Canadian Network of Toxicology Centres

Metals In The Environment

Research Network

ANNUAL REPORT

March 1, 2002 - February 28, 2003

MITE-RN Secretariat, Canadian Network of Toxicology Centres Head Office
University of Guelph, Guelph, Ontario N1G 2W1
Telephone: 519-837-3320 Fax: 519-837-3861
Email: dwarner@tox.uoguelph.ca
Web site: http://www.mite-rn.org

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1 THE METALS IN THE ENVIRONMENT RESEARCH NETWORK

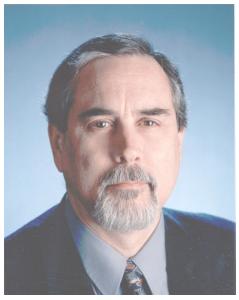
The MITE Research Network was formally initiated on July 1, 1998, after the Mining Association of Canada (MAC) agreed on the importance of MITE-RN and committed $1.25 million and in-kind support for the Research Network for a five-year period. MAC has also committed an additional $100,000 per year over 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 annually 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



The MITE Research Network has continued its steady progress toward providing sound scientific information for improving risk assessment and risk management of metals in the environment. While it took some time in the early years of the Network to design and carry out experiments, particularly in the case of field experiments, analytical results are now available for most studies and interpretation of results and framing their relevance for public policy development are underway.

Impressive examples of the impact of the Network and its program are contained in Human and Ecological Risk Assessment, volume 9 (4), which was published in June 2003. In this international journal, Network scientists have published ten scientific papers covering the major Network research domains of sources, processes affecting metal speciation, and ultimate fate of metals and effects on environmental receptors. One of these papers, authored by Dr. P.M. Chapman (and co-colleagues), who is the leader of the Network's program to link science with risk assessment, is entitled "Conducting Ecological Risk Assessments of Inorganic Metals and Metalloids – Current Status". The paper puts into context all of the other papers and clearly satisfies one of the major objectives of the Network's program.

Another important event of the last year was the Mining Association of Canada – Canadian Network of Toxicology Centres workshop held in May in Kingston, Ontario, for evaluating what on-going knowledge gaps require priority attention. This workshop was attended by MITE-RN stakeholders and many of the MITE-RN researchers. In addition, other agencies were invited to attend in order to broaden the discussion of information needs for metals. The meeting was very successful in facilitating open and frank discussions among government, industry, and academia and in enabling possible collaboration and engagement in several new areas of metals research. These new areas will be the subjects for funding proposals so that the scientific momentum built up by the MITE Research Network can be sustained and significantly extended in scope.

I would like to express, on behalf of the Board of Directors, our gratitude for the work accomplished by each of the scientific teams and the degree of cooperation and collaboration that has and is taking place within the Network. We salute you!

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

3 YEAR FOUR MESSAGE FROM THE RESEARCH DIRECTOR

The Canadian <Metals in the Environment> Research Network, or MITE-RN, grew out of a multi-stakeholder workshop held in 1996. The initial cohort of partners included the Mining Association of Canada, Ontario Power Generation Inc., Environment Canada, Fisheries and Oceans Canada, and Natural Resources Canada. Funding from the Natural Sciences and Engineering Research Council (NSERC) was obtained in 1999 and shortly afterwards we added links to international metal organisations (NiPERA, ICA, ILZRO). This core group of partners has been maintained since that time.

MITE-RN completed the fourth year of its five-year research plan in February 2003. In Year 4, a total of 17 university-based projects were funded (35 research scientists; 15 universities; >40 graduate students, 5 post-doctoral fellows); two new projects were introduced (A7, C5) and two projects (A1, C4) were completed. This influx of new projects and winding-down of some of the original projects reflects the Network's commitment to regular project review, to monitoring progress towards our research objectives, and to bringing new researchers into the Network. Year 4 was also marked by changes in the membership of the Expert Advisory Panel, with Dr. Steve Norton (University of Maine) and Dr. Dave Mount (US EPA, Duluth, MN) participating in the annual review for the first time.

Research activities in the Network are grouped into three research domains: <Sources>, <Processes> and <Impacts>, each of which has specific research objectives. Highlights of our progress towards these research goals are documented in the domain summaries that appear in this Annual Report, and in the synthesis report prepared by Dr. Peter Chapman that summarizes the implications of these research findings for the ecological risk assessment of metals.

To facilitate the integration of MITE-RN research into risk assessment for metals in Canada, the Network created two post-doctoral intern positions during Year 4. Dr. Richard Goulet accepted an internship with Environment Canada's Existing Substances Branch (partially funded by EC) in September 2002. His mandate is to link MITE-RN research results to current Environment Canada screening level ERA activities. The feasibility of applying the "unit-world" concept to metal assessments, as is often done for organic micro-contaminants, will be among the issues to be examined by Dr. Goulet. A second intern, Dr. Collins Kamunde, was placed with EVS Environment Consultants in November 2002, with complementary funding from the NSERC Industrial Research Fellowship programme. His role will be to integrate MITE-RN research into the ongoing debate within ERA circles about the relative importance of water versus food as uptake vectors for metals in indigenous aquatic organisms.

In Year 4, linkages were maintained with the metals risk assessments being undertaken by the European scientific community. Industry representatives have attended the last three MITE-RN Annual Research Symposia and participated in ERA workshops. They have learned of our research results and have updated us on approaches being used in Europe to evaluate the environmental risks posed by metals. A follow-up to this initiative is planned for our final 2004 Symposium.

A written document such as this annual report cannot adequately capture the dynamic nature of our Network. However, I do hope that it will stimulate you, the reader, to visit our web site (www.mite-rn.org) on a regular basis and follow the successes of the MITE-RN researchers!

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

4 MITE-RN 2002-2003 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) Chemical speciation and quantitative determination of some metals associated with airborne particulate matter of varying sizes <Cd Cu Ni Pb Se Zn>
R. Carignan	(A4) Geochemical mobility of metals in surface sediments: Influence of sediment diagenesis <Ag Al As Cd Cu Fe Hg Mn Ni Pb Pd Pt Rh Ti Zn>
J. Lu	(A5) Development, evaluation and applications of analytical methods for chemical speciation of metals associated with atmospheric particulate matter/aerosols and with suspended matter in wet precipitation <Hg>
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>
W. Hendershot	(A7) Rates of trace metal release due to mineral weathering <Cd Cu Ni Pb Zn>

Government

W.D. Gould	(AF8) Redistribution of metals in lake sediments by bacterially mediated oxidation-reduction reactions <Co Cu Fe Mn Ni Zn>
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 <Cd Cu Ni Pb Zn>

4.2 <Processes> Research Grants

University	
B. Hale	(B1) Post-deposition mobility of trace metals in boreal forest ecosystems: root soil interactions <Cu Ni Pb Zn>
L. Hare	(B2) Development of rational models for relating metal accumulation by aquatic organisms to metal concentrations in their environment: relative importance of ambient metals sources <Cd Cu Ni Zn>
C.L. Chakrabarti	(B4) Metal speciation in freshwaters, soil pore waters, throughfall precipitation with aqueous solutions resulting from wetting of atmospheric particles <Al Ca Cd Co Cu Fe Hg Mg Ni Pb Zn>
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 <As Cd Co Cr Cu Ni Pb Rb Sc Sn Sr V Y Zn>
F. Wang	(B7) Importance of reduced sulfur species in controlling metal speciation in surface waters on the Canadian Shield <Cd Cu Fe Hg Ni Pb Zn>

4.3 <Impacts> Research Grants

University	
D.G. Dixon	(C1) Predicting metals and metal mixture effects in aquatic biota <As Cd Co Cu Cr Mn Ni Pb Tl Zn >
C.M. Wood	(C2) Assessing biological effects of chronic metal exposure to fish - laboratory studies <Cd Cu 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 Ni Pb Zn >
L.H.M. Chan	(C4) Accumulation and effects of environmental metals in fish-eating birds <Hg Pb>
P. Couture	(C5) Population and physiological effects of industrial metal contamination on wild fish <Cd, Cu, Ni, Zn>

5 MITE-RN STUDENTS

<SOURCES>	<PROCESSES>	<IMPACTS>
University of Guelph Goretty Dias Post-doc Fellow INRS-ETE Catalina Alfaro, Ph.D. student Celine Gallon, Ph.D. student Luc Berube, M.Sc. student Renee Quirion, M.Sc. student Ryerson University Xinbin Feng, Post-doc Fellow Kevin Ji, M.Sc. student James Lu, Ph.D. student Minesh Panchal, M.Sc. student Luke Hazlett, M.Sc. student Université de Montréal 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 University of Ottawa Ralph Rowe, M.Sc. student Laurentian University John Hechler, M.Sc. student Lizane Pamer, M.Sc. student David Marshall, M.Sc. student Al Rogers, M.Sc. student Dana Wilson, M.Sc. student	University of Guelph Dallas Johnson , Ph.D. student Paula Cypas, Ph.D. student Kristina Rudnitski, M.Sc. student McGill University Doug MacDonald, Ph.D. student Ying Ge, Ph.D. student Astrid Voigt, Ph.D. student Kate Taillon, M.Sc. student Université de Montréal Benoit Cloutier-Hurteau, M.Sc. student Pascale Legrand, M.Sc. student INRS-ETE Marie-Noële Croteau, Ph.D. student Louis Croisetière , Ph.D. student Anne Gosselin, M.Sc. student Jord Orvoine, M.Sc. student Joëlle Marion, M.Sc. student University of Toronto Satyendra Bhavsar, M.Sc. student Carleton University Jamaluddin, Ph.D. student Momiruzzaman, Ph.D. student University of Manitoba Katrina Sukola, M.Sc. student Junwei Jiang, M.Sc. student	University of Guelph Juliska Princz, M.Sc. student University of Waterloo Warren Norwood, Ph.D. student Julie Schroeder, Ph.D. student Monica Nowerski, M.Sc. student Angela Wallace, M.Sc. student McMaster University Soumya Niyogi, Post-doc Fellow Lisa N. Taylor, Ph.D. student Collins Kamunde, Ph.D. student Carrie Ho, M.Sc. student INRS-ETE Anik Giguère, Ph.D. student Lisa Kraemer, Ph.D. student UQAM Alexandra Lacroix , Ph.D. student Haude Levesque, M.Sc. student Alexandra Gagnon, M.Sc. student Amélie Gravel, M.Sc. student McGill University Graham Sherwood, Ph.D. student Jennifer Kovesces, M.Sc. student Alison Isles, M.Sc. student Alex Ferran, M.Sc. student Laurentian University James Rajotte, Ph.D. student Mehran Bakhtiari, M.Sc. Student

6 NETWORK COMMUNICATIONS

6.1 MITE-RN Web Site

See <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	- Contact Information
	- Guiding Principles
	- Research Overview
Research Priorities	- Research Domains (<Sources>, <Processes>, <Impacts>)
	- Domain Executive Summaries
	- Research Priorities (1999 - 2003)
	- Quality Assurance/Quality Control
	- Research Project Archives
Contacts	Management Structure:
	- Science Director
	- Domain Leaders
	- Science Steering Committee
	- Board of Directors
	- Expert Advisory Panel
	- Secretariat
Ecological Risk Assessment	- Status Report, Vision Statement, Internships, HERA publications
Announcements	- Conferences & Symposia
	- Press Releases and Media Coverage
How Do I Get Involved	- MITE-RN Guiding Principles
	- Contact Information
Annual Symposium	
Publications & Reports	- MITE-RN Newsletters
	- Annual Reports (1999-2002)
	- Subscriptions to Newsletter, Publications database for Network
Data Archiving	- Metadata for field projects
	- Scientific publications
Files & Forms	- Downloadable Files & Forms
Links	- Metals Related WWW Links
Help	- Web Site Help/Search Engine
Archive	- Archive of Out of Date Web Pages
MITE-RN Intranet	- Internal Communications
Link	- Link to Canadian Network of Toxicology Centres

6.2 MITE-RN News

A winter 2003 newsletter was published and distributed in February. People are encouraged to view the web site (http://www.mite-rn.org) for updates on Network activities between electronic issues of the newsletter.

6.3 Annual Research Symposium

Although the number of research principal investigators and co-investigators was approximately 70 for Year 4 of the program, we are delighted to report that participation in the February 25-26, 2003 annual research symposium was 105 which suggests approximately 33% 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>

Stable Pb isotope ratios as indicators of atmospheric Pb sources around Rouyn-Noranda
Gallon, C., R. Carignan, A. Tessier and C. Gobeil

Mineralogy of soils in the vicinity of smelters in Rouyn-Noranda and Sudbury areas
Percival, J. B.

7.2 <Processes>

A method for modeling bioavailability in non-equilibrated systems
Antunes, P.M.C. and B.A. Hale

Metal speciation in an extremely sulfidic inland water (I) cycling of sulphur species
De Vries, C. and F. Wang

PhyavQL: A computer model for estimating metal bioavailability and translocation within plants
Hale, B.A., P.M.C. Autunes and L.J. Evans

Metal uptake routes for the biomonitor Sialis
Hare, L., L. Croisetière and A. Tessier

Effect of cadmium on the behaviour of a burrowing mayfly (*Hexagenia limbata*)
Hare, L., A. Gosselin and A. Tessier

Determining the trophic level at which Cd and hydrogen ions compete for biological uptake sites in the food chain leading to the biomonitor *Chaoborus*
Hare, L., J. Orvoine and A. Tessier

A kinetic exploration of metal speciation in Sudbury and Rouyn-Noranda areas
Hassan, N.M., J. Murimboh, I.I. Fasfous, C.L. Chakrabarti and D.C. Grégoire

Modeling proton dissociation from organic horizons of podzolic soils
Hendershot, W.H. and J.D. MacDonald

Influence of liming of the fluxes of cadmium in soils observed by DGT (Diffusive Gradient in Thin film)
Rachou, J., W. Hendershot and S. Sauvé

Speciation of cadmium in lake waters from Rouyn-Noranda
Salam, M.S.A., R. Wang, J.W. Guthrie, J. Murimboh, C.L. Chakrabarti and D.C. Grégoire

Partitioning coefficients for Cd, Cu, Ni, Pb and Zn in the organic horizons of a forest soil
Sauvé, S., S. Manna, M.C. Turmel, F. Courchesne and A.G. Roy

Stability and characterization of metal-sulfide species in oxic waters
Sukola, K. and F. Wang

7.3 <Impacts>

Lake recovery from metal-contamination: the importance of the benthic community for fish energetics
Iles, A., J.B. Rasmussen and P.G.C. Campbell

Metal accumulation in the field: Is the diet an important route of exposure for yellow perch (*Perca flavescens*)
Kraemer, L., P.G. Campbell and L. Hare

Accumulation and effects of mercury in fish-eating birds
Chan, H.M., A.M. Scheuhammer, S. Weech, J. Holloway and A. Farren

Ontogenetic changes in dietary and tissue metal concentration in wild yellow perch from a metal contamination gradient
Couture, P., R. Stewart and G. Pyle

Variability of age, gender and season on fish condition in wild yellow perch (*Perca flavescens*) populations along a metal contamination gradient
Couture, P., P. Busby and G. Pyle

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

Importance of dietary uptake on metal toxicity to *Hyalella azteca*
Dixon, G., U. Borgmann and A. Wallace

Effects of Cu, Cd and Ni on the physiological status of yellow perch
Gagnon, A., P.G.C. Campbell, J.B. Rasmussen and A. Hontela

Can metal subcellar partitioning help predict effects in indigenous yellow perch?
Giguére, A., P.G.C. Campbell, L. Hare, C. Cossu-Leguille, P. Couture, D.G. McDonald and J.B. Rasmussen

Comparison of the adrenotix effects of Cd in Rainbow trout (*Oncorhynchus mykiss*) and yellow perch (*Perca flavescens*)
Lacroix, A., A. Gravel and A. Hontela

Effects of sublethal waterborne Cu on feeding pattern in rainbow trout (*Oncorhynchus mykiss*): interactions between dietary Na dn waterborne Cu uptake
Niyogi, S., C. Kamunde, D.G. McDonald and C.M. Wood

Population effects of industrial metal contamination in wild Yellow perch (*Perca flavescens*)
Pyle, G. and P. Couture

Effects of acclimation to waterborne copper on copper turnover and gill binding in rainbow trout (*Oncorhynchus mykiss*)
Wood, C. and C. Kamunde

8 MILESTONES FOR YEAR FOUR: RESEARCH DOMAINS

8.1 <Sources>

Executive Summary for FY 2002 - 2003

Domain Co-Leaders:
Dr. Marc Lamoureux, St. Mary's University
Dr. Robert G. Garrett, NRCan, Geological Survey of Canada

Projects included in <Sources> Domain:

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 Chemical speciation and quantitative determination of some metal pollutants associated with airborne particulate matter of varying sizes	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, U. de Montréal INRS-ETE, Univ. du Québec
A5 Development, evaluation and applications of analytical methods for chemical speciation of mercury associated with atmospheric particulate matter/aerosols and with suspended matter in wet precipitation	Lu, J.Y.	Dept. of Chemistry Biology & Chem. Engineering, Ryerson University
A6 Application of sensitive techniques for the chemical analysis of aerosolic particulates	Spiers, G.A.	Centre for Environmental Monitoring, Laurentian University
A7 Rates of trace metal release due to mineral weathering	Hendershot, W.	McGill University
AF8 Redistribution of metals in lake sediments by bacterially mediated oxidation-reduction reactions	Gould, D. Alpay, S.	Mining and Mineral Sciences Laboratory, 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
AF10 Examination of mineral weathering and release of trace elements in selected soil profiles	Percival, J. Hendershot, W.	Geological Survey of Canada, NRCan McGill University

Progress Toward Achievement of Objectives

The research objectives in the <Sources> domain involve; i) estimating site specific metal loadings in differing ecosystems due to the atmospheric deposition of metals from anthropogenic and natural sources; and ii) determining if diagenetic processes modify chemical records in lake sediments preventing them from 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 seven ongoing projects (A1-A6) from 2002-2003, two new projects were initiated in 2001-2002. These two new projects (A7 and AF10) will fulfill an important knowledge gap, and the main question to be studied is:

What is the rate of trace metal release from particulate matter due to mineral weathering?

Project A1 Development and application of methods for measurement of metals on aeolian dust from natural settings (G. Edwards, University of Guelph): Due to the resignation of Professor Edwards as Associate Professor, mercury lab research and the PM modeling component have been cancelled from the objectives. A field intercomparison of the PIXE cascade impactor technique with other particulate collectors was completed, and sample analysis will begin as soon as the PIXE facility renovations are completed. As part of the evaluation of appropriate lab methods for studying fractionation of soils into aerosols and to understand the effect of friction velocity on aerosol fractionation and composition, an existing wind-tunnel at the School of Engineering was evaluated. The wind-tunnel was found to be inadequate due to problems of providing a clean air source and acquiring the amount of soil needed for such a study. Thus, a resuspension chamber has been built which houses PIXE cascade impactors and stacked filter units to collect particles by size. Its characteristics will be evaluated shortly, followed by the study of aerosol-soil fractionation in the chamber. This part of the study is still in progress. Preliminary relationships between field and lab data, and soil and aerosol data, were finished by end of winter 2003 (March). Although not in the original proposal, a field study to collect aerosols from a bare soil has been completed and soil collected will be analyzed and tested in the chamber.

Project A2 Chemical speciation and quantitative determination of some metal pollutants associated with airborne particulate matter of varying sizes: Samples collected in the Rouyn-Noranda vicinity have been analysed by ICP-MS. The quantitative determination of Pb, Ni, Cu, Cd, and Zn was completed for the July/August 2000 and the October 2001 collection. Results showed that Zn is not a good indicator of the impact of the Horne Smelter stack on the environment, but Pb and Cu are definitely more abundant in particulates that are downwind from the Horne Smelter compared to particulates collected upwind from the stack. The Pb isotope ratio was determined for the July/August 2000 collection and showed that the Pb isotopic signature for airborne particulate matter collected downwind from the Horne smelter stack is different from that collected upwind. The Pb isotope ratio determination for the October 2001 collection is in progress. The determination of Cu, Ni, Pb, Cd and Zn using laser ablation ICP-MS on the October 2001 and future sample collection from the Sudbury region began at the end of the Fall 2002. Chemical speciation, using x-ray absorption fine structure (XAFS), of Cu, Ni and Pb for the July/October 2000 is completed and Cu was completed for the October 2001 collection. Results show that the chemical nature of Cu and Pb from particulate matter collected downwind is different from the upwind samples. Furthermore, the speciation is particle size dependent. Collections of airborne particulate matter from the Sudbury area are scheduled to begin at the end of Fall 2002 (collaboration with project A6). Samples from wet events from the Rouyn-Noranda and Sudbury areas (under Will Hendershot's supervision - project A7) were collected and will be investigated during Fall 2002/Winter 2003 for chemical characterization (quantitative and speciation).

Project A4 Geochemical mobility of metals in surface sediments: influence of sediment diagenesis (R. Carignan, Université de Montréal): Main project. Duplicate sediment cores were collected in July 2002 in three lakes at a low metal loading site (Île René-Levasseur on Manicouagan Reservoir). Total Hg, total carbon and nitrogen, ^{137}Cs, ^{210}Pb, ^{214}Pb, ^{226}Ra and ^{241}Am measurements will be completed in February 2003. Chemical digestions of the sediment samples are underway and were completed in December 2002, and measurements of Al, As, Cd, Cu, Fe, Mn, Ni, Pb, Ti and Zn were completed in March 2003. Similar analyses for the samples collected in 2001(Rouyn-Noranda) are complete and ready for archiving. Measurements of Al, As, Cd, Cu, Fe, Hg, Mg, Mn, Na, K, Ni, Pb and Zn in the porewater samples from L. Despériers (Rouyn-Noranda) are complete. The WHAM 6 speciation computer code was modified to include metal complexation by polysulfides and metal speciation calculations were completed for porewaters from the three regions. Diagenetic modelling is well underway and results to date indicate that post-depositional remobilization appears to be negligible for Pb and Hg, intermediate for Cu, and important for As, Cd and Zn. Results show a potentially important effect of wildfires on Hg cycling at the watershed scale and on Hg deposition chronologies in lakes. To confirm this phenomenon, other boreal lakes were cored (August 2002) in the Haute-Mauricie region, where the fire history is well documented. Total Hg combined with geochronological analyses confirm the importance of wildfires on Hg cycling. Charcoal measurements on these samples will be completed early in 2003. High-resolution porewater sampling. Diffusive Gradient in Thin-films (DGT) approach was abandoned because extensive measurements of metal species diffusion within the types of hydrogels currently used in DGT samplers indicated that sampling with this technique is prone to artifacts. Stable Pb isotopes. Sediment cores (August-September 2002) were

obtained from the vicinity and extended region of Rouyn-Noranda for Pb and $^{206}Pb/^{207}Pb$, $^{206}Pb/^{208}Pb$ and $^{206}Pb/^{204}Pb$ measurements. Porewaters using peepers were also collected in that region to determine Pb mobility. Fish and *Hexagenia limbata* (Ephemeroptera) were collected for measurement of Pb isotopic ratios. Measurements of Pb ratios are complete for L. Vose sediments while the other measurements are underway. The large differences in isotopic signature between L. Vose and L. Tantaré indicate that the geographical influence of smelter emissions can be traced using lake sediments. Ag and platinoids. Two projects on Ag and platinoid metals geochemistry were initiated. Cores and porewater samples from L. Tantaré and L. Vose have been analyzed.

Project A5 Development, evaluation and applications of analytical methods for chemical speciation of mercury associated with atmospheric particulate matter/aerosols and with suspended matter in wet precipitation (J.Y. Lu, Ryerson University): Temperature programs that combine step-wise and linear ramping have been developed and tested, and have been compared with the linear ramping program for separating mercury species associated with airborne particulate matter. Samples of airborne particulate matter have been collected in an industrial area in Nanticoke region (with support from Mr. Robert Kozopas, OPG) and in the Arctic (in collaboration with Dr. W.H. Schroeder, Environment Canada). Samples of suspended particulate matter in rainwater have also been collected (in collaboration with Dr. W. Hendershot) from Sudbury, Ontario, and Rouyn-Noranda, Québec. The methodology for mercury speciation using Electrothermal Vaporization-Inductively Coupled Plasma-Mass Spectroscopy (ETV-ICP-MS) developed in the lab has been tested using the samples collected from the industrial area and the Arctic. The samples of suspended particulate matter in rainwater are to be analyzed. Since the homogeneity of the coal-fly ash samples spiked with solid mercury compounds is poor, a new methodology using vapours of mercury compounds has been developed for preparing standards containing mercury compounds.

Project A6 Application of sensitive techniques for the chemical analysis of aerosolic particulates (G.A. Spiers, Laurentian University): In May 2002, a new generation EMMA analytical system incorporating a specially designed high resolution Ge detector for small samples was installed. This EMMA system is designed to allow analyses of soil and sediment powders, finely ground organic samples, materials on filters, and small individual grains. Students and staff of the CEM have been trained in operation and quality control techniques on the new EMMA, with analyses currently proceeding on the filters collected from snowpack during the previous winter. Collections from a smaller number of sites (~25) at varying distances from the smelter heartland through to the Quebec border are planned for the upcoming winter. Another project utilizing the MITE-RN support includes a detailed examination of road dusts within the Ramsey Lake watershed, the major drinking water source for the Greater City of Sudbury. The road dusts have been analysed for chemical, mineralogical and morphological properties. At selected sampling sites adjacent to both high and low density use roads, as well as car parks, modern anthropogenic aerosols were collected and characterized. Preliminary data from this undergraduate thesis project was presented at the MITE-RN workshop in 2003. The recent arrival of the Cascade Air Samplers from Dr. Lamoureux enable a collaborative research program to be initiated, with Stage I being with research projects examining the nature of aerosol and road dust input to Ramsey Lake, the Sudbury drinking water supply. Then the samplers will be installed at selected sites from the snow

aerosol-sampling program completed over the past two winters. Selected samples will be shipped to Dr. Lamoureux (A2) for detailed speciation analyses. Samples of colloidal material from the soil lysimetry project established by Dr. Hendershot (B1) will also be analysed by EMMA on arrival at the CEM laboratories in Sudbury. Examination of the morphological, chemical and mineralogical nature of the mobile colloidal phase of these soil solutions from soils in industrially contaminated sites will be compared with those collected previously from soils under mixed aspen-spruce from pristine sites. Columns from the "Rates of trace metal release due to mineral weathering" (Hendershot, A7) will be impregnated at the end of the leaching experiments. The columns will then be sectioned and analyzed by electron beam techniques at CEM to quantify the removal of selected metals from mineral grain surface layers.

Project A7 Rates of trace metal release due to mineral weathering (W. Hendershot, McGill University). Two series of whole soil weathering experiments have been conducted to test and perfect the methodology to determine the rate of input of trace metals into the soil environment by weathering of trace metal rich minerals or polymineralic fragments. The column leaching protocol appears to be working very well with stable and repeatable results. In the proposal, the importance of being able to measure the amounts of trace metal released from the mineral phase and then re-adsorbed was stressed since it was thought that the metals released by weathering would not remain in solution. The experimental results confirm that this is the case. However, the EDTA solution used to displace the re-adsorbed metals seems to be working and it is expected release rates will be measured. The chemical analysis from the second experiment is underway and a final decision on the details of the methodology will be taken in January 2003. At that time, soil fractions from collaborator, Jeanne Percival, will be the focus of further weathering experiments. Another objective is to use the data obtained to calibrate a mineral weathering model that will predict the release rate of trace metals as a function of mineralogy and environmental conditions. A working model that will simulate the behaviour of the leaching columns is being developed and combines solution speciation, surface adsorption and mineral weathering.

Project AF8 Redistribution of metals in lake sediments by bacterially mediated oxidation-reduction reactions (D. Gould, Natural Resources Canada): A series of microcosm experiments were set up in November 2001 to study the key hypotheses in the lake sediment study based on fresh sediment samples taken by divers in September 2001. The cores incubated at 6^{o}C were sampled over a time series, in January 2002 and in October 2002. The room temperature samples without organic matter addition were sampled in January 2002 and in August 2002. Chemical analyses of the sediments from the last sampling of the microcosm experiment are currently being completed and the microbial data and the available chemical data from the microcosm study are presently being interpreted. Preliminary results indicate that elevated concentrations of soluble iron in the porewater fraction are observed throughout most of the sediment column when ferrihydrite was added. Also increased concentrations of solid phase iron were observed in the two cm of sediments above the ferrihydrite-amended layer. Additional experiments will be undertaken in order to determine if the effect is due to mobilization and redeposition of iron, or to an artifact of the sampling procedure. The addition of organic matter had no effect on either the microbiology or the chemistry of the microcosms which supports the view that electron acceptors

rather than electron donors are limiting in these particular sediments. During 2002, the PI was absent for 4 ½ months on secondment to a laboratory in Singapore and the experiments have fallen two months behind schedule. Future plans involve a series of triplicate microcosm studies at 6°C with and without ferrihydrite and an abiotic control (gamma radiation sterilized). Labelled iron (^{57}Fe) and nickel (^{61}Ni) will be used.

Project AF9 The role of bacteria in the mobilization of arsenic from mine impacted sediments (V. Palace, Dept. of Fisheries and Oceans): This project aims at studying the community structures of iron, arsenic and sulphate reducing bacteria in Balmer Lake sediments. Results will be used to focus further studies on the most relevant organisms for As release from sediments. As well, physiological and genetic characterization of arsenic, iron and sulphate reducers has been continued. To this date, studies to determine total diversity of microbial colonies with sediment depth have been completed. The microbial numbers have also been correlated with arsenic and iron concentrations at each depth. Phylogenetic characterization of the iron, arsenic and sulfate reducing microbes present at each depth are continuing. Total diversity studies are also ongoing using primer specific analysis by PCR. An arsenic respiring bacteria from Balmer Lake sediments has been isolated and phylogenetic characterization has been completed. An analysis of arsenic flux in lab microcosms under varying redox regimes has been initiated at the University of Montana laboratories. These experiments are comparing the biotic driven release of arsenic from sediments relative to sterilized cores. This work will continue through the 2003-04 study year.

Project AF10 Examination of mineral weathering and release of trace elements in selected soil profiles (J. Percival, Geological Survey of Canada): This project aims at providing a detailed mineralogical characterization of six soil profiles located in Sudbury and Rouyn-Noranda. Specifically, the determination of trace minerals that can be a source of trace metals in the weathering environment was undertaken. Detailed mineralogical analyses by X-ray diffraction and scanning electron microscopy determined that some minerals may be potential substrates for metal retention, including biotite, chlorite and Fe-oxides. SEM analyses to X-ray map specific metals have not yet started, but polished thin sections of grain mounts are in hand. The identification and preparation of appropriate grain size fraction or discrete minerals for weathering experiments is another objective to be achieved. Sample fractionation was completed on 6 B/C soil samples from the Rouyn-Noranda and Sudbury soil stations that are instrumented with bulk precipitation collectors, through-fall collectors and lysimeters. Samples were also separated into magnetic and non-magnetic heavy mineral fractions. Discussions with Hendershot to select appropriate fraction(s) for weathering experiments are in progress. The sequential extraction of trace metals from selected samples to determine mobility potential is earmarked for 2003-2004.

8.2 <Processes>

Executive Summary for FY 2002-2003

Domain Co-Leaders:
Dr. Beverley Hale, Land Resource Science, University of Guelph
Dr. Gary Rawn, Department of Fisheries and Oceans

Projects included in <Processes> Domain:

Project Title	Principal/Co Investigators	Affiliation
B1 Post-depositional mobility of trace metals in boreal forest ecosystems: root-soil interactions.	Hale, BA Hendershot, W	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-ETE, U du Québec INRS-ETE, U du Québec Ontario Ministry of the Environment, York University
B4 Metal speciation in freshwaters, soil pore waters, through-fall precipitation, atmospheric precipitation and in aqueous solutions resulting from wetting of atmospheric particulates.	Chakrabarti, C Grégoire, DC	Dept. Chemistry Carleton University GSC, Natural Resources Canada
B5 The availability of trace metals in the rhizosphere of contaminated soils from the Sudbury area.	Courchesne, F	Dept. of Geography Univ de Montréal
B6 Metal budgets of lakes and catchments on the Precambrian Shield: compartment sizes and fluxes between compartments.	Dillon, P Watmough, S	Environmental and Resource Studies / Chemistry Trent University
B7 Importance of reduced sulphur species in controlling metal speciation in surface waters on the Canadian Shield.	Wang, F Tessier, A	Dept. of Chemistry University of Manitoba INRS-ETE

Progress toward Achievement of the Objectives:

The <Processes> domain currently includes six projects that focus on partitioning of metals among terrestrial and aquatic environmental compartments. The studies focus on: cycling of metals between soils and plants; bioaccumulation of metals in the aquatic environment related to differences in organism exposure routes; validation of methods for speciating metals in dilute aqueous solution; speciation of non-essential metals in the rhizosphere; speciation of metals relative to the oxic state of sulphur in water; and, watershed mobility of microelements. The broad questions addressed in the <Processes> Domain are:
- What are the relationships among total metal, bioavailable metal and bioaccumulation in environmental compartments?
- What is the role of organic and mineral surfaces in metal binding in abiotic compartments of the environment and how does this metal binding affect metal availability?

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

This research project has two main objectives. The first is to develop and test a comprehensive soil – soil solution – root model to predict metal bound to root surface as a function of soil chemistry and environmental conditions. Work on this objective is advancing well. To date a number of modeling approaches have been tested to describe the adsorption of trace metals on both mineral and organic soil materials. The NICA-Donnan model describes the behaviour of the system very well and this model has been calibrated using surface adsorption data. It has also been determined that the adsorption of trace metals on roots can be described using binding constants for the acetate ligand (with some minor adjustments). The second objective is to determine the metal binding capacity of decomposing fine roots and foliage in order to predict when they might act as metal sources or sinks to soils. Progress on this objective is tangential, as the graduate student who was to start in Fall 02, declined in the first week of September. There was no immediately available student to take her place, so D. Johnson was hired as a post-doctoral fellow until December 02, for the purpose of writing manuscripts. Three have been submitted, including the HERA paper, and two more are being written. Since January, Paula Cypas (Ph.D. student) has been supported by MITE; her project has been to develop conditional stability constants for Cu binding to roots, using wheat and hydroponic solutions.

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, INRS, Université du Québec):

This project involves three main research objectives. The first is to understand the exposure of burrowing animals to sedimentary metals. Significant progress was made by developing a means of measuring the velocity of the currents that invertebrates produce in their burrows. By measuring the diffusive loss of a tracer gas through a membrane-tipped micro-sensor the low current velocities (< mm per second) produced by the burrowing mayfly *Hexagenia limbata* (Ephemeroptera) can be measured. These data are currently being analyzed for publication. Measurements have also been made on the impact of sedimentary metals on invertebrate behaviour. Behavioural endpoints included burrow length, form and depth measured on radiographs, as well as the duration of irrigation, walking and feeding movements recorded by infrared camera. A second objective was to determine the relative importance of food and water for insect larvae in nature. Progress was made on this objective by comparing Pb uptake by the alderfly *Sialis velata* from food and water in a field setting and by measuring Pb losses by *Sialis* from a contaminated lake (Dufault, Rouyn-Noranda). A further field experiment to compare the relative importance of food and water as sources of several metals was conducted. Preliminary results indicate that *Sialis* larvae take up nearly all of their Cd, Cu and Pb from their food. Because food is the major metal source for *Sialis*, its trophic position in various lakes could influence its metal concentrations. N isotope ratios are being measured as a means of comparing trophic positions. A third objective to determine the site(s) of Cd^{2+}-H^{+} competition in the food chain leading to *Chaoborus* has also been pursued.

Project B4 Metal speciation in freshwaters, soil pore waters, throughfall precipitation, atmospheric precipitation and in aqueous solutions resulting from wetting of atmospheric particulates (C.L. Chakrabarti, Carleton University):

Two interrelated objectives of this research project are: i) to determine the environmental factors that control free metal ion availability in freshwaters, soil pore waters and atmospheric precipitation, and ii) to develop new techniques for determination of metal speciation parameters including the dissociation rate coefficient (which is a measure of the chemical reactivity), the diffusion coefficient (which is a measure of the mobility), and the stability constant (which is a measure of the equilibrium availability of free metal ions). Substantial progress has been made in developing and applying metal speciation techniques and methods for determining metal speciation in soil pore water samples and rain throughfall samples from Sudbury and Rouyn-Noranda provided by Project B1 and in lake water samples from Rouyn-Noranda provided by Project C3. Metal speciation techniques that have been developed and applied to the MITE samples include: Competing Ligand Exchange and Adsorptive Cathodic Stripping Voltammetry, Anodic Stripping Voltammetry using a Rotating Disk Electrode, Classical Anodic Stripping Voltammetry at a Hanging Mercury Drop Electrode, and Competing Ligand Exchange and Graphite Furnace Atomic Absorption Spectrometry for the kinetic speciation of metals. Important progress has also been made in applying the new equilibrium speciation model, WHAM/VI, to the MITE samples of Projects B1and C3.

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

Significant progress has been made on both the field and laboratory portions of this project. Soils were collected at three locations in the Sudbury area and these sampling sites were chosen among a series of sites already studied by researchers in Project B1 and are the same as those used in the fall of 2001 to sample the rhizosphere of white birch (*Betula papyrifera*). The separation of soil samples into bulk and rhizosphere components (both inner and outer rhizosphere) was completed in the laboratory.The textural and mineralogical analyses of 2001 samples were conducted in April-May 2002 together with pH (H_2O) and organic C determinations. Synchrotron – XRF and XANES analyses were also conducted on selected rhizosphere aggregates from the Rouyn site. The fractionation of trace metals in the rhizosphere and the bulk soils and the subsequent analyses by ICP-AES or ICP-MS started last March. The H_2O, $BaCl_2$ and pyrophosphate extractions for Al, Cd, Cr, Co, Cu, Fe, Mn, Ni, Pb, and Zn on the 9 sites from Rouyn under *Populus tremuloïdes* were completed in December 2002. All analyses should be completed in June 2003. Method development (ion selective electrode) for measuring the free Cu^{2+} ion activity in water extracts from the rhizosphere under *Betula papyrifera* was initiated early December 2002 and method development for the oxalate extraction will be done next spring.

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

This project was initiated in mid-2001, and data collection has been underway for seventeen months. The purpose of the project is to establish the size of the compartments of metals (including but not limited to the five key metals, Cu, Ni, Zn, Pb, Cd) and the fluxes between compartments in a catchment (Plastic Lake, Haliburton County, Ontario) that is not impacted by local point sources of metals. This is an integrated study of the terrestrial and aquatic portions of the catchment, and includes analysis of the transport of metals between the land and water, the role of both acid deposition and dissolved organic carbon (DOC) in this transport, and the evaluation of the major sinks and sources of metals within the lake and its catchment. Almost all of the stated objectives in the 2002-03 proposal have been met with only a few slightly behind schedule. The pool or compartment sizes have all been estimated with the exception of the wetland (plant material and sediment) and the lake sediments. These will be completed before the summer of 2003. Measurement of the fluxes between compartments is ongoing, with all instrumentation in place and data collection underway. Work has recently begun to separate the particulate (>0.45 m) and dissolved fractions of the metals as the first step in speciation. This has included extensive QA/QC studies of various filters. As well new studies focusing on the use of stable isotope ratios for source identification using the new high resolution MS instrumentation at the Trent Water Quality Centre have now begun (funded independently of MITE at this point), with a focus on Pb.

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

The objectives of this 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. The year 2002 marked the second year of this project and was characterized by intensive studies on the stability of metal-sulfide species in oxic waters and the structural identification of these species. Significant progress was made on the development of analytical techniques for the measurement of total sulfide. The Cr(II)-reducible-sulfide (CRS) method was found to effectively recover the sulfide in the Cd-S and Cu-S species. As a result, two different analytical methods were used for all the subsequent studies: the AVS method for the study of sulfide species of Fe, Mn, Zn and Pb, and the CRS method for sulfide species of Cd and Cu. In order to identify metal-sulfide species by mass spectrometry (MS) two direct structural analytical methods have been tested: electrospray ionization – mass spectroscopy (ESI-MS) and high performance liquid chromatography – high resolution mass spectroscopy (HPLC-HRMS). The electrochemical determination of RSS and metal-RSS complexes was started in January 2002 to develop methods for determining metal-sulfide and metal-polysulfide species by voltammetry. Methods were developed to make the solid-state Au-Hg microelectrodes. Unfortunately, this investigation was subsequently stopped in May 2002 when the graduate student relocated to another university to pursue other interests. As a result, the electroanalytical determination of metal-RSS species has been delayed until a suitable graduate student is available.

The determination of formation constants for Hg-RSS complexes was initiated in November of 2002 with the arrival of a new postdoctoral research fellow and will be continued for most of Year 3. A new ultra-trace analytical technique for the analysis of mercury is being developed with a state-of-the-art DRC II ICP-MS (Perkin Elmer) in the metal-free Ultra-Clean Trace Element Laboratory. Progress was made on field sampling and analysis of metal speciation. In addition to the four lakes studied in Year 1, two more lakes in western Ontario, Lakes 658 and Wabigoon, were added in the Year 2's field study. Each lake was visited once in the summer and overlying water peepers were used to collect dissolved water samples from the surface epilimnion layer. In addition to the AVS and CRS, samples were also collected for analysis of the 8 metals of interest (Fe, Mn, Cd, Cu, Hg, Ni, Pb and Zn), as well as pH, major cations (e.g., Ca^{2+}, Mg^{2+}, Na^{+}, K^{+}), anions (DIC, SO_4^{2-}, Cl^{-}) and DOC. Once all the analyses are completed, calculations will be made to estimate the relative importance of metal-sulfide species in determining metal speciation in these surface waters. Investigation of biogenic thiols in surface and sediment porewaters was initiated in the summer of 2002 and will be carried on by a PDF for most of Year 3.

Partnerships and Collaboration

In the <Processes> domain, projects B1 and B5 work on the same forest sites, and, as rhizospheric processes are widely assumed to modify metal bioavailability, the rhizosphere soil project (B5) will help bridge the work on trace metal activity and speciation in the bulk soil solution to that on metal accumulation in the vegetation, being carried out in B1. The laboratory-derived methods of measuring metal speciation in solution (B4) are being applied to field collected samples of surface water, precipitation and soil solution, collected in projects B1 and C3. This benefits both projects, as it allows validation of the techniques for B4 investigators, and provides speciation information that B1 and C3 investigators can incorporate into their biological investigations. The flux model for a catchment not influenced by local sources of metals (B6) is in notable contrast with the box model being developed in B1, a catchment that is influenced by local sources; the outputs from these two models form the basis for a very powerful comparison.

8.3 <Impacts>

Executive Summary for FY 2002-2003

Domain Co-Leaders:

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

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

Projects Included in <Impacts> Domain:

Project Title	Principal/Co Investigators	Affiliation
C1 Predicting metal and metal mixture effects in aquatic biota.	Dixon, DG Borgmann, U	Department of Biology University of Waterloo NWRI, Environment Canada
C2 Assessing biological effects of chronic metal exposures to fish – laboratory studies.	Wood, CM McDonald, DG	Dept. Biology McMaster University
C3 Links between metal burdens in indigenous fish and metal-induced effects at the organism and population levels.	Campbell, PGC Hontela, A Rasmussen, JB	INRS-ETE, INRS, U. du Québec Dépt. Biologie, U. du Québec Montréal Dept. Biology, McGill University
C4 Accumulation and effects of metals in fish-eating birds.	Chan, LHM Scheuhammer, AM	Dept. Diet. Human Nutrition McGill University CWS, Environment Canada
C5 Population and physiological effects of industrial metal contamination on wild fish.	Couture, P Pyle, G	Dept. Biology, Laurentian University Dept. Biology, Nipissing University

Progress toward Achievement of the Objectives

In the <Impacts> Domain, emphasis has been on research into freshwater ecosystems. 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 following research questions were identified in the original proposal and are being addressed in the <Impacts> Domain:

- How is metal speciation, in the exposure medium and within the exposed organism, related to metal-induced effects at the cellular and individual levels?
- Under conditions of chronic exposure, how does food ration (quality; quantity) affect metal toxicity at the organism level?

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

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

The main objectives of this project 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 modeling or body concentration measurements can improve our ability to predict the effects of metals in mixtures. A series of metal mixture 1-week bioaccumulation tests has been completed and the compilation of the data and analyses of the samples are ongoing. Metal species and competing inorganic ions were determined with the MINTEQA2 model. Binding constants for nickel, hydrogen and calcium to the biological receptor were estimated from the exposures since these were the only factors shown to affect nickel uptake. A Biotic Ligand Model (BLM) for short term nickel toxicity was developed and toxicity tests were conducted under different exposure conditions to compare observed to expected toxicity. The model showed that BLM modelling was possible for nickel in *Hyalella*. Results from metal bioaccumulation studies conducted using water and sediments collected from five lakes near Sudbury, Ontario and Rouyn-Noranda, Quebec were interpreted for nickel and cadmium. Overall, water chemistry was found to have a substantial effect on cadmium bioavailability from sediment, but only a minimal effect on nickel bioavailability from sediment. Preliminary work began to study the effect of metals accumulated through food on *Hyalella*. This work includes development of culture methods for periphyton, testing of growth and survival of *Hyalella* fed exclusively on periphyton, and preliminary studies on Cd accumulation kinetics by periphyton in preparation for future experiments on exposure of *Hyalella* to Cd-contaminated periphyton.

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

The overall long term objectives of this study 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 aim of developing a BLM for chronic toxicity via both exposure routes. There were four important objectives for 2002/03. The first, which focussed on the interrelation between ration quantity and chronic sublethal Cd toxicity in rainbow trout (RBT), is now complete and the results indicate that ration quantity can influence Cd uptake, tissue accumulation and toxicity. Significant progress has been made on the second objective, which was to further develop our understanding further of the influence of dietary quality and quantity on the impacts of both waterborne and dietary metals with emphasis on Cd & Zn, using RBT as a model system. Dietary quality (Ca content) has been shown to reduce the uptake and accumulation of both waterborne Cd and Zn, thereby suggesting the protective role of dietary Ca against waterborne Cd and Zn toxicity. The third objective was to evaluate the effect of sublethal waterborne Cu on feeding pattern and food selection in RBT. This study indicates that sublethal waterborne Cu severely affects food selection, feeding rate and growth in RBT. Finally, the fourth

objective was to complete the work on the development of an acute BLM for Cd in yellow perch (YP), a fish species which is endemic to metal-impacted lakes of Eastern Canada (Rouyn-Noranda, Sudbury) and to move on to the development of an acute Zn BLM in the same species. The development of the acute Cd BLM for YP is now complete and the results suggest that the acute Cd BLM framework, originally developed in model species (RBT), can be extended to YP by simple adjustment of the value of Lethal Cd Accumulation in the gill (LA_{50}). The results further strengthen previous studies showing that gill-metal binding characteristics change with acclimation to metal exposure (both by aqueous and dietary route), a phenomenon that is not considered in the present version of BLM and needs further research.

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

This field project has been designed to assess inter-lake variability in the responses of indigenous fish (yellow perch, YP) collected from lakes situated along a metal concentration gradient. Relations are being sought between the physiological condition of the fish and their population status *versus* i) ecological factors (habitat quality, food resources), ii) toxicological factors (ambient [M]) and iii) metal detoxification factors (metallothionein (MT) induction and subcellular metal partitioning). At INRS, variations in the efficiency of metal detoxification along a metal concentration gradient and the dynamics of metal accumulation in juvenile yellow perch in the field are being assessed. Inter-lake variability has been analyzed by examining: i) changes in metal partitioning among YP tissues as ambient metal levels increase, and ii) responses of juvenile YP along the metal concentration gradient at the tissue level. In 2002 a full-scale habitat-swap (transplant) experiment to study the dynamics of metal uptake and MT induction in juvenile YP was also carried out. At UQAM, the relationship between physiological fitness and metal tissue concentrations in young stages of yellow perch is being assessed. Analysis of physiological data from the Abitibi lakes has been completed. Based on these results, the study has been extended to lakes in the Sudbury area. Thus far, plasma cortisol levels have been measured in all the sampled fish; the other biochemical analyses (*in vitro* cortisol secretion by head kidney tissues, plasma thyroid hormone levels, plasma glucose, liver glycogen) and histomorphological analyses of tissues (gill, thyroid, gonads) are in progress. The gonadosomatic, hepatosomatic indices have been calculated and the statistical analyses are also in progress. It is anticipated that the comparison of physiological, hormonal and population responses in yellow perch sampled from the two regions (Abitibi and Sudbury) will be very important for the validation of the biomarker responses to metals. At McGill, in parallel with the field activities described above, studies have been extended to assess the responses of populations and communities to metal impacts by examining lakes in different stages of recovery from historic metal impacts in the Sudbury area. Analysis of benthic samples from Abitibi lakes has been completed.

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

The objective of this study is to determine the extent to which environmental metal contamination is causing adverse effects in wildlife populations in Canada. A direct relationship was not seen between Hg exposure and immunotoxicity in common loons both *in vivo* and *in vitro*. Good progress is being made in the field study for comparing fish-Hg levels, and Hg exposure in loons breeding in environments with differing natural background levels of Hg, differing environmental chemistry, and differing levels of anthropogenic activity, especially metal mining and smelting. A good correlation of Hg/Se was observed in various tissues in common loons. Hg and Se speciation was found to be different in different tissues. All Hg in loon eggs were found to be associated with Se.

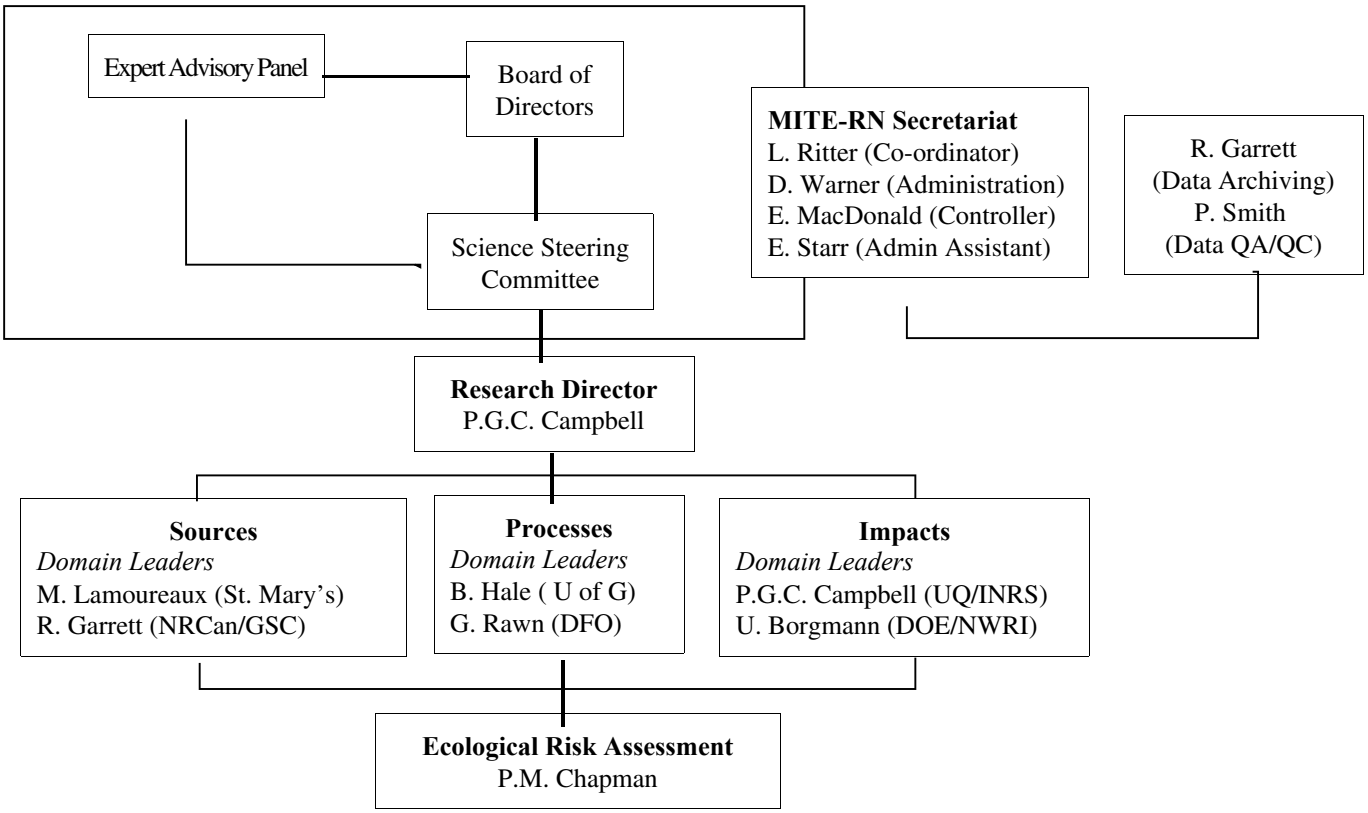
Project C5 Population and physiological effects of industrial metal contamination on wild fish (P. Couture, Laurentian University):

Significant progress has been made with respect to the objectives stated in the original proposal. The overall objective was to understand the extent of metabolic impairment and the factors influencing growth, reproductive fitness, and physiological condition in wild fish inhabiting metal-contaminated lakes. The specific objectives were: i) to identify and characterise population-level metal effects in wild yellow perch (YP) and other forage fish inhabiting industrially-contaminated lakes around Sudbury, ON; ii) to increase understanding of direct effects (i.e., toxic metabolic effects) vs. indirect effects (i.e., food web disturbances, investigated by C3 in the same lakes) of environmental metal contamination on wild fish condition, growth, and metabolic performance; and iii) to assess the ionic composition and metal contamination of natural YP diets, and to determine if they relate to effects identified in (ii). All sampling required to reach these objectives was successfully completed and most laboratory analyses are complete. Data analysis is underway and will be complete before the start of the next MITE field season.

Partnerships and Collaboration

In the <Impacts> Domain, projects C1 and C3, as well as one of the government projects funded by the Network (Project CF1, CF2) with funds from the Mining Association of Canada (EC-NWRI; L. Grapentine), share a common interest in the influence of metals on benthic invertebrates. A common set of lakes has been sampled by all three teams in the Rouyn-Noranda area, and data have been exchanged among the projects. Researchers from projects B2 and C1 are collaborating on writing a commentary manuscript for Human and Ecological Risk Assessment on metal uptake from food in invertebrates, and influence from project B2 has resulted in the initiation of a new study by a new graduate student in C1 looking at the toxicity of metal accumulated from food. Similar links exist among projects C2, C3, and C5 where the yellow perch has been chosen both as a sentinel species for the field-based research and as a test species for the ongoing physiological and dietary studies in the McMaster University fish toxicology laboratories. Students and researchers from INRS-ETE have profited from the physiological expertise of their counterparts at McMaster University and Laurentian University. INRS-ETE researchers have helped with the metal speciation simulations used by the McMaster researchers in designing their exposure media.

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:

Dr. Peter G. C. Campbell, INRS-ETE - Université du Québec, 2700, rue Einstein - Case Postale 7500
Sainte-Foy, Québec G1V 4C7
Tel.: 418-654-2538
Fax: 418-654-2600
Email: campbell@uquebec.ca

9.2 Data Archiving

A web site has been 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 was 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 for all field projects have been posted on the web site.

MITE-RN Data Archiving Co-ordinator
Dr. Robert G. Garrett
Geological Survey of Canada - Natural Resources Canada
601 Booth Street, Ottawa, Ontario K1A 0E8
Tel.: 613-995-4517 ext. 6556
Fax: 613-996-3726
Email: garrett@gsc.nrcan.gc.ca

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).

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.

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, percent recovery of metals and an estimate of accuracy and precision for a typical set of data generated from their laboratory.

QA/QC Co-ordinator:
Mr. Peter Smith, Land Resource Science, University of Guelph
Guelph, Ontario N1G 2W1
Tel.: 519-824-4120, ext. 3507
Fax: 519-824-5730
Email: psmith@lrs.uoguelph.ca

9.4 Ecological Risk Assessment

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 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 is located at Environment Canada, under the supervision of Dr. Pat Doyle, and the other is at EVS Environment Consultants in Vancouver, under the supervision of Dr. Peter Chapman, the MITE-RN ERA coordinator. Incumbents are carrying out projects 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.
- 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

MITE-RN ERA Co-ordinator:
Dr. Peter Chapman, Senior Environmental Scientist, EVS Environment Consultants
195 Pemberton Avenue, North Vancouver, British Columbia , V7P 2R4
Tel.: 604-904-4005
Fax: 604-662-8548
Email: pchapman@attglobal.net

9.5 Science Steering Committee (SSC)

The purpose of the SSC, chaired by Dr. P.G.C. Campbell, is to monitor research progress and make recommendations 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.

Dr. Uwe Borgmann
National Water Research Institute
Environment Canada
867 Lakeshore Road
Burlington, Ontario
L7R 4A6
Tel.: 905-336-6280
Fax.: 905-336-6430
Email: uwe.borgmann@ec.gc.ca

Dr. Peter Campbell (SSC Chair)
INRS-ETE
Université du Québec
2700, rue Einstein
Sainte-Foy, Québec
G1V 4C7
Tel.: 418-654-2538
Fax.: 418-654-2600
Email: campbell@uquebec.ca

Dr. Peter Chapman
Senior Environmental Scientist
EVS Environment Consultants
195 Pemberton Avenue
North Vancouver, British Columbia
V7P 2R4
Tel.: 604-904-4005
Fax: 604-662-8548
Email: pchapman@attglobal.net

Dr. Marc Lamoureux
St. Mary's University
Department of Chemistry
923 Robie Street
Halifax, Nova Scotia
B3H 3J5
Tel.: 902-420-5652
Fax.: 902-496-8104
Email: marc.lamoureux@stmarys.ca

Dr. Robert G. Garrett
Geological Survey of Canada
601 Booth Street
Ottawa, Ontario
K1A 0E8
Tel.: 613-995-4517
Fax.: 613-996-3726
Email: garrett@gsc.nrcan.gc.ca

Dr. Beverley Hale
University of Guelph
Land Resource Science
Guelph, Ontario
N1G 2W1
Tel.: 519-824-4120 Ext. 3434
Fax.: 519-824-5730
Email: bhale@uoguelph.ca

Dr. Gregory Pope
Electricity Production
Ontario Power Generation
700 University Avenue
Toronto, Ontario
M5G 1X6
Tel.: 416-592-2529
Fax.: 416-592-4841
Email: greg.pope@ontariopowergeneration.com

Dr. Lisa Ortego
NiPERA
Ste. 200 - 2605 Meridian Parkway
Durham, North Carolina
27713
Tel.: 919-544-7722 X174
Fax.: 919-544-7724
Email: lortego@nipera.org

Dr. Gary Rawn
Environmental Science Branch
Dept. of Fisheries & Oceans
200 Kent Street
Ottawa, Ontario
K1A 0E6
Tel.: 613-993-3065
Fax.: 613-998-3329
Email: rawng@dfo-mpo.gc.ca

Mr. Robert Prairie
Noranda Inc./Noranda Technology Centre
240 Hymus Boulevard
Pointe-Claire, Québec
H9R 1G5
Tel.: 514-630-9357
Fax. 514-630-9379
Email:prairie@ntc.noranda.com

Dr. Cathy Banic
Atmospheric Environment Service
4905 Dufferin Street
Downsview, Ontario
M3H 5T4
Tel.: 416-739-4613
Fax.: 416-739-5708
Email: cathy.banic@ec.gc.ca

Dr. Len Ritter
C.N.T.C. Executive Director
and MITE-RN Coordinator
University of Guelph
Gordon Street, Bovey Building
Guelph, Ontario
N1G 2W1
Tel.: 519-837-3320
Fax.: 519-837-3861
Email: lritter@tox.uoguelph.ca

Ms. Donna Warner
C.N.T.C. and
MITE-RN Program Coordinator
University of Guelph
Gordon Street, Bovey Building
Guelph, Ontario
N1G 2W1
Tel.: 519-837-3320
Fax.: 519-837-3861
Email: dwarner@tox.uoguelph.ca

9.6 Expert Advisory Panel (EAP)

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

Dr. Dominic M. DiToro
HydroQual Inc.
One Lethbridge Plaza
Mahwah, New Jersey 07430-2127
Tel.: 201-529-5151
Fax.: 201-529-5728
Email: dditoro@hydroqual.com

Dr. Jack Klaverkamp (EAC Chair)
Fisheries and Oceans Canada
Freshwater Institute
501 University Crescent
Winnipeg, Manitoba R3T 2N6
Tel.: 204-983-5003
Fax.: 204-984-6587
Email: klaverkampJ@dfo-mpo.gc.ca

Dr. Murray B. McBride
Cornell University
Department of Soil, Crop and
Atmospheric Sciences
910 Bradfield Hall
Ithaca, New York 14853
Tel.: 607-255-1728
Fax. 607-255-7656
Email: MBM7@cornell.edu

Dr. David Mount
US Environmental Protection Agency
Office of Research and Development
6201 Congdon Boulevard
Duluth, MN 55804
Tel.: 218-529-5169
Fax: 218-529-5003
Email: mount.dave@epamail.epa.gov

Dr. Stephen A. Norton
Dept. of Geological Sciences
Brand Global Sciences Centre
University of Maine
Orono, Maine
04469-5790
Tel.: 207-581-2156
Fax: 207-581-2202
Email: norton@maine.edu

9.7 Board of Directors

The Board of Directors, chaired by Dr. Bruce Conard, has final authority with respect to all affairs regarding management of MITE-RN. The Board reviews recommendations made by the Expert Advisory 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.

Dr. John Carey
Director General
National Water Research Institute
Environment Canada
867 Lakeshore Blvd.
P.O. Box 5050
Burlington, Ontario
L7R 4A6
Tel.: 905-336-4625
Fax: 905-336-6444
E-mail: john.carey@ec.gc.ca

Dr. Peter Campbell
INRS-ETE
Université du Québec
2700, rue Einstein
Case postale 7500
Sainte-Foy, Québec
G1V 4C7
Tel.: 418-654-2538
Fax: 418-654-2600
Email: campbell@uquebec.ca

Dr. Bruce Conard (Chair)
V.P. Health Science
INCO Limited
145 King Street West
Toronto, Ontario
M5H 4B7
Tel.: 416-361-7938
Fax: 416-361-7941
E-mail: bconard@inco.com

Dr. Irwin Itzkovitch
Assistant Deputy Minister ADM/ESS
Earth Sciences Sector
Natural Resources Canada
14 - 580 Booth Street
Ottawa, Ontario
K1A 0E4
Tel.: 613-992-9983
Fax: 613-992-8874
Email: irwin@NRCan.gc.ca

Dr. Sinh LeQuoc
INRS
Université du Québec
Tour de la Cité
2600 boulevard Laurier bureau 640
Case postale 7500
Sainte-Foy, Québec
G1V 4C7
Tel.: 418-654-2500
Fax: 418-654-3858
Email: sinh_lequoc@inrs.uquebec.ca

Mr. Robert Kozopos
Manager, Environmental Planning
Electricity Production
Ontario Power Generation Inc.
700 University Avenue, H15 A09
Toronto, Ontario
M5G 1X6
Tel.: 416-592-6438
Fax: 416-592-4841
Email: bob.kozopas@ontariopower
generation.com

Dr. Alan Wildeman
Vice President, Research
University of Guelph
Guelph, Ontario
N1G 2W1
Tel.: 519-824-4120 X 3081
Fax: 519-837-1639
E-mail: julier@exec.admin.uoguelph.ca

Dr. Wendy Watson-Wright
Assistant Deputy Minister
Science Sector
Fisheries and Oceans Canada
200 Kent Street
Ottawa, Ontario
K1A 0E6
Tel.: 613-990-5123
Fax: 613-990-5113
E-mail: watson-wright@dfo-mpo.gc.ca

Dr. Len Ritter
C.N.T.C. Executive Director and
Coordinator of MITE-RN
University of Guelph
Gordon Street, Bovey Building
Guelph, Ontario
N1G 2W1
Tel.: 519-837-3320
Fax: 519-837-3861
Email: lritter@tox.uoguelph.ca

Mr. Robert Telewiak
Vice President, Environment,
Health & Safety
Noranda Inc./Falconbridge Limited
95 Wellington St. W., Ste. 1200
Toronto, Ontario
M5J 2V4
Tel.: 416-982-7199
Fax: 416-982-3543
E-mail: robert.telewiak @toronto.norfalc.com

Mr. Alan Young
2704 Don Street
Ottawa, Ontario
K2B 6Y5
Tel: 613-820-1529
Email: alan.young@sympatico.ca

9.8 Network Secretariat

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

- Organization and administration of Network management meetings; liaising with members of the Science Steering Committee, Expert Advisory Panel, and Board of Directors;

- Development and distribution of communications such as: MITE-RN News, MITE-RN Annual Report;

- Development and maintenance of a Network web site to facilitate the dissemination of research data;

- Oversight of a management reporting system to facilitate the annual research peer review process;

- Organization and facilitation of research meetings, workshops and conferences; and

- Financial and administrative management and accountability of Network funds.

Dr. Len Ritter
C.N.T.C. Executive Director and
Coordinator of MITE-RN
University of Guelph
Gordon Street, Bovey Building
Guelph, Ontario, N1G 2W1
Tel.: 519-837-3320
Fax.: 519-837-3861
Email: lritter@tox.uoguelph.ca

Mr. Ellis MacDonald
Controller
C.N.T.C. and MITE-RN
University of Guelph
Gordon Street, Bovey Building
Guelph, Ontario, N1G 2W1
Tel.: 519-837-3320
Fax.: 519-837-3861
Email: elmacdon@uoguelph.ca

Ms. Donna Warner
Program Co-ordinator
C.N.T.C.and MITE-RN
University of Guelph
Gordon Street, Bovey Building
Guelph, Ontario, N1G 2W1
Tel.: 519-837-3320
Fax.: 519-837-3861
Email: dwarner@tox.uoguelph.ca

Ms. Elayne Starr
Administrative Assistant
C.N.T.C. and MITE-RN
University of Guelph
Gordon Street, Bovey Building
Guelph, Ontario, N1G 2W1
Tel.: 519-837-3320
Fax.: 519-837-3861
Email: estarr@tox.uoguelph.ca

10 SCIENTIFIC PUBLICATIONS 2002 AND PRESENTATIONS

The following publications are for calendar year 2002; presentations cover the period March 1, 2002 to February 28, 2003.

10.1 <Sources> Publications

Alfaro-De la Torre, M.C. and A. Tessier. 2002. Cadmium deposition and mobility in the sediments of an acidic oligotrophic lake. Geochim. Cosmochim. Acta. 66: 3549-3562.

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Nicholas, D., S. Ramamoorthy, V.P. Palace, S. Spring, J. Moore, R.F. Rosenzweig. 2002. Biogeochemical transformations of arsenic in circumneutral freshwater sediment. Biodegredation 14 (2): 123-37.

10.2 <Processes> Publications

Chapman, P.M., F. Wang, J.D. Germano and G. Batley. 2002. Pore water testing and analysis. The good, the bad and the ugly. Mar. Pollut. Bull. 44: 359-366.

Croteau, M.N., L. Hare and A. Tessier. 2002. Increases in food web cadmium following reductions in atmospheric inputs to some lakes. Environmental Science & Technology 36: 3079-3082.

Croteau, M.N., L. Hare, P.G.C. Campbell and Y. Couillards. 2002. Metallothionein-like metal-binding protein in the biomonitor *Chaoborus*; occurrence and relationship to ambient metal concentrations in lakes. Environmental Toxicology & Chemistry 21: 737-741.

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Outridge, P.M., R. Mcneely, K.A. Hobson and A. Dyke. 2002. A comparison of modern and preindustrial levels of mercury in the teeth of beluga in the Mackenzie Delta, Northwest Territories, and walrus at Igloolik, Nunavut, Canada. Arctic 55: 123-132.

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10.3 <Impacts> Publications

Kamunde, C., C. Clayton and C.M. Wood. 2002. Waterborne vs dietary copper uptake in rainbow trout and the effect of previous waterborne copper exposure. American J. Physiology, 283(1): R69-78.

Levesque, H., T.W. Moon, P.G.C. Campbell and A. Hontela. 2002. Seasonal variation in carbohydrate and lipid metabolism of yellow perch (*Perca flavescens*) chronically exposed to metals in the field. Aquat. Toxicol. 60: 257-267.

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Sherwood, G.D., J. Kovecses, A. Hontela and J.B. Rasmussen. 2002. Simplified food webs lead to energetic bottlenecks in polluted lakes. Can J. Fish Aquat. Sci 59: 1-5.

Sherwood, G.D., I. Pazzia, A. Moeser, A. Hontela and J.B. Rasmussen. 2002. Shifting gears: enzymatic evidence for the energetic advantage of switching diet in wild-living fish. Can J Fish Aquat. Sci. 59: 229-241.

Taylor, L.N., D.W. Baker, C.M. Wood and D.G. McDonald. 2002. An *in vitro* approach for modelling branchial copper binding in rainbow trout. Comp. Biochem. Physiol. Part C, special BLM 133: 111-124.

10.4 <Sources> Presentations

Alfaro-De la Torre, C. and A Tessier. 2002. Cadmium biogeochemistry in an acidic pristine lake. ASLO, Victoria, BC. June 10-14.

Edwards, G.C., P.E. Rasmussen, W.H. Schroeder, G. Dias, L. Halfpenny-Mitchell, R.J. Kemp and D. Wallace. 2002. Micrometeorological measurements of gaseous mercury fluxes: theory and practice. 25th Agricultural and Forest Meteorology, 12th Joint Conference on the Applications of Air Pollution Meteorology with the Air and Waste Management Association, Fourth Symposium on the Urban Environment, Norfolk, VA. May 20-24.

Feng, W., J. Lu, W. H. Schroeder, D. C. Gregoire, C. Banic, and Y. Hao. 2002. Methodology for chemical speciation of mercury associated with atmospheric particulate matter. Arctic Atmospheric Mercury Research Workshop, Toronto, ON. August 26-28.

Gallon, C., A. Tessier, C. Gobeil, and L. Beaudin. 2002. Isotopic detection of historical sources of lead in a Canadian Shield Lake. ASLO, Victoria, BC. June 10-14.

Goulet, R.R., A. Tessier, L. Rancourt, R. Quirion and A. Perron. 2002. Validation of the diffusion gradient in thin-film technique for assessment of metal bioavailability in surface waters. SETAC Annual Meeting, Salt Lake City, UT. November 16-20.

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Lamoureux, M.M., N. Warner, J. Samson, J. Enright and C. Grégoire, 2002. *In Situ* solid state chemical speciation of some airborne metal species associated with atmospheric particulate matter of varying size. 29th Annual Conference of the Federation of Analytical Chemistry and Spectroscopy Societies, Providence, RI. October 13-17.

Lu, J.Y. 2002. Mercury species in the atmosphere – method development and evaluation. The 85th CSC Conference and Exhibition, Vancouver, BC. June 1-5.

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Rasmussen, P.E., G.C. Edwards and W.H. Schroeder. 2002. TSRI Project 105: Regional scale natural mercury Emissions in Yukon Territory. Health Canada Toxic Substances Research Initiative Forum: From Science to Policy, Ottawa, ON. November 18-19.

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Spiers, G.A. and A. Cheburkin. 2002. Application of sensitive techniques for the chemical analysis of aerosolic particulates. MITE-RN Annual Research Symposium, Ottawa, ON. February 27-28.

10.5 <Processes> Presentations

Chakrabarti, C.L. 2002. The competing ligand exchange method (CLEM): Determination of speciation parameters. MITE-RN Annual Symposium, Ottawa, ON. February 28-29.

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Chakrabarti, C.L. 2002. Metal-organic interactions in MITE-RN lake waters, soil pore waters, and throughfall samples. MITE-RN Annual Research Symposium, Ottawa, ON. February 27-28.

Croisetière, L., L. Hare and A. Tessier. 2002. Metal uptake routes for a sediment biomonitor. Society of Environmental Toxicology & Chemistry, Salt Lake City, UT. November 16-20.

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Giguère, A., P.G.C. Campbell and L. Hare. 2002. Subcellular partitioning of metals in indigenous yellow perch collected along a polymetallic environmental gradient. Saint Lawrence Chapter of SETAC, Québec. QC. June 6-7.

Gosselin, A., L. Hare and A. Tessier. 2002. Effect of sedimentary cadmium on the burrowing behaviour of an aquatic insect. Society of Environmental Toxicology & Chemistry, Salt Lake City, UT. November 16-20.

Guthrie, J.W. and C.L. Chakrabarti. 2002. Can metal speciation be predicted in freshwaters with low nickel concentrations using the competing ligand exchange method and adsorptive cathodic stripping voltammetry? MITE-RN Annual Research Symposium, Ottawa, ON. February 27-28.

Guthrie, J.W., R. Mandal, M.S.A. Salam, M. Moniruzzam and F. Raofie. 2002. Humic Acid - The little-known complexant of the freshwater environment. Canadian Society for Chemistry Conference and Exhibition, Vancouver, BC. June 1-5.

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Murimboh, J., N.M. Hassan, L. Si, J.W. Guthrie, C. Burroughs and C.L. Chakrabarti. 2002. Speciation parameters of metals in freshwaters by anodic stripping voltammetry at a rotating disk electrode. Canadian Society for Chemistry Conference and Exhibition, Vancouver, BC. June 1-5.

Orvoine, J., L. Hare and A. Tessier. 2002. Determining the trophic level at which Cd and hydrogen ions compete for biological uptake sites in the food chain leading to the biomonitor *Chaoborus.* Society of Environmental Toxicology & Chemistry, Salt Lake City, UT. November 16-20.

Raoufi, F., N.M. Hassan, A. Jamaluddin, J. Murimboh and C.L. Chakrabarti. 2002. Speciation parameters of copper in freshwaters by square wave adsorptive cathodic stripping voltammetry using the competing ligand exchange method. MITE-RN Annual Research Symposium, Ottawa, ON. February 27-28.

Salam, M.S.A., N.M. Hassan, A. Jamaluddin, F. Raufi, J. Murimboh and C.L. Chakrabarti. 2002. Speciation parameters of cadmium in lake waters by the competing ligand exchange method using square wave anodic stripping voltammetry. MITE-RN Annual Research Symposium, Ottawa, ON. February 27-28.

Sukola, K., F. Wang and A. Tessier. 2002. A preliminary study on the stability of metal-sulfide complexes in oxic waters. MITE-RN Annual Research Symposium, Ottawa, ON. February 27-28.

Sukola, K., F. Wang and A. Tessier. 2002. Do metal-sulfide complexes exist in oxic surface waters? A preliminary study on the stability of metal-sulfide complexes in oxic waters. Canadian Society for Chemistry Conference, Vancouver, BC. June 1-5.

Wang, F. and A. Tessier. 2002. Importance of reduced sulfur species in controlling metal speciation in the surface waters on the Canadian Shield: Methodological development and preliminary results. MITE-RN Annual Research Symposium, Ottawa, ON. February 27-28.

Wang, F. 2002. Environmental analytical chemistry. From *ex situ* to *in situ* techniques. Environmental Chemistry Symposium. Canadian Society for Chemistry - Atlantic Division, Corner Brook, NF. May 19.

Wang, F., A. Tessier and R. Carignan. 2002. Mercury speciation in sulfidic waters. 45th Annual Conference of International Association for Great Lakes Research, Winnipeg. MN. June 2-6.

10.6 <Impacts> Presentations

Borgmann, U. 2002. Nickel bioavailability and toxicity in lake sediments near Sudbury and evidence of recent improvements. International Nickel Conference, Murmask, Russia. September 1-6.

Baldisserotto, B., C. Kamunde, A. Matuso and C.M. Wood. 2002. Effect of calcium in the diet on cadmium and calcium uptake kinetics. SETAC Annual Meeting, Salt Lake City, UT. November 16-20.

Dixon, D.G., U. Borgmann, and W.P. Norwood. 2002. Critical body concentrations of 10 metals. The relationship between bioaccumulation and chronic toxicity. MITE-RN Annual Research Symposium, Ottawa, ON. February 27-28.

Gravel, A., P.G.C. Campbell and A. Hontela. 2002. Disruption of the hypothalamo-pituitary-interrenal axis in 1^{+} and YOY yellow perch exposed to metals. Annual Meeting, Can. Soc. Zool., Lethbridge, AB. May 8-11.

Grosell, M., P.J. Walsh and C.M. Wood. 2002. Mechanisms of copper uptake across fish gills. International Meeting on Copper Homeostasis and its Disorders: Molecular and Cellular Aspects. Ischia, Italy. October 4-8.

Ho, C.G., K.A. Sloman, C.M. Wood and D.G. McDonald. 2002. What you think should happen doesn't: the cadmium mystery. Annual Fish Physiology and Biochemistry Workshop. Rice Lake, ON., February 8-10.

Ho, C.G., K.A. Sloman, C.M. Wood and D.G. McDonald. 2002. Modification of waterborne Cd toxicity of rainbow trout through ration quantity. Annual Meeting of the Canadian Society of Zoologists. Lethbridge, AB. May 8-11.

Hontela, A. and A. Lacroix. 2002. Effects of metals and pesticides on the signalling pathways leading to cortisol in teleost fish. Annual Meeting, Can. Soc. Zool., Lethbridge, AB. May 8-11.

Kamunde, C. and C.M. Wood. 2002. Dietary versus waterborne exposure in rainbow trout: uptake and turnover during acclimination to waterborne copper. SETAC Annual Meeting. Salt Lake City, UT. November 16-20.

Kraemer, L, P.G.C. Campbell and L. Hare. 2002. A field study examining the uptake of metals in yellow perch (*Perca flavescens*). Annual Meeting, Soc. Environ. Toxicol. Chem., Salt Lake City, UT. November 16-20.

Matsuo, A., R.C. Playle, A.L. Val and C.M. Wood. 2002. Kinetics of Na^{+} uptake in rainbow trout exposed to copper and dissolved organic matter. SETAC Annual Meeting, Salt Lake, City, UT. November 16-20.

Niyogi, S., C. Kamunde, D.G. McDonald and C.M. Wood. 2002. Interaction between sublethal waterborne Cu and feeding pattern in fish: physiological implications. SETAC Annual Meeting, Salt Lake City, UT. November 16-20.

Norwood, W.P., G. D. Dixon and U. Borgmann. 2002. Critical body concentrations of 10 metals. The relationship between bioaccumulation and chronic toxicity. Society of Environmental Toxicology and Chemistry SETAC, Baltimore, MD. November 16-20.

Nowierski, M., D.G. Dixon and U. Borgmann. 2002. Effect of water chemistry on Ni and Cd bioavailability and toxicity from sediment. Aquatic Toxicity Workshop, Whistler, BC. October 23.

Nowierski, M., J. Schroeder, W.P. Norwood, D.G. Dixon and U. Borgmann. 2002. Predicting metal and metal mixture effects in aquatic biota. Annual Laurentian Chapter of SETAC Meeting, Guelph, ON. May 25.

Nowierski, M. D.G. Dixon, and U. Borgmann. 2002. Effects of water source on metal bioavailability and toxicity from field collected sediments. Society of Environmental Toxicology and Chemistry SETAC, Baltimore, MD. November 16-20.

Nowierski, M., D.G. Dixon and U. Borgmann. 2002. Effect of different water sources on metal toxicity and bioaccumulation from field collected sediments. University of Waterloo Graduate Student Research Symposium, Waterloo, ON. April 5.

Rasmussen, J. 2002. Effects of diet shift and velocity on drift pattern in streams – population shifts in brook trout. Annual meeting, Can. Soc. Zool., Lethbridge, AB. May 8-11.

Schroeder, J., U. Borgmann and D.G. Dixon. 2002. Modelling toxicity of nickel to *Hyalella azteca* using a biotic ligand model approach. Annual Aquatic Toxicity Workshop, Whistler, BC. October 23.

Taylor, L.N., C.M. Wood and D.G. McDonald. 2002. Can indicators of susceptibility predict the toxic effects of copper in trout? SETAC Annual Meeting. Salt Lake City, UT. November 16-20.

Weech, S.A., A.M. Scheuhammer, and J.E. Elliott. 2002. Mercury and selenium in fish from the Pinchi Lake Region of British Columbia, Canada: Relation to age, fork length and trophic position. SETAC Annual Meeting, Salt Lake City, UT. November 16-20.

Weech, S.A, A.M. Scheuhammer and J.E. Elliott. 2002. Blood mercury levels and reproductive success of bald eagles (*Haliaeetus leucocephalus*) breeding in the Pinchi Lake Region of British Columbia, Canada, 2000-2001. SETAC Annual Meeting, Salt Lake City, UT. November 16-20.

Wood, C.M. 2002. Chemistry, toxicology, physiological homeostasis, and environmental regulation of copper, an essential element in freshwater fish. SETAC Interact. Sydney, Australia. July **DATE**.

Wood, C.M., C. Kamunde, J. McGeer, M. Grosell and D.G. Mcdonald. 2002. Copper toxicity and homeostasis in freshwater fish. International Meeting on Copper Homeostasis and its Disorders: Molecular and Cellular Aspects. Ischia, Italy. October 4-8.

Wood, C.M., and E.F. Pane. 2002. Biotic ligand models for environmental regulation of metals: applicability to nickel? International Nickel Conference. Murmansk, Russia. September 1-6.