



ANNUAL REPORT 2000-2001

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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, now in its third year.

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. MAC has also committed an additional \$100,000 per year over five years in support of government/MITE-RN related research activity. Ontario Power Generation Inc. (formerly Ontario Hydro) committed \$500,000 over five years. 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 the period 2000/2002. This award along with the industry and government funding support has provided this national metals research program with \$6.97 million over a five-year period. 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. 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.

To ensure the objectivity and continuing scientific excellence of the MITE Research Network, all 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.

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.

MITE-RN's goals are 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.

2 MESSAGE FROM THE CHAIR OF THE BOARD OF DIRECTORS



I am pleased to report that the work of scientists within the Metals in the Environment Research Network continues with high energy, dedication, and, as displayed at the annual research symposium, quality results. With the scientific part of the Network well underway, the Board and Network management have initiated a number of activities that will help in the timely delivery of sound science to public policy development.

First, the Board has clarified the role of the ecological risk assessment (ERA) component of the Network. In issuing a Vision Statement on this important component, the Board makes it clear that the knowledge generated by the Network must have rapid and effective delivery in an integrated manner to people engaged in assessing and managing the safe production and use of metals. The integration of the Network's science into a meaningful framework for governmental risk assessors, policy developers and decision-makers is the job of the ERA team.

This team, led by Dr. Peter Chapman and overseen by Dr. Peter Campbell, will facilitate the communication needed between scientists and policy makers. The Board is requesting that the team be concerned with both directions of communications, namely, that scientists must be informed about the ways in which ecological risk assessment is conducted and how their data might be used, and that risk assessors need to be informed about the scientists' understandings arising from their research and how the new results may apply to policy issues.

In a second initiative, the Network held a Science-Policy Workshop in March. This workshop, the first of several that will be conducted over the next few years, was attended by 30 people including key officials within federal ministries. The workshop focussed on discussing gaps in knowledge regarding metals in the environment and on identifying ways to enhance communication for public policy development. Of the many topics of discussion, recurring themes occurred, including observations that: most current knowledge gaps cross many fields of interest; information on fluxes between environmental compartments is essential in developing models for behaviours and fates within local, regional and international systems; speciation remains an important, but technically difficult, issue; and, scaling up effects seen in the laboratory to predict effects in the real environment is necessary. Discussion of instruments for communication included regular newsletters, policy briefs, white papers, face-to-face briefing sessions, formal presentations at policy-relevant conferences, and blue-ribbon panels.

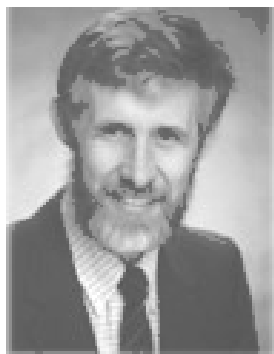
On behalf of the Board of Directors, I want to thank the scientists of the Network, the governmental personnel who regularly interact with the Network, the administrative personnel who grease the wheels of the Network, the domain leaders, the members of the Expert Advisory Panel, and the members of the Scientific Steering Committee for donating so much of their time to our common work, and to NSERC for the lion's share of the financial support.

In particular, I want to express our appreciation to Peter Campbell, whose diligence and scientific leadership have been an outstanding contribution to the Network's success.

A handwritten signature in black ink, appearing to read "B. Conard". The signature is written in a cursive style with a period at the end.

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

3 YEAR-TWO MESSAGE FROM THE RESEARCH DIRECTOR



The <Metals in the Environment> Research Network, or MITE-RN, completed the second year of its five-year research plan in February 2001. The MITE-RN program is designed to advance Canada's understanding of the risk to ecosystem health from metals in the environment. This goal is to be achieved through quantifying anthropogenic inputs relative to inputs from natural sources, thus more specifically identifying the potential benefits of emission control, and by clarifying the biogeochemical cycling behaviour of these metal inputs. The research addresses the issue of metal-induced effects relative to the forms of metals that actually occur in the environment, rather than to the simple metal forms so often used in toxicity testing, thus more closely estimating the true environmental response to metals. The research also includes biological endpoints that

assess chronic exposure to metals, thus addressing the risk of sustained metal releases and use on a global scale.

In Year 2, the Network supported 12 university-based research projects and 3 projects in federal government laboratories; these activities involved some 30 research scientists and 40 students (10 MSc, 23 PhD, 7 PDFs). Scientists from our industrial partners were also involved, notably those with Ontario Power Generation Inc. and Noranda Inc. It is important to note that this group of researchers is not a "closed shop". On the contrary, the Network is committed to the regular review of progress within each of the projects making up the overall research programme, and to bringing new researchers into the Network, starting in Year 3. To this end, we organised a workshop in October 2000 to identify gaps in our current research activities (in an Ecological Risk Assessment context). Based on this analysis, we issued a Call for New Proposals in October 2000 which generated 22 new research proposals. Following peer review by the Network's Expert Advisory Panel (EAP) and internal review by the Science Steering Committee (SSC), a suite of 9 new proposals was approved for Year 3 funding by the Board of Directors (5 university-based, 4 in federal government laboratories).

Although the Network has only completed its second year of operation, we are already generating new and exciting research results (*cf.* the extensive list of papers and communications in section 10 of this Annual Report). MITE-RN is committed to synthesising these new research results and to communicating them to environmental regulators deciding on appropriate policies regarding the use of metals. We take this commitment very seriously, and are aware of the challenges involved in developing an effective communications strategy. In this context, we organised a <Policy Makers' Workshop> as part of the most recent MITE-RN Annual Research Symposium. Scientists and decision makers were invited to the workshop to discuss the policy implications of research on metals in the environment. The final report from this workshop is available on the MITE-RN web site

http://www.mite-rn.org/publicat/mite_news/mite_pub.shtml#misc

Finally, in a concerted exercise involving the Network's Domain Leaders and the Secretariat, we submitted our first full progress report to NSERC's Research Networks Selection Committee in December 2000. Following internal and external peer review of this progress report, NSERC confirmed the Network's funding for Years 3 and 4.

A handwritten signature in black ink that reads "P.G.C. Campbell". The letters are cursive and fluidly connected.

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

4 MITE-RN 2000-2001 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

University

- 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

- 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

University

- 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

M. Savard Biogeochemical cycling in the boreal forest - metal concentrations in woody tissues < Cd Cu Pb Zn>

4.3 <Impacts> Research Grants

University

D.G. Dixon (C1) Predicting metals and metal mixture effects in aquatic biota <Cd Cu Ni Pb Zn As Cr Co Mn Tl>

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>

Government

L. Grapentine Assessment of benthic invertebrate communities in metal-contaminated lakes <As, Cd, Cu, Hg, Pb, Ni, Zn + Ag, Al, Ba, Ca, Cr, Co, Fe, K, Mg, Mn, Mo, Na, Sr, V, Y>

5 MITE-RN STUDENT STIPENDS

<SOURCES>	<PROCESSES>	<IMPACTS>
<p><u>Guelph:</u> Goretty Dias Postdoctoral Fellow Zdenek Nejedly Postdoctoral Fellow Sonia Beaulieu M.Sc. student Laurie Halfpenny-Mitchell Ph.D. student</p> <p><u>Saint Mary's:</u> Eric Sullivan Postdoctoral Fellow Nick Warner Undergraduate student</p> <p><u>INRS-Eau:</u> Catalina Alfaro Ph.D. student François Bilodeau M.Sc. student</p>	<p><u>Guelph:</u> Dallas Johnson Ph.D. student Kristina Rudnitski M.Sc. student</p> <p><u>McGill:</u> Douglas MacDonald Ph.D. student</p> <p><u>Western:</u> Gina Wong Won M.Sc. student Emma Watts M.Sc. student Ying Zhang Ph.D. student</p> <p><u>INRS-Eau:</u> Marie-Noële Croteau Ph.D. student Louis Croisetière Ph.D. student Céline Gallon M.Sc. student Anne Gosselin M.Sc. student</p> <p><u>Toronto:</u> Satyendrakumar Bhavsar M.Sc. student</p> <p><u>Carleton:</u> Jeff Guthrie Ph.D. student Jamaluddin Ph.D. student Rupasri Mandal Ph.D. student</p>	<p><u>Waterloo:</u> Warren Norwood M.Sc./Ph.D. student Julie Schroeder Ph.D. student Monica Nowerski M.Sc. student</p> <p><u>McMaster:</u> Greg G. Pyle Postdoctoral Fellow Lisa N. Taylor Ph.D. student Collins Kamunde Ph.D. student</p> <p><u>INRS-Eau:</u> Anik Giguère Ph.D. student Lisa Kraemer Ph.D. student</p> <p><u>UQAM:</u> Alexandra Lacroix Ph.D. student Haude Levesque M.Sc. student Amélie Gravel M.Sc. student</p> <p><u>McGill:</u> Graham Sherwood Ph.D. student Jennifer Kovescs M.Sc. student Jennifer Holloway M.Sc. student Pengcheng Ha M.Sc. student</p>

6 NETWORK COMMUNICATIONS

6.1 MITE-RN Web Site

New direct site <www.mite-rn.org> to view research Domain activities, research 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	<ul style="list-style-type: none">- Contact Information- Guiding Principles- First Year Report- Second Year Report	Management Structure: <ul style="list-style-type: none">- Science Steering Committee- Board of Directors- Expert Advisory Panel- Secretariat
Research Priorities	<ul style="list-style-type: none">- Research Domains (<Sources>, <Processes>, <Impacts>)- Domain Executive Summaries- Research Priorities (1998 - 2001)- Ecological Risk Assessment- Quality Assurance/Quality Control- Data Archiving	
Announcements	<ul style="list-style-type: none">- Conference & Symposia- Press Releases and Media Coverage	
How Do I Get Involved	<ul style="list-style-type: none">- MITE-RN Guiding Principles- Contact Information	
Publications	<ul style="list-style-type: none">- MITE-RN Newsletters- Annual Reports (1999) (2000)- Subscriptions	
Files & Forms	<ul style="list-style-type: none">- Downloadable Files & Forms	
Links	<ul style="list-style-type: none">- MITE-RN Related WWW Links	
Help	<ul style="list-style-type: none">- Web Site Help/Search Engine	
Archive	<ul style="list-style-type: none">- Archive of Out of Date Web Pages	

6.2 MITE-RN News

A Fall 2000 newsletter was published and distributed to 1,000 Network participants, sponsors and others 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 on Network activities between issues of the newsletter. MITE-RN researchers and collaborators are encouraged to distribute copies of the MITE-RN News at conferences and meetings they attend nationally and internationally.

6.3 Annual Research Symposium

Although the number of research principal investigators and co-investigators was approximately 24 for Year 1 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 niomonitor *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-occurring 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 sub-lethal 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 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 TWO: RESEARCH DOMAINS

8.1 <Sources>

Development of Methods for Quantification and Apportionment of Metal Sources, 2000

Research Team: C. Banic (MSC, Environment Canada), J. Campbell (U of Guelph), R. Carignan (U de Montréal), A. Chatt (Dalhousie U), G.C. Edwards (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)

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?

Role in Risk Assessment of Metals in the Environment

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 characterization. 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.

A1 The development and application of methods for the measurement of methods for the measurement of metals on aeolian dust from natural settings (G. Edwards, J.L. Campbell, P.E. Rasmussen, W.H. Schroeder)

The objective of this research 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.

A2 *In situ* solid chemical speciation of some metals associated with atmospheric particulate matter (M. Lamoureux, C. Grégoire)

The objective 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.

A3 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.

A4 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 was 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.

A5 Physical and Chemical Evolution of Aerosols in Smelter and Power Plant Plumes (C. Banic)

The objectives of this project over the three-year period of funding are:

Determine the size distribution of particles emitted from the sources.

Determine the metal content of the particles, with emphasis on Ni, Cu, Pb, Zn, Cd, As, Se and Hg and the amount of total gaseous mercury (TGM) emitted from the sources.

Determine the distribution of metals by particle size for metals with high source strength.

Determine the ability of clouds to scavenge the particles and mercury.

Apply the knowledge gained in (a) through (d) in models to estimate the concentration in air and the deposition to the surface, on both local and regional scales, of the metals emitted by these sources.

Use the results of (e) to assess the influence of potential emission control strategies.

8.2 <Processes>

Metal Mobility Among Biotic and Abiotic Compartments of A Shield Watershed, 2000

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 (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).

Summary

The <Processes> Domain consists of five projects which focus on partitioning of metals among terrestrial and aquatic environmental compartments. The studies will 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 addressed the <Processes> 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?

Role in Risk Assessment for Metals in the Environment

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.

B1 Post-deposition 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, Ontario and Rouyn-Noranda, Québec. 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.

B2 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 trends 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.

B3 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 metals' fate 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.

B4 Chemical speciation of metals in fresh waters, atmospheric precipitation, and other liquid/solid environmental media. (C.L. 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 ubiquitous 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.

B5 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 ¹³C 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.

8.3 <Impacts>

Research Team: U. Borgmann (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?

Role in Risk Assessment for Metals in the Environment

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.

C1 Predicting metal and metal mixture effects in aquatic biota. (G. Dixon, U. Borgmann)

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 *Hyaella azteca* and will seek relationships among water chemistry, metal toxicity and metal tissue residues within the organisms.

C2 Assessing biological effects of chronic metal exposures in fish. (C. Wood, G. McDonald)

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).

C3 Links between tissue metal burdens in indigenous fish and metal-induced effects at the organism & population levels (P.G.C. Campbell, A. Hontela, J. Rasmussen)

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 centered 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.

C4 Accumulation and effects of environmental metals in fish eating birds (L.H.M. Chan, T. Scheuhammer)

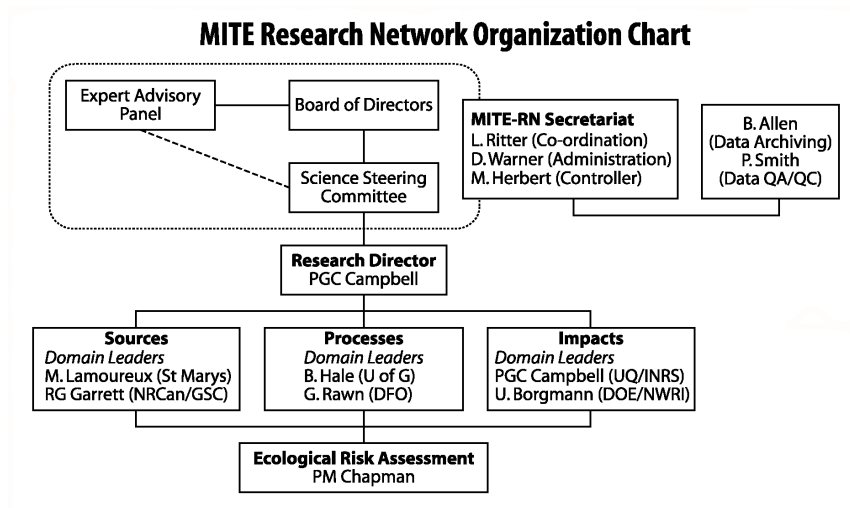
This research seeks to determine whether, and where, fish-eating wildlife in Canada are exposed to mercury (Hg) at sufficiently high levels to produce measurable impacts on their health and reproductive success; to investigate the genotoxic and immunotoxic effects of methylmercury in birds; to study 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.

**C5 Assessment of benthic invertebrate communities in metal-contaminated lake
(L. Grapentine)**

The Rouyn-Noranda area (Abitibi, Québec) offers an opportunity to assess relations between benthic invertebrate communities and environmental metal contamination. This area, with its long history of mining and smelting, was chosen as a major site for inter-disciplinary research by the MITE Research Network. Approximately 30 lakes in the area have been or are currently being studied. Data from most of the lakes exist for a series of variables for the water column, sediment and clam tissue. Included are concentrations for several forms of cadmium, copper and zinc. An assessment of community level effects would complement these studies. The assessment of benthic macroinvertebrate communities will involve sampling from a series of lakes along an existing metal gradient (e.g., downwind and downstream of the mining / smelter complex). Based on a review of existing data, a subset of 10 lakes will be selected to maximize the range of metal concentrations, while minimizing differences in natural conditions (e.g., trophic status, sediment grain size, water chemistry). Soft bottom benthic samples will be collected from three locations at similar depths in each lake. Invertebrates will be taxonomically identified and counted.

Relations between benthic community structure and environmental chemistry will be analyzed using a correlation approach. Multivariate statistical methods (mainly ordination) will be applied to accommodate co-varying and interacting variables, and to identify variables most importantly associated with benthic invertebrate patterns. In particular, the strengths of metal and benthic community associations will be determined.

9 MITE-RN ADMINISTRATION



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

A web site is being designed in collaboration with the Dr. Brian Allen, Department of Mathematics and Statistics at the University of Guelph to display network meta-data files. When completed, a hot link will be added to the MITE-RN web site to facilitate access. A prototype meta-data format has been developed based on a MITE-RN Processes Domain project (Drs. Hale/Hendershot), and that prototype will be used for the field projects. Meta-data files do not contain data. Rather, they contain specific descriptors concerning the data set, such as locations, experimental design, measured variables, biological end points, and processes being studied. It is anticipated that these meta-data files will be posted on the web site in late 2001, and actual data set would be available on request in late 2002.

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9.3 Quality Assurance/Quality Control

In order to evaluate the quality of data generated by MITE-RN researchers, each participating laboratory is required to submit a Quality Assurance / Quality Control report outlining training requirements of analytical staff and graduate students, type of analytical measurements carried out, and quality control protocols used in the laboratory. They are also required to participate in periodic inter-laboratory performance studies. To date, MITE-RN researchers have participated in five evaluation exercises. These studies are conducted by the National Laboratory for Environmental Testing, of Environment Canada at the National Water Research Institute.

These inter-laboratory performance studies provide MITE-RN researchers with an important tool for evaluating and improving data quality. By participating in ongoing performance assessments, the data being generated within the MITE-RN will remain accurate and reliable. Dr. Peter Smith, Land Resource Science, University of Guelph is coordinating the QA/QC aspects of collecting MITE-RN research data.

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9.4 Ecological Risk Assessment Co-ordinator

The research projects being conducted under the MITE Research Network will follow the ecological risk assessment 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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9.5 Science Steering Committee (SSC)

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 Secretariat representation.

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9.6 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. Steve Hrudey is Chair of this panel.

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9.7 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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9.8 Network Secretariat

The MITE-RN Secretariat's function is to support the national science program liaising with Dr. Peter Campbell, MITE-RN Science Director. Other responsibilities include:

- 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 communications such as: MITE-RN News, MITE-RN Annual Report;
- Development and maintenance of a Network web site to facilitate the dissemination of research data;
- Oversight of a management reporting system to facilitate the annual research peer review process;
- Organization and facilitation of research meetings, workshops and conferences; and
- Financial and administrative management and accountability of Network funds.

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10 SCIENTIFIC PUBLICATIONS AND PRESENTATIONS

The following publications and presentations cover calendar year 2000.

10.1 <Sources> Publications

Alfaro-De la Torre, M.C., P.Y. Beaulieu and A. Tessier. 2000. *In situ* measurement of trace metals in lakewater using the dialysis and DGT techniques. *Anal. Chim. Acta*, 418: 53-68.

Gobeil, C., R.W. Macdonald and J.N. Smith. 2000. Mercury profiles in sediments of the Arctic Ocean basins. *Environ. Sci. Technol.* 33: 4194-4198.

10.2 <Processes> Publications

Evans, L.J. 2000. Fractionation and aqueous speciation of zinc in a lake polluted by mining activities, Flin Flon, Manitoba, Canada. *Wat. Soil Air Pollut.* 122: 299-316.

Mandal, R., M.S.A. Salam, J. Murimboh, N.M. Hassan, C.L. Chakrabarti and M.H. Back. 2000. Competition of Ca(II) and Mg(II) with Ni(II) for binding by a well-characterized fulvic acid in model solutions. *Environ. Sci. Technol.* 34: 2201-2208.

Munger, C. and L. Hare. 2000. Influence of ingestion rate and food types on Cd accumulation by the aquatic insect *Chaoborus*. *Can. J. Fish. Aquat. Sci.* 57: 327-332.

Murimboh, J., M.T. Lam, N.M. Hassan and C.L. Chakrabarti 2000. A study of Nafion-coated and uncoated thin mercury film-rotating disk electrodes for Cd and Pb speciation in model solutions of fulvic acid. *Anal Chim. Acta.* 423: 115-126.

10.3 <Impacts> Publications

Borgmann, U., D.G. Dixon and W.P. Norwood. 2000. Metal bioavailability and toxicity in sediments from lakes near Rouyn-Noranda and identification of the cause of toxicity. National Water Research Institute - Environment Canada (00-066): 1-19.

Laflamme J.-S., Y. Couillard, P.G.C. 2000. Campbell and A. Hontela. Interrenal metallothionein and cortisol secretion in relation to Cd, Cu, and Zn exposure in yellow perch, *Perca flavescens*, from Abitibi lakes. *Can. J. Fish. Aquat. Sci.* 57: 1692-1700.

Pyle, G.G., C.M. Wood and D.G. McDonald. 2000. The influence of diet on metal uptake, accumulation, and toxicity to fish. *SETAC Globe* 1(4): 25-26.

Pyle, G.G., L.N. Taylor, C. Kamunde, C.M. Wood and D.G. McDonald. 2000. Metal effects on fish - laboratory studies. Canadian Network of Toxicology Centres, MITE-RN News, p.4: Fall.

Taylor, L.N., J.C. McGeer, C.M. Wood and D.G. McDonald. 2000. The physiological effects of chronic copper exposure to rainbow trout (*Oncorhynchus mykiss*) in hard and soft water: an evaluation of chronic indicators. Environ. Toxicol. Chem. 19: 2298-2308.

10.4 <Sources> Presentations

Alfaro-De la Torre, M.C. and A. Tessier. 2000. *In situ* measurement of trace metals in an oligotrophic lake: Comparison of results obtained by peepers and DGT. Proceedings of the 25th International Conference on Heavy Metals in the Environment, Ann Arbor, MI. August 6-8. (Contribution No.1376, CD-ROM).

Banic, C.M., W.R. Leitch, K. Strawbridge, S. Daggupaty, N. Shantz, J.Y. Lu, N. Bhyat, R. Tanabe, J.I. MacPherson, H.K.T. Wong, Z. Nejedly, J.L. Campbell, C. Gariepy, A. Simonetti, J. Skeaff, A. Chatt, and M. Lamoureux. 2000. Aircraft study of the physical and chemical evolution of aerosols in smelter and power plant plumes. Proceedings of the 25th International Conference on Heavy Metals in the Environment, Ann Arbor, MI. August 6-8.

Carignan, R. and A. Tessier. 2000. Geochemical mobility of metals in surface sediments: Influence of sediment diagenesis. Annual MITE-RN Workshop, Hull, PQ. March 20-21.

Chatt, A., A. Perez-Gramatges and Youqing Shi. 2000. Determination of copper, cadmium and manganese by cloud point extraction and speciation of arsenic in wet precipitation by HPLC-NAA. Metals in the Environment Research Network (MITE-RN) Annual Research Symposium, Hull, PQ. March 20-21.

Dias, G., G. Edwards, P. Rasmussen, W. Schroeder, J. Kemp, C.F.- Hubble and L. Halfpenny-Mitchell. 2000. Developing relationships between fluxes of natural sources of mercury and environmental and biogeochemical parameters for the purpose of scaling up fluxes. Proceedings of the 25th International Conference on Heavy Metals in the Environment, Ann Arbor, MI. August 6-8.

Edwards, G.C., P.E. Rasmussen, W.H. Schroeder and G.M. Dias. 2000. Metal fluxes on particulates from natural settings. Metals in the Environment Research Network (MITE-RN) Annual Research Symposium, Hull, PQ. March 20-21.

Edwards, G.C., P.E. Rasmussen, G. Dias, W.H. Schroeder, R.J. Kemp, D. Wallace and L. Halfpenny-Mitchell. 2000. Measurements to estimate natural mercury emissions. Mercury in the Environment Policy Workshop, Meteorological Service of Canada, Downsview, ON. November 24-25.

Francis, J., T. Gordon and M. Lamoureux. 2000. Investigation of dissociation kinetics of metal-humic acid complexes. Atlantic Student Chemistry Conference. ChemCon 2000. Fredericton, NB. May 19-21.

Huggins, F.E. and F. Goodarzi. 2000. Program and book of abstracts. 4th International Symposium on Speciation of Elements in Biological, Environmental and Toxicological Sciences. Whistler, BC. June 25-July 1.

Lu, J. Y., C. M. Banic and W. H. Schroeder. 2000. Mercury species in smelter and power plant plumes. Proceedings of the 25th International Conference on Heavy Metals in the Environment, Ann Arbor, MI. August 6-8.

Perez-Gramatges, A. and A. Chatt. 2000. Preconcentration neutron activation analysis for copper by cloud point extraction with PAN. 5th International Topical Conference on Methods and Applications of Radioanalytical Chemistry (MARC-V), Kona, HI. April 9-14.

Savard, M.M., C. Begin, M. Parent, A. Smirnov, M.R. Luzincourt, S. Boivin, J. Cloutier and J. Marion. 2000. DINAMITE-Multi-tracer chemistry of tree rings as a high resolution biomonitoring tool for point source atmospheric pollutants. Geoscience Canada 2000 meeting. Calgary, AB. May 20.

Schroeder, W.H., G.C. Edwards, P.E. Rasmussen, R.J. Kemp, G. M. Dias, L. Halfpenny-Mitchell and C. Fitzgerald-Hubble. 2000. The significance of measuring mercury emissions from natural sources. GeoCanada, Calgary, AB. May 30 - June 2.

Strawbridge, K.B., C.M. Banic and W.R. Leitch. 2000. Scanning LIDAR observations of the evolution of aerosols from both a smelter and power plant plume. NARSTO Symposium on Tropospheric Aerosols: Science and Decisions in an International Community, Queretaro, Mexico. October 23-26.

Sullivan, E., M. Lamoureux, K. Duggan, T. Gordon and C. Gregoire. 2000. *In situ* solid state chemical speciation of some metal pollutants associated with ground level particulate matter. The 3rd Biennial International Conference on Monitoring and Measurement of the Environment. Ottawa, ON. May 8-11.

Sullivan, E., M. Lamoureux, K. Duggan, V. MacKinnon and C. Gregoire. 2000. Determination of the concentration of Cu, Ni, and Pb in metal-containing airborne particulate matter using ultrasonic slurry sampling graphite furnace atomic spectrometry. 46th International Conference on Analytical Sciences and Spectroscopy. Winnipeg, MN. August 13-16.

Sullivan, E., M. Lamoureux, K. Duggan, V. MacKinnon and C. Gregoire. 2000. Chemical speciation of Cu and Ni in metal-containing airborne particular matter using synchrotron x-ray absorption spectroscopy. 46th International Conference on Analytical Sciences and Spectroscopy. Winnipeg, MN. August 13-16; and 27th Annual Conference of the Federation of Analytical Chemistry and Spectroscopy Societies. Nashville, TN. September 24-28.

Sullivan, E., M. Lamoureux, K. Duggan, T. Gordon and C. Gregoire. 2000. Chemical speciation of some metal-containing airborne particulate matter as a function of particle size. 4th International Symposium on Speciation of Elements in Biological, Environmental and Toxicological Sciences. Whistler, BC. June 25-July 1.

Warner, N., V. MacKinnon and M. Lamoureux. 2000. Chemical characteristics of airborne particulate matter. Atlantic Student Chemistry Conference. ChemCon 2000. Fredericton, NB. May 19-21.

Youqing Shi, and A. Chatt. 2000. Speciation of arsenic in natural waters by chemical separations and neutron activation analysis. 5th International Topical Conference on Methods and Applications of Radioanalytical Chemistry (MARC-V), Kona, HI. April 9-14.

10.5 <Processes> Presentations

Back, M.H., A.L.R. Sekaly, C.L. Chakrabarti and D.C. Gregoire. 2000. Analysis of dissociation rate of metal complexes in model systems and freshwaters by non-linear regression and the distribution analysis method. 46th International Conference on Analytical Sciences and Spectroscopy (ICASS), Winnipeg, MB. August 13-16.

Bhavsar, S.P., M.L. Diamond, L.J. Evans, P. Cypas and K. Rudnitski. 2000. Coupling a speciation/complexation and QWASI fugacity models to estimate the fate of metals in lakes. Society of Environmental Toxicology and Chemistry, 21st Annual Meeting, Nashville, TN. November 12-16.

Celo, V., M.S.A. Salam, J. Murimboh and C.L. Chakrabarti. 2000. The kinetics of nickel speciation in model solutions using competing ligand exchange/adsorptive cathodic stripping voltammetry. Metals in the Environment Research Network (MITE-RN) Annual Research Symposium, Hull, PQ. March 20-21.

Chakrabarti, C.L. 2000. Chemical transformation of nickel-organic complexes in model solutions (simulating fresh waters) into free Ni²⁺ ions: the role of Ca²⁺ and Mg²⁺ ions in the transformation. Metals in the Environment Research Network (MITE-RN) Annual Research Symposium, Hull, PQ. March 20-21.

Chakrabarti, C.L. 2000. The quest for free-metal ion: the elusive holy grail of metal speciation in the natural environment. 46th International Conference on Analytical Sciences and Spectroscopy (ICASS) Winnipeg, MB. August 13-16.

Croisetière, L., L. Hare and A. Tessier. 2000. Aquatic mosses as metal biomonitors. Poster presentation. 21st Annual Meeting, Society of Environmental Toxicology and Chemistry, Nashville, TN. November 12-16.

Croteau, M.-N., L. Hare and A. Tessier. 2000. Food as a cadmium source for aquatic insects. Proceedings of the 25th International Conference on Heavy Metals in the Environment, Ann Arbor, MI. August 6-8. (Contribution No.1013, CD-ROM).

Croteau, M.-N., L. Hare and A. Tessier. 2000. Cadmium accumulation from prey by three species of the biomonitor *Chaoborus*; influence of temperature. Poster presentation. 21st Annual Meeting, Society of Environmental Toxicology and Chemistry, Nashville, TN. November 12-16.

Croteau, M.-N., L. Hare, P.G.C. Campbell and A. Tessier. 2000. Does the biomonitor *Chaoborus* possess metal-binding proteins and do the concentrations of these proteins reflect Cd concentrations in lakes? 21st Annual Meeting, Society of Environmental Toxicology and Chemistry, Nashville, TN. November 12-16.

Croteau, M.-N., L. Hare and A. Tessier. 2000. Explaining differences in Cd concentrations among sympatric *Chaoborus* species. American Society of Limnology & Oceanography, Copenhagen, Denmark. June 5-9; and Metals in the Environment Research Network (MITE-RN) Annual Research Symposium, Hull, PQ. March 20-21.

Evans, L., M. Diamond, K. Rudnitski, P. Cypas and S. Bhavsar. 2000. Quantification and modelling of metal mobility in a zinc contaminated lake. Metals in the Environment Research Network (MITE-RN) Annual Research Symposium, Hull, PQ. March 20-21.

Gallon, C., A. Tessier and L. Hare. 2000. The micro-environments created by benthic tube-dwellers. Metals in the Environment Research Network (MITE-RN) Annual Research Symposium, Hull, PQ. March 20-21.

Guthrie, J. and C.L. Chakrabarti. 2000. Kinetic speciation in freshwater samples from the Sudbury mining area. Metals in the Environment Research Network (MITE-RN) Annual Research Symposium, Hull, PQ. March 20-21.

Guthrie, J., N.M. Hassan, R. Mandal, J. Murimboh, C.L. Chakrabarti, M.H. Back and D.C. Gregoire. 2000. A kinetic study of model systems containing a well-characterized humic acid using the competing ligand exchange method. 46th ICASS, Winnipeg, MB. August 13-16.

Hassan, N.M. and C.L. Chakrabarti. 2000. Kinetic speciation in ultrafiltered fractions of freshwater samples. Metals in the Environment Research Network (MITE-RN) Annual Research Symposium, Hull, PQ. March 20-21; and 46th ICASS, Winnipeg, MB. August 13-16.

Gallon, C., A. Tessier and L. Hare. 2000. Exposure of benthic animals to metal sources: clues from their irrigation behaviour. Proceedings of the 25th International Conference on Heavy Metals in the Environment, Ann Arbor, MI. August 6-8. (Contribution No.1219, CD-ROM).

Guthrie, J.W., N.M. Hassan, R. Mandal, J. Murimboh, C.L. Chakrabarti, M.H. Back and D.C. Gregoire. 2000. A kinetic study of model systems containing a well-characterized humic acid using the competing ligand exchange method. 46th International Conference on Analytical Sciences and Spectroscopy (ICASS), Winnipeg, MB. August 13-16.

Hassan, N.M., J. Murimboh, R. Mandal, J.W. Guthrie, C.L. Chakrabarti and M.H. Back. 2000. Kinetic speciation of aluminium, iron, and nickel in freshwaters using competing ligand exchange method after fractionation by cascade ultrafiltration. 46th International Conference on Analytical Sciences and Spectroscopy (ICASS), Winnipeg, MB. August 13-16.

Johnson, D. and B. Hale. 2000. Trace metal dynamics in contaminated northern forest ecosystems. 21st Annual Meeting, Society of Environmental Toxicology and Chemistry, Nashville, TN. November 12-16.

Johnson, D., D. MacDonald, Y. Zhang, B. Hale, W. Hendershot and R. Martin. 2000. Post-depositional mobility of trace metals in contaminated northern forest ecosystems. Metals in the Environment Research Network (MITE-RN) Annual Research Symposium, Hull, PQ. March 20-21.

Mandal, R., M.S.A. Salam, C.L. Chakrabarti and M.H. Back. 2000. Voltammetric study of complexation of Pb(II) with a well-characterized fulvic acid in model system effect of competition with major ions. 46th International Conference on Analytical Sciences and Spectroscopy (ICASS), Winnipeg, MB. August 13-16.

Mandal, R. and C.L. Chakrabarti. 2000. Competition of major ions on the speciation of nickel in model solutions of a well-characterized fulvic acid: the role of calcium and magnesium. Metals in the Environment Research Network (MITE-RN) Annual Research Symposium, Hull, PQ. March 20-21.

Murimboh, J. and C.L. Chakrabarti. 2000. Electrochemical techniques for metal speciation. Metals in the Environment Research Network (MITE-RN) Annual Research Symposium, Hull, PQ. March 20-21.

Murimboh, J. and C.L. Chakrabarti. 2000. The kinetics of nickel speciation in model solutions using competing ligand exchange/adsorptive cathodic stripping voltammetry. Metals in the Environment Research Network (MITE-RN) Annual Research Symposium, Hull, PQ. March 20-21.

Murimboh, J., N.M. Hassan and C.L. Chakrabarti. 2000. The quest for free-metal ions and other labile species in contaminated soils. 46th International Conference on Analytical Sciences and Spectroscopy (ICASS), Winnipeg, MB. August 13-16.

Murimboh, J., N.M. Hassan, R. Mandal, M.S.A. Salam, and C.L. Chakrabarti. 2000. Metal speciation in aqueous environmental samples using anodic stripping voltammetry with a thin mercury film-rotating disk electrode. 46th International Conference on Analytical Sciences and Spectroscopy (ICASS), Winnipeg, MB. August 13-16.

Murimboh, J., A.L. R. Sekaly, R. Mandal, N.M. Hassan, M.S.A. Salam, J. Guthrie, C.L. Chakrabarti, M.H. Back. 2000. Metal speciation in the freshwater environment. Varian Day Symposium, Carleton University, Ottawa, ON. April 10.

Salam, M.S.A., R. Mandal, C.L. Chakrabarti and M.H. Back. 2000. Effects of competition by trace metals: copper, zinc and lead, on cadmium complexation by polyacrylic acid and Laurentian fulvic acid, studied by square wave anodic stripping voltammetry. 46th International Conference on Analytical Sciences and Spectroscopy (ICASS), Winnipeg, MB. August 13-16.

Salam, M.A. and C.L. Chakrabarti. 2000. Chemical speciation of nickel in freshwaters from the Sudbury (Canada) mining area by competing ligand exchange/adsorptive cathodic stripping voltammetry. Metals in the Environment Research Network (MITE-RN) Annual Research Symposium, Hull, PQ. March 20-21.

Sekaly, A.L.R. and C.L. Chakrabarti. 2000. Metal binding by naturally-occurring organic ligands in freshwaters – a kinetic approach. Metals in the Environment Research Network (MITE-RN) Annual Research Symposium, Hull, PQ. March 20-21.

Sekaly, A.L.R., M. Ben Younes, J. Murimboh, C.L. Chakrabarti and M.H. Back. 2000. Comparative study of Co(II), Ni(II), Cu(II), and Zn(III) complexes in model systems containing a well characterized fulvic acid and in freshwaters. 46th International Conference on Analytical Sciences and Spectroscopy (ICASS), Winnipeg, MB. August 13-16.

Wang, F., A. Tessier and L. Hare. 2000. Predicting cadmium concentrations in aquatic organisms in nature. 21st Annual Meeting, Society of Environmental Toxicology and Chemistry, Nashville, TN. November 12-16.

10.6 <Impacts> Presentations

Chan, H.M. and A.M. Scheuhammer. 2000. Potential effects of mercury from mining activities on fish eating wildlife. Metals in the Environment Research Network (MITE-RN) Annual Research Symposium, Hull, PQ. March 20-21.

Chan, H.M. and A.M. Scheuhammer. 2000. Interactions of mercury and selenium in common loons. Poster presentation. Metals in the Environment Research Network (MITE-RN) Annual Research Symposium, Hull, PQ. March 20-21.

Giguère, A., J.S. Laflamme, Y. Couillard, P.G.C. Campbell and A. Hontela. 2000. Accumulation and subcellular partitioning of metals (Cd, Cu, Zn) in indigenous aquatic organisms sampled along an environmental metal gradient. 21st Annual Meeting, Society of Environmental Toxicology and Chemistry, Nashville, TN. November 12-16.

Giguère, A., A. Hontela, J.B. Rasmussen and P.G.C. Campbell. 2000. Links between tissue metal burdens in indigenous fish and metal-induced effects at the organism level. Poster presentation. Metals in the Environment Research Network (MITE-RN) Annual Research Symposium, Hull, PQ. March 20-21.

Holloway J.C., H.M. Chan and A.M. 2000. Scheuhammer. Immune function in birds exposed to dietary methylmercury. 21st Annual Meeting, Society of Environmental Toxicology and Chemistry, Nashville, TN. November 12-16.

Hontela, A. 2000. Impaired adrenal steroidogenesis in fish chronically exposed to environmental xenobiotics. International Congress of Fish Biology, Aberdeen, Scotland. July 23-27.

Hontela, A., V. Leblond, P.G.C. Campbell, G. Sherwood and J. Rasmussen. 2000. Effets des métaux sur la stéroïdogénèse adrénale et la fonction physiologique chez les poissons. 4th Colloque du Chapitre St-Laurent, Quebec City, PC. June 8-9.

Kamunde, C.N. and C.M. Wood. 2000. Dietary and waterborne copper exposure in fish: interactions and implications for the biotic ligand model and risk assessment. 21st Annual Meeting, Society of Environmental Toxicology and Chemistry, Nashville, TN. November 12-16.

Kamunde, C. and C.M. Wood. 2000. Effects of dietary ration on copper homeostasis in rainbow trout during chronic sublethal exposure to diet-borne copper. Metals in the Environment Research Network (MITE-RN) Annual Research Symposium, Hull, PQ. March 20-21.

Kamunde, C.N. and C.M. Wood. 2000. Physiological responses of rainbow trout to sublethal dietary copper exposure. 39th Annual Meeting, Canadian Society of Zoologists, St. Andrews, NB. May 2-5.

Kovasces J. and J.B. Rasmussen. 2000. The impacts of metals on lake invertebrate communities along a metal pollution gradient. 21st Annual Meeting, Society of Environmental Toxicology and Chemistry, Nashville, TN. November 12-16.

Levesque H., P.G.C. Campbell, T.W. Moon and A. Hontela. 2000. Seasonal variation in metabolic enzymes of cortisol-impaired yellow perch (*Perca flavescens*) exposed to an environmental metal gradient. 39th Annual Meeting, Canadian Society of Zoologists, St. Andrews, NB. May 2-5.

Levesque H., T.W. Moon, G.J. Van Der Kraak, P.G.C. Campbell and A. Hontela. 2000. Seasonal variation of intermediary metabolism and hormonal status of adult yellow perch (*Perca flavescens*) chronically exposed to metals. 27th Annual Aquatic Toxicity Workshop, St. John's, NFLD. October 1-4.

Levesque, H., A. Gravel, A. Hontela and P.G.C. Campbell. 2000. Metabolic and hormonal responses of adult and young-of-the-year yellow perch exposed to metals. Poster presentation. Metals in the Environment Research Network (MITE-RN) Annual Research Symposium, Hull, PQ. March 20-21.

McDonald, D.G. 2000. Metal uptake by gills and gut of fish. 4th International Symposium on Speciation of Elements in Biological, Environmental and Toxicological Sciences. June 26-30.

McDonald, D.G. 2000. The effect of water chemistry on copper uptake and toxicity in freshwater fish. INRS-Eau, Université du Québec. May 25.

McDonald, D.G. Metal regulation and toxicity in freshwater fish. 2000. Danisco-cultor Development Centre. Kantvik, Finland. November 2.

Norwood, W., U. Borgmann and D.G. Dixon. 2000. Metal toxicity to *Hyalella azteca*: relationship to body and water concentrations. Metals in the Environment Research Network (MITE-RN) Annual Research Symposium, Hull, PQ. March 20-21.

Pyle, G.G., C.M. Wood and D.G. McDonald. 2000. Comparing copper uptake, distribution, and toxicity between a sensitive (*Oncorhynchus mykiss*) and tolerant (*Perca flavescens*) freshwater fish species. 39th Annual Meeting, Canadian Society of Zoologists, St. Andrews, NB. May 2-5.

Pyle, G.G., L.N. Taylor, C. Kamunde, C.M. Wood and D.G. McDonald. 2000. Copper uptake, distribution, and toxicity in yellow perch and rainbow trout. Metals in the Environment Research Network (MITE-RN) Annual Research Symposium, Hull, PQ. March 20-21.

Sherwood G., J.B. Rasmussen and A. Hontela. 2000. Elevated activity costs due to metal exposure in wild-living fish: insights from metabolic enzymes. 39th Annual Meeting, Canadian Society of Zoologists, St. Andrews, NB. May 2-5.

Sherwood G., Kovescs J., A. Hontela and J.B. Rasmussen. 2000. Simplified prey communities lead to energetic bottlenecks for yellow perch inhabiting metal-contaminated lakes. 27th Annual Aquatic Toxicity Workshop, St. John's, NFLD. October 1-4.

Scheuhammer, A.M. 2000. Mercury and selenium in tissues and eggs of birds fed different dietary levels of these elements. Poster Presentation, 21st Annual Meeting, Society of Environmental Toxicology and Chemistry, Nashville, TN. November 12-16.

Scheuhammer, A.M., J.A. Perrault and D.E. Bond. 2000. Mercury and selenium in eggs of common loons (*Gavia immer*) from Canada. 21st Annual Meeting, Society of Environmental Toxicology and Chemistry, Nashville, TN. November 12-16.

Schroeder, J., U. Borgmann and D.G. Dixon. 2000. Creating a model for predicting metal toxicity to invertebrates. 27th Annual Aquatic Toxicity Workshop, St. John's, NFLD. October 1-4.

Schroeder, J. and D.G. Dixon. 2000. Developing a model of metal toxicity to *Hyaella azteca* - Phase I: Answering fundamental questions. Metals in the Environment Research Network (MITE-RN) Annual Research Symposium, Hull, PQ. March 20-21.

Sherwood, G.D, A. Giguère, A. Gravel, J. Kovescs, H. Levesque, A. Hontela, J.B. Rasmussen and P.G.C. Campbell. 2000. Links between tissue metal burdens in indigenous fish and metal-induced effects at the organism and population levels. Metals in the Environment Research Network (MITE-RN) Annual Research Symposium, Hull, PQ. March 20-21.

Sherwood, G.D., J. Kovescs, A. Hontela and J.B. Rasmussen. 2000. Simplified prey communities lead to energetic bottleneck for yellow perch inhabiting metal-polluted lakes. Poster presentation. Metals in the Environment Research Network (MITE-RN) Annual Research Symposium, Hull, PQ. March 20-21.

Taylor, L.N., C.M. Wood and D.G. McDonald. 2000. Developments in the biotic ligand model for copper using yellow (*Perca flavescens*) and rainbow trout (*Oncorhynchus mykiss*). Metals in the Environment Research Network (MITE-RN) Annual Research Symposium, Hull, PQ. March 20-21.

Taylor, L.N., C.M. Wood and D.G. McDonald. 2000. Testing the biotic ligand model for copper using yellow perch (*Perca flavescens*) and rainbow trout (*Oncorhynchus mykiss*). 21st Annual Meeting, Society of Environmental Toxicology and Chemistry, Nashville, TN. November 12-16.

Weech, S.A. and A.M. Scheuhammer. DNA strand breakage in liver and blood of ring doves from chronic dietary exposure to methylmercury and selenium. 2000. Poster Presentation, 21st Annual Meeting, Society of Environmental Toxicology and Chemistry, Nashville, TN. November 12-16.

Wood, C.M., D.G. McDonald and J.C. McGeer. 2000. Copper homeostasis and toxicity in fish: interactions between waterborne and dietary exposure routes. Annual Symposium of the International Copper Association, Montebello, PQ. April 5-8.

Wood, C.M. 2000. Copper homeostasis and toxicology – can extrapolation between mammals and fish help us? U.S. EPA Workshop on Species Extrapolation in Toxicology. Duluth, WI. October 15-16.

Wood, C.M. 2000. An integrated research program for studying the homeostasis, essentiality, and chronic toxicity of copper. Workshop on the Molecular Biology of Copper, International Copper Association, Washington, DC. July 7-9.

Wood, C.M. 2000. Dietary toxicity of metals in freshwater fish. U.S. EPA Workshop on Dietary Metal Toxicity. Duluth, MN. March 17.

Wood, C.M. 2000. Ecotoxicología y homeostatis de cobre en peces dulceacuicolas: importancia de investigacion basica en regulacion de metales en ambientes acuaticos. XLIII Reuin Annual de la Sociedad de Biologia de Chile, Pucon, Chile. November 17-20.

10.7 Ecological Risk Assessment: Publications

Chapman, P. M. and F. Wang. 2000. Issues in ecological risk assessment of metals and metalloids. Human Ecol. Risk Assess. 6: 965-988.

Chapman, P. M. and F. Wang. 2000. Issues in environmental risk assessment of metals. pp. 505-507. In: J. A. Centeno, P. Collery, G. Vernet, R. B. Finkelman, H. Gibb and J. C. Etienne (eds.), Metal Ions in Biology and Medicine, Volume 6. John Libbey, Montroge, France.

