



ANNUAL REPORT
March 1, 2001 - February 28, 2002

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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 having completed 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



A year ago, I reported that the work of the Network scientists was continuing with high energy and dedication, and that we looked forward to the generation of scientific advances that would provide important input into public policy development.

I am therefore pleased to report a number of noteworthy achievements over the last year. Examples include: advances have been made in understanding contributions from both local and regional sources of metals to overall metal loadings in environmental compartments; recent data from Network research laboratories now indicate chemical speciation may be possible for complex metal mixtures in dusts and soils; new methodologies for the analysis of mercury species in airborne particulate matter and in suspended matter have been developed and are in the validation stage; data indicate that aqueous speciation of zinc varies over time and the variation may affect the fate of zinc in the environment; Network scientists have developed a new methodology for measuring the concentration of inorganics in standing wood and are applying this technique to derive estimates of historical metal loadings; and using a standard aquatic test organism, the amphipod *Hyaella azteca*, critical body concentrations related to chronic toxicity have been determined for all ten MITE-RN priority metals. We believe these and other scientific achievements will make important contributions to the development of scientifically robust public policy and support Canada's international leadership position in the developing of effective risk management of metals in the environment.

A number of other initiatives are taking shape as well. The Science-Policy Workshop, organized by the Network in March 2001, identified several key communications instruments, including policy briefs. I am pleased to note that a number of potential topics for policy briefs have been nominated by the Network and preparation and distribution of these briefs to key stakeholders should be underway in the last quarter of 2002. The Network has also been carefully, and critically, re-evaluating its progress against its original objectives as it prepares its Year Four progress report to NSERC, a requirement for release of the final year's funding. I am delighted to report that all stakeholders have concluded that progress has been laudable, and the decision has been taken to seek funding for a continuing Network research program (MITE II) when the initial five-year term concludes in the spring of 2004. In order for the Network to continue in areas of metals' research where data gaps are identified, the Network must demonstrate that its results are being translated into sound policy and risk management. The Board is committed to this objective.

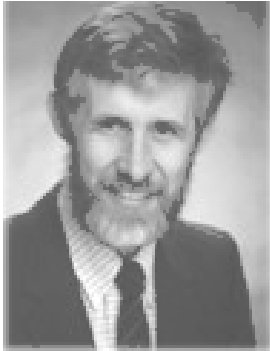
Finally, it is indeed a privilege to recognize the Network's Principal Scientist, Peter Campbell, for his continuing record of achievements, recently highlighted by his election to

Fellowship in the Royal Society of Canada and his appointment as a Canada Research Chair. On behalf of all Network participants, I extend to Peter our congratulations and wishes for good health and success in all that he does.

A handwritten signature in black ink, reading "Bruce R. 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-THREE MESSAGE FROM THE RESEARCH DIRECTOR



The Canadian <Metals in the Environment> Research Network, or MITE-RN, a network of collaborating institutions with participants from academia, government and industry, completed the third year of its five-year research plan in February 2002. The MITE-RN research program is designed to advance our understanding of the risk to ecosystem health from metals in the environment. The Network has emphasised the importance of distinguishing between anthropogenic and natural inputs of metals to the Earth's surficial environment, and the need to clarify the behaviour of these metal inputs once they enter the biogeochemical cycle. Network research addresses the bioaccumulation of metals, both in the laboratory and in field settings, and the prediction of metal-induced toxicity in those organisms that are exposed to metals. Highlights of our progress towards these research goals are documented in the domain summaries that appear in this Annual Report, and in his synthesis report, Peter Chapman discusses the implications of these research findings for the ecological risk assessment of metals.

In Year 3, the Network supported a total of 16 university-based projects, of which five were new studies that started up in 2001-2002, and 5 projects based in government laboratories, of which 4 were initiated during the year. This influx of new projects is tangible evidence of the Network's commitment 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 progressively, starting in Year 3. During this period, approximately 35 Ph.D. research scientists, 3 Post-doctoral Fellows, 28 Ph.D. students and 25 M.Sc. students were involved in Network research activities.

Year 3 also brought changes within the Network's management structure. Grant Edwards has stepped down as <Sources> Domain Leader, to be replaced by Marc Lamoureux of St. Mary's University. On the Science Steering Committee (SSC), Gary Rawn of Fisheries and Oceans Canada has replaced Ron Pierce as <Processes> co-domain leader. Steve Hrudey has been replaced by Jack Klaverkamp of Fisheries and Oceans Canada as Chair of the Expert Advisory Panel (EAP). Finally, two new University representatives have been named to the MITE-RN's Board of Directors: Alan Wildeman (University of Guelph) and Sinh LeQuoc (Université du Québec, INRS).

During Year 3, MITE-RN established productive links to two other research networks in the metals area: COMERN, a «Collaborative Mercury Research Network» funded by NSERC (director = Marc Lucotte, Université du Québec à Montréal), and CSME, the «Center for the Study of Metals in the Environment» funded by the U.S. Environmental Protection Agency (director = Herb Allen, University of Delaware).

To foster interaction between the two NSERC-funded research networks, we have invited Dr. Lucotte to attend our SSC meetings and COMERN has agreed to reciprocal membership on their science advisory committee. A similar arrangement has been struck with CSME.

Finally, I would like to acknowledge the invaluable contributions made by our industry and government colleagues, as members of the Science Steering Committee, as co-leaders of our three research domains, and at the level of many of our individual Network research projects.

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 2001-2002 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 metals associated with atmospheric particulate matter <Cu Ni Pb Se>
- R. Carignan (A4) Geochemical mobility of metals in surface sediments: Influence of sediment diagenesis <As Cd Cu Hg Ni Pb Zn>
- J. Lu (A5) Development of analytical methods for chemical speciation of metals associated with atmospheric particulate matter/aerosols <Hg, As, Se, Cr, Ni, Cd, Zn, Pb>
- G. Spiers (A6) Development of sensitive techniques for the chemical analysis of aerosolic particulates <As, Bi, Cd, Co, Cr, Cu, Fe, Mn, Ni, Pb, Sr, Ti, V, Y, Zn>
- C. Banic (A7) Physical and Chemical Evolution of Aerosols in Smelter and Power Plant Plumes<Cu, Cd, Ni, Hg, Pb, Zn, As>

Government

- W.D. Gould (AF8) Redistribution of metals in lake sediments by bacterially mediated oxidation-reduction reactions <Fe, Cu, Ni>
- V. Palace (AF9) The role of bacteria in the mobilization of arsenic from mine-impacted sediments <As, Fe>
- J. Percival (AF10) Examination of mineral weathering and release of trace elements in selected soil profiles

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 organisms to metal concentrations in their environment <Cd Cu Ni Zn>
- C.L. Chakrabarti (B4) Metal-organic interactions in soils, soil solutions and fresh waters <Cu Cd Hg Pb Ni Zn Al Fe Ca Mg Co>
- F. Courchesne (B5) The availability of trace metals in the rhizosphere of contaminated soils from the Sudbury area <Al, Cd, Cu, Fe, Pb, Zn>
- P. Dillon (B6) Metal budgets of lakes and catchments on the Precambrian Shield: compartment sizes and fluxes between compartments <Cu, Zn, Pb, Ni, Cd, Co, V, Cr, Sc, Y, Sn, Rb, Sr, As>
- F. Wang (B7) Importance of reduced sulfur species in controlling metal speciation in surface waters on the Canadian Shield <Cd, Cu, Hg, Pb, Zn>

Government

- M. Savard BF1 Biogeochemical cycling in the boreal forest - metal concentrations in woody tissues Phase I <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 in indigenous fish and metal-induced effects at the organism and population levels.
<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 (CF1) Quantitative synthesis of aquatic environmental effects studies metal mines of the Precambrian Shield
<As, Cd, Cu, Hg, Pb, Ni, Zn + Ag, Al, Ba, Ca, Cr, Co, Fe, K, Mg, Mn, Mo, Na, Sr, V, Y>

R. Scroggins (CF2) Impacts of metal-contaminated forest soils from the Canadian Shield on terrestrial organisms <Cd, Cu, Ni, Pb, Zn>

5 MITE-RN STUDENTS

<SOURCES>	<PROCESSES>	<IMPACTS>
<p><u>University of Guelph:</u> Sandra Ausma, Post-doc Fellow Sonia Beaulieu, M.Sc. student</p> <p><u>Saint Mary's University:</u> Eric Sullivan , Ph.D. student Nick Warner, M.Sc. student</p> <p><u>INRS-Eau:</u> Catalina Alfaro, Ph.D. student François Bilodeau , M.Sc. student Celine Gallon, Ph.D. student</p> <p><u>Ryerson University:</u> Xinbin Feng, Post-doc Fellow Kevin Ji, M.Sc. student</p> <p><u>Université de Montréal</u> François Lafrenière, M.Sc. student Pascale Legrand, M.Sc. student Sylvie Manna, M.Sc. student Véronique Séquin, Ph.D. student Michel Courcelles, Post-doc Fellow</p>	<p><u>University of Guelph:</u> Dallas Johnson , Ph.D. student Kristina Rudnitski, M.Sc. student</p> <p><u>McGill University:</u> Doug MacDonald, Ph.D. student Ying Ge, Ph.D. student Astrid Voigt, Ph.D. student</p> <p><u>Université de Montréal</u> Pascale Legrand, M.Sc. student</p> <p><u>INRS-Eau:</u> Marie Croteau , Ph.D. student Louis Croisetière , Ph.D. student Anne Gosselin, M.Sc. student Jord Orvoine, M.Sc. student Joëlle Marion, M.Sc. student</p> <p><u>University of Toronto:</u> Satyendra Bhavsar, M.Sc. student</p> <p><u>Carleton University:</u> Jamaluddin, Ph.D. student Momiruzzaman, Ph.D. student</p> <p><u>University of Manitoba:</u> Katrina Sukola, M.Sc. student Junwei Jiang, M.Sc. student</p> <p><u>GSC - Quebec</u> Anna Smirnov, M.Sc. student</p>	<p><u>University of Guelph:</u> Juliska Princz, M.Sc. student</p> <p><u>University of Waterloo:</u> Warren Norwood, Ph.D. student Julie Schroeder, Ph.D. student Monica Nowerski, M.Sc. student</p> <p><u>McMaster University:</u> Lisa N. Taylor, Ph.D. student, Collins Kamunde, Ph.D. student Carrie Ho, M.Sc. student Sam Niyogi, Post-doc Fellow</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 University:</u> Graham Sherwood, Ph.D. student Jennifer Kovescs, M.Sc. student Alison Isles, M.Sc. student Alex Ferran, 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- Research Overview	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 - 2002)- 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 Winter 2002 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. 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.

6.3 Annual Research Symposium

Although the number of research principal investigators and co-investigators was approximately 52 for Year 2 of the program, we are delighted to report that participation in the February 27-28, 2002 annual research symposium included 119 people which suggests approximately 44% 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>

Metal concentrations and source apportionment of particulates at remote sites in Canada

Dias, G.M., G.C. Edwards, G. Dharwarkar, A. Steffen, P. Hazelwood, P.E. Rasmussen, W.H. Schroeder

Micrometeorological and chamber measurements of gaseous mercury flux in the Selwyn Basin, Yukon

Edwards, G.C., P.E. Rasmussen, W.H. Schroeder, G.M. Dias, S. Ausma, A. Steffen, P. Hazlewood

Chemical speciation of some metal pollutants associated with atmospheric particulate matter of varying size using X-ray Absorption Fine Structure (XAFS)

Lamoureux, M., N. Warner, J. Samson, V. MacKinnon, K. Lantz, T. Gordon, G. Grégoire

Localization of particulate fallout in soils of the Sudbury smelter footprint

Spiers, G.A., D. Pearson, A. Cheburkin, F. Prevost, A. Lock

7.2 <Processes>

Biogeochemical cycling in the Boreal forest - metal concentrations in woody tissues - Phase II

Bégin, C., M. Savard, M. Parent, J. Marion, A. Smirnov

Quantification and modelling metal mobility in Ross Lake, Manitoba, Canada: A TRANSPEC model application

Bhavsar, S., M.L. Diamond, L. Evans, P. Cypas, K. Rudnitski

The fate and speciation of zinc in Ross Lake: a mine-impacted lake in Flin Flon, Manitoba

Evans, L.J., K.D. Rudnitski, P. Cypas, M.L. Diamond, S. Bhavsar

Metal uptake routes for the biomonitor *Sialis*

Croisetière, L., L. Hare, A. Tessier

Increases in food web cadmium following reductions in atmospheric inputs to some lakes: value of a biomonitor to ERA

Croteau, M.N., L. Hare, A. Tessier

Burrowing behaviour of aquatic insect larvae as a determinant of metal exposure and effects

Gosselin, A., L. Hare, A. Tessier

Can metal speciation be predicted in fresh waters with low nickel concentrations using the competing ligand exchange method and adsorptive cathodic stripping voltammetry?

Guthrie, J.W., C.L. Chakrabarti

Relative fluxes of metals from foliage and fine roots to soils

Hale, B., D. Johnson

Speciation parameters for characterization of Ni, Cu, Pb and Zn species in lake waters, soil pore waters and throughfall samples

Hassan, N.M., J. Murimboh, F. Raoufi, A. Jamaluddin, L. Si, C.L. Chakrabarti

Foliar trace metal (Cu, Ni, Cd, Pb and Zn) input to surficial soils in contaminated northern forest ecosystems

Hale, B., D. Johnson

Evaluation of soil surface charge using a back-titration technique

Henderson, W., Y. Ge

Column soil solution extraction method produces solutions comparable to zero-tension lysimeter solutions. Applications to trace metals

Hendershot, W.H., J.D. MacDonald

Medium-scale variations in trace metal concentrations in podzolic soils of northern forests exposed to smelter emissions

Hendershot, W.H., J.D. MacDonald

Fluxes of trace metals between ecosystems pools, the influence of soil pH, organic matter, and species composition. Model design.

Hendershot, W.H., J.D. MacDonald, D. Johnson

Alleviation of trace metal rhizotoxicity

Hendershot, W.H., A. Voigt, G. Sunahara

Speciation parameters of copper in freshwaters by square wave adsorptive cathodic stripping voltammetry using the competing ligand exchange method

Raoufi, F., N.M. Hassan, A. Jamaluddin, J. Murimboh, C.L. Chakrabarti

Speciation parameters of cadmium in lake waters by the competing ligand exchange method using square wave anodic stripping voltammetry

Salam, M.S.A., N.M. Hassan, A. Jamaludin, F. Raoufi, J. Murimboh, C.L. Chakrabarti

In situ two-dimensional high-resolution profiling of sulfide in sediment interstitial waters

Wang, F., C. DeVries

A preliminary study on the stability of metal-sulfide complexes in oxic waters

Wang, F., K. Sukola, A. Tessier

7.3 <Impacts>

Effects of water source on metal bioavailability and toxicity from field collected sediments
Dixon, D.G., U. Borgmann, M. Nowierski

Critical body concentrations of 10 metals. The relationship between accumulation and chronic toxicity
Dixon, D.G., U. Borgmann, W.P. Norwood

Calculating equilibrium constants for metals and competing ions to the biological receptor in *Hyalella azteca*
Dixon, D.G., U. Borgmann, J. Schroeder

Subcellular partitioning of metals (Cd, Cu, Ni, Zn) in indigenous yellow perch collected along a polymetallic environmental gradient
Giguère, A., P.G.C. Campbell, L. Hare

Disruption of the HPI axis in 1⁺ yellow perch (*Perca flavescens*) exposed to metals
Gravel, A., P.G.C. Campbell, A. Hontela

Effect of ration quantity on tissue burden and cadmium toxicity in rainbow trout
Ho, C.G., K.A. Sloman, C.M. Wood, D.C. McDonald

The importance of a diverse prey base for efficient energy transfers to fish in lakes recovering from metal contamination
Iles, A., J. Rasmussen

Effects of dietary quality on the response to waterborne copper and cadmium exposure in trout: implications for Biotic Ligand Model-based risk assessment
Kamunde, C., A. Matsuo, B. Baldisserotto, G. Pyle, D.G. McDonald, C.M. Wood

Metals and aquatic communities: Interactions between metal exposure and fish diet
Kövecses, J., G. Sherwood, J.B. Rasmussen

Metal dynamics in juvenile yellow perch - a caging study
Kraemer, L., P.G.C. Campbell, L. Hare

The *in vitro* effect of cadmium on cortisol secretion by interrenal cells from Rainbow trout (*Oncorhynchus mykiss*) and yellow perch (*Perca flavescens*)
Lacroix, A., A. Hontela

Is there any relationship between critical tissue burden of cadmium and cadmium toxicity in comparing two disparate fish species?
Niyogi, S., C.M. Wood, D.G. McDonald

An *in vitro* approach for modeling branchial copper binding in rainbow trout
Taylor, L.N., D.W. Baker, D.G. McDonald, C.M. Wood

8 MILESTONES FOR YEAR THREE: RESEARCH DOMAINS

8.1 <Sources>

Executive Summary for FY 2001 - 2002:

Domain Co-Leaders:

Dr. Marc Lamoureux, St. Mary's University

Dr. Robert G. Garrett, NRCan, Geological Survey of Canada

Projects included in <Sources> Domain in FY 2001 - 2002:

Project Title	Principal/Co-Investigators	Affiliation
A1 Development and application of methods for measurement of metals on aeolian dust from natural settings	Edwards, G.C. Campbell, J.L.	School of Engineering, University of Guelph Dept. of Physics, University of Guelph
A2 <i>In situ</i> solid-state chemical speciation of metals in air particulates	Lamoureux, M.	Dept. of Chemistry, St. Mary's University
A4 Geochemical mobility of metals in surface sediments: influence of sediment diagenesis	Carignan, R. Tessier, A.	Dépt. Sci. Biologiques, Université de Montréal INRS-ETE, Univ. du Québec
A5 Development of analytical methods for chemical speciation of metals associated with atmospheric particulate matter/aerosols	Lu, J.Y.	Dept. of Chemistry, Biology & Chem. Engineering, Ryerson University
A6 Development of sensitive techniques for the chemical analysis of aerosolic particulates	Spiers, G.A.	Centre for Environmental Monitoring, Laurentian University
AF7 Health effects and continued use of the metals listed below as well as other metals defines a need for improved health from metals released <Cu, Cd, Ni, Hg, Pb, Zn, As>	Banic, C.	Meteorological Service of Canada
AF8 Redistribution of metals in lake sediments by bacterially mediated oxidation-reduction reactions	Gould, W. D. Alpay, S.	CANMET, NRCan Geological Survey of Canada, NRCan
AF9 The role of bacteria in the mobilization of arsenic from mine impacted sediments	Palace, V.	Freshwater Institute, DFO

Progress Toward Achievement of Objectives:

The research activities (approved 1998) in the <Sources> domain have the objective of estimating site specific metal loadings in differing ecosystems due to the atmospheric deposition of metals from anthropogenic and natural sources; and to determining if diagenetic processes modify chemical records in lake sediments preventing them being interpreted as records of historical deposition. These studies address the issue of origin in the ecosystem of metals that may pose public health and/or environmental threats, and will help identify appropriate risk management strategies. The objective will be achieved 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?

Studies in the <Sources> domain involve both field and laboratory components. Field work is undertaken both up- and down-wind from known metal sources to the atmosphere, and at remote sites. Laboratory studies include experiments under controlled conditions, and the development and use of appropriate analytical chemistry tools. In addition to the three ongoing projects (A1-A4) from 2000-2001, four new projects were initiated in 2001-2002. Two focus on the development of analytical and speciation procedures suitable for use with fine airborne and soil particulates, and two address biotic processes in lake sediments that influence the mobilization and sequestration of metals and trace elements. The methodologies developed for particulate analysis and speciation in 2001-2002 will be applied to samples collected in field-based projects in 2002-2003.

During the year, meetings of participants were held in conjunction with the 6th International Conference on the Biogeochemistry of Trace Elements, Guelph, July 29 - August 2, 2001, where a special poster session was presented that focussed on studies supported jointly by the Toxic Substances Research Initiative (TSRI) and by MITE-RN on metal emissions from smelters and stationary power facilities. Additional meetings were held in the fall (Montreal and Toronto) that brought together participants in the Environment Canada - TSRI - MITE-RN supported study of smelter and power facility emissions to discuss and integrate research results.

At the Science Steering Committee meeting in Guelph, October 4, 2001, a knowledge gap concerning the fluxes of metals due to weathering processes was identified, as was the need for a water/precipitation filtration protocol to separate fluids from particulates. The co-domain leaders worked with members of the Research Network and a potential new member to develop a proposal to address the identified knowledge gap. Also, a draft protocol for handling fluid samples was prepared and is currently open for discussion, with plans for implementation in 2002 field studies. Progress reports have been submitted on a regular basis since 1999 outlining progress towards annual milestones, achievement of objectives, and problems encountered. The highlights from the 2001-2002 submissions have been compiled below.

Project A1 Development and application of methods for measurement of metals on aeolian dust from natural settings (G. Edwards, University of Guelph): The planned field work in the Selwyn Basin, Yukon, was successfully completed, though wet and rainy conditions influenced data and sample acquisition. Both chamber and micro-meteorological determinations of gaseous mercury fluxes indicated similar evasion rates (i.e. no significant difference in measurement techniques) at sites characterized by both bare and vegetated surfaces. Cascade impactor filters were collected to study airborne particulate matter concentrations, and to determine trace metal concentrations fractionated by particle size. These samples are currently being analyzed. The resulting data, together with wind speed and direction, will be used for source apportionment studies. Source apportionment studies using PIXE cascade impactor data were completed for the previous field investigations at Thunder Bay and Rouyn-Noranda that differentiated between locally (substrate erosion) and non-locally derived particulates.

Project A2 In situ solid-state chemical speciation of metals in air particulates (M. Lamoureux, St. Mary's University): Speciation is critical to determining the fate and bioavailability of metals in airborne particulates. This project is investigating the applicability of synchrotron light source X-ray Absorption Fine Structure (XAFS) analysis of particulates collected with high-volume samplers equipped with 5-stage cascade impactors up- and down-wind from the Horne smelter at Rouyn-Noranda, Quebec. Studies of Cu and Ni speciation as a function of particle size have been completed and indicate that Cu speciation varies with particle size, with CuSO_4 dominant in finest size fractions. The detection limit for Ni was too high for Ni speciation to be studied in all but the finest size fraction, where Ni was observed in the oxide form. Results for Pb speciation will be available in 2002. Pb-isotope determinations have been completed and show clear differences between isotope ratios up and down-wind from the Horne smelter; some ratios decrease with decreasing particle size. Combination of this new information with speciation results will provide greater insight as to the source(s) of Pb in different aerosol size fractions, and facilitate source apportionment between natural and anthropogenic aerosol sources.

Project A4 Geochemical mobility of metals in surface sediments: influence of sediment diagenesis (R. Carignan, Université de Montréal): This year sediments from three lakes in a high metal loading area (Rouyn-Noranda) were sampled together with sediment porewaters. Analyses of these sediments, and sediments previously collected from medium and low metal loading areas, were continued for a range of metals of MITE-RN concern and environmental indicators (C and N). In addition, isotopic analyses have been completed in order to establish sedimentation rates and verify the undisturbed status of the profiles. One lake in the low metal loading area has been recognized as disturbed, possibly due to water level changes, and an alternate lake will be sampled in 2002. Analyses of the 2001 porewaters are underway and are partially completed at this time. The investigation of the application of diffusive gel technology (DGT) to low ionic strength Boreal Shield lake porewaters continues, but a number of challenges still prevent successful application of this potentially very useful tool to Shield lakes. With the exception of the re-sampling exercise, field phases of this project are now complete. This project will contribute new knowledge concerning the diagenetic processes taking place in lake sediments, and determining which chemical elements under what conditions yield historical records that reflect metal deposition into a lake basin.

Project A5 Development of analytical methods for chemical speciation of metals associated with atmospheric particulate matter/aerosols (J.Y. Lu, Ryerson University): The fate of a trace element (metal) in the environment is a function of its speciation, and therefore its reactivity with other chemical species present. This may lead to sequestration or deposition, or transport to another compartment, and will affect its ability to be incorporated in biotic processes (bioavailability). This project is focussing on determining the speciation of mercury in the atmosphere, where it is presently associated with fine particulates, aerosols, and as gaseous mercury. A thermal desorption - ICP-MS procedure has been developed that requires no sample pre-treatment, and has been calibrated using fly-ash spiked with various inorganic mercury compounds, i.e. Hg^0 , HgCl_2 , HgS and HgO . These are released over characteristic temperature ranges, which permits their identification in “unknown” samples of atmospheric aerosols. Research has commenced on As, Se, Cr, Ni, Cd, Zn and Pb; high condensation temperatures are posing operational challenges which require practical solutions. Links have been established with other Network researchers which will result in this methodology being applied to samples collected in their studies.

Project A6 Development of sensitive techniques for the chemical analysis of aerosolic particulates (G.A. Spiers, Laurentian University): A major challenge in a number of areas of MITE-RN research is obtaining reliable chemical analyses of small particles, which may result from anthropogenic processes or by natural mineral fragments. This project builds on recent progress in non-destructive Micro-Beam X-ray spectrometry (EMMA) to develop an advanced version capable of meeting MITE-RN science needs, i.e. $>20 \mu\text{m}$ single particle analysis with detection limits of the order of 1-5 ppm ($\mu\text{g}\cdot\text{g}^{-1}$) for high mass elements of interest to Network researchers, e.g., Ni, Cu, Zn, Pb, As, Se, etc. A prototype instrument has been constructed and successfully tested using natural and anthropogenically produced particles recovered from snow. Development of instrument calibration procedures, to ensure accuracy of determinations, is underway; resolution of this problem requires innovation to ensure standard reference material homogeneity due to the very small amounts of material being analyzed. Links have been established with a number of current and proposed projects that will lead to the utilization of the EMMA technology to assist them in achieving their objectives.

Project AF7 Physical and Chemical Evolution of Aerosols in Smelter and Power Plant Plumes (C.M. Banic, Meteorological Service of Canada, Environment Canada):

National and international concern about the health effects and continued use of Pb, Cd, As, and Hg as well as other metals has defined a need for improved estimates of the long term risks to ecosystems and human health from metals released from mining, metallurgical, and energy production activities. In this project a research aircraft was used to determine the microphysical and chemical properties of airborne particulate metal emissions from the Nanticoke coal-fired power generating station located on the north shore of Lake Erie, Ont. and the Horne copper smelter at Rouyn, Que. Four intensive field campaigns, each of almost 3 weeks, were conducted in 2000. Both plumes were sampled up to 40 km downwind of the source for ageing times of up to 1 hour in a variety of meteorological conditions. The size distribution of particles emitted from the sources, the metal content of the particles (with emphasis on Ni, Cu, Pb, Zn, Cd, As, Se and Hg) and the distribution of metals by particle size were determined. These data are being used in a model to estimate the concentration of metals in air and their deposition to the surface on both local and regional scales. Results of the study show that the deposition to the surface of metals in the particle size range observed in the plume is insignificant within 100 km of the sources. The data collected in this study are needed for policy decisions regarding emissions from different sources.

Project AF8 Redistribution of metals in lake sediments by bacterially mediated oxidation-reduction reactions (D. Gould, Natural Resources Canada): The focus of this new project is to investigate the role of biotic processes in mediating species changes in iron and sulphur in lake sediments, and their subsequent mobilisation and fate. Field sampling of lake sediments was successfully completed in August and October 2001, and bacterial enumeration studies have quantified the occurrence of acid producing, iron reducing and sulphur reducing bacteria. The sulphur-reducing bacteria show similar trends in all profiles with increases in abundance by several orders of magnitude in the upper parts of the profiles. A series of microcosm experiments are underway where sediments spiked with combinations of iron as ferrihydrite and organic carbon as casamino acids are covered by unamended sediments and water. Sampling of these commenced in January 2002 and the distribution of bacteria and the translocation of iron in the microcosms is being determined. The results will provide insight into the processes, in particular biotic processes, that influence metal distributions in lake sediments. This knowledge is important in determining the fate of metals introduced into lake sediments from anthropogenic sources, and for assessing the validity of lake sediment geochemical records as valid historical records of deposition (cf. project A4).

Project AF9 The role of bacteria in the mobilization of arsenic from mine-impacted sediments (V. Palace, Dept. of Fisheries and Oceans): This new project is investigating bacterial mobilization of As(V) in gold-mining impacted lake sediments (Balmer Lake, NW Ontario). Work this year has largely focussed on isolating and characterizing As-reducing bacteria from Balmer Lake sediments. A bacterial strain, designated VC-1, has been identified that rapidly accumulates As(III). This species will be focus of studies in a series of limnocorral experiments to be carried out in 2002 to determine the capacity of Balmer Lake sediments to reduce As(V) to As(III), the

species with the greater ecotoxicity, and the role of organic carbon in influencing the kinetics of the transformation. The knowledge accrued will assist in reducing the uncertainty in determining the risks associated with past and future As-containing effluent releases to the aquatic environment.

Partnerships and Collaboration:

Participants in the <Sources> domain include: Iain Campbell and Zdenek Nejedly (A1, Department of Physics, University of Guelph); Pat Rasmussen (A1, Health Canada); Bill Schroeder, Cathy Banic and Sunling Gong (A1 & A5 [except S. Gong], Meteorological Service of Canada); Dr. T. Sholtz (A1, Ortech International Inc.); Conrad Grégoire (A2 & A5, Natural Resources Canada); Grant Edwards (A5, University of Guelph); Andriy Cheburkin, (A6, Laurentian University); F. Rosenzweig (AF1, University of Florida); Chris Le (AF1, University of Alberta); J. McGeer, C.W. Smith, and J. Dutrizac (AF2, Natural Resources Canada). In summary, 25 scientists from 13 institutions (universities, Federal departments and industry) are collaborating in 7 funded projects. Networking is strengthened by participation of some scientists in more than one project. In addition, the 7 projects are supporting 6 students working towards graduate degrees and 8 undergraduates; and are supported by 7 P.D.F.s and research assistants, and 4 technicians.

8.2 <Processes>

Executive Summary for FY 2001-2002

Domain Co-Leaders:

Dr. Beverley Hale, Land Resource Science, University of Guelph

Dr. Gary Rawn, Fisheries and Oceans Canada

Projects included in the <Processes> Domain:

Project Title	Principal/Co- Investigators	Affiliation
B1 Post-depositional mobility of trace metals in boreal forest ecosystems	Hale, B.A. Hendershot, W.H.	Land Resource Science, University of Guelph Natural Resources, McGill University
B2 Development of rational models for relating metal accumulation by aquatic animals to metal concentrations in their environment: Relative importance of ambient metal sources	Hare, L. Tessier, A. Yan, N.	INRS-Eau, INRS, Université du Québec INRS-Eau, INRS, Université du Québec Ontario Ministry of the Environment
B3 Quantification and modelling of metal mobility in lakes and watersheds	Evans, L. Diamond, M.	Land Resource Science ,University of Guelph Geography, University of Toronto
B4 Metal-organic interactions in soils, soil solutions and freshwaters	Chakrabarti, C.L. Grégoire, D.C.	Chemistry, Carleton University Geological Survey of Canada
B5 The availability of trace metals in the rhizosphere of contaminated soils from the Sudbury area	Courchesne, F.	Université of Montréal
B6 Metal budgets of lakes and catchments on the Precambrian Shield: Compartment sizes and fluxes between compartments	Dillon, P.J. Watmough, S.	Environmental and Resource Studies/Chemistry, Trent University
B7 Importance of reduced sulfur species in controlling metal speciation in surface waters on the Canadian Shield	Wang, F. Tessier, A.	Chemistry, University of Manitoba INRS-Eau, INRS, Université du Québec
BF1 Biogeochemical cycling in the boreal forest – metal concentrations in woody tissues – Phase II	Bégin, C. Savard, M.M.	Geological Survey of Canada Sainte-Foy, Quebec

Progress Toward Achievement of the Objectives:

The <Processes> Domain focuses on the partitioning of metals among terrestrial and aquatic environmental compartments. Studies in this domain are designed to establish relationships between the total metal in an environmental compartment and the proportion of this metal that is available for accumulation by aquatic and terrestrial organisms. Data generated from these studies will contribute to a better understanding of the relationship between total metal and the bioavailable fraction. These relationships are being determined in environments that are typical of those receiving metal loadings from anthropogenic sources of metals in Canada. This will allow researchers to develop stronger chemical and biological relationships between trace metal exposure and organism response and will strengthen our ability to assess ecological risk.

Current projects in the <Processes> Domain focus on:

- the cycling of metals between soils and plants;
- the establishment of relationships between metal concentrations in aquatic organisms and those in their surroundings;
- the determination of the importance of food as a metal source for aquatic animals; and
- the modeling of trace metal complexation and partitioning in soils and water.

Project B1 Post-depositional mobility of trace metals in boreal forest ecosystems (B. Hale, University of Guelph):

The goal of this project is to characterise the distribution and movement of trace elements, which are emitted from smelters, within a boreal forest ecosystem. This goal has largely been achieved, with the identification of fine roots and the upper layers of soil as the most important sites for the biogeochemical cycling of trace elements. This information is needed in order to predict the long-term fate of metals after deposition and this research will ultimately contribute to the ecological risk assessment (ERA) of metal emitting activities on forest health and productivity by improving estimates of exposure. The following objectives have been completed and are the subject of three Ph.D. theses that will be defended in the spring of 2002:

- Determination of trace metal fluxes through soils along transects downwind from smelters in Sudbury and Rouyn, as well as the properties of the soils responsible for the high concentrations of trace metals near the soil surface.
- Quantification of trace metal concentrations and pools in the roots, bark, trunk and foliage of plant species, as well as the return of trace metals to the surficial soil environment through decomposition of foliage and fine root biomass.

Project 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, Université du Québec, INRS):

The overall goal of this research is to develop and field test theoretically-based models that relate metal concentrations in organisms to those in their surroundings. To develop such models the chemical and biological processes involved in metal bioavailability and bioaccumulation must be better understood. Identifying whether food or environmental media (or both) are the important metal exposure pathways for aquatic animals has ramifications for the exposure characterization step of ERA. Much progress has been made to determine the influence of animal burrowing and irrigation behaviour on metal exposure in sediment. Techniques incorporating micro-electrodes, infrared photography, and X-ray imaging were used to determine the depth to which larvae burrow, and their orientation and movements in the sediment. Investigations to determine the relative importance of food and water as metal sources for insect larvae continued throughout the year. The feeding habits of two contrasting *Chaoborus* species were compared. Stomach content analyses of the two *Chaoborus* species are underway, as are counts of zooplankton prey and *Chaoborus* densities at various depths, times and days. Water as well as the insect *Sialis* and the crustacean *Hyaella* were collected from several lakes in the Rouyn-Noranda and Sudbury areas to determine if these animals could be used as biomonitors. The aquatic moss *Fontinalis* was also collected to determine if this plant could be used as a metal biomonitor in running waters.

Project B3 Quantification and modelling of metal mobility in lakes and watersheds (L. Evans, University of Guelph):

The goal of this research project is to develop a general model of metal chemistry and fate in an aquatic system. There is a need to link metal emissions and loadings to lakes with resultant concentrations and distributions within lakes. This linkage provides the pathways analysis component necessary to predict compartment-specific concentrations of metals, thus improve the ERA exposure characterization for biota in those compartments. To allow for model application and evaluation, the model was used to estimate the fate of zinc and copper in Ross Lake, Manitoba. Due to its complexity, this lake has provided a rigorous test for various aspects of the model, TRANSPEC (Transport and Speciation Model). Weekly water, pore-water, and sediment samples were collected from December 1999 to January 2001. These samples have been, and continue to be, analyzed in order to ascertain chemical processes and seasonal trends occurring in the lake. A multi-species version of QWASI (Quantitative Water Air Sediment Interaction) model for aquatic systems has been adapted for coupling with a speciation/complexation model. The steady-state model provided results for metal fate and transport for four seasonal snapshots, namely spring, summer, fall and winter. Development of the unsteady-state version of the fate model has now been completed and is being calibrated and tested with results from the field studies. The main tasks of coupling the speciation/complexation and fate models have been accomplished. The coupled model, TRANSPEC, has been parameterized to estimate metal fate in Ross Lake. Model accuracy is defined as the proximity of model results, after calibration, to the observed field data. Model testing is ongoing.

Project: B4 Metal-organic interactions in soils, soil solutions and fresh waters (C.L. Chakrabarti, Carleton University)

Substantial progress has been made on the determination of metal speciation in two groups of samples: soil pore waters and through-fall precipitation samples supplied from the Rouyn-Noranda and Sudbury areas by W.H. Hendershot (Project B1, <Processes>) and fresh water samples supplied by P.G.C. Campbell (Project C3, <Impacts>) from Opasitica Lake, Vaudray Lake, Osisko Lake, and Dufault Lake. Analysis has been accomplished by electrochemical techniques using the Competing Ligand Exchange Method (CLEM) for Cu, Cd, Zn, Pb, and Ni. In addition, total organic carbon, dissolved organic carbon, other metals, metalloids, NH₄ cations, anions, conductivity and pH were determined for these samples. The sample volumes of soil pore waters were often so small (usually 100–200 mL) as to make them generally unsuitable for electrochemical metal speciation techniques. While electrochemical metal speciation techniques are generally superior in terms of accuracy, the only metal speciation techniques that could be applied to such small samples volumes were CLEM/GFAAS and ULTRAFILTRATION/GFAAS. The development and application of methods to assist in differentiating natural from anthropogenic sources of metals and to provide speciation data needed for assessing the risk to ecosystems from these sources is critical to ERA exposure characterization.

Project B5 The availability of trace metals in the rhizosphere of contaminated soils from the Sudbury area (F. Courchesne, Université de Montréal):

The long-term objective of this project is to establish the contribution of rhizospheric processes to the cycling of trace metals in forest soils. Ultimately, this work will help address questions such as whether rhizosphere soil or bulk soil should be used for quantifying and modelling the exposure, mobility and uptake of metals by the plants. The answer to this question may have serious implications for characterizing exposure of plants to metals for ERA. Soils were collected at three locations in the Sudbury area and the soil material adhering to the roots (rhizosphere) was collected in the B horizon under different trees. The soil matrix (bulk soil free from roots) was also collected away from individual roots. The process of separating soil samples into bulk and rhizosphere components (both inner and outer rhizosphere) was completed in the laboratory. This separation process was a delicate operation that took about four to twelve hours per sample. It necessitated more than six weeks of work for the whole set of twenty rhizosphere materials. Textural and mineralogical analyses of the soil samples will be conducted in 2002 together with pH (H₂O) and organic C determinations. The fractionation of metals (Al, Cd, Cu, Fe, Pb and Zn) and the subsequent analyses by ICP-AES or ICP-MS will then be carried out. The method development for measuring the free Cu²⁺ activity in water extracts from these soils using an ion selective electrode or ASV will follow.

Project B6 Metal budgets of lakes and catchments on the Precambrian Shield: Compartment sizes and fluxes between compartments (P Dillon, Trent University):

The goal of this project is to establish the size of the compartments or pools of metals and the fluxes between compartments in a catchment (Plastic Lake) that is not impacted by local point sources. The work conducted in this study will provide information on two critical components of ERA exposure characterization: on metal budgets in uncontaminated Canadian Shield lakes and catchments (for comparison with budgets of contaminated ecosystems), and on factors controlling fluxes of metals between aquatic and terrestrial environments. This project was initiated part-way through 2001-02, with actual work beginning in August. The specific objectives for the first year included establishing the necessary new field instrumentation which is now complete with the exception of the precipitation collectors. Evaluation of suitable analytical methods for aqueous samples is on schedule, and sample collection to measure metal fluxes through the catchment is underway. As part of other ongoing studies, samples suitable for estimating the metal pool sizes in the soil and forest biomass were collected and will be analyzed this winter/spring (ahead of schedule). Samples for wetland biomass and lake sediments will be collected and analyzed in early summer. Database design is almost complete.

Project B7 Importance of reduced sulfur species in controlling metal speciation in surface waters on the Canadian Shield (F. Wang, University of Manitoba):

The objectives of this proposed project are: i) to investigate the presence of metal complexes with reduced sulfur species (RSS) in oxygenated surface waters on the Canadian Shield; and ii) to determine the relative importance of metal-RSS complexes in controlling metal speciation in these surface waters, as well as in sediment interstitial waters. This research will provide important information on the origins of the metal-RSS complexes and will allow better predictions of metal speciation in water, a key component of exposure characterization for ERA. All of the methodological development and testing has either been completed or is ongoing. Method development and testing included: colorimetric methylene blue (MB) method for the measurement of sulfide in metal-RSS complexes, square-wave cathodic stripping voltammetric (SWCSV) method for the measurement of sulfide in metal-RSS complexes, and identification of metal-RSS clusters/complexes by mass spectrometry (MS). By using dialysis samplers and SWCSV, the solubility of rhombic sulfur was determined. The determination of the solubility of rhombic sulfur allowed for important revisions to both the HYDRAQL and WHAM equilibrium speciation models. As well, the original computer codes of WHAM were revised. HYDRAQL and WHAM models can now be readily used for calculating metal speciation in the presence of sulfide and polysulfides. Four lakes were studied in the field program. Sampling was conducted with dialysis samplers (“peepers”) and calculations will be made to estimate to what extent sulfide concentrations can affect metal speciation. Porewater data on polysulfide, sulfur, pH, DOC, major ions and metals have been or are being analyzed. Once all the data are available, HYDRAQL and WHAM will be used to calculate the speciation of polysulfides and metals.

Project BF1 Biogeochemical cycling in the boreal forest – metal concentrations in woody tissues – Phase II (C. Bégin, Natural Resources Canada, M.M. Savard, Geological Survey of Canada):

The quantitative characterization of heavy metals in wood of the boreal forest is the main objective of the proposed research. This type of survey in the northern environment constitutes a major Canadian environmental need for ecological, health, and political reasons. A 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 ERA process for metals in the environment. Two boreal forest sites were re-sampled for the evaluation of the total metal content in woody tissues. The biomass evaluation methodology developed last year (Report 2000-01) was adapted to the study of the balsam fir, paper birch, and aspen species. The number of investigated trees has been reduced in response to the funding level we received for the period of investigation. Detailed measurements were made to calculate the biomass of every tree. At the GSC Tree-ring laboratory, all wood samples were prepared for metal analysis. Samples (n: 648) were submitted to the INRS geochemistry lab for metal analysis by ICP-MS / ICP-AES. Analyses are ongoing as are calculations of total biomass of woody tissues.

Partnerships and Collaboration

Hendershot (Hale project) is sharing field lysimeter solution samples with Chakrabarti, who is testing his analytical methods for trace metal concentrations and speciation. There will be interaction between the Dillon and Hale projects, in the sharing of our compartment data with theirs, for the purposes of validation. The Bégin project will provide information on deposition of woody tissues to forest soils and their decomposition. These data will be combined with the Hale decomposition data for fine roots and leaf litter to complete the estimates of biogeochemical cycling of trace elements in northern forests.

8.3 <Impacts>

Executive Summary for FY 2001-2002

Domain Co-Leaders:

Dr. Peter G.C. Campbell, Université du Québec, INRS, INRS-Eau

Dr. Uwe Borgmann, Environment Canada, National Water Research Institute

Projects included in the <Impacts> Domain:

Project Title	Principal/Co-Investigators	Affiliation
C1 Predicting metal and metal mixture effects in aquatic biota	Dixon, D.G. Borgmann, U.	Biology, University of Waterloo NWRI, Environment Canada
C2 Assessing biological effects of chronic metal exposures to fish-laboratory studies	Wood, C.M. McDonald, D.G.	Biology, McMaster University
C3 Links between tissue metal burdens in indigenous fish and metal-induced effects at the organism and population levels	Campbell, P.G.C. Hontela, A. Rasmussen, J.B.	INRS-Eau, INRS, Université du Québec Biologie, Université du Québec à Montréal Biology, McGill University
C4 Accumulation and effects of environmental metals in fish-eating birds	Chan, L.H.M. Scheuhammer, A.M.	Diet . Human Nutrition McGill University CWS, Environment Canada
CF1 Quantitative synthesis of aquatic environmental effects studies for metal mines of the Precambrian Shield	Graptine, L.	NWRI , Environment Canada
CF3 Impacts of metal-contaminated forest soils from the Canadian Shield on terrestrial organisms	Scroggins, R. Stephenson, G. Feisthauer, N.	ETC, Environment Canada Aquaterra Environmental, Guelph, ON. ESG International, Guelph, ON.

Progress Toward Achievement of the Objectives:

The <Impacts> Domain specifically targets research on freshwater ecosystems. Aquatic environments, and in particular sediments, represent a very important sink for metals that are introduced into the surficial environment. As well, aquatic organisms are inherently vulnerable to metal pollution because dissolved metals are recognized to be more bioavailable than those associated with solids. The research includes both laboratory studies under controlled conditions and fieldwork along existing metal gradients (downwind and downstream from past/current metal smelters). At the conceptual level, clear linkages exist among the projects making up the <Impacts> program, e.g.: influence of metal speciation on metal bioavailability; importance of food and/or sediments as vectors for metal uptake; elucidation of metal detoxification mechanisms; detection of sub-clinical metal-induced effects in indigenous aquatic organisms and their predators.

The current <Impacts> projects are designed to strengthen the links between metal speciation / partitioning in the exposure media and:

- metal accumulation by exposed organisms (tissue/body metal concentrations in indigenous organisms);
- metal speciation within the exposed organism (notions of metal essentiality, metal detoxification); and
- metal-induced effects at the organism and population levels.

Project C1 Predicting metal and metal mixture effects in aquatic biota (D.G. Dixon, University of Waterloo):

The objectives of the proposed research are: i) to determine which methodology most accurately predicts biological effects of single metals (free metal-ion concentrations, alkalinity-pH-DOC-water concentration regressions, or body concentrations); and ii) to determine if metal speciation modelling or body concentration measurements can improve our ability to predict the effects of metals in mixtures. This work will allow metal speciation and uptake (pharmacokinetic) models to be linked for more meaningful and defensible metals ecological risk assessment (ERA). Using *Hyalella azteca* individual chronic bioaccumulation/toxicity tests have been completed for As, Co, Cr and Mn. Modeling of the bioaccumulation to toxicity relationships is complete and accurate prediction of biological effects based on whole body concentrations is possible. These results and previously published data for Cd, Cu, Ni, Pb, Tl and Zn have been combined into metal mixture models. Chronic metal mixture bioaccumulation/toxicity testing will verify these models and detect metal interactions. Nickel bioaccumulation studies are completed and metal species and competing ions were calculated with the MINTEQA2 chemical speciation model. Experiments will be conducted under different exposure conditions to confirm estimations of nickel and the true amount of ligand available for binding. Food and gauze effects on bioaccumulation and time to equilibrium were estimated from measurements of body concentrations over a 7-day period. This estimate established the minimum exposure time required to compare nickel uptake between fed and non-fed organisms. These experiments will be completed early in 2002. Bioaccumulation and toxicity tests using sediments collected from two lakes in Sudbury, Ontario and from three lakes in Rouyn-Noranda, Quebec are complete. Site and laboratory overlay waters were compared

with bioaccumulation and toxicity results to determine impact on metal bioavailability/toxicity. Critical body concentrations (LBC25) in *Hyaella* have been used: i) to identify those metals causing adverse effects; and ii) to compare the effects of various overlay waters on metal bioavailability and toxicity.

Project C2 Assessing biological effects of chronic metal exposures to fish – laboratory studies (C. Wood, McMaster University):

The long term objectives of this project are to use laboratory studies to understand and model the chronic impacts of waterborne and dietary Cu, Cd and Zn on the health of fish in the environment with the ultimate goal of developing a Biotic Ligand Model (BLM) for *chronic* toxicity via both exposure routes. Chronic BLMs will be of particular use in Canada, where the regulatory emphasis in ERA is placed more strongly on chronic impacts. This work will thereby benefit all three ERA objectives of the MITE-RN program - a re-evaluation of the overall risk of metals in the global environment, and an improved framework for both regional and local risk assessment in metal-impacted areas of Canada. The important objectives for this year were: (i) to develop an *in vitro* gill binding method for assessing copper toxicity; (ii) to develop our understanding further on the influence of dietary quality and quantity on the impacts of both waterborne and dietary metals, using rainbow trout (RBT) as a model system; (iii) to develop an acute BLM for Cd in yellow perch; and (iv) to explore all those factors that may affect the development of BLMs for chronic toxicity. Development of an *in vitro* gill binding assay for copper in RBT is now complete and the results suggest that gill-binding characteristics are not in equilibrium, but rather reflect a continually changing process over time with respect to water chemistry variables. Major progress has been made in the ongoing study on the role of quantity and quality of diet on metal toxicity. The protective role of dietary quality (Na⁺ content) on waterborne copper toxicity and Na⁺ homeostasis have been demonstrated. Work is now being extended to Cd and is at an advanced stage. The results so far support the hypothesis that reduced bioavailability of Cd to the gill might explain some of the inter-species differences in Cd sensitivity. They also imply a probable role for Ca in differentiating species sensitivity to Cd.

Project C3 Links between tissue metal burdens in indigenous fish and metal-induced effects at the organism and population levels (P.G.C.Campbell, Université du Québec, INRS):

Inter-lake variability in the responses of indigenous yellow perch (YP) collected from lakes situated along a marked metal concentration gradient is being assessed. The following generalizations are based on the work to date: (i) in juvenile and adult YP, metal levels increase in all body parts along the metal concentration gradient, with higher concentrations in the kidney and liver than the other tissues, but there is no indication of a change in relative tissue burdens along the gradient; (ii) in juvenile YP (liver), at the subcellular level, marked accumulation of Cd and Cu occurs in the subcellular fraction containing mitochondria and lysosomes; (iii) tissue metallothionein levels increase along the exposure gradient; (iv) physiological effects tend to increase in the sequence YOY < 1⁺ < adult perch; (v) adult and 1⁺ perch collected from the more contaminated lakes exhibit endocrine impairment and a reduced capacity to mobilize glycogen reserves, but YOY do not; (vi) growth efficiency is lower in the more contaminated lakes; (vii)

benthic invertebrate communities become depauperate (less diverse, less favourable as prey items) in the more contaminated lakes. Aspects that remain to be elucidated include (i) the relative importance of direct metal effects on the indigenous fish (via aqueous and/or dietary exposure) *vs.* indirect effects on the fish population via the food web, and (ii) variations in the reproductive status of perch populations in the various lakes along the metal concentration gradient. The results of this project will contribute most to the ERA of Cd and Zn, but should also yield relevant results for Cu, Ni and Pb. In ERA environmental managers must establish credible links between metal exposure and metal bioaccumulation, and then between metal accumulation and the incidence of deleterious metal-induced effects. The research in this project, together with the laboratory work on yellow perch being carried out in Project C2 (Wood and McDonald), will improve our understanding of both these links.

Project C4 Project: Accumulation and effects of environmental metals in fish-eating birds (L.H.M. Chan, Macdonald College, McGill University):

The general objective of this proposal is to determine the extent to which environmental metal contamination is causing adverse effects in avian wildlife populations in Canada. Specifically the research is aimed at determining where, and under what physico-chemical conditions, fish-eating wild birds in Canada are at risk for mercury (Hg) exposure sufficiently high to produce negative impacts on their health or reproductive success. ERAs will benefit from an improved predictability of the adverse effects of dietary methyl Hg exposure in fish-eating wildlife. Field collections for studies of food chain Hg accumulation and transfer are now complete at three sites (Rouyn-Noranda, Lake Pinchi and Clyde Forks). Hg and Se analyses on all samples are currently underway. There was no direct relationship between Hg exposure and immunotoxicity in common loons both *in vivo* and *in vitro*. Good progress is being made in the field study comparing fish-Hg levels and Hg exposure in loons living in different environments (different natural background levels of Hg, different environmental chemistry, and different levels of anthropogenic activity). Hg and Se speciation are currently being characterized in two experiments in which doves were dosed with different levels of Hg and Se to study how the interactions of Hg and Se may modulate the toxicity of both elements.

Project CF1 Quantitative synthesis of aquatic environmental effects studies for metal mines of the Precambrian Shield (L. Grapentine, Environment Canada, NWRI):

The objective of this project is to quantitatively evaluate existing data sets and/or reports of effects of metal mining activities on natural aquatic communities in the Canadian Shield using meta-analysis. The results of the analyses will be directly applicable to the ERA for metals. The problem formulation and study outline, including identification of research questions (testable hypotheses), scope of study, potential sources of data sets, and statistical procedures has been completed. Compilation of aquatic environmental effects data from studies on metal mine sites of the Canadian Shield has also been completed. The conversion of compiled data into the proper format for meta-analyses is ongoing but the stated research questions will not be answered until the completion of data analyses in 2002.

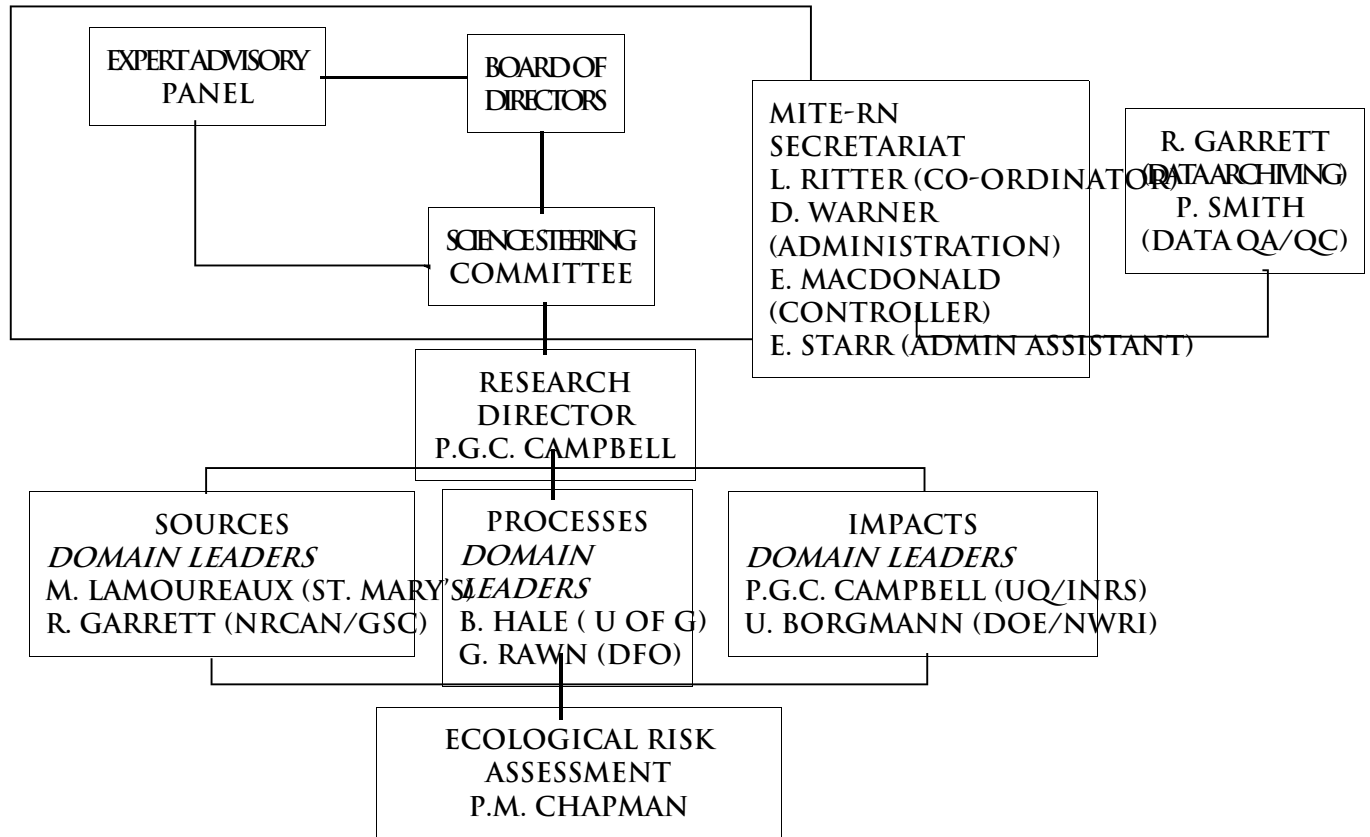
Project CF3 Impacts of metal-contaminated forest soils from the Canadian Shield on terrestrial organisms (R. Scroggins, Environment Canada, ETC):

The project objectives of Phase 1 were: i) to determine the toxicity of metal-contaminated forest soils, collected from three sites on each of two established transects, to a terrestrial test battery using single species sublethal toxicity tests and functional assays, and ii) to assess the applicability of the terrestrial toxicity test methods, developed by Environment Canada using agricultural soils, to forest soils and to determine any methodological modifications that might be required. Acute (lethal) and chronic (sublethal) tests have been conducted in all six (undiluted) soils with one plant, one earthworm and one arthropod species. Acute soil toxicity dilution tests are currently underway with soils that were found to be toxic following undiluted tests. Dilution tests will investigate the proportion of toxic site soil (diluted with forest soil with background metal soil levels) where toxicity no longer occurs. Chronic dilution tests will follow the completion of acute tests. Testing with functional assays has not yet been conducted. The test methods developed by Environment Canada for assessing acute and sublethal responses in invertebrates and plants were applied successfully to measure soil toxicity using forest soils as a measure of soil quality. Acute lethality tests as well as definitive and chronic reproduction tests methods developed by Environment Canada were successfully applied. The data derived from this research should be utilized to complement existing MITE-RN studies in the Processes Domain and to ultimately provide additional data required for assessing the potential risk to terrestrial organisms associated with metal contamination in soil. The effects data will provide a crucial link between the metal levels in the environment and the potential risk to terrestrial organisms associated with the deposition of metals.

Partnerships and Collaboration

Participants in the <Impacts> domain from non-university sectors include U. Borgmann (C1: NWRI, Environment Canada), R. Prairie (C3: Noranda Technology Centre), L. Belisle (C3: Quebec Department of Wildlife, Agriculture and Fish) and A.M. Scheuhammer (C4: Canadian Wildlife Service, Environment Canada). University partnerships include P. Couture (Laurentian University) as a partner for field studies on physiology of perch in metal impacted lakes, and R. Playle (Wilfrid Laurier University) for collaboration on Biotic Ligand Modelling. Informal meetings of <Impacts> students and researchers have been held with researchers from the <Processes> domain at the last three annual meetings of the Society for Environmental Toxicology and Chemistry, including that held in Baltimore in November 2001.

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 Network partners and for integrating research results into a comprehensive and useful product for potential stakeholders, lies with the MITE-RN Science Director:

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9.2 Data Archiving Co-ordinator

A web site is being designed by Mr. Steve Kingston in collaboration with Dr. Robert Garrett, Geological Survey, Natural Resources Canada, to display network meta-data files. A prototype meta-data format has been developed 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. These meta-data files will be posted on the web site in late 2002, and actual data set should be available on request in late 2003.

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9.3 Quality Assurance/Quality Control

In order to evaluate the quality of data generated by MITE-RN researchers, each laboratory is required to submit a QA/QC report outlining: training requirements of analytical staff and graduate students, type of analytical measurements carried out and quality control protocols used. To date, all MITE laboratories have submitted a QA/QC report.

They are also required to participate in one of the two inter-laboratory performance studies conducted annually by NLET (National Laboratory for Environmental Testing, of Environment Canada at the National Water Research Institute). To date MITE-RN researchers have participated in eight evaluation exercises. Six of these studies have focused on trace elements in surface waters with one preliminary study on sediments and one on trace metals and methyl mercury in biota.

Data quality is evaluated in terms of the percent biased parameters (systematic bias) and flagged results (precision measurement). Results for a parameter (element) are assessed to be biased when they are consistently ranked to be approximately 5% higher or lower than the median result. Results are flagged when a value is beyond the median(target value) plus or minus the acceptable difference. Over the six trace elements in surface waters studies MITE-RN researchers have been rated from moderate, satisfactory to good. The definition of % biased and flagged results ratings is as follows: Good = 0- 4.99% , Satisfactory = 5-12.49% , Moderate = 12.5- 29%, Poor = >30%.

As part of the ongoing commitment to quality control and assurance for MITE-RN laboratories, researchers are now required to submit annual reports. These reports include: any changes in personnel, procedures, or laboratory equipment, a summary of participation in the NLET inter-laboratory studies including why they had problems (if any) with particular elements and how they remedied them, and a summary of typical QA/QC results from the laboratory. These results include method detection limits, % recovery of metals and an estimate of accuracy and precision for a typical set of data generated from their laboratory.

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9.4 Ecological Risk Assessment Co-ordinator

The research projects being conducted under the MITE Research Network follow the ecological risk assessment paradigm for ecological risk assessment as it applies to metals. The results of the research projects 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. See following website:
<www.mite-rn.org/files/ERA_report__2002.pdf>

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9.5 ERA Interns

A key objective of the Network has been the need to interpret new knowledge generated through MITE research in the context of an environmental risk assessment (ERA) framework. This objective is being addressed in two important ways. As described above, the Network structure includes an ongoing evaluation of all projects for their potential contribution toward resolution of important risk assessment issues related to the potential impact of metals in the environment. In addition, the MITE-RN has created two “intern” positions. Recruited at the post doctoral level, and reporting through the MITE-RN, one position will be located at Environment Canada, under the supervision of Dr. Pat Doyle, and the other is planned for appointment at EVS Environment Consultants, under the supervision of Dr. Peter Chapman, the MITE-RN ERA coordinator. In both cases, incumbents will carry out projects intended to evaluate the contribution of MITE-RN achievements within the context of a Government and industrial ERA framework respectively. Co-sponsorship of the MITE-RN intern program is provided by Environment Canada, with additional support anticipated from the NSERC industrial post doc program.

9.6 Science Steering Committee (SSC)

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

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9.7 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. Jack Klaverkamp is currently the Chair of this panel.

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9.8 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 Panel 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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9.9 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 are for calendar year 2001; presentations cover the period March 1, 2000 to February 28, 2001.

10.1 <Sources> Publications

Edwards, G.C., P.E. Rasmussen, W.H. Schroeder, R.J. Kemp, G.M. Dias, C.R. Fitzgerald-Hubble, E.K. Wong, L. Halfpenny-Mitchell and M.S. Gustin. 2001. Sources of variability in Hg flux measurements. *Journal of Geophysical Research* 106 (D6), 5421-5435.

10.2 <Processes> Publications

Celo, V., J. Murimboh, M.S.A. Salam and C.L. Chakrabarti. 2001. A kinetic study of nickel complexation in model systems by adsorptive cathodic stripping voltammetry. *Environmental Science and Technology* 35: 1084-1089.

Croisetière, L., L. Hare and A. Tessier. 2001. Influence of current velocity on Cd accumulated by an aquatic moss and consequences for its use as a biomonitor. *Environmental Science and Technology* 35: 923-927.

Croteau, M.N., L. Hare and A. Tessier. 2001. Differences in Cd accumulation among species of the lake-dwelling biomonitor *Chaoborus*. *Canadian Journal of Fisheries and Aquatic Sciences* 58: 1737-1746.

Hale, B., E. Berkelaar, D. Chan, W. Black and D. Johnson. 2001. Plants as modifiers of cadmium bioavailability. *Geoscience Canada* 28 (2): 55-58.

Lam, M.T., J. Murimboh, N.M. Hassan and C.L. Chakrabarti. 2001. Kinetic speciation of lead and cadmium in freshwaters using square-wave anodic stripping voltammetry with a thin mercury film rotatin disk electrode. *Electroanalysis* 13: 94-99.

Martin, R.R., Naftel, S.J. and F. Courchesne. 2001. Metals in contact with tree-root surfaces: Investigations of the rhizosphere using X-ray fluorescence. *Advanced Photon Source (APS) Activity Report*, Argonne National Laboratory.

Voigt, A., W.H. Hendershot and A. Renoux. 2001. Adsorption of Cd, Cu, Ni, and Pb on petri dishes and filter materials used in bioassay procedures. *Bulletin of Environmental Contamination and Toxicology* 66: 44-49.

Wang, F., A. Tessier and L. Hare. 2001. Oxygen measurements in the burrows of freshwater insects. *Freshwater Biology* 46: 317-327.

10.3 <Impacts> Publications

Scheuhammer, A.M., J.A. Perrault and D.E. Bond. 2001. Mercury, methylmercury, and selenium concentrations in eggs of common loons *Gavia immer* from Canada. *Environmental Monitoring and Assessment* 72: 79-94.

Zohouri, M.A., G.G. Pyle and C.M. Wood. 2001. Dietary Ca inhibits Cd uptake, but not hypocalcemia, in Cd exposed rainbow trout *Oncorhynchus mykiss*. *Comparative Biochemistry and Physiology C*. 13-(3): 347-356.

10.4 <Sources> Presentations

Alfaro-De la Torre, M.C. and A. Tessier. 2001. Historical record of anthropogenic cadmium in sediments of a pristine lake. International Conference on the Biogeochemistry of Trace Elements. Guelph, Ontario. July 31 - August 2.

Alpay, S., L. Lortie, W.D. Gould, D.G. Rancourt, B. Mayer, F. Rosa, H.K.T. Wong, S.S. Dixit, A.S. Dixit, C.K. Prevost and G.E.M. Hall. 2001. Diagenetic metal remobilization versus chronological metal loading in lake sediments. International Conference on the Biogeochemistry of Trace Elements. Guelph, Ontario. July 31 - August 2.

Beaulieu, S., Z. Nejedly, J.L. Campbell, G.C. Edwards and G.M. Dias. 2001. Improvement of detection limits of PIXE by substrate signal reduction. PIXE Conference. Guelph, Ontario. June 8-12.

Beaulieu, S., G. Edwards, G.M. Dias, L.A. Halfpenny-Mitchell, Z. Nejedly and J.L. Campbell. 2001. Naturally occurring metal concentrations in remote areas. 2001. PIXIE Conference. Guelph, Ontario. June 8-12; International Conference on the Biogeochemistry of Trace Elements. Guelph, Ontario. July 31 - August 2.

Courcelles, M., R. Carignan and A. Tessier. 2001. Geochemical mobility of metals in surface sediments: Influence of sediment diagenesis. MITE-RN Annual Meeting. Ottawa, Ontario. February 27-28.

Edwards, G.C., P.E. Rasmussen, W.H. Schroeder, R.J. Kemp, G. Dias, L. Halfpenny-Mitchell, D. Wallace and A. Steffen. 2001. Measurements of gaseous elemental Hg from naturally mercuriferous soils. Workshop on the Fate, Transport, and Transformation of Hg in Aquatic and Terrestrial Environments. West Palm Beach, Florida. May; TSRI Metals Regional Conference, Montreal, Quebec. November 2-3; International Conference on the Biogeochemistry of Trace Elements. Guelph, Ontario. July 31 - August 2.

Edwards, G.C., P.E. Rasmussen, W.H. Schroeder, R.J. Kemp, G. Dias, L. Halfpenny-Mitchell, D. Wallace and A. Steffen. 2001. Measurements of Hg flux from natural soils. International Conference on the Biogeochemistry of Trace Elements. Guelph, Ontario. July 31 - August 2.

Edwards, G.C., P.E. Rasmussen, W.H. Schroeder, S. Beauchamp and L. Poissant. 2001. Biogeochemical cycling of Hg in the Canadian environment. Toxic Substances Research Initiative Meeting. Montreal, Quebec. November 2-3.

Lamoureux, M.M., N. Warner, K. Lantz and V. MacKinnon. 2001. Can laser ablation be an effective sample introduction device for the analysis of atmospheric particulate matter using ICP-MS? International Conference on Analytical Sciences and Spectroscopy. Toronto, Ontario. August 19-22.

Lamoureux, M.M., N. Warner and E. Sullivan. 2001. X-ray absorption fine structure spectroscopy as a tool for metal speciation of environmental solids? International Conference on Analytical Sciences and Spectroscopy. Toronto, Ontario. August 19-22.

Lamoureux, M.M., N. Warner, N. Nixam, T. Gordon and E. Sullivan. 2001. X-ray absorption fine structure spectroscopy: Shining new lights on metal speciation of environmental solids. International Conference on the Biogeochemistry of Trace Elements. Guelph, Ontario. July 31-August 2.

Rasmussen, P.E., G.C. Edwards and W.H. Schroeder. 2001. Natural Hg emissions: Point, area and linear sources. International Conference on the Biogeochemistry of Trace Elements. Guelph, Ontario. July 31-August 2.

Schroeder, W.H., G.C. Edwards, P.E. Rasmussen, R.J. Kemp, G. Dias, D. Wallace, A. Steffan and J.Y. Lu. 2001. Mercury: Rising and falling? International Conference on Mercury as a Global Pollutant. Minamata, Japan. October 15-19.

Tessier, A. 2001. Diagenetic reactions of trace elements in sediments. Invited presentation, 1st Late Summer Workshop "Interfaces in Aquatic Systems - Colloids, Biofilms, Sediment/Water Air", Lake Constance, Germany. October 1-3.

Twiss, M., A. Tessier, L. Rancourt and R. Goulet. 2001. Validation of the diffusion gradients in thin-films (DGT) technique. Toxic Substances Research Initiative Meeting. Montreal, Quebec. November 2-3.

Warner, N., J. Francis, M.M. Lamoureux and E. Sullivan. 2001. Chemical characterization of metal-containing airborne particulate matter. International Conference on Analytical Sciences and Spectroscopy. August 19-22. Toronto, Ontario; CSC Conference and Exhibition. Montreal, Quebec. May 26-30.

10.5 <Processes> Presentations

Ababneh, F., N.M. Hassan, J. Murimboh, R. Mandal, C.L. Chakrabarti, U. Rahayu, and D.R.S. Lean. 2001. Nickel speciation and bioavailability in nickel-polluted freshwater. International Conference on the Biogeochemistry of Trace Elements. Guelph, Ontario. July 29-August 2.

Bégin, C., M.M. Savard, M. Parent, J. Marion and A. Smirnov. 2001. Biochemical cycling in the Boreal Forest - metal concentrations in woody tissues. MITE-RN Annual Meeting. Ottawa, Ontario. February 27-28.

Bégin, C., M.M. Savard, M. Parent and J. Marion. 2001. Tree-ring Studies - DINAMITE. GSC MITE - Smelter Group Workshop. Ottawa, Ontario. October 25.

Bhavsar, S.P., M.L. Diamond, L.J. Evans, P. Cypas and K. Rudnitski. 2001. Estimating metal mobility using dynamic TRANSPEC (coupled TRANsport and SPECiation) model. SETAC. Baltimore, Maryland. November 11-15; International Conference on the Biogeochemistry of Trace Elements. Guelph, Ontario. July 29-August 2.

Bhavsar, S.P., M.L. Diamond, L.J. Evans, P. Cypas and K. Rudnitski. 2001. Modeling metal mobility in lakes. MITE-RN Annual Meeting. Ottawa, Ontario. February 27-28.

Croisetière, L., L. Hare and A. Tessier. 2001. Use of the insect *Sialis* as a biomonitor of trace metals in lakes. SETAC Annual Meeting. Baltimore, Maryland. November 11-15.

Croteau, M.N., L. Hare and A. Tessier. 2001. Metallothionein in the biomonitor *Chaoborus*. SETAC - Europe. Madrid, Spain. May 6-10.

Croteau, M.N., L. Hare and A. Tessier. 2001. Metal accumulation from food by aquatic invertebrates and Using a biomonitor *Chaoborus* to determine if Cd in Shield lakes declined during the nineties. International Conference on the Biogeochemistry of Trace Elements. Guelph, Ontario. July 29-August 2.

Ge, Y., Sauve, S. and W. Hendershot. Equilibrium speciation of Cd, Cu and Pb in soil solutions. Proceedings of the 6th International Conference on the Biogeochemistry of Trace Elements. Guelph, Ontario. July 2001.

Ge, Y., Sauve, S. and W. Hendershot. Chemical speciation of Cd, Cu and Pb in soil solutions. Poster presentation at MITE-RN Annual Meeting. Ottawa, ON., February 2001.

Gosselin, A., L. Hare and A. Tessier. Burrowing behaviour of *Chaoborus* larvae and their exposure to sedimentary trace metals. Society of Environmental Toxicology and Chemistry, Baltimore, MD. November 2001.

Guthrie, J.W., N.M. Hassan, J. Murimboh, R. Mandal, C.L. Chakrabarti and M.H. Back. 2001. Kinetic studies of nickel speciation in model solutions of a well-characterized humic acid using the competing ligand exchange method. MITE-RN Annual Meeting. Ottawa, Ontario. February 27-28; The Varian Day Symposium. Ottawa, Ontario. April 30.

Guthrie, J.W., N.M. Hassan, R. Mandal, J. Murimboh and C.L. Chakrabarti. 2001. The effect of metal/humic acid mole ratios on the binding of Ni(II) by a well characterized humic acid in aqueous model solutions. International Conference on the Biogeochemistry of Trace Elements. Guelph, Ontario. July 29-August 2.

Hassan, N.M., J. Murimboh, J.W. Guthrie, D.R.S. Lean, R. Mandal and C.L. Chakrabarti. 2001. Effect of UV irradiation on nickel and copper speciation in Raisin River water samples. MITE-RN Annual Meeting. Ottawa, Ontario. February 27-28.

Hassan, N.M., J. Murimboh, J.W. Guthrie, D.R.S. Lean, R. Mandal and C.L. Chakrabarti. 2001. Effect of UV-B radiation on nickel and copper speciation in Raisin River water samples. The Varian Day Symposium. Ottawa, Ontario. April 30.

Jamaluddin, R. Mandal, I.F. Almomani, J. Murimboh, N.M. Hassan and C.L. Chakrabarti. 2001. Can ion-selective electrode potentiometry used to measure free copper ion activity down to 10^{-15} M in soil solutions? MITE-RN Annual Meeting. Ottawa, Ontario. February 27-28; International Conference on the Biogeochemistry of Trace Elements. Guelph, Ontario. July 29-August 2.

Johnson, D. and B. Hale. 2001. Foliar trace metal (Cu, Ni, Pb and Zn) input to surficial soils in contaminated northern forest ecosystems. SETAC Annual Meeting. Baltimore, Maryland. November 24-28.

Johnson, D. and B. Hale. 2001. Biogenic trace metal (Cu, Ni, Cd, Pb and Zn) inputs to surficial soils in contaminated northern forest ecosystems. International Conference of Biogeochemistry of Trace Elements. Guelph, Ontario. July 31 - August 2.

Johnson, D. and B. Hale. 2001. Trace metal input to soils through the decomposition of foliage in metal-contaminated northern forest ecosystems. MITE-RN Annual Meeting. Ottawa, Ontario. February 27-28.

Macdonald, J.D. and W.H. Hendershot. 2001. Column soil solution extraction method produces solutions comparable to zero-tension lysimeters. Applications to trace metals; International Conference on the Biogeochemistry of Trace Metals. Guelph, Ontario. July 31 - August 2; Toxic Substances Research Initiative Meeting. Montreal, Quebec. November 2-3.

Mandal, R., C.L. Chakrabarti and M.H. Back. 2001. An electrochemical investigation of complexation of Pb (II) by a well-characterized fulvic acid in model systems - effect of

competition with major cations. Ca^{2+} and Mg^{2+} . MITE-RN Annual Meeting. Ottawa, Ontario. February 27-28.

Murimboh, J. N.M. Hassan, R. Mandal, J. Guthrie, A.L.R. Sekaly, M.S.A. Salam, C.L. Chakrabarti and M.N. Back. 2001. Metal speciation in the freshwater and the terrestrial environment. MITE-RN Annual Meeting. Ottawa, Ontario. February 27-28.

Murimboh, J. N.M. Hassan, R. Mandal, J. Guthrie, A.L.R. Sekaly, M.S.A. Salam, C.L. Chakrabarti, M.N. Back and D.C. Gregoire. 2001. Kinetic speciation in freshwaters from Sudbury. The Varian Day Symposium. Ottawa, Ontario. April 30.

Murimboh, J. N.M. Hassan, R. Mandal, J. Guthrie and C.L. Chakrabarti. 2001. Some electrochemical techniques for metal speciation in model solutions of a well-characterized fulvic acid. International Conference on the Biogeochemistry of Trace Elements. Guelph, Ontario. July 29-August 2.

Savard, M.M., C. Bégin and M. Parent. 2001. A geoscientific historical perspective on toxic substances in the mining district of Rouyn-Noranda. Toxic Substances Research Initiative meeting. Montreal, Quebec. November 2-3.

Savard, M.M., C. Bégin and M. Parent. 2001. A high resolution historical perspective on anthropogenic accumulation of metals in the environment using H, C and Pb Isotopic Dendrogeochemistry. International Conference on the Biogeochemistry of Trace Elements. Guelph, Ontario. July 29-August 2.

Savard, M.M., C. Bégin, M. Parent, J. Marion, A. Smirnov and X. Hou. 2001. New dendrogeochemical data and estimation of reduction of photosynthesis rate in response to smelter pollution. GSC MITE - Smelter Group Workshop. Ottawa, Ontario. October 25.

10.6 <Impacts> Presentations

Borgmann, U. and W.P. Norwood. 2001. Some water quality issues in laboratory toxicity tests with *Hyalella azteca*. SETAC Annual Meeting. Baltimore, Maryland. November 11-15.

Giguère, A. P.G.C. Campbell, L. Hare, A. Hontela and J. Rasmussen. 2001. Partitioning of metals (Cd, Cu, Ni, Pb, Zn) among various tissues in indigenous yellow perch *Perca flavescens* collected along a polymetallic environmental gradient. International Conference on the Biogeochemistry of Trace Elements. Guelph, Ontario. July 31-August 2; SETAC Annual Meeting. Baltimore, Maryland. November 11-15.

Gravel, A., P.G.C. Campbell and A. Hontela. 2001. Sensitivity of the hypothalamo-pituitary-interrenal axis of young yellow perch *Perca falvenscens* to cadmium. Canadian Society of

Zoologists Annual Meeting. Sudbury, Ontario. May 9-12; International Conference on the Biogeochemistry of Trace Elements. Guelph, Ontario. July 31-August 2.

Grosell, M., C. Kamunde, P.J. Walsh and C.M. Wood. 2001. Mechanisms of copper uptake across the gills of freshwater teleost fish. Canadian Society of Zoologist Annual Meeting. Sudbury, Ontario. May 9-12.

Ho, C., K.A. Sloman, C.M. Wood and D.G. McDonald. 2001. Influence of ration quantity during waterborne cadmium exposure in rainbow trout. SETAC Annual Meeting. Baltimore, Maryland. November 11-15.

Ho, C., C.M. Wood and D.G. McDonald. 2001. The interaction of ration and waterborne cadmium exposure in rainbow trout *Oncorhynchus mykiss*. Canadian Society of Zoologist Annual Meeting. Sudbury, Ontario. May 9-12.

Kamunde, C., C. Clayton and C. Wood. 2001. Copper homeostasis in fish: Interactions between dietary and waterborne uptake. Annual Fish Physiology and Biochemistry Workshop. Keene, Ontario. February 2-4.

Kamunde, C., G. Pyle, C. Clayton, D.G. McDonald and C.M. Wood. 2001. Ionoregulatory responses of rainbow trout *Oncorhynchus mykiss* during dietary salt intake and waterborne Cu exposure. SETAC-Europe Annual Meeting. Canterbury, United Kingdom. April 2-6.

Kamunde, C., C. Clayton and C. Wood. 2001. Interactions between dietary and waterborne copper in fish: effects of waterborne Cu acclimation. Canadian Society of Zoologist Annual Meeting. Sudbury, Ontario. May 9-12; MITE-RN Annual Meeting. Ottawa, Ontario. February 27-28

Kamunde, C., G. Pyle, C. Clayton, D.G. McDonald and C.M. Wood. 2001. Effect of dietary quality on copper uptake in rainbow trout. International Conference on the Biogeochemistry of Trace Elements. Guelph, Ontario. July 29-August 2.

Kamunde, C., G. Pyle, D.G. McDonald and C.M. Wood. 2001. Assessment of the modifying role of diet-variables on toxicity of dietary and waterborne Cu in fish. SETAC Annual Meeting. Baltimore, Maryland. November 11-15.

Lacroix, A. and A. Hontela. 2001. Role of calcium channels in Cd-induced disruption of cortisol secretion in teleost adrenocortical cells. Canadian Society of Zoologist Annual Meeting. Sudbury, Ontario. May 9-12.

Leblond, V., J.P. Chang and A. Hontela. 2001. Purification of cortisol-secreting cells from rainbow trout *Oncorhynchus mykiss* and effects of exposure to metals. Canadian Society of Zoologist Annual Meeting. Sudbury, Ontario. May 9-12.

- Levesque, H.M., J. Dorval, G. Van Der Kraak, P.G. C. Campbell and A. Hontela. 2001. Hormonal, morphological and physiological responses of yellow perch *Perca flavescens* to chronic environmental metal exposures. International Conference on the Biogeochemistry of Trace Elements. Guelph, Ontario. July 31 - August 2.
- McDonald, D.G. 2001. Metal homeostasis and toxicity in freshwater fish. Canadian Society of Zoologist Annual Meeting. Sudbury, Ontario. May 9-12.
- McGeer, J.C., L.N. Taylor, D.G. McDonald and C.M. Wood. 2001. The application of biotic ligand modeling approaches for the chronic effects of waterborne metals. International Conference on the Biogeochemistry of Trace Elements. Guelph, Ontario. July 29-August 2.
- McGeer, J.C., L.N. Taylor, L. Hollis, D. Alsop, D.G. McDonald and C.M. Wood. 2001. Biotic ligand modeling for the chronic effects of waterborne metals. SETAC Annual Meeting. Baltimore, Maryland. November 11-15.
- Niyogi, S., G.G. Pyle, L.N. Taylor, P. Couture, C.M. Wood and D.G. McDonald. 2001. A comparative study on the tolerance and accumulation to acute Cd exposure in yellow perch. SETAC Annual Meeting. Baltimore, Maryland. November 11-15.
- Norwood, W.P., D.G. Dixon and U. Borgmann. 2001. Determination of bioaccumulation and chronic toxicity (critical body concentrations) of As, Co, Cr and Mn in *Hyaella azteca* together with a summary of seven other metals. Aquatic Toxicity Workshop. Winnipeg, Manitoba. October 3.
- Norwood, W.P., D.G. Dixon and U. Borgmann. 2001. Bioaccumulation and chronic toxicity (critical body concentrations) of metals in *Hyaella azteca*. An Ecological Risk Assessment Tool. SETAC Annual Meeting. Baltimore, Maryland. November 11-15; MITE-RN Annual Meeting. Ottawa, Ontario. February 27-28.
- Nowierski, M., D.G. Dixon and U. Borgmann. 2001. Effects of different water sources on metal toxicity and bioaccumulation from field collected sediments. Aquatic Toxicity Workshop. Winnipeg, Manitoba. October 3; MITE-RN Annual Meeting. Ottawa, Ontario. February 27-28.
- Schroeder, J., G. Dixon and U. Borgmann. 2001. Creating a model to predict metal toxicity to invertebrates. TIME Workshop. Ottawa, Ontario. November 23.
- Schroeder, J., G. Dixon and U. Borgmann. 2001. Nickel accumulation by *Hyaella azteca* in different media after 7-day exposures: Estimation of binding constants and Acclimation of *Hyaella azteca* to different media prior to short-term nickel exposure: Effects on Toxicity. SETAC Annual Meeting. Baltimore, Maryland. November 11-15.

Schroeder, J., G. Dixon and U. Borgmann. 2001. Creating a model for predicting metal toxicity to invertebrates. Aquatic Toxicity Workshop. Winnipeg, Manitoba. October 3; MITE-RN Annual Meeting. Ottawa, Ontario. February 27-28.

Taylor, L.N., C. Kamunde, G.G. Pyle, C.M. Wood and D.G. McDonald. 2001. Mechanisms of waterborne and dietary metal toxicity in rainbow trout. *Oncorhynchus mykiss* and yellow perch *Perca flavescens* and their implications for risk assessment and Effects of dietary Na⁺ on the uptake kinetics and sublethal effects of Cu in rainbow trout. MITE-RN Annual Meeting. Ottawa, Ontario. February 27-28.

Taylor, L.N., V.L. Loughheed, C.M. Wood and D.G. McDonald. 2001. Using individual variation as a tool in determining the toxic effects of waterborne copper on rainbow trout *Oncorhynchus mykiss*. Canadian Society of Zoology. Sudbury, Ontario. May 9-12.

Taylor, L.N., C.M. Wood and D.G. McDonald. 2001. Can the gill copper binding explain the differences in copper toxicity between two disparate species, yellow perch *Perca flavescens* and rainbow trout *Oncorhynchus mykiss*? International Conference on the Biogeochemistry of Trace Elements. Guelph, Ontario. July 29-August 2.

Taylor, L.N., C.M. Wood and D.G. McDonald. 2001. An *in vitro* gill binding method for assessment copper toxicity. SETAC Annual Meeting. Baltimore, Maryland. November 11-15.

Wood, C.M. 2001. Copper metabolism and homeostasis: the fish as a model system. International Copper Association Symposium. Santa Fe, New Mexico. April 22-26.

10.7 Ecological Risk Assessment: Publications

Chapman, P.M. and F. Wang. 2001. Assessing sediment contamination in estuaries. Environment of Toxicology and Chemistry 20: 3-22.

10.8 Ecological Risk Assessment: Presentations

Chapman, P.M. 2001. The utility and use of sediment quality values (SQVs). 10th Annual Meeting of the North Pacific Marine Science Organization (PICES). Victoria, British Columbia. October 11-13.

Chapman, P.M. 2001. Does hormesis have a role in ecological risk assessment (ERA)? Risk management of contaminated sediments in Homebush Bay, Australia: Sediment quality triad studies (SQT) and ecological risk assessment (ERA). SETAC Annual Meeting. Baltimore, Maryland. November 11-15.

