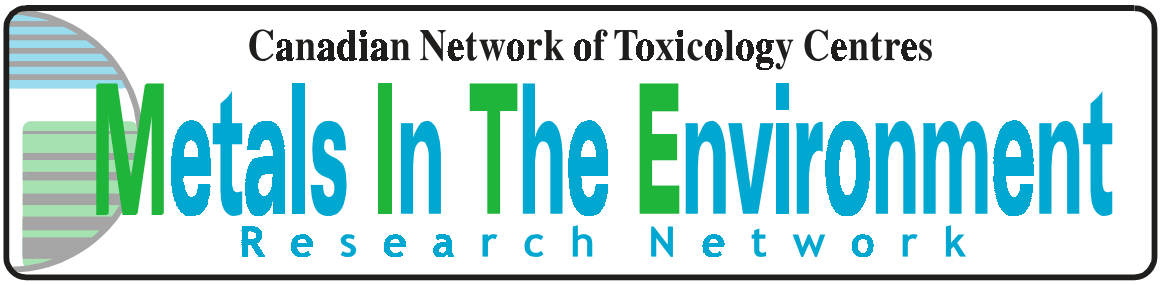

ANNUAL REPORT

March 1, 1999 - February 28, 2000

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1 THE METALS IN THE ENVIRONMENT RESEARCH NETWORK

Metal research in Canada is at the dawn of a new era, thanks to the Metals in the Environment (MITE) Research Network.

The MITE Research Network was formally initiated on July 1, 1998, after the Mining Association of Canada (MAC) agreed on the importance of MITE-RN and committed $1.25 million and in-kind support for the Research Network for a five-year period. Ontario Power Generation Inc. (formerly Ontario Hydro) has also committed a further $500,000 over five years.

Similarly, research partners at Environment Canada, Natural Resources Canada and Fisheries and Oceans Canada also pledged support for the objectives of, and cooperation with, the MITE Research Network. MAC has also committed an additional $100,000 per year over five years in support of government/MITE-RN related research activity.

MITE-RN aims to understand the sources of metals in the environment, how metals move and transform within the environment, and how they can affect ecosystems. This understanding is essential for assessing the risk they may pose and determining how to reduce that risk. As one of the world's largest producers and exporters of metals, Canada has a vital interest in developing effective ways to deal with these issues.

Through a series of workshops, the Canadian Network of Toxicology Centres (CNTC), in cooperation with its partners in government and industry, identified important gaps in metals research and developed a multi-disciplinary research program.

Metals are naturally present throughout the earth in varying concentrations. The concentration of a metal in a particular area can also be affected by human activities. But too much -- or not enough -- of a metal in a bioavailable form (a form that plants or animals can absorb) can damage ecosystems and human health. Reducing the release of metals into the environment is good, but what should the ultimate goal be? Is existing "best available technology" good enough? Many metal products are recycled — metals like gold, copper, iron and lead are the most recycled materials used by society. But some smaller consumer products end up in landfills or incinerators. Does such disposal pose a long term risk? Should use of certain metals in some products be discontinued? National governments and international organizations are currently discussing these questions.

To ensure the objectivity and continuing scientific excellence of the MITE Research Network, all MITE-RN research projects are peer reviewed annually, and all funds are held and administered in trust through the Canadian Network of Toxicology Centres/University of Guelph head office.

The Natural Sciences and Engineering Research Council of Canada (NSERC) is contributing $3.5 million to the MITE Research Network, in the form of a Network grant award. In addition, the MITE-RN was also very pleased to welcome the International Lead Zinc Research Organization (ILZRO), the International Copper Association (ICA) and the Nickel Producers' Environmental Research Association (NiPERA), who have committed $22,000 to the Network for year 2000, and hope to be able to do the same in subsequent years as well. This award with the industry and government funding support has provided this national metals research program with $6.97 million over a five year period. All corporate and government sponsors are represented on the Network's Science Steering Committee, which meets regularly throughout the year to monitor progress and ensure the continuing relevance of the Network's research priorities.

2 MESSAGE FROM THE CHAIR OF THE BOARD OF DIRECTORS

In creating the Metals in the Environment (MITE) Research Network, Canada is demonstrating to the world how government and industry can work together to develop effective and sound policies for the environmental risk management of metal-containing substances. Stakeholders in Canada have recognized that such policies are best developed with open and frank discussions based on scientific information. When critical information is missing, Canadian stakeholders have shown the ability, through initiatives such as the Network, to jointly define the areas where more work is needed.

In the case of metals in the environment, information gaps and priorities were identified through a joint industry-government workshop in 1996. The academic community responded with research proposals to fill some of the important gaps and NSERC and industry committed to funding the work. The Network was formed to manage the program, to foster cross-disciplinary interaction among the researchers and to integrate the findings using a risk assessment foundation.

The research being done by the Network is not easy. If it were easy, it would have been done already. And integrating results from a variety of disciplines is not easy. That is why the Network has focussed on a high quality of communication among and between researchers and stakeholders. The Network is distinctive in several aspects, among which are:

(1) That leadership at the Board comes from senior industry, government and NGO officials. This involvement is essential to ensure timely and effective application of the results to the development of Canadian environmental policies;

(2) That most of the Network research has a field component. This is particularly important when complex chemistry exists and when the real environment is a reliable laboratory;

(3) That the Network is looking outward to research being done in other countries. The intention is to link with those researchers so that Canadian resources are maximized and duplication of effort is avoided;

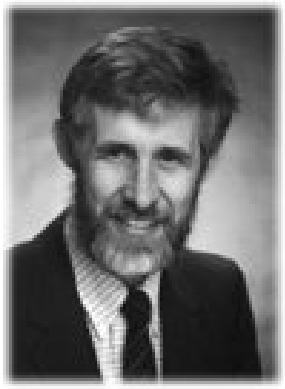
(4) That the Network has co-leaders from government and industry in each of the three research domains. This enables other relevant programs being carried out by the stakeholders in Canada to be firmly linked to the Network;

(5) That the Network has an over-arching data integration using a risk assessment foundation.

The Network is well established: The Board of Directors, the Science Steering Committee, the Expert Advisory Panel and the Canadian Network of Toxicology Centres as Secretariat are all active with duties and responsibilities defined. All projects within the Network have started and have reported to the annual Symposium on results from the first year. On behalf of the Board of Directors, I wish Dr. Peter Campbell and his colleagues continued success in carrying out their studies within this remarkable initiative.

Bruce R. Conard
Chairman of the Board of Directors
Metals in the Environment Research Network

3 YEAR-ONE MESSAGE FROM THE RESEARCH DIRECTOR



MITE-RN is a metals research Network of twelve Canadian universities, government departments and industries formed to jointly address research gaps in our understanding of the sources, pathways, fates and effects of metals in the environment. The MITE-RN initiative is aimed at significantly increasing our understanding of the impacts metals have on the environment, and it will guide the development of effective and science-based policies and regulations to protect the environment.

The MITE-RN recently concluded its first, and very successful annual research symposium. The Symposium included presentations from the collaborating investigators and students participating in the Network, as well as a lively and well-attended poster session in which MITE-RN investigators had an opportunity to present and discuss some of their initial results for the first year of the Network studies. Some of the initial work presented included preliminary results from a study to determine the chemical and physical evolution of aerosol particles in plumes, as well as promising results on new methods to better understand the relative contributions of geogenic and anthropogenic sources of metals and to integrate the concept of metal speciation into the risk assessment process. Symposium participants also heard of the excellent cooperation between Network scientists and industry in the planning and conduct of several studies. The Symposium attracted ninety participants including research scientists, industry representatives and government regulatory officials, many of whom were unattached to the Network. This success in attracting new participants fits in with the Network's goal of information exchange among the broadest possible sector of users of the data generated by the Network. The Symposium also included the inaugural session of the Expert Advisory Panel, the external review panel that annually evaluates the progress and research plans of Network scientists, as well as meetings of the Science Steering Committee and the Network Board of Directors. The Board had the opportunity to review the first MITE-RN progress report to NSERC in which the granting council applauded the Network's "excellent communications strategy with the web site, the newsletter and annual symposium"; the MITE-RN issued two newsletters in the last fiscal year with a current mailing list that includes one thousand recipients.

The MITE-RN Secretariat is based at the Canadian Network of Toxicology Centres at the University of Guelph, and the Network draws on the expertise of 12 universities: Carleton, Dalhousie, Guelph, Institut national de la Recherche scientifique (UQ-INRS), McGill, McMaster, Université de Montréal, Université du Québec à Montréal, St. Mary's, Toronto, Waterloo, Western. Environment Canada, Natural Resources Canada, and Fisheries and Oceans Canada are the lead government participants.

P.G.C. Campbell
Metals in the Environment Research Director
INRS-EAU, Université du Québec

4 MITE-RN 1999-2000 RESEARCH DOMAIN PROJECTS

The core "priority metals" addressed are Cd Cu Ni Pb Zn and Hg. Some projects address metals other than "core" metals.

4.1 <Sources> Research Grants

G. Edwards — (A1) The development and application of methods for the measurement of metals on aeolian dust from natural settings <Cd Cu Hg Ni Pb Zn>

M. Lamoureux — (A2) *In situ* solid state chemical speciation of some metal pollutants associated with atmospheric particulate matter <Cu Ni Pb Se>

A. Chatt — (A3) Chemical speciation of metals in atmospheric wet deposition and multi-element content of wet and dry precipitations <Al As Cd Co Cr Cu Hg In Mn Sb Se U V>

R. Carignan — (A4) Geochemical mobility of metals in surface sediments: Influence of sediment diagenesis <As Cd Cu Hg Ni Pb Zn>

Government Funded:

C. Banic — Overview of the aircraft study to determine the chemical and physical evolution of aerosol particles in plumes from specific sources <SO2 Zn Cd Cu Pb Hg Ni Se>

4.2 <Processes> Research Grants

B. Hale — (B1) Post-deposition mobility of trace metals in boreal forest ecosystems <Cd Cu Ni Pb Zn>

L. Hare — (B2) Development of rational models for relating metal accumulation by aquatic animals to metal concentrations in their environment: relative importance of ambient metal sources <Cd Cu Ni Zn>

L. Evans — (B3) Quantification and modelling of metal mobility in lakes and watersheds <Cd Co Cu Hg Ni Pb Zn>

C.L. Chakrabarti — (B4) Chemical speciation of metals in fresh waters, atmospheric precipitation <Cu Cd Hg Pb Ni Zn Al Fe Ca Mg Co>

Government Funded:

M. Savard	Assimilation of carbon isotopes, nutrients and heavy metals in black spruce specimens near the Horne smelter in Rouyn <C-isotopes H-isotopes Zn Cd Cu Pb Mn Ca Mg>
P. Outridge	Tooth aging study of pre-industrial beluga <Hg Pb Cd Ca Sr>
R. Stewart	Recent temporal trends of Hg in ringed seal teeth <Hg Pb Cd Ca Sr>

4.3 <Impacts> Research Grants

D.G. Dixon	(C1) Predicting metals and metal mixture effects in aquatic biota <Cd Cu Ni Pb Zn>
C.M. Wood	(C2) Assessing biological effects of chronic metal exposure to fish - laboratory studies <Cu Cd Zn>
P.G.C. Campbell	(C3) Links between tissue metal burdens and metal-induced effects in indigenous aquatic organisms <Cd Cu Zn Ni Pb>
L.H.M. Chan	(C4) Accumulation and effects of environmental metals in fish-eating birds <Hg Pb>

5 MITE-RN STUDENT STIPENDS

<SOURCES>	<PROCESSES>	<IMPACTS>
Guelph: Goretty Dias, Postdoctoral Fellow Zdenek Nejedly, Postdoctoral Fellow Sonia Beaulieu, M.Sc. student Laurie Halfpenny-Mitchell, Ph.D. student Annalise Czerny, Undergraduate co-op student Sara Kime, Undergraduate co-op student Saint Mary's: Eric Sullivan, Postdoctoral Fellow Nick Warner, Undergraduate student Kathleen Duggan, Undergraduate student Nadia Nizam, Undergraduate student Wade Rourke, Undergraduate student Dalhousie: Marina Laferova, Graduate student Aurora Perez Gramatges, Postdoctoral Fellow Youqing Shi, Ph.D. student INRS-Eau: Catalina, Alfaro, Ph.D. student Université de Montréal: Michel Courcelles, Postdoctoral Fellow	Guelph: Dallas Johnson, Ph.D. student Douglas MacDonald, Ph.D. student Kristina Rudnitski, M.Sc. student McGill: Douglas MacDonald M.Sc. student Western: Gina Wong Won, M.Sc. student Emma Watts, M.Sc. student, Ying Zhang, Ph.D. student INRS-Eau: Marie-Noële Croteau, Ph.D. student Catherine Munger, Postdoctoral Fellow Isabelle Roy, M.Sc. student Céline Gallon, M.Sc. student Anne Gosselin, Undergraduate student Toronto: Satyendrakumar Bhavsar, M.Sc. student Carleton: N.M. Hassan, Ph.D. student John Murimboh, Ph.D. student M.S.A. Salam, Ph.D. student A.L.R. Sekaly, Ph.D. student J. Guthrie, M.Sc. student V. Celo, Ph.D. student R. Mandal, Ph.D. student	Waterloo: Warren Norwood, M.Sc./Ph.D. student Julie Schroeder, Ph.D. student McMaster: Greg Pyle, Postdoctoral Fellow, Lisa Taylor, Ph.D. student Collins Kamunde, Ph.D. student Ali Zohouri, Honours Thesis Student INRS-Eau: Anik Giguère, Ph.D. student Y. Couillard, Research Associate UQAM: Alexandra Lacroix, Ph.D. student Haude Levesque, M.Sc. student Amélie Gravel, B.Sc. (Hon.) student V. Leblond, Research Associate McGill: Graham Sherwood, Ph.D. student Jennifer Kovesces, M.Sc. student Jennifer Holloway, M.Sc. student Pengcheng Ha, M.Sc. student Heather Jones, Undergraduate student

6 NETWORK COMMUNICATIONS

6.1 MITE-RN Web Site

Current web site: www.uoguelph.ca/cntc/mite

New direct site after October 30, 2000 will be http://www.mite-rn.org to view research domain activities, priorities, contacts, and instructions on how to become involved in the Network. A site overview follows:

MITE-RN Home Page (www.mite-rn.org)

- **Background**
  - Contact Information
  - Guiding Principles
  - First Year Report
  - Management Structure
  - Science Steering Committee
  - Board of Directors
  - Expert Advisory Panel
- **Research Priorities**
  - Research Domains (Sources, Processes, Impacts)
  - Research Listings (1998 - 2000)
  - Ecological Risk Assessment Project & Contact
  - Domain Executive Summaries
- **Announcements**
  - Conferences & Symposia
  - Press Releases and Media Coverage
- **How Do I Get Involved?**
  - MITE-RN Guiding Principles
  - Contact Information
- **Publications**
  - MITE-RN Newsletters
  - Annual Report (1999 - 2000)
  - Subscriptions
- **Files & Forms**
  - Downloadable Files & Forms
- **Links**
  - MITE-RN Related WWW Links
- **Help**
  - Web Site Help / Search Engine
- **Archive**
  - Archive of Out of Date Web Pages

6.2 MITE-RN News

Two issues of a newsletter were published and distributed to 1,000 Network participants, sponsors and other interested in metals research including the MITE-RN industry and government sponsors. Subsequent issues of MITE-RN News will be on an annual basis. People are encouraged to view the web site (http://www.mite-rn.org) for updates between issues of the newsletter. MITE-RN researchers and Board and committee members are encouraged to distribute copies of the MITE-RN News at conferences and meetings they attend both nationally and internationally.

6.3 Annual Research Symposium

Although the number of research principal investigators and co-investigators was approximately 24 for Year l of the program, we are delighted to report that participation in the March 29-30, 2000 annual research symposium included 90 people which suggests approximately 40 per cent of participants attended to foster research collaborations or be updated on MITE-RN progress.

7 SYMPOSIUM POSTER TITLES BY RESEARCH DOMAIN

7.1 <Sources>

PRELIMINARY ANALYSIS OF SIZE-SEGREGATED AEROSOL SAMPLES COLLECTED IN THE NANTICOKE PLUME AND IN AMBIENT AIR
Bhyat, N., C. Banic, Z. Nejedly, I. Campbell, H. Wong

GEOCHEMICAL MOBILITY OF METALS IN SURFACE SEDIMENTS: INFLUENCE OF SEDIMENT DIAGENESIS
Carignan, R., A. Tessier, M. Courcelles

SPECIATION OF ARSENIC IN WATER SAMPLES
Chatt, A., Y. Shi

THE DEVELOPMENT AND APPLICATION OF METHODS FOR THE MEASUREMENT OF METALS ON AEOLIAN DUST FROM NATURAL SETTINGS
Edwards, G., J. Campbell, P. Rasmussen, W. Schroeder, G. Dias, Z. Nejedly, L. Halfpenny-Mitchell, S. Beaulieu

IN SITU SOLID STATE CHEMICAL SPECIATION OF SOME METAL POLLUTANTS ASSOCIATED WITH GROUND LEVEL PARTICULATE MATTER
Lamoureux, M.M.

PARTICLE SIZE DISTRIBUTIONS IN PLUMES FROM A COAL-FIRED POWER PLANT AND A COPPER SMELTER
Leaitch, W.R., N.C. Shantz, C. Banic, S. Bacic, J.I. MacPherson

DETERMINATION OF MERCURY SPECIES IN PLUMES FROM SPECIFIC ANTHROPOGENIC SOURCES
Lu, J., C. Banic

THERMAL VOLATILITY OF PARTICLE SIZE DISTRIBUTION IN THE EFFLUENTS FROM A COPPER SMELTER
Shantz, N.C., W.R. Leaitch, C. Banic, S. Bacic, J.I. MacPherson

PLUME PASSES AND ATMOSPHERIC CONDITIONS DURING THE NANTICOKE AND HORNE AIRCRAFT MISSIONS
Tanabe, R., C. Banic, W.R. Leaitch, J.I. MacPherson

STACK PLUME MEASUREMENTS USING A SCANNING LIDAR SYSTEM
Travis, M.S., K.B. Strawbridge

7.2 <Processes>

THE KINETICS OF NICKEL SPECIATION IN MODEL SOLUTIONS USING COMPETING LIGAND EXCHANGE/ADSORPTIVE CATHODIC STRIPPING VOLTAMMETRY
Celo, V., M.S.A. Salam, J. Murimboh, C.L. Chakrabarti

EXPLAINING DIFFERENCES IN CD CONCENTRATIONS AMONG SPECIES OF THE BIOMONITOR *CHAOBORUS*
Croteau, M.-N., L. Hare, A. Tessier

QUANTIFICATION AND MODELLING OF METAL MOBILITY IN A ZINC CONTAMINATED LAKE
Evans, L., M. Diamond, K. Rudnitski, P. Cypass, S. Bhavsar

THE MICROENVIRONMENTS CREATED BY BENTHIC TUBE-DWELLERS
Gallon, C., A. Tessier, L. Hare

KINETIC SPECIATION IN FRESHWATER SAMPLES FROM THE SUDBURY MINING AREA
Guthrie, J.

KINETIC SPECIATION IN ULTRAFILTERED FRACTIONS OF FRESHWATER SAMPLES
Hassan, N.M.

POST-DEPOSITIONAL MOBILITY OF TRACE METALS IN CONTAMINATED NORTHERN FOREST ECOSYSTEMS
Johnson, D., D. MacDonald, Y. Zhang, B. Hale, W. Hendershot, R. Martin

COMPETITION OF MAJOR IONS ON THE SPECIATION OF NICKEL IN MODEL SOLUTIONS OF A WELL-CHARACTERIZED FULVIC ACID: THE ROLE OF CALCIUM AND MAGNESIUM
Mandal, R.

ELECTROCHEMICAL TECHNIQUES FOR METAL SPECIATION
Murimboh, J.

THE KINETICS OF NICKEL SPECIATION IN MODEL SOLUTIONS USING COMPETING LIGAND EXCHANGE/ADSORPTIVE CATHODIC STRIPPING VOLTAMMETRY
Murimboh, J.

CHEMICAL SPECIATION OF NICKEL IN FRESHWATERS FROM THE SUDBURY (CANADA) MINING AREA BY COMPETING LIGAND EXCHANGE/ADSORPTIVE CATHODIC STRIPPING VOLTAMMETRY
Salam, M.A.

METAL BINDING BY NATURALLY-OCCURING ORGANIC LIGANDS IN FRESHWATERS - A KINETIC APPROACH
Sekaly, A.L.R.

7.3 <Impacts>

POTENTIAL EFFECTS OF MERCURY ON FISH-EATING WILDLIFE FROM MINING ACTIVITIES
INTERACTIONS OF MERCURY AND SELENIUM IN BIRDS
Chan, H.M., A. Scheuhammer

LINKS BETWEEN TISSUE METAL BURDENS IN INDIGENOUS FISH AND METAL-INDUCED EFFECTS AT THE ORGANISM LEVEL
Giguère, A., A. Hontela, J. Rasmussen, P.G.C. Campbell

EFFECTS OF DIETARY RATION ON COPPER HOMEOSTASIS IN RAINBOW TROUT DURING CHRONIC SUBLETHAL EXPOSURE TO DIET-BORNE COPPER
Kamunde, C.

METABOLIC AND HORMONAL RESPONSES OF ADULT AND YOUNG OF THE YELLOW PERCH EXPOSED TO METALS
Levesque, H.

SYNCHROTRON MICRO X-RAY FLUORESCENCE AND METAL DISTRIBUTION ACROSS THE SAPWOOD/HEARTWOOD BOUNDARY
Martin, R.R., W. Skinner, K.W. Jones, H. Feng

Ca/Mn RATIOS IN TREE RINGS AS AN INDICATOR OF SOIL ACIDIFICATION
Martin, R.R., Y. Zhang

METAL TOXICITY TO *HYALELLA AZTECA*: RELATIONSHIPS TO BODY AND WATER CONCENTRATIONS
Norwood, W., W.P. Dixon, U. Borgmann

COPPER UPTAKE, DISTRIBUTION, AND TOXICITY IN RAINBOW TROUT (*ONCORHYNCHUS MYKISS*) AND YELLOW PERCH (*PERCA FLAVESCENS*): AN OVERVIEW OF OUR FIRST YEAR IN MITE-RN
Pyle, G., L. Taylor, C. Lamunde, C. Wood, G. McDonald

METABOLIC ENZYMES AS MARKERS OF THE ENERGETIC COSTS OF HEAVY METALS IN WILD-LIVING FISH: FIELD VALIDATION AND APPLICATION
FISH GROWTH AS A RESPONSE VARIABLE IN ECOTOXICOLOGICAL STUDIES: THE IMPORTANCE OF FEEDING ECOLOGY
Sherwood, G., A. Hontela, J.B. Rasmussen

SIMPLIFIED PREY COMMUNITIES LEAD TO ENERGETIC BOTTLENECK FOR YELLOW PERCH IN METAL-POLLUTED LAKES.
Sherwood, G.

DEVELOPMENTS IN THE BIOTIC LIGAND MODEL FOR COPPER USING YELLOW PERCH (*PERCA FLAVESCENS*) AND RAINBOW TROUT (*ONCORHYNCHUS MYKISS*)
Taylor, L.N., C.M. Wood, D.G. McDonald

8 MILESTONES FOR YEAR ONE: RESEARCH DOMAINS

8.1 <Sources>

Development of Methods for Quantification and Apportionment of Metal Sources

Research Team: C. Banic (MSC, Environment Canada), J. Campbell (U of Guelph), R. Carignan (U de Montréal), A. Chatt (Dalhousie U), G.C. Edwards, Domain Leader (U of Guelph), C. Grégoire (NRCan, Geological Survey of Canada), M. Lamoureux (St. Mary's U), P. Rasmussen (Health Canada), W. Schroeder (MSC, Environment Canada), and R. Garrett, Co-domain Leader, NRCan.

Summary

Metals in the environment can arise from both natural and anthropogenic sources. The overall issue is to determine whether the metals that are posing public health and environmental problems originate from natural or anthropogenic sources, and thus identify the most appropriate risk management strategy. The goal of the Sources research team is to determine what proportion of observed metal loadings in various ecosystems are due to atmospheric deposition from anthropogenic activities versus natural sources by addressing the following research questions:

• What is the magnitude of metal emissions from natural sources? What are the metal species present in natural particulate fluxes?

• What are the most appropriate criteria and methodologies for source apportionment, natural vs. anthropogenic, of metal releases?

• What is the speciation of metals deposited from the atmosphere? Is the speciation determined by source characteristics or by transformations during transport?

Scientific Activity

a) **Development and Application of Methods for the Measurement of Metals on Aeolian Dust from Natural Settings (G. Edwards, J. Campbell, P. Rasmussen, W. Schroeder):**
The objective of this research project is to develop and apply methods to better constrain the magnitude and the chemical nature of metals on particulates in natural settings. This is to be accomplished through *in situ* measurements of particulates in natural settings across Canada to determine the elemental chemical composition as a function of particulate size and through the development of micrometeorological techniques for flux measurements of aeolian dust. The equipment and experimental methods have been field-tested and modified as necessary. PIXE cascade impactor collections successfully showed that there were emissions of metal-bearing particulates from a remote site containing the same metals in the substrate. Total suspended particulate flux measurements revealed that hi-vol cascade impactors should be used in future studies in order to obtain enough particulates at various heights to determine the total particulate flux as well as the size-fractionated flux.

b) *In situ* solid chemical speciation of some metal pollutants associated with ground level particulate matter (M. Lamoureux, C. Grégoire)

The objective of this research project is to develop methods for chemical speciation of metal pollutants associated with ground level particulate matter. A method for the analysis of particulate matter has been developed which does not require digestion of collection substrate for subsequent analysis using ultrasonic slurry sampling (USS) directly coupled with either graphite furnace atomic absorption spectrometry (GFAAS) or inductively coupled plasma mass spectrometry (ICP-MS). Pb, Cu and Ni have been determined as a function of particulate size for different collection periods without any sample digestion. Extended x-ray absorption fine structure (EXAFS) spectroscopy has been shown to be suitable for the determination of *in situ* solid-state chemical speciation of some metal-containing particulate matter as a function of particulate size. Results show that both methods are conceptually plausible.

c) Chemical speciation of metals in atmospheric wet deposition and multi-element content of wet and dry precipitations (A. Chatt)

Although trace element signatures and elemental ratios have been used for source identification, research is practically non-existent for the use of the ratios of As, Se, and Sb species in wet deposition to locate pollutant sources. A preconcentration method is being developed for the simultaneous determinations of selected trace elements in wet deposition, and a method for the identification of various species of arsenic in samples of wet deposition. Methods developed include preconcentration of samples to be analyzed using NAA, as well as a solid phase extraction method for the isolation of organically bound As. These methods will be applied for the determination of various As species in wet deposition samples from the Sudbury sites.

d) Geochemical mobility of metals in surface sediments: Influence of Sediment Diagenesis (R. Carignan)

The objective of this project is to determine to what extent and under what circumstances lake sediments can provide useful historical records of trace-metal loadings from the atmosphere. The approach is to compare sediment metal profiles between sites exposed to atmospheric deposition of anthropogenic metals with those obtained in remote sites receiving negligible amounts of airborne metals. Three undisturbed lakes (considered to be exposed to moderate levels of atmospheric pollution) at Haute-Mauricie have been selected and duplicate cores taken. Porewater samplers for various analyses were installed and removed. Cores were sectioned and freeze-dried for analysis. Lakes at a remote site (Sept Iles), which are chemically similar to the Haute-Mauricie lakes, were identified and fieldwork will be conducted in July 2000. Results from Haute-Mauricie lakes show that there are no signs of bioturbation. Pb demonstrates no post-depositional mobility, while Cs and dissolved Hg profiles indicate substantial mobility of these elements. Porewater sampler and sediment solids analysis will be completed in March 2000. Method development for *in situ* measurements of labile trace metals show that the technique of Diffusion Gradients in Thin Films is not useful for measuring trace metal species in lakes with low cation concentrations.

e) Ageing of pre-industrial teeth of beluga (P. Outridge)

This project was a supplementary one to the 1998-99 research, and had the purpose of ageing the pre-industrial beluga teeth and thus allowed us to factor age out of the historical vs. modern comparison. At the end of the project, the results showed whether the 10-fold temporal Hg increase was due to age differences, to substantially increase recent Hg inputs, or to a combination of both.

f) Recent trends of Hg in ringed seal, reconstructed using Hg archived in the incremental layers of teeth (R.E.A. Stewart)

Elucidation of the temporal trends of Hg concentrations in Arctic biota is a priority science issue because of the continuing importance of country foods, including marine mammals such as ringed seals, in Inuit diets. These mammals are known to contain relatively high, and possibly increasing amounts of Hg. The teeth of mammals are useful biomonitors of Hg exposure.

This project used laser ablation (CP-mass spectrometry to analyse Hg in growth layers spanning the period of 1961-1994. It determined the cross-sectional pattern of Hg in a sub-set of seal teeth to ascertain how Hg exposure changed during the lives to individual seals, and tested for correlations between Hg in the final year layer and soft tissues at the time of death.

g) Physical and chemical evolution of aerosols in smelter and power plant plumes (C. Banic)

The objective of this research is to determine the speciation of metals deposited from the atmosphere, and whether it is influenced more by source characteristics or transformation during transport. In plume flights and ground-based collection of particulates by size occurred in January of this year, at Nanticoke, Ontario. Analyses of the data are pending.

Role of the Sources Domain Research Activities in Ecological Risk Assessment

The <Sources> research team is determining the partitioning of observed metal loadings in various ecosystems between atmospheric deposition from anthropogenic activities versus natural sources. This is particularly important for ecological risk assessments (ERA) pertaining to metals in the environment, which require exposure characterisation. The <Sources> research will aid in this important step in ERA through a better understanding of the relative contributions of natural and anthropogenic sources, through the development of criteria for source apportionment, and through a more thorough understanding of transformations of particulates as well as their final transport and fate in the atmosphere.

8.2 <Processes>

Metal Mobility Among Biotic and Abiotic Compartments of a Shield Watershed

Research Team: C. Bégin (NRCanada-GSC), C. Chakrabarti (Carleton), M. Diamond (U. of Toronto), L. Evans (U of Guelph), D.Grégoire (NRCan, Geological Survey of Canada), B. Hale, Domain Leader (U. of Guelph), L. Hare (INRS-Eau), W. Hendershot (McGill University), R. Martin (U. of Western Ontario), M. Parent (NRCanada-GSC), M.M. Savard (NRCanada-GSC), N. Yan (Ontario Ministry of Environment and Energy) and R. Pierce (DFO) co-Domain Leader.

Summary

The <Processes> domain consists of four university and one government project which focus on partitioning of metals among terrestrial and aquatic environmental compartments. The studies focus on: cycling of metals between soils and plants; bioaccumulation of metals in the aquatic environment, related to differences in organism exposure routes; and improved modelling of complexation and partitioning of metals in the soil water and watersheds. The questions within the <Processes> Domain are:

What are the relationships among total metal, bioavailable metal and bioaccumulation in environmental compartments?

What is the role of organic and mineral surfaces in metal binding in abiotic compartments of the environment and how does this metal binding affect metal availability?

Scientific Activity

a) Post-depositional mobility of trace metals in boreal forest ecosystems (B. Hale, W. Hendershot, R. Martin)

The long term objective of this project is to determine the principal factors from which the movement of trace metals between soil and vegetation in terrestrial ecosystems can be predicted, and to integrate that information into a process-based understanding of the fate of metals that are deposited to terrestrial ecosystems. Permanent transects have been established along gradients of soil metal concentrations in Sudbury, ON and Rouyn-Noranda, QC. At the same sites along these two transects, soils and vegetation (key species) were intensively sampled in 1999. Permanent soil solution and throughfall samplers have been installed. Soils have been collected, and laboratory analyses are underway to determine the soil properties that could be responsible for generating the adsorption sites, and leaching experiments will begin shortly to quantify the binding strength between soil particles and the metals in solution. Key plant species studied (include black spruce (*Picea mariana*), red pine (*Pinus resinosa)*, white birch (*Betula papyrifera*), blueberry (*Vaccinium augustifolium*), bunchberry (*Cornus canadensis*) and bluebead lily (*Clintonia borealis*) have been sampled for metals. Plant community characterization is partially completed, for allometric estimates of phytomass. Leaf and fine root decomposition experiments have been initiated for determination of relative contribution to total soil metals. Core samples have been collected from selected trees in the Sudbury area. The core metal content is being measured using ICP-OES, and will indicate whether dendroanalysis can be used effectively for individual elements.

b) Development of rational models for relating metal accumulation by aquatic animals to metal concentrations in their environment: relative importance of ambient metal sources (L. Hare, A. Tessier, N. Yan)

The major objective of this project is to improve the ability to predict the accumulation of trace metals by aquatic animals. To do that, determinations of the following are necessary: the importance of food versus water as metal sources for invertebrates; influence of food-related variables on consumer metal content; and, influence of animal behaviour on metal accumulation from sediment. The importance of food versus water as metal sources for invertebrates has been determined for *Chaoborus punctipennis*: planktonic food is the major Cd source for this insect, and preliminary laboratory results for *Sialis velata* suggest the same thing. The influence of food-related variables on metal bioaccumulation has been determined for *Chaoborus*: through the use of a one-compartment model, values for key parameters such as metal assimilation efficiency as well as constants for metal uptake and loss have been estimated. The values of these parameters can be compared both for a given species feeding on various prey types as well as among species feeding on a given prey type, helping to explain the traneds in metal concentrations in various field populations of this insect. The influence of animal behaviour on metal accumulation from sediment is being investigated in laboratory studies of animal burrowing and irrigation behaviour.

c) Quantification and modelling of metal mobility in lakes and watersheds (L.Evans, M. Diamond)

The objective of this proposal is to develop general models of metal speciation/partitioning and fate that can be used to link metal emissions with bioavailable concentrations that result in metal exposure to biota. Improved metal complexation constants for soils has begun with extraction of humic and fulvic acid fractions from soils; additionally, two synthetic minerals (goethite and birnessite) have been prepared. Aqueous speciation and surface complexation models, originally written in QuickBasic, are being converted to Visual Basic. Mass balance models of metal fates in lakes and rivers are also being converted to Visual Basic, so that the two models can be combined and tested on Ross Lake. A joint research project has been initiated between the investigators and Hudson Bay Mining and Smelting for water and sediment data collection; these data will be used to test the combined aqueous speciation-surface speciation/mass balance models for Ross Lake.

d) Chemical speciation of metals in freshwaters and in atmospheric precipitation (C. Chakrabarti, D.Grégoire)

The first objective of this project is to determine the environmental factors that control the release of humic-bound trace metals as free metal ions (which are widely reported to be bioavailable and toxic) in freshwaters. This goal is important, as humic substances are ubiquitious in the aquatic and the terrestrial environment. A second important goal is to develop new techniques for determination of speciation parameters: dissociation rate coefficient (which is a measure of the chemical reactivity), diffusion coefficient (which is a measure of the mobility), and stability constant (which is a measure of the equilibrium availability of free metal ions. Investigation into the competitive binding of metal ions revealed the crucial role of major cations, Ca^{2+} and Mg^{2+} in the release of humic-bound target metal

nickel as free Ni^{2+} ion. Also, recently developed techniques for metal speciation were explored in synthetic solutions: Adsorptive Cathodic Stripping Voltammetry and Rotating Disk Electrode Voltammetry/Anodic Stripping Square Wave Voltammetry to determine free-metal ion concentrations in soil solutions and in soil samples.

e) Biogeochemical cycling in the boreal forest - metal concentrations in woody tissues (M.M. Savard, C. Bégin, M. Parent)

The combination of carbon isotopes, nutrients and heavy metals (tracers) in tree-rings constitutes a new environmental monitoring tool that can *distinguish between natural and anthropogenic* accumulation of metals. The carbon isotope ratios (^{13}C) and nutrient concentrations in rings of polluted trees inversely co-vary and are marked by an abrupt shift right at the onset of smelter activities, whereas the increase of heavy metals due to these activities occurs 20 years later. These trends were established by investigating well dated ~120-year ring series extracted as cores at breast level in black spruce stems, and by comparing trees from the contaminated and control sites. However, the dendrogeochemical tracers have never been used to investigate the bulk composition for complete trees as it requires a quantitative assessment of the biogeochemical cycling of heavy metals. In breast-level stem samples, the carbon isotope ratios in cellulose of black spruce rings from the control site ranged between -26 and -23 ‰, and the heavy metals such as Cd between 0.01 and 0.03 ppm. The ^{13}C ratios in cellulose of spruce rings from contaminated sites near Rouyn ranged from -26 to -20 ‰, and Cd from 0.02 to 1.05 ppm. Similar investigations for whole stem samples, at different levels along trees will estimate the bulk composition of the trees, thus the contribution of trees to the biogeochemical cycle of heavy metals can be quantified.

Role of the Processes Domain Research Activities in Ecological Risk Assessment

The linkage of the research being carried out under <Processes> to ecological risk assessment is that these data will provide better estimates of the concentrations of metals to which biological receptors are likely exposed, after emissions deposited to the environment have undergone transportation and transformation. The proposed research will contribute to a better understanding of the relationship between total metal and the bioavailable fraction of that total metal, in environmental compartments that are typical of those receiving anthropogenic sources of metals in Canada. This better understanding of what constitutes bioavailable metal, and how to estimate it in ecosystem components, will lead to stronger relationships between exposure and response, and thus strengthen the risk assessment process for metals in the environment.

8.3 <Impacts>

Detection of Metal-Induces Effects of Indigenous Fauna and Flora

Research Team: U. Borgmann co-Domain Leader (Environment Canada, NWRI; co-domain leader), P.G.C. Campbell (Université du Québec, INRS-Eau; co-domain leader), L.H.M. Chan (Macdonald College, McGill University), D.G. Dixon (University of Waterloo), L. Grapentine (EC-NWRI), A. Hontela (Université du Québec à Montréal, UQAM), J.B. Rasmussen (McGill University), D.G. McDonald (McMaster University), A.M. Scheuhammer (Environment Canada, CWS), C.M. Wood (McMaster University).

Summary

The ongoing research activities in the <Impacts> domain specifically target the freshwater environment. The aquatic environment, and in particular aquatic sediments, represents a very important sink for metals that are introduced into the surficial environment, whether they be from natural or anthropogenic sources. Additionally, aquatic organisms are inherently vulnerable to metal pollution, dissolved metals being recognized as more "bioavailable" than those associated with the solid phase. Research in the <Impacts> domain is designed to strengthen the links between metal speciation / partitioning in the exposure media metal accumulation by exposed organisms (tissue / body metal concentrations in indigenous organisms) metal speciation within the exposed organism (notions of metal essentiality, metal detoxification), metal-induced effects at the organism and population levels. The research includes both laboratory studies under controlled conditions and field work along existing metal gradients, e.g., downwind and downstream from past/current metal smelters.

Clear linkages exist among the projects in the <Impacts> domain at the conceptual level, e.g.: influence of metal speciation on metal bioavailability; importance of food and / or sediments as a vector for metal uptake; elucidation of metal detoxification mechanisms; detection of subclinical metal-induced effects in indigenous aquatic organisms and their predators.

The following research questions are addressed in the <Impacts> program:

- How is metal speciation in the exposure medium related to metal-induced effects at the cellular and individual levels?

- Under conditions of chronic exposure, how does food ration (quality; quantity) affect metal toxicity at the organism level?

- How is metal speciation within the organism related to metal-induced effects?

- Can metal body concentrations in exposed organisms provide a better insight into metal-induced effects at the organism and population levels of organization than obtainable from environmental concentrations?

Scientific Activity

a) Predicting metal and metal mixture effects in aquatic biota (D.G. Dixon, Waterloo; U. Borgmann, EC-NWRI)

All Canadian water quality guidelines for metals are based on single metals, despite the fact that aquatic organisms are invariably exposed to mixtures of metals, as opposed to single metals one at a time. A unified approach that addresses the interactions of metals, for both uptake and impact, is one of the most pressing needs in metals toxicology. The overall objectives of this project are to compare free metal-ion concentrations and body metal concentrations as predictors of biological effects of *single metals* in freshwater invertebrates (amphipods), and to determine if metal speciation modeling or body concentration measurements can improve predictions of effects of *metals in mixtures*. This research examines the interactions of waterborne metal mixtures with the aquatic invertebrate *Hyalella azteca* and will seek relationships among water chemistry, metal toxicity and metal tissue residues within the organisms.

b) Assessing Biological Effects of Chronic Metal Exposures in Fish (C.M. Wood and D.G. McDonald, McMaster)

This research employs laboratory studies to model chronic impacts of waterborne and dietary Cu, Cd, and Zn on fish. Emphasis is placed on the modifying effects of water chemistry and dietary ration on toxicity. The ultimate goal is to develop a Biotic Ligand Model (BLM) for *chronic* toxicity comparable to the *acute* BLM that is currently being used to develop new *site-specific*, *acute* Ambient Water Quality Criteria for metals. In this context, the first major objective is a detailed examination of chronic sublethal effects of waterborne Cu, Cd, and Zn on yellow perch (*Perca flavescens*), a species native to metal-impacted lakes of Rouyn-Noranda and elsewhere. The goal is to compare chronic physiological effects of Cu, Cd and Zn in yellow perch with those in rainbow trout (a less environmentally relevant "model" species on which most BLM development work has been performed to date), and to determine role of dietary ration in toxicity modification in both yellow perch and rainbow trout. Year 1 tasks included establishing yellow perch in the McMaster fish laboratory and determining acute and chronic toxicity endpoints for yellow perch (these will serve as benchmarks for the subsequent chronic studies).

c) Links between tissue metal burdens in indigenous fish and metal-induced effects at the organism and population levels (P.G.C. Campbell, UQuébec, INRS; A. Hontela, UQAM; J.B. Rasmussen, McGill)

This field project has been designed to assess inter-lake variability in the responses of indigenous fish collected from lakes situated along a metal concentration gradient. The key hypothesis to be tested is that there exists a mechanistic link between the intracellular speciation of the metals and the manifestation of deleterious effects at the organism (physiology, endocrine and metabolic status, growth, reproductive status) and population (abundance, production, reproductive fitness) levels. The main study area is centred around Rouyn-Noranda, in northwestern Quebec, and yellow perch (*Perca flavescens*) has been chosen as the trial biosentinel species. Sampling was carried out in June and September 1999 in lakes located along a metal concentration gradient to verify the seasonal variability of physiological and toxicological parameters in yellow perch, to determine the age structure of the perch populations, and to document variations in invertebrate prey populations in lakes along the metal gradient. In parallel, considerable effort has been devoted to the development and testing of analytical methods for determining subcellular metal partitioning in various fish tissues and to the testing the long-term stability of these fish tissue samples.

d) Accumulation and effects of environmental metals in fish-eating birds (L.H.M. Chan, McGill; A.M. Scheuhammer, EC-CWS)

This research seeks to determine whether, and where, fish-eating wildlife in Canada are exposed to mercury (Hg) at sufficiently high levels to produce measurable impacts on their health and reproductive success; to investigate the genotoxic and immunotoxic effects of methylmercury in birds; to study various environments, especially areas affected by non-ferrous mining/smelting activities or by the presence of underlying geology high in Hg, in order to identify habitats at greatest risk for Hg bioaccumulation and toxicity; and to investigate the demethylation of methyl-Hg in tissues of animals, especially the nature of Hg/Se interactions. Field surveys were carried out in summer 1999 to identify and characterize possible sampling sites. Survey results from 12 lakes in the Rouyn-Noranda and Val d'Or areas suggest that loons are plentiful, but that they are not

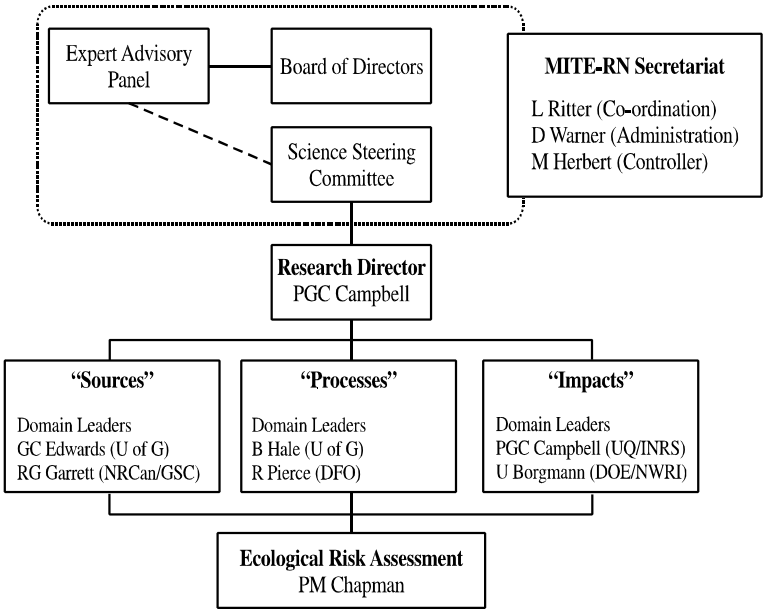
reproducing (very low number of chicks); alternative sites are being considered in Ontario and in British Columbia. Laboratory work has been initiated to characterize Hg speciation, including Hg/Se species, in previously archived liver, kidney and brain tissues from common loons.

Role of the Impacts Domain Research Activities in Ecological Risk Assessment

Research in the <Impacts> domain, together with that in the <Sources> and <Processes> domains, has been designed to advance our understanding of risks to environmental health posed by metals in the environment. Attempts to define the impacts of metals on aquatic ecosystems have traditionally involved laboratory experiments under defined conditions (toxicity tests) and, to a lesser extent, field observations on impacted indigenous populations (abundance; condition; growth; reproduction). To link these two approaches, one needs a common measure of metal exposure in laboratory and field settings. The determination of metal concentrations or burdens in tissues (or whole organisms) has been suggested as a means of achieving this linkage. In the <Impacts> domain, we are currently exploring this approach with aquatic biota, including benthic invertebrates, indigenous fish and waterfowl. The ongoing research will provide data on metal-induced effects relevant to the effects characterization step in Ecological Risk Assessment.

9 MITE-RN ADMINISTRATION

MITE Research Network Organization Chart



9.1 Science Director

Overall science leadership for the MITE-RN Research Network, including responsibility for ensuring the relevance of the research to the Network partners and for integrating the results into a comprehensive and useful product for potential stakeholders, lies with our Science Director:

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9.2 Data Archiving Co-ordinator

To facilitate the sharing of data among Network participants, a Network archive is being developed. The co-ordinator for this component of Network activities is:

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9.3 Ecological Risk Assessment Co-ordinator

The research projects being conducted under the MITE Research Network will closely align with the Canadian paradigm for ecological risk assessment as it applies to metals. The results of the research projects will feed into a Risk Characterisation to produce the following major products (in addition to the individual reports and publications that are normally produced as part of a scientific study):

- a re-evaluation of the overall risk of metals in the global environment based on the new information gathered by the above noted studies, and incorporation of other relevant and appropriate studies conducted by other researchers (not restricted to Canada or to researchers or organizations with whom linkages have been developed)

- a revised ecological risk assessment framework for metals in the environment, for both regional (e.g. Canadian Shield) and local risk assessment

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9.4 Science Steering Committee (SCC)

The purpose of the SSC, chaired by Dr. P.G.C. Campbell, is to monitor research progress and make recommendations for new Network research. This committee has representation from all MITE-RN sponsors (government and industry), and academia (six research domain leaders), and Secretariate representation.

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9.5 Expert Advisory Panel (EAP)

The EAP is the independent peer review panel for the academic research activities of MITE-RN. The EAP reports to the Board of Directors and makes recommendations regarding termination and/or alteration of funding to Network projects as a result of their annual review of each project's progress toward agreed-upon objectives. Dr. S. Hrudey is Chair of this panel.

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9.6 Board of Directors

The Board of Directors, Chaired by Dr. Bruce Conard, has final authority with respect to all affairs regarding management of MITE-RN. The Board reviews recommendations made by the Expert Advisory Committee with respect to the scientific merit of research, taking into account advice from the Science Steering Committee on matters relating to progress, relevance and priority of proposed research.

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9.7 Network Secretariat

The MITE-RN Secretariat's function is to support the national science program liaising with Dr. Peter Campbell, MITE-RN Science Director and members of the MITE-RN's research community: project investigators, Expert Advisory Committee, Science Steering Committee, and Board members:

- organization and administration of Network management meetings; liaising with Members of the Science Steering Committee, Expert Advisory Panel and Board of Directors;
- development and distribution of documents such as: MITE-RN News, MITE-RN Annual Report and management reports;
- development and maintenance of a Network web site to facilitate the dissemination of research data;
- initiation of a reporting system to facilitate the annual research peer review process;
- organization and facilitation of research workshops and conferences;
- financial management and accountability of Network funds.

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10 SCIENTIFIC PUBLICATIONS

The following publications and presentations include 1999 (January 1, 1999 - December 31, 1999). Any publications or presentations in calendar 2000 will appear in the next annual report.

10.1 <Sources> Publications

Nothing to report for the above period.

10.2 <Processes> Publications

Mandal, R., A.L.R. Sekaly, N.M. Hassan, J. Murimboh, C.L. Chakrabarti, M.H. Back, D.C. Grégoire, and W.H. Schroeder. Effect of the competition of copper and cobalt on the lability of nickel (ID-organic ligand complexes, Part H: in freshwaters (Rideau River surface waters). Anal. Chim. Acta, 395, 323-334: 1999.

Munger, C., L. Hare and A. Tessier. Cadmium sources and exchange rates for *Chaoborus* larvae in nature. Limnol. Oceanogr. 44, 1763-1771: 1999.

Sekaly, A.L.R., R. Mandal, N.M. Hassan, J. Murimboh, C.L. Chakrabarti, M.H. Back, D.C. Grégoire and W. H. Schroeder. Effect of metal/fulvic acid mole ratios on the binding of Ni(II) Pb(II), Cu(II), Cd(III), and AI(III) by two well-characterized fulvic acids in aqueous model solutions. Anal. Chim. Acta, 402, 211-221: 1999.

Roy, I. and L. Hare. Relative importance of water and food as Cd sources to the predatory insect *Sialis velata* (Megaloptera). *Can. J. Fish. Aquat. Sci.* 56, 1143-1149: 1999.

10.2.1 <Processes> Presentations

Celo, V., M.S.A. Salam, R. Mandal, J. Murimboh and C.L. Chakrabarti. Kinetics of Ni speciation in model solutions studies by adsorptive cathodic stripping voltammetry. 26th Annual conference of the Federation of Analytical Chemistry and Spectroscopy Societies (FACSS) / 45th International Conference on Analytical Sciences and Spectroscopy (ICASS), Vancouver, BC, October 1999.

Croteau, M.-N., L. Hare and A. Tessier. Differences in cadmium concentrations among species of the biomonitor *Chaoborus*. 20th Annual Meeting, Society of Environmental Toxicology and Chemistry. Philadelphia, PA, November 1999.

Guthrie, J.W. , R. Mandal, N.M. Hassan, J. Murimboh and C.L. Chakrabarti. Speciation parameters for nickel in the freshwater samples from the Sudbury mining area. 26th Annual Conference of the Federation of Analytical Chemistry and Spectroscopy Societies (FACSS) / 45th International Conference on Analytical Sciences and Spectroscopy (ICASS), Vancouver, BC, October 1999.

Hassan, N.M., J. Guthrie, R. Mandal, J. Murimboh, and C.L. Chakrabarti. Competing ligand exchange method for determining the speciation of Al, Fe, Cu and Ni in ultrafiltered fractions of natural water samples. 26th Annual conference of the Federation of Analytical Chemistry and Spectroscopy Societies (FACSS) / 45th International Conference on Analytical Sciences and Spectroscopy (ICASS), Vancouver, BC, October 1999.

Mandal, R., N.M. Hassan, J. Murimboh and C.L. Chakrabarti. Competition between calcium, magnesium and nickel for complexation by humic material in fresh waters. 26th Annual conference of the Federation of Analytical Chemistry and Spectroscopy Societies (FACSS) / 45th International Conference on Analytical Sciences and Spectroscopy (ICASS), Vancouver, BC, October 1999.

Murimboh, J., N.M. Hassan, M.S.A. Salam, V. Celo and C.L. Chakrabarti. Some electrochemical techniques for determination of speciation parameters of metal species in fresh waters. Part 1: Theory. 26th Annual conference of the Federation of Analytical Chemistry and Spectroscopy Societies (FACSS) / 45th International Conference on Analytical Sciences and Spectroscopy (ICASS), Vancouver, BC, October 1999.

Murimboh, J., N.M. Hassan, M.S.A. Salam, V. Celo and C.L. Chakrabarti. Some electrochemical techniques for determination of speciation parameters of metal species in fresh waters. Part 1: Experimental. 26th Annual conference of the Federation of Analytical Chemistry and Spectroscopy Societies (FACSS) / 45th International Conference on Analytical Sciences and Spectroscopy (ICASS), Vancouver, BC, October 1999.

10.3 <Impacts Publications>

Nothing to report for above period.

10.3.1 <Impacts> Presentations

Cabral, C.P., U. Borgmann and D.G. Dixon. Metal mixture toxicity in aquatic invertebrates. 26th Annual Aquatic Toxicity Workshop, Edmonton, AB, October 1999.

Chan, H.M. Subcellular binding of mercury and selenium in seal tissues. Invited talk presented at the Canadian Wildlife Service, National Wildlife Toxicology Program Science Meeting. Government Conference Centre, Ottawa, ON, October 1999.

Hontela A. Physiological and biochemical markers of toxic stress in amphibians. Invited talk presented at the Canadian Wildlife Service, National Wildlife Toxicology Program Science Meeting. Government Conference Centre, Ottawa, ON, October 1999.

Hontela A., V. Leblond, G. Sherwood and J.B. Rasmussen. Effects of xenobiotics on adrenal steroidogenesis and growth in fish. 5th International Congress of Comparative Biochemistry and Physiology. (Hontela - invited speaker at the Symposium: Environmental endocrine disruptors and their impact on growth and development), Calgary, AB, August 1999.

Levesque H., G. Van Der Kraak, P.G.C. Campbell and A. Hontela. Réponse métabolique et physiologique chez la perchaude (*Perca flavescens*) en défaillance cortisolique exposée aux métaux lourds. 38th Annual Meeting, Canadian Society of Zoologists. Ottawa, ON, May 1999.

Sherwood G.D., A. Hontela and J.B. Rasmussen. Partitioning the metabolic costs of heavy metals in wild fish using an enzymatic marker technique: addressing the “sick fish - sick community” question. 38th Annual Meeting, Canadian Society of Zoologists, Ottawa, ON, May 1999.

Scheuhammer, A.M. Mercury and selenium accumulation in eggs of birds fed different dietary levels of these elements. Invited talk presented at the Canadian Wildlife Service, National Wildlife Toxicology Program Science Meeting, Government Conference Centre. Ottawa, ON., October 1999.

Schroeder, J., M. Rinker, R. Playle and D.G. Dixon. Toxicity testing of mine effluent and contaminated surface water using simulated site water on dilution and associated effects on bioavailability of metals. 26th Annual Aquatic Toxicity Workshop, Edmonton, AB, October 1999.

Taylor, L.N., J.C. McGeer, C.M. Wood and D.G. McDonald. Recent developments in the biotic ligand model for copper: an evaluation of the effects of pH, hardness and duration of exposure. 20th Annual Meeting, Society of Environmental Toxicology and Chemistry. Philadelphia, PA, November 1999.

Taylor, L.N., W.J. McFarlane, C.M. Wood and D.G. McDonald. Heavy metal exposure in yellow perch from the Sudbury Region. 8th Ann. Fish Physiol. Biochem. Workshop, Keene, ON., February 1999.