLOW LAKES RECEIVING URBAN RUNOFF

R. Leduc[1] and M.R. Anderson[2]

Two small, shallow lakes in series located in the municipality of Saint-Bruno-de-Montarville (15 km southeast of Montreal) were studied in order to determine the extent of, and to support alleviation solutions for the EMS (eutrophication, macrophyte growth and silting) problem occurring therein. The upstream one, Ruisseau Lake, is the receiving body of drainage flow from (1) Lac-du-Moulin, (2) an undeveloped area (65 ha), and (3) a developed area (85 ha). The downstream one, Village Lake, receives the discharge from Ruisseau Lake and surface runoff from a developed area (45 ha). Both lakes are located in a park in the heart of the City of Saint-Bruno. Physical characteristics of these lakes appear in the table below, which also shows the extent of silting in Ruisseau Lake:

	Ruisseau Lake	Village Lake
Area (m^2)	4,350* 3,600+	15,700
Average depth (m)	0.9	1.8
Volume (m^3)	3,900* 3,250+	28,000

* Including accumulated sediments
+ Excluding accumulated sediments

Dry weather as well as storm runoff flow and their quality constituents were monitored sequentially during the 1987 Winter, Spring and Summer seasons. Monitoring in the lakes was also effected. Water quality parameters included suspended solids, total dissolved solids, BOD_5, TKN, $NO_2 + NO_3$, soluble and total phosphorus, conductivity, dissolved oxygen, seston, transparency (Secchi disk), pH and temperature. Sedimentation tests were also conducted in settling columns. In Village Lake, macrophytes were harvested by SCUBA ("self-contained underwater breathing apparatus") divers, who used quadrats made of PVC pipe. Harvested plants were put in nylon bags, and then washed, dried during 48 h and weighted. The MGG model (Mathieu, Gentes and Gauthier, 1979) was used to establish the trophic classification of the lakes.

Flows measured showed wide variations between dry and wet weather conditions, resulting in retention times ranging from 3 hours to 21 days and from 21 hours to 180 days for Ruisseau and Village lakes respectively.

Significant concentrations of suspended solids (SS) were recorded during rainfall periods, reaching 97 mg/L during the "first-flush" phenomena. Sedimentation tests resulted in 16%, 21% and 24% SS removal at 10, 20 and 30 min settling times, respectively. The MGG model revealed that the lakes could be classified as highly eutrophic.

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The dominant macrophyte specie was identified to be *Myriophyllum spicatum*. Biomass densities at four different locations in Village Lake yielded values of 206, 40, 212 and 395 g/m^2.

A number of alternatives which could mitigate the EMS problem were evaluated both in terms of technical feasibility and cost. These alternatives included diversion of storm runoff, structural as well as non-structural sedimentation, dredging of accumulated sediments, control of macrophytes, treatment of runoff including in-lake treatment, and nutrient control at the source. Among these, dredging and non-structural in-lake sedimentation, partial control of macrophyte, and source control of nutrients were recommended.

WATER QUALITY PROBLEMS AND MANAGEMENT IN DEER LAKE, BURNABY, BRITISH COLUMBIA

T.G. Northcote[1] and B. Luksun[2]

Deer Lake and its watershed, entirely within the municipality of Burnaby, is located at the geographic centre of the Greater Vancouver, metropolitan area (population 1.5 million). The lake has had a long history of gradually escalating water quality problems that have included high coliform bacterial levels, bans on swimming, "swimmers itch" outbreaks, heavy surface algal blooms, dense weed growths in the shallows, low water transparency, and dominance by "coarse" fish species. Nevertheless, the lake has served the community as a regional park providing various outdoor recreational opportunities that have included walking, boating, swimming and fishing. The history of its water quality problems are reviewed, the results of the various investigations and research on the system are summarized, and the attempts to improve and manage lake conditions by the District of Burnaby are outlined. The role that the community, senior levels of government and educational institutions have played in this process will also be discussed.

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APPLICATION OF LIME AND ALUM TO STORMWATER RETENTION LAKES TO IMPROVE WATER QUALITY

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Urban stormwater retention lakes receive enormous amounts of nutrients from point (sewers) and non-point (domestic runoff) sources. Consequently, water quality in these lakes is poor and characterized by high nutrient (*i.e.*, phosphorus) and chlorophyll a concentrations, and turbidity, and macrophyte overabundance, and excessive growth of filamentous algae along the shoreline. These lakes are characterized by: 1) relatively poor buffering capacity (alkalinity often less than 80 mg/L as $CaCO_3$); 2) highly variable and high sulfate concentrations (often in excess of 200 mg/L); and 3) high pH (often greater than 9). Thus, chemical treatments which alter pH will have to be carefully considered. Further, the flushing time of these lakes can be extremely short (*i.e.*, less than 1 day during heavy rainfall), further complicating treatment protocol.

Traditionally, the water quality problems in stormwater lakes have been addressed with routine use of weedharvesters (for the macrophytes) and application of herbicides (copper sulfate and Diquat; for algal growth). These approaches are costly and often ineffective since they treat the symptoms and not the causes of the problem. Recently, we have used lime ($Ca(OH)_2$) and/or alum ($Al_2(SO_4)_3 \cdot 14H_2O$) to reduce phosphorus concentrations in the water column and also to precipitate out particulate matter. Of the two chemical treatments, we found that lime is better at controlling macrophytes and shoreline filamentous algae, but alum controls planktonic algal growth and turbidity better than lime. A combination of both chemical, lime which elevates pH and alum which lowers pH, can be used to maintain the pH within a desirable range (6-10). Results of microcosm and whole-lake additions show that lime and alum mixtures significantly reduce turbidity and planktonic and attached filamentous algae in stormwater retention lakes.

Work done on three Edmonton stormwater retention lakes in 1988, 1989, and 1991, suggests that a whole-lake final dosage of 75 mg/L $Ca(OH)_2$ alone will significantly reduce open-water total phosphorus and chlorophyll a concentrations. However, the associated pH increase may be excessive and prove deleterious to biota. The magnitude of the pH increase with lime additions is dependant upon alkalinity of the water and the amount of $Ca(OH)_2$ added. For improvements in water quality without an excessive pH excursion, the general rule of thumb is 1 meq/L $Ca(OH)_2$ for every meq/L alkalinity expressed as $CaCO_3$ (*i.e.* 0.740 mg/L $Ca(OH)_2$ per mg/L alkalinity expressed as $CaCO_3$).

Alum ($Al_2(SO_4)_3 \cdot 14H_2O$) is a more powerful flocculant than $Ca(OH)_2$; however, temporarily elevated aluminum concentrations caused by a decrease in pH (associated with alum addition) poses a concern for the environment. The whole water columns of two lakes were treated with alum in 1991: Valencia Lake (dosages of 150 and 73.6 mg/L alum) and Andorra Lake (115 mg/L alum). In all instances, there were significant improvements in the water quality (*i.e.*, lower chlorophyll a and total phosphorus concentrations, and turbidity); furthermore, water quality improvements in the open-water following alum treatments were greater than those observed following lime treatments.

Both lime and alum improved water quality in the open-water; however, in the Edmonton stormwater retention lakes, a more significant problem of filamentous algal growth is found along the shoreline. Filamentous algal growth is directly related to nutrient concentration in water; however, the normal method of lime/alum application to the lakes does not treat the shoreline due to the shallowness of the water.

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Thus, separate shoreline treatments with lime and alum were attempted. Visual observations indicate that lime treatments caused filamentous algal biomass to decrease more than alum treatments. The reason for better filamentous algal control with lime is probably due to physical factors associated with lime additions such as a significant pH increase, or a physical coating of lime particles on the cell surfaces interrupting biological processes.

Overall water quality can be improved through the application of alum/lime and control of filamentous algal growth can be achieved through application of lime. However, these measures, as with other mitigative ones (such as aquatic weed harvesting and use of Diquat) will have to be continuously applied throughout the open-water season due to continuous inputs of nutrients from point- and non-point sources. Better stormwater retention lake design (*i.e.* only one stormsewer input per lake) would be amenable to an automatic flow-weighted treatment of the inflow. Public education on the effects of watershed activity (*e.g.* fertilizer use) and lake trophic status would result in improved water quality in these dynamic systems.

AN INVESTIGATION OF LONG-TERM INTERMITTENT HIGH DISCHARGES OF LINDANE INTO HAMILTON HARBOUR, ITS CORRELATION WITH CHLOROBENZENES AND CHLOROANISOLES, AND A COMPARISON WITH GEOGRAPHICALLY DIFFUSE SOURCES OF LINDANE

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W.G. Booth[1], B.R. Kerman[2], and J.T. Sharples[3]

Episodic high concentrations of lindane (γ-hexachlorocyclohexane or γ-HCH) were observed between 1987 and 1991 in the dissolved phase and suspended solids of Hamilton Harbour at the western end of Lake Ontario. Concurrent high concentrations of α-HCH, pentachloroanisole, di- and trichlorobenzenes and several presently unidentified compounds were strongly correlated to the lindane concentrations. These compounds could be related to the manufacture and environmental weathering of lindane.

Typical concentrations of lindane in Hamilton Harbour whole water are 1-5 ng/L which is somewhat higher than the <1ng/L found in Lake Ontario. The transient high concentrations were often more than 50 ng/L and were almost always highest in the SE portion of the harbour. Highly elevated levels of these compounds were also found intermittently in the settling solids collected in sediment traps deployed at four sites in Hamilton Harbour. Since the traps integrated settling solids over 3-4 week periods and elevated levels of lindane did not carry over to the next period, the episodes could be shown to last for less than this time period. However, a duration of at least several days would be required to generate the concentrations observed.

Further investigation of the origin of the lindane and related compounds revealed a source from Redhill Creek, draining into Windemere Basin in the SE corner of the harbour. The contaminants are believed to be discharged from the Hamilton STP since no elevated levels of the contaminants were found in Redhill Creek upstream from the STP discharge.

The typical lindane:α-HCH ratio of 2:1 during these episodes was much higher than the approximately 1:4 ratio found in Lake Ontario and many other bodies of fresh water in North America. This ratio is characteristic of unweathered commercial lindane and suggests a point source discharging intermittently into the Hamilton sewer system, possibly mediated by heavy rainfall events. The origin of this material awaits further investigation, as does the significance to the Hamilton Harbour Remedial Action Plan and discharges to Lake Ontario.

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Section II

VULNERABILITY OF INLAND WATERS TO LEACHATE FROM ANIMAL WASTES

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In agriculture drainage basins, particulary when the cattle production is very intensive, the surface water quality is low. In the province of Quebec, the loads in nitrogen and phosphorous of some rivers is extremely high. In the Châteauguay River the concentration of phosphorous is 0.133 mg P/l, ammonia 0.1 mg NH_4 /l, nitrate and nitrite 0.55 mg/l. Near Trois Rivières, the concentration of the St. Lawrence River water in phosphorous is 0.095 mg P/l and in St-Louis Lake this concentration is 0.043 mg P/l.

In spite of provincial governmental funds to improve the disposal system of manure, the farmers dispose the manure directly on barn yard soil. Among 16 000 Quebec dairy farms, only 10.5% of these farms have concrete structures for all disposal forms of manure including: solid, semi-solid and liquid.

This type of manure management without any protection has an evident environmental impact, because the animal wastes from a dairy farm are rich in phosphorous, potassium, and nitrogen. These compounds, under certain, favourable conditions can be subjected to leaching, runoff, infiltration, and vaporisation.

The evaluation of the impact of manure piles for surface water quality is the objective of this paper. This evaluation has been based on case studies performed on three Quebec dairy farms situated in areas with extremely intensive production of cattle.

Those dairy farms had the same system of classic conveyor, slightly different cattle populations but each had different physiographic factors. Each farm was equipped with an electronic rain gauge, which permitted the evaluation of the quantity, the intensity, and the frequency of rainfalls. For each farm the drainage basin in which the pile of manure was situated was mapped. Every basin outlet was equipped with a V-notch and a water level recorder to permit the detection of flow through the basin area. The quality of surface water was measured periodically. Some special measurements were performed to evaluate the relationship between storm intensity and surface water concentrations.

The increase of elements in the inland waters depends directly on the discharge of surface runoff and indirectly on the infiltration, as well as the groundwater runoff discharge. The runoff, from the hydrological point of view, is influenced by two groups of factors: climatic and physiographic. The barn yard, where the manure is disposed, is a very small drainage basin, consequently, some factors affect runoff more than others.

All three sites characterize high intensity rainfall and low frequency of events. A daily storm is often a half or a third of monthly precipitation. This phenomenon is valable for summer as well as for spring and fall. The intensity of storms is high.

In these specific climatic conditions, runoff is mainly influenced by intensity of precipitation. The surface runoff peak follows maximum precipitation; however, the cumulative value of runoff is bigger than the cumulative value of precipitation for the same period of time. A pile of manure situated in a drainage basin changes the conditions of the runoff phenomena. Cattle manure has variable humidity dependent on

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feeding products and manure management. However, a pile still has a capacity to absorb some quantity of precipitation as a sponge. The pile manages the retention time of a small basin. This retention is time variable and dependent of manure pile characteristics.

The surface runoff is carrying all elements discharged by the leaching process from the manure pile. In the clayey sites, the surface runoff is the principal overflow in the basin. The runoff reaches its peak at the same time as the peak of precipitation. Values of different element concentrations rise in the same rhythm as runoff; only different elements are more or less sensitive for leaching and dissolving. During the typical intensive storm, near the St. Louis Lake shore, the discharge from the manure pile is very intensive and concentration of phosphorous and ammonia can increase 10 to 20 times, but potassium and nitrate about 50%. If animal waste is disposed directly on the soil, leachate from the pile flows in the runoff to the inland water. The result is a remarkable increase in contamination by phosphorous, ammonia, potassium, nitrates and nitrites.

EVALUATION OF SEDIMENT MANIPULATIONS ON CHRONIC SEDIMENT BIOASSAYS USING FOUR SPECIES OF BENTHIC INVERTEBRATES

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Sediments are an integral part of the aquatic environment providing habitat, food and refuge for many aquatic biota. Many toxic contaminants occur in only trace amounts in the water column but may accumulate in sediments to elevated levels. These levels may have deleterious effects on aquatic biota living in close association with the sediment either through direct ingestion of contaminated particles or through passive diffusion from the pore water. Unfortunately, little information on the toxicity of contaminated sediments to aquatic biota is available and few methodologies to determine sediment toxicity have been standardized.

Research is presently being conducted at the National Water Research Institute to develop methodologies for whole sediment bioassays using multiple species of freshwater benthic invertebrates i.e., the amphipod, *Hyalella azteca*, the tubificid worm, *Tubifex tubifex*, the chironomid, *Chironomus riparius* and the mayfly, *Hexagenia limbata/rigida*. The objectives of the study include an assessment of the chronic toxicity of field-collected sediments from areas of concern and the spiking of sediments with contaminants under laboratory conditions as well as the development of sediment quality objectives. The measured endpoints for the bioassays include survival of organisms, growth and reproduction. Methodologies will be incorporated into Environment Canada's guidance documents which describe "core" aquatic toxicity tests for ensuring consistency and quality in environmental protection.

Although the need for standardized sediment bioassay procedures is great, the science is still in its infancy and methods are constantly evolving. For example, it is well-known that the collection of field sediments and their preparation for laboratory sediment toxicity tests disrupts the natural state of the sediment and may alter the bioavailability and chemical equilibrium of associated contaminants. As a result, most protocols for sediment bioassays suggest that field-collected sediments not be sieved and that only large objects or obvious endemic organisms be removed. This is impossible to do with sediment toxicity tests utilizing organisms such as tubificids and/or chironomids in which similar endemic species may be present in field-collected sediments. For example, we have run toxicity tests with sediment collected from Long Point, Lake Erie, which contains an endemic chironomid very similar to *C. riparius*. Even sieving through 250 µm mesh did not remove this species and the presence of such similar organisms makes interpretation of toxicity endpoints such as survival, impossible. Therefore, we have been experimenting in our laboratories with ways to remove endemic species other than sieving. This paper discusses results from bioassays where comparisons of sediment manipulations e.g., sieving through two mesh sizes (500 and 250 µm mesh), autoclaving, freezing and irradiation, etc., were conducted. For example, total production of young *T. Tubifex* was reduced in sediment which was autoclaved. A suggested reason is the removal of bacteria or other microorganisms which are a food source for tubificids in the sediment ingested. Freezing and irradiating sediment allowed the highest production of young; the level of gamma irradiation such that organisms at a higher trophic level were killed, and not bacteria, thus allowing the source of food to remain while removing all competing species and/or predators.

The paper will include results and discussions on the effects of the above sediment manipulations on the toxicity of contaminated sediment collected from the field e.g., Hamilton Harbour, as well as the use of terrestrial soil as a negative sediment control. Information will also be presented on the spiking of sediment with pesticides and the effects of these contaminants on benthic invertebrates.

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VISUALIZATION OF SCIENTIFIC DATA: HAMILTON HARBOUR

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Visualization in science and engineering is emerging as a vital tool for research and development. This work deals with ways of showing the research results using animation and computer graphics, also called multi-media. Two main areas of research will be presented. One is conceptual and basic techniques to create animations with ecological data. For this purpose both software developed at the National Water Research Institute and commercial software will be presented. Details of the creation processes will be discussed for interested users. A computer graphics display will show animations of data collected in Hamilton Harbour. Display will take place whether using an Amiga 3000 computer or through a television. The Amiga 3000 platform was chosen for the following reasons:

1) The 3000 can be used both in North American and in Europe. The 3000 comes with a standard switchable power supply (110 and 220 volts). The 3000 has a video output for both the North American standard and the PAL standards used in Europe; 2) Multimedia presentations developed on the Amiga 3000/25 can be shown on any other Amiga computer, i.e., the Amiga 2000, 1000 and 500. Programs are downward compatible; 3) The video strengths of the Amiga have attracted a host of video peripherals, including frame buffers, digitizers, time-base correctors, and special effects devices. Also there is a large amount of professional video software available for the Amiga.

Multi-media is defined as a computer generated output that, at the very least, can show at the same time a graph in one window, a rotating three-dimensional object in another (animation) while a speech synthesized voice explains what is going on and sound effects mimic the real world. The computer must also be able to interface, in real time, computer graphics with colour pictures taken from camcorders. Computer originated animations must be displayed on computer screens as well as on video tapes that can be played on VCRs.

The Amiga is a multi-media machine. It can perform all the above requirements. In addition, it combines standard data processing with graphics, animation, speech synthesis, audio and video all at the same time. The computer can also be used to control diverse electronic media such as computer screens, videodisc plays, CD-ROM disks, speech and audio synthesizers.

Desktop Video: The Amiga hardware is adept at graphics, animation and sound manipulation. The hardware is inhabited by a multi-tasking operating system that can interweave the various media. The native video system in the Amiga already conforms to the National Television System Committee (NTSC) video standards. The frequency compatibility makes it easy to synchronize, or genlock, the Amiga's computer output with a video signal. The display system includes non-interlaced, interlaced and overscan capabilities. The Amiga's custom sound processors can handle four channels of stereo digitized sound and speech synthesis.

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Poster Session

RESPONSE AND RECOVERY OF ANAEROBIC GRANULES FROM SHOCK LOADING

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Bench scale (20 L) Upflow Anaerobic Sludge Blanket Reactors were employed in a study to evaluate the continuous treatment of effluent from a Corn Wet Milling operation (Casco, London, Ontario, Canada). The plant effluent was comprised primarily of low molecular weight carbohydrates and salts (daily averages 780 000 USGPD, 720 ppm TOC). Early in the study anaerobic granules experienced a shock loading from a large fluctuation in pH and temperature, and high BOD and sulfite concentration. Granules were maintained under shock conditions for two days. After the shock treatment, reactor productivity declined but granules remained active and produced gas. In the days that followed, the granules lost their activity to settle and began to float to the top of the reactor due to gas collection within granules. Gentle stirring caused gas to be liberated from the granules, allowing them to settle until gas accumulation reoccurred (12 to 24 hours).

Studies were redirected to focus on the effect and recovery of the granules from the shock loading. Reactor performance was monitored with and without nutrient supplementation. Nutrient addition to the plant effluent resulted in increased biomass accumulation but did not recover the damaged granules. It was hypothesized that the high sulphur concentrations combined with low pH during the shock loading could decrease the population of methanogenic bacteria and increase the population of sulphate reducing bacteria within the granules.

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RESIDENTIAL STORMWATER QUALITY IN GUELPH

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Measurements of stormwater quality were taken from several locations in two urban catchments in Guelph. The locations included runoff samples from roofs, from street catchbasins, and from the inlets and outlets of stormwater treatment facilities. Stormwater from a commercial site was also sampled. The stormwater treatment facilities included a dry detention pond in one catchment, while the second catchment had a wet detention pond. Stormwater at the commercial site was discharged directly into a wetland. Grab samples were collected twice at each location for four storms at the wet pond; for three storms at the dry pond and for four storms at the commercial site. Water samples were collected immediately after the start of runoff and again within two hours after the beginning of the event. Water samples were analyzed for solids, dissolved ions (Na^+, Cl^-, NH_4^+, NO_3), pH, temperature, BOD_5, dissolved oxygen, conductivity, total coliform, faecal coliform, total lead and total phosphorus.

Suspended solids were effectively removed by both ponds with an average suspended solids concentration reduction of around 95% for both the wet and dry ponds. The average BOD_5 concentration was reduced by about 10% in the wet pond and by about 50% in the dry pond. The highest concentrations of total lead and total phosphorus were recorded at the commercial site, 0.51 mg/l and 1 mg/l respectively.

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TADPOLES BLOOD PARAMETERS AS INDICATORS OF CADMIUM WATER POLLUTION

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Many studies have demonstrated the high sensibility of the haematological parameters to water pollution. The aim of the present study is to evaluate the possibility of using the tadpoles red blood cells morphology and the proportion of leucocytes and thrombocytes in the blood as bioindicators of cadmium contamination.

Green frog tadpoles (*Rana clamitans*) were collected from a pond near Trois-Rivières (Québec). At their arrival in the laboratory, they were placed in reconstituted water for an acclimatization period of 7 days before treatments. Groups of 10 tadpoles were exposed during 15 days at different cadmium concentrations: 0 mg Cd/L (control), 1 mg Cd/L and 5 mg Cd/L. In addition, 16 tadpoles were placed in 1 mg Cd/L solution, and 4 individuals were removed after 5, 10, 20 and 25 days to give information about the temporal variations of the studied parameters. At the end of the test periods, a droplet of blood from each individual was withdrawn by cardiac puncture. Blood smears were air dried and stained with Wright's solution. For each tadpole, the length (A) and the width (B) of 50 randomly selected red blood cells were measured with an occular micrometer. These measures were used to compute the erythrocyte area ($1/4\pi AB$) and ratio (A/B). Proportions of thrombocytes and leucocytes were determined by classifying 500 cells. Then, 100 leucocytes were classified as being lymphocytes, monocytes, eosinophils, neutrophils or basophils.

The results show that cadmium produces a significant rounding of the tadpoles erythrocytes and a significant increase of the proportion of thrombocytes in the blood. These effects are greater at the higher concentration. Data on temporal variations (tadpoles exposed at 1 ppm) show that the rounding is more pronounced after 5 days and seems to recover up to the 15th day approximately. The thrombocytes proportion in blood of tadpoles from the temporal experiment increases gradually from the 5th day to the 25th day.

Preliminary results indicate that tadpoles blood parameters, mainly the erythrocyte A/B ratio and thrombocyte proportion, seem to be good indicators of cadmium water pollution. The mode of action of cadmium related to those haematological effects will be discussed.

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IRON AND MANGANESE REMOVAL AND SEQUESTRATION FROM GROUNDWATERS: DRINKING WATER AND SITE REMEDIATION APPLICATIONS

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BACKGROUND

Roughly forty percent of the public water supplies in Canada and the United States contain iron and manganese at concentrations which exceed the recommended maximum levels of 0.30 mg/L and 0.05 mg/L, respectively. The problems associated with these two metals extend beyond aesthetics and potability, and relate to their impact, through precipitation, on physical and biological fouling of water treatment processes.

Research on the development of effective iron and manganese removal and sequestration process trains by the Wastewater Technology Centre (WTC) is aimed at both drinking water treatment and contaminated groundwater remediation.

DRINKING WATER APPLICATION

Because they are prone to precipitation, iron and manganese are associated with fouling problems in drinking water applications. In addition to causing physical fouling, iron and manganese precipitates may also stimulate biological growth (iron bacteria, *Pseudomonads*) in groundwater wells, treatment plants, distribution systems, and reservoirs.

SITE REMEDIATION APPLICATION

The contamination of groundwater by undesirable organics, has stimulated the development of process trains (Pump-and-Treat technologies) aimed at the removal of the organics of concern from the groundwater. However, when iron and manganese are present in groundwater contaminated by toxic organics, treatment efforts must first focus on either the removal of inorganics prone to precipitation, or their sequestration. This will minimize physical and biological fouling of downstream unit operations (such as Advanced Oxidation, GAC Adsorption, Air Stripping) which are used for the removal of toxic organics.

SCOPE

The objective of the ongoing research at the WTC is to develop improved design and operating strategies for iron and manganese removal and sequestration processes.

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A variety of technologies, including those listed below, has been evaluated to date through bench and pilot scale tests:

1. Chemical oxidant addition (NaOCl; Cl_2; ClO_2; H_2O_2; $KMnO_4$), followed by granular media filtration.

2. Chemical oxidant addition, followed by coagulation, flocculation, sedimentation and granular media filtration.

3. Greensand filtration.

4. Diffuse aeration, followed by chemical oxidant addition, coagulation, flocculation, sedimentation and granular media filtration.

5. Diffuse aeration with continuous recycle loop (aerator effluent recirculated to influent line), followed by chemical oxidant addition and direct contact granular media filtration.

6. Diffuse aeration with solids recycle (solids from filter backwash water recirculated to aerator influent line), followed by chemical oxidant addition and direct contact granular media filtration.

7. Diffuse aeration, followed by chemical oxidant addition and rapid direct contact granular media filtration.

8. Diffuse aeration, followed by chemical oxidant addition and oxide-coated granular media filtration.

9. Sequestrant addition, followed by chemical oxidant addition (NaOCl, ClO_2, NH_2Cl).

TYPICAL EXAMPLES OF WTC TREATABILITY STUDIES

A site remediation project, at Ville Mercier (Québec), evaluated the performance of a number of iron removal process trains. The pilot scale study demonstrated that the diffuse aeration-direct contact sand filtration process train was more effective than the conventional technology, presently used at the full scale groundwater treatment plant. The process train was operated continuously for a period of three months and found to be highly effective for the removal of inorganics prone to precipitation. Mean influent and effluent total iron concentrations were 8.33 mg/L and 0.09 mg/L, respectively.

A bench scale study, conducted at McGill University for the national Groundwater and Soil Remediation Program (GASReP) and the Québec Ministry of the Environment, investigated the catalytical effect of iron (III) oxides on the oxygenation of iron (II) and manganese (II) in a diffuse aeration vessel. The study demonstrated that the recirculation of an iron (III) stream into the diffuse aeration vessel, increased substantially the rate of oxygenation of iron (II), but had little impact on the rate of manganese (II) oxygenation.

A field pilot scale iron and manganese removal study was recently completed for the Regional Municipality of Waterloo and GASReP, during which the performance of various diffuse aeration processes was evaluated. These were: co-current diffuse aeration process; recycle of a fraction of the aeration vessel effluent to its influent line; and the recirculation of sludge collected from the sand filter backwash water to the diffuse aeration vessel influent line. The process train selected for demonstration under a continuous mode of operation was the diffuse aeration-on-line chemical oxidation (ClO_2) addition -

direct contact sand filtration process train. Mean influent and effluent total iron concentrations were 2.02 mg/L and 0.05 mg/L, respectively. Mean influent and effluent total manganese concentrations were 0.17 mg/L and 0.02 mg/L, respectively.

A bench scale study, conducted at McGill University, is presently investigating the performance of a novel sequestrant for manganese. In addition, the stability of the manganese-sequestrant complex will be assessed, following the addition of hypochlorite (OCl), chlorine dioxide (ClO_2) and chloramine (NH_2Cl).