Canadian Network of Toxicology Centres

Metals In The Environment Research Network News

Volume 2
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Metals in the Environment Research Network (MITE-RN) receives $3.5 million from NSERC

New multi-million-dollar funding for a research network investigating the impact of metals on ecosystems in Canada was announced on June 7, 1999 at the University of Guelph.

The Natural Sciences and Engineering Research Council (NSERC) is the national instrument for making strategic investments in Canada's capability in science and technology. NSERC will contribute $3.5 million over the next five years to the Metals in the Environment Research Network (MITE-RN). NSERC's support for the MITE-RN will be enhanced by $1.95 million from the Mining Association of Canada (MAC) and Ontario Power Generation Inc. (formerly Ontario Hydro). Funding for research into metals in the environment will now total $6.97 million with in-kind contributions from our government partners, Environment Canada, Dept. of Fisheries and Oceans, and Natural Resources Canada, which includes $500,000 over five years from MAC to support related research in government laboratories.

Brenda Chamberlain (MP, Guelph-Wellington) announced the federal government's investment on behalf of Dr. Ron Duhamel, Secretary of State (Science, Research and Development and Western Economic Diversification). “This is a bold interdisciplinary research initiative that will study metals in our environment on a scale never seen in Canada,” said Mrs. Chamberlain. “The information produced by this network will be very useful in the formulation of environmentally-responsible policies for the federal government and its partners.”

Dr. Tom Brzustowski, President of NSERC, announcing the NSERC five year MITE-RN grant. Dr. Brzustowski (extreme left) is joined in making the announcement by (second from left), Mrs. Brenda Chamberlain, Guelph M.P.; Dr. Len Ritter, Executive Director, CNTC & MITE Research Network Co-ordinator; Dr. Peter Campbell, INRS-EAU Université du Québec & Research Director, MITE Research Network; Mr. Gordon Peeling, President, Mining Association of Canada; Mr. Robert Lyng, Ontario Power Generation Inc.; and Dr. M. Rozanski, President, University of Guelph.

“This is research critical to our understanding of metals and to improving the environmental quality of our ecosystems,” said University of Guelph president Mordechai Rozanski. “Government, industry and university researchers are to be applauded for this multidisciplinary initiative. ”

Research within the MITE-RN is structured in three interacting domains:

- sources of metals in the environment;
- processes by which metals move and transform within the environment;
- and impacts of metals on ecosystems.

These research domains are essential for assessing the risk metals may pose and determining how to reduce that risk,” said Prof. Peter Campbell, research director and principal investigator for the MITE-RN.

Professor Campbell, from the Institut national de la recherche scientifique, Université du Québec, is also leader of the research domain looking at the environmental impacts of metals. Other domain leaders looking at processes and sources of metals respectively are Prof. Beverley Hale, Department of Land Resource Science, University of Guelph and Prof. Grant Edwards, School of Engineering, University of Guelph.

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Sources Research Domain

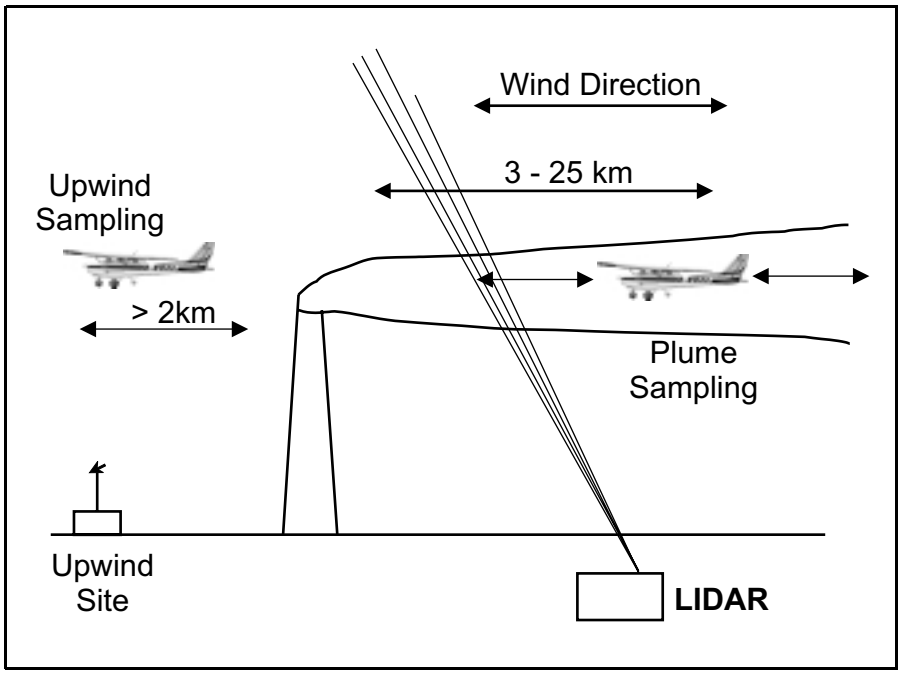
Flying for answers...

Domain Executive Summary

The ability to assess whether the presence of metals in the environment originates from anthropogenic or natural sources is crucial for determining the most appropriate regulation of sources. This requires both a more complete quantification and characterization of metal emissions from natural and anthropogenic sources, and analytical techniques or criteria to determine the source at the receptor site through knowledge of the chemical speciation of metal particulates. The Sources Domain is actively addressing these knowledge gaps through a program that includes methods development and natural metal emission measurement research, development of analytical techniques for metal speciation, and the study of diagenesis to determine whether remote lake sediment records can be used as evidence of long-range transport of metals from anthropogenic sources. ❖

Researchers at the Atmospheric Environment Service, in collaboration with the National Research Council of Canada and scientists from the University of Québec, Dalhousie University, St. Mary's University, University of Guelph, Natural Resources Canada, and the National Water Research Institute will be undertaking aircraft studies of plumes released from mining, metallurgical, and energy production activities with the objective of understanding the atmospheric cycling of metal emissions from these sources. National and international concern about the health effects and continued use of Cadmium (Cd), Copper (Cu), Mercury (Hg), Nickel (Ni), Lead (Pb), and Zinc (Zn), has defined a need for improved estimates of the long term risks to ecosystems and human health from metals released from anthropogenic sources.

The size and chemical composition of aerosol particles that the metals are associated with are key components in determining the distance that metals are transported in the atmosphere. Very fine particles ($<0.1 \times 10^{-6}$ m) coalesce with each other or onto larger particles while large particles ($>5 \times 10^{-6}$ m) deposit relatively rapidly. However, particles of the order of 0.1 to 1×10^{-6} m in diameter can be well-mixed to altitudes of 3 km or can be lofted even higher in clouds. The efficiency of removal in clouds becomes the critical factor in their lifetime and long-range transport. Scavenging by clouds is a particularly important atmospheric removal process if the metal is associated with aerosol larger than 0.1×10^{-6} m diameter. In addition, gaseous species which are weakly soluble in cloud water have a long lifetime in the atmosphere (e.g. Hg). Thus, if particles are in the correct size range, they can be transported long distances before being removed by wet deposition. The data collected from these sources may also aid in the understanding of transformations in the plume and thus assist in developing criteria to fingerprint sources at the metal-contaminated sites.



Schematic of the plume study (not to scale). LIDAR = light detection and ranging.

The DHC-6 Twin Otter aircraft, operated by the Institute for Aerospace Research of the National Research Council of Canada, is a well established platform for making aerosol and cloud measurements. This aircraft will be used in conjunction with ground-based sampling and remote sensing instruments to determine the size distribution and chemical composition of airborne particulate metal emissions from the Nanticoke coal-fired power generating station located north of Lake Erie, Ont. and the Horne copper smelter at Rouyn, Québec.

The collected data will be used to map density, size distribution of particles, and metal content of particles emitted by the sources as a function of distance from the source (3 to 25 km) under different meteorological conditions. These measurements will be made in summer and winter to see the influence of the extremes in ambient temperature and meteorology. Each source will be studied with at least 10 flights of 2.5 h each in each season. The study will be co-ordinated with operations at the smelter and power generating station so that the fuel and ore in use will

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Trace metal dynamics in contaminated northern forest ecosystems

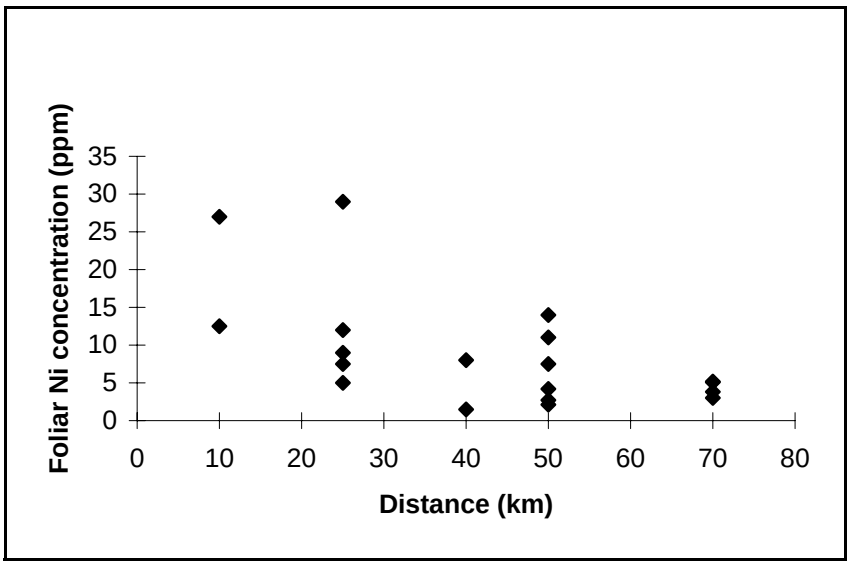
Domain Executive Summary

Research in the Processes Domain consists of three projects that focus on the mobility of metals among the biotic and abiotic compartments of the terrestrial and aquatic environment, and the consequent changes in bioavailability of the metals. The studies are currently investigating: the environmental compartment from which benthic invertebrates take up metals; metal mobility in Shield watersheds; and, cycling of metals between the soil and vegetation compartments of Boreal ecosystems. These studies will improve estimates of risk to ecosystems from metals, as it is critical that movement and transformation of the metals after deposition be included in the process of estimating the metal exposures that various biota receive, and that exposure concentrations are not simply calculated from total metal deposition rates without regard for the forms of metal being deposited or the post-depositional transformations undergone by these metals.❖

Phytoavailability, uptake and partitioning of trace metals within contaminated forest ecosystems are not well understood due to the complex web of interacting plant, climatic and edaphic variables. The objective of our study is to determine, via soil metal concentrations, the contribution of plants to the cycling of selected trace metals that are added to forest ecosystems by smelter emissions. These values are needed to calculate the metal concentrations and consequent risk to which plants are exposed. Our methodology is designed to estimate the concentrations of metals in standing biomass, and the rates at which metals are returned to the soil through plant decomposition.

In a preliminary survey of the Sudbury region, plant species were comprehensively sampled along a transect following a historic gradient of atmospheric metal deposition. These plant species proved remarkably variable in the concentrations of trace metals accumulated in root, bark, foliar and stem tissues. The data indicate that foliar concentrations of Lead (Pb), Cadmium (Cd) and Zinc (Zn) do not follow any discernible trend in relation to increasing distance from the Sudbury area smelters. Foliar concentrations of Copper (Cu) and Nickel (Ni), however, were elevated at sites closest to Sudbury and then slowly reached background levels with increasing distance. This work led us to initiate a range of soil and plant studies at sites established along transects in the regions of Sudbury, Ontario and Rouyn-Noranda, Québec. Three sites were chosen along each transect to correspond with high, medium and background soil trace metal concentrations. Other site selection criteria include similar soil morphology, plant community composition and tree stand age.

A metal budget will be constructed for each site that will include estimates of annual metal input from atmospheric deposition, weathering of soil minerals, and decomposing plant material. Plant metal concentration data that are gathered by hot-acid tissue digestion and ICP-OES or GF analysis, will be used in conjuction with site specific calculations of standing plant biomass and annual biomass production to estimate trace metal pool sizes within the vegetative compartments of the forest plant communities. Fine root biomass (the production of which can rival that of foliar biomass) is thought to be a major sink for metals. We will examine this biological compartment in detail, through a series of soil coring experiments, to allow for inclusion in the overall calculation of trace metal cycling. Rates of return of trace metals from decomposition of foliage to surface soils will be determined by litter bag experiments in the field. The phytoavailability of these trace metals from decomposing plant material will be tested through lab experiments. Composted foliage of metal-contaminated plants will be used as a growth substrate for selected indicator species. Cropping and resowing of the indicator species will provide a good estimate of the phytoavailability of metals with time. ❖



Foliar nickel concentration as a function of increasing distance from source.

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W. Hendershot,
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Fishing for answers...

Domain Executive Summary

Attempts to define the impacts of metals on aquatic ecosystems have traditionally involved laboratory experiments under defined conditions (toxicity tests) and, to a lesser extent, field observations on impacted indigenous populations (abundance; condition; growth; reproduction). To link these two approaches, one needs a common measure of metal exposure in laboratory and field settings. The determination of metal concentrations or burdens in tissues (or whole organisms) has been suggested as a means of achieving this linkage. Researchers in the Impacts Domain are actively exploring this approach with aquatic biota, and are seeking to expand the concept of metal "body burden" to take into account the speciation of the metal within the organism, i.e. the organism's ability to detoxify the metal. The aquatic biota under consideration include benthic invertebrates, indigenous fish and waterfowl. ❖

The MITE-RN has several research teams working on projects designed to help us understand the way metals are distributed in the environment and the mechanisms through which they influence living organisms exposed to them. The research team of Dr. Peter Campbell from INRS-Eau in Québec City, Dr. Joe Rasmussen from McGill University in Montréal and Dr. Alice Hontela from Université du Québec à Montréal (UQAM) is working to explain the role of metallothionein, a protein that binds metals in animal tissues, in protecting the organism against potentially harmful effects of metals.

This summer the researchers, six graduate students (Alexandra Lacroix, Graham Sherwood, Anik Giguère, Haude Levesque, Jennifer Kovecsos, Jocelyn Dorval) and two undergraduate students (Amélie Gravel, Janvier Doire) carried out an intensive sampling of yellow perch, *Perca flavescens*, in the Abitibi region. Fish were sampled around Rouyn-Noranda in a series of lakes representing a gradient of metal loading into the aquatic system, ranging from relatively clean lakes used as reference to lakes where the levels of Cadmium (Cd), Copper (Cu) and Zinc (Zn) are well above the level of detection. Ongoing work by the Campbell, Rasmussen, Hontela team, as well as previous studies by researchers from INRS-Eau, have already demonstrated that some of the lakes are similar in important limnological characteristics but vary in their metal levels in the sediments and the overlying water column. This subset of lakes thus lends itself to ecotoxicological studies aimed at understanding the effects of metals on indigenous species.

The objectives of the work done by the UQAM researchers are to assess the physiological and endocrine status of the perch from the Abitibi lakes and determine if effects can be linked to metals and metallothionein. Fish were captured by nets, then kept in enclosures in the lake for 24 hours to allow recovery from the capture stress. Following this period, blood and tissues from the fish were collected for analyses of plasma hormones secreted by the adrenal tissue and the thyroid gland (cortisol, triiodothyronine and thyroxine) to assess the endocrine fitness of the fish. The adrenal tissue was also tested for its capacity to respond to adrenocorticotropin hormone (ACTH) *in vitro* - a sensitive indicator of the functional integrity of this important endocrine organ. These analyses are in progress. Liver and muscle glycogen as well as lipids will be analyzed to determine if fish exposed to metals have metabolic problems or if they are unaffected by metals. This work, which relies mainly on biochemical analyses of tissues and plasma from fish exposed to metals in the field, will provide important quantitative data about the capacity of metals to interfere with normal endocrine function of fish.

The McGill researchers are investigating the impact of metals on growth of the yellow perch. Fish are captured and the concentrations of the cesium-137 radioisotope in their tissues as well as in their prey are measured in the laboratory using gamma counters with a very high sensitivity. Use of the isotopic marker and the age/size distributions of fish populations provide data for a good estimate of

Graduate students Graham Sherwood (McGill) and Alexandra Lacroix (UQAM), fish for yellow perch, a key species for the MITE-RN projects in the Abitibi region.

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October 1999

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growth efficiency, the capacity of the fish to convert consumed food into body mass. This summer, they also started work to identify and quantify the populations of benthic invertebrates, to further characterize the prey items available to the fish in each lake. The results from these studies will be important for the assessment of effects of metals on growth of natural fish populations.

In all these studies, metal concentrations will be also measured in samples of fish tissues (liver, kidney, gill), to provide a quantitative framework within which the observed effects on physiological performance and growth can be tested. The INRS-Eau researchers are extending these analyses to the subcellular level, to determine whether or not the host organism (fish) has been able to detoxify the incoming metal, e.g. by binding it to induced metallothionein.

By determining biochemical indices of metal detoxification in indigenous sentinel organisms, and by linking these indices to effects at the organism and population levels, we are addressing one of the major knowledge gaps that currently handicaps the ecological risk assessment of metals. The results will be of practical importance to those in the public and private sectors who are interested in the biological monitoring of the effects of toxic metals in the aquatic environment, and to regulators charged with establishing rational water and sediment quality criteria for metals. ❖

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NSERC Funding,
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"This research effort is an impressive undertaking that will allow researchers from industry, government and twelve Canadian universities to focus their energies to better understand how metals behave in the environment," said Dr. Tom Brzustowski, president of NSERC. "I'm convinced that students, too, will benefit greatly from working with the network and industry partners."

The MITE-RN will include more than 20 scientists from 12 universities, and eventually, approximately 30 postdoctoral fellows and graduate students.

In order to capitalize on research currently being conducted in Canada, within all sectors of the scientific community, and to foster a co-operative, integrated approach to problem solving, each of the three research domains in MITE-RN has two leaders – one each from the academic and public sectors. This collaboration will ensure integration among a broad spectrum of researchers at the level of research planning and data collection, interpretation and report preparation.

The NSERC award will help answer critical research questions being asked by scientists and policy makers. This research network brings together scientists from universities, industry, and government to establish a framework for managing metals in the environment. Established in 1998, the Network is managed by the Canadian Network of Toxicology Centres (CNTC), which is headquartered at the University of Guelph.

A science steering committee and a board of directors composed of senior government representatives and industry leaders will oversee the MITE-RN. An expert advisory panel will conduct an annual peer review. "This external peer review panel will ensure that the most relevant research issues are being addressed, and a system for risk management of metals is established in Canada," said Prof. Len Ritter, executive director of the CNTC and MITE-RN Co-ordinator.

"We need to ensure that the research issues being addressed are relevant and that results are communicated as quickly as possible to decision makers," said Ritter.

Current MITE-RN projects include studies of the distribution of metals in the atmosphere, their deposition and cycling in the terrestrial environment, and their effects on a variety of aquatic organisms.

The funding will allow the Network to establish research teams across Canada to strengthen its scientific investigations and ensure that a range of issues are represented. The funds will be allocated to support metals research in Canada at: Institut national de la recherche scientifique (UQ-INRS), Carleton, Waterloo, Toronto, McMaster, Université du Québec à Montréal, Université de Montréal, Western, Dalhousie, St. Mary's, McGill and Guelph. Support for graduate students is a key component of the project. The Network has also made provisions to attract further participation from scientists and institutions not initially involved in MITE-RN.

The web site for the MITE-RN is: http://www.uoguelph.ca/cntc/mite ❖

Flying for answers,
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be documented at the time of the sampling.

As part of the effort to understand atmospheric transport of metals, the data will be used with existing atmospheric models to predict the concentrations and deposition patterns of current emissions of metals in particulates from both individual point sources and the regional-scale background and to estimate the proportion subject to long range transport. This will allow a prediction of the impact of proposed emission-reduction strategies on the local to regional metals burden. ❖

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Ecological Risk Assessment and MITE-RN

Ecological risk assessment (EcoRA) is a process that evaluates the potential for adverse ecological effects occurring as a result of exposure to contaminants or other stressors. EcoRA provides necessary information for decision-making related to environmental policies, remedial targets, management and future use scenarios.

EcoRA has four successive major steps in Canada:

- hazard identification, equivalent to problem formulation in the U.S., consists of the identification of major issues related to potential adverse effects;
- dose-response or effects assessment provides information on the relationship between contaminant concentrations and the incidence and (or) severity of adverse effect(s);
- exposure assessment determines the emissions, pathways and rates of movements of contaminants in the environment in order to estimate the concentrations to which biological systems are or may be exposed; and,
- risk characterization integrates the previous three steps to estimate the incidence and severity of any adverse effects likely to occur.

The MITE-RN is based on the above four components of the EcoRA paradigm (see diagram below), and involves all three environmental compartments (air, water, land).

Hazard identification (or problem formulation) related to MITE-RN began with a workshop at Val Morin, Québec, in October 1996. This workshop developed research needs required to more accurately estimate long-term risks to ecosystems from metals. These research needs were then further refined in subsequent formal and informal discussions involving a variety of stakeholders (industry, government, universities) and in the process of developing (and redeveloping) the MITE-RN proposal. Because EcoRA is an iterative process, hazard identification remains an essential component of MITE-RN.

MITE-RN researchers are studying a variety of metals and metalloids; however, six metals provide a common linkage among the various studies. These six metals are representative of metals and metalloids and are significant relative to anthropogenic sources to the environment: Mercury (Hg), unique because when methylated it can biomagnify, and Cadmium (Cd), both of which are non-essential metals; Zinc (Zn), Nickel (Ni) and Copper (Cu), essential metals.

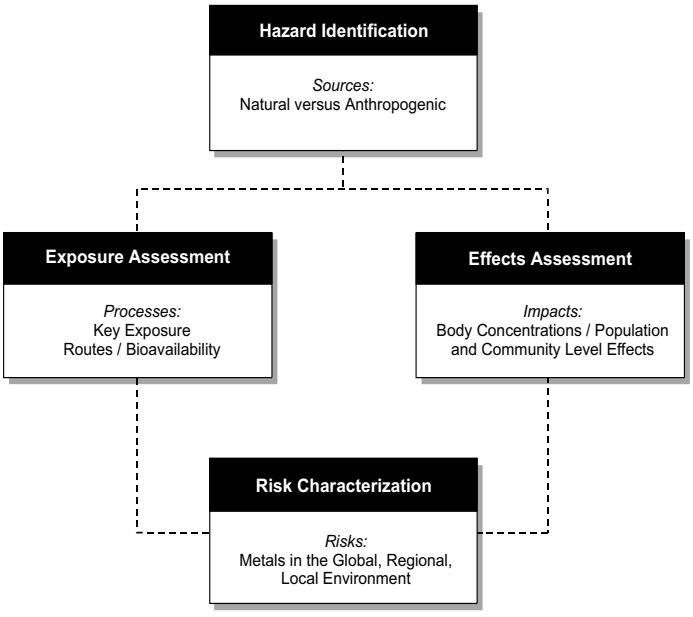
Key metal EcoRA issues presently addressed directly by MITE-RN research include:

- natural versus anthropogenic sources, particularly related to long-range transport;
- essential versus non-essential metals, particularly related to body burdens and effects;
- bioavailability of metals related to persistence in the environment;
- the role of metals speciation and environmental chemistry in bioavailability and toxicity.

Other key EcoRA issues are being addressed through other research being tracked by MITE-RN, including the ability of organisms to modify their exposure to contaminants and to adapt to contaminant exposure.

The findings of the 12 major, individual studies comprising MITE-RN will be used in a final risk characterization to provide (together with other relevant and appropriate studies by other researchers):

- A re-evaluation of the overall risk of metals in the global environment.
- A revised regional and local ecological risk assessment framework for metals in the environment. ❖



The EcoRA paradigm and the MITE Research Network.

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Network Announcements & Updates

Awards and Honours

- Edwina Wong won first place ($500.00 USD) and Laurie Halfpenny took third place ($100.00 USD) for poster presentations at the AWMA international conference this year. Their research related to flux methods and measurement and modelling the dispersion of pollutants in the atmospheric boundary layer. Both students are studying with Dr. Grant Edwards, University of Guelph.
- We have a new member of the MITE Secretariat, located at the CNTC Head Office. Mr. Michael Herbert has assumed the responsibilities of Controller for the Research Network. Welcome, Michael.

Noranda Meeting

June 14 - 15, 1999, Rouyn-Noranda. Numerous projects from the MITE-RN and from the Geological Survey of Canada MITE programs have their study location around the Horne smelter in Rouyn-Noranda, QC. Scientists involved in these projects gathered with Noranda personnel last June with three objectives in mind: to better understand the Horne smelter; to allow researchers and industry to know more about each project being carried out near the facility; and, last but not least, to stimulate exchange between people. Overall, this two-day meeting was quite successful as it was felt to be very instructive by all participants. It is anticipated that similar meetings will take place on a regular basis.

Sudbury Meeting

April 21, 1999, Sudbury. Presentations were given on the MITE-RN proposal by B. Conard, G.Edwards, M. Lamoureux and K. Puckett. Following these presentations, mining association participants, associated with the MITE-RN (INCO, Sudbury, Horne smelter, Noranda, and Falconbridge) presented current stack sampling protocols at the three smelters. The discussion centered on clarification of the MITE-RN research effort and what would be required by the MITE-RN from the smelters in terms of non-regulatory and non-routine stack sampling efforts. Considerable discussion was focused on the suitability of the Horne smelter region for the Atmospheric Environmental Service (AES) plume research and the *in situ* studies on the ground within the Horne footprint. All mining representatives at the meeting agreed to support MITE-RN. Additionally, it was agreed that existing and routinely collected stack sampling data would be made available to the MITE-RN on request. In the first year, all three smelters will provide a particulate sample to M. Lamoureux of St. Mary's University for analysis. The particulates will be analysed for metal concentrations and species as a function of particle size where viable. The purpose of the sample analysis is both to assist in the experimental design for the AES plume studies and those studies on the ground in the footprint, and for site selection for the MITE-RN research. Depending on the outcome of these results, the smelter representatives agreed to consider extraordinary stack sampling activities during the AES plume flybys and associated experimentation on the ground.

How to Become Involved in this Research Network

New researchers are encouraged to become familiar with the Network activities and research priorities by viewing the research priorities on the MITE-RN postings on the Canadian Network of Toxicology Centres' web site at http://www.uoguelph.ca/cntc and by contacting one of the six research domain leaders (contact information on web site).

It is important to note that scientists not currently involved in the Network should be aware that the MITE-RN is not a grant agency; collaboration and involvement do not necessarily imply a flow of funds from the MITE-RN to an investigator. The Network has built in an opportunity to fund new investigators from year three onwards of the initial five year program.

In the first 12-18 months, participation of new researchers will be limited in order to provide an opportunity for those investigators who participated in the successful NSERC application to develop their respective research programs.

CNTC/ MITE-RN Annual Meetings & Research Symposia

CNTC Annual Research Symposium March 27-28, 2000; MITE-RN Research Symposium, March 29-30, 2000. Anticipated location Ottawa / Hull. MITE-RN Board Meeting scheduled for March 31, 2000.

If you would like to be added to the mailing list to receiving registration details for these upcoming symposia, please forward your name, mailing address, fax and e-mail address to dwarner@tox.uoguelph.ca at the MITE-RN Secretariat.

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