WORKSHOP

An Ecosystem Approach to the Health Effects of Mercury in the Great Lakes Basin

Program and Abstracts

Cleary International
Conference Centre
201 Riverside Drive W.
Windsor, Ontario, Canada

February 26-27, 2003

International Joint Commission

United States and Canada

Great Lakes Commission
des Grands Lacs

Program

Wednesday, February 26, 2003

8:30 a.m. **Welcome**
Dr. Michael Donahue and Dr. David Carpenter

8:40 a.m. 1. **Keynote Address: An Ecosystem Approach to Environmental Mercury**
Dr. Marc Lucotte, Université du Québec, Montréal, Québec

9:15 a.m. **Session Chair: Dr. Milton Clark**

2. **Current and Historic Sources, Pools and Sinks of Mercury**

Modeling the Atmospheric Transport and Deposition of Mercury to the Great Lakes
Dr. Mark Cohen, National Oceanic and Atmospheric Administration, Silver Springs, Maryland

9:50 a.m. **Break**

10:10 a.m. **Assessing Inventories to Understand the Impacts of Mercury Emissions**
Luke Trip, SENES Consulting, Ottawa, Ontario

Discussion
Bruce Lourie, Environmental Consultant, Toronto, Ontario

10:40 a.m. **United States Inventory: Opportunities to Prevent Environmental Releases of Mercury**
Frank Anscombe, U.S. Environmental Protection Agency, Chicago, Illinois

Discussion
Dr. Michael Murray, National Wildlife Federation, Ann Arbor, Michigan

11:10 a.m. **Discussion and Questions from the Floor**

Noon **Lunch**

12:30 p.m. **Session Chair: Glen Fox**

3. **Lunchtime Keynote Address**
Introductory Remarks: The Right Honourable Herb Gray, Canadian Cochair, International Joint Commission

State of the Science: Environmental Transport, Distribution and Fate of Mercury
Dr. Don Mackay, Trent University, Peterborough, Ontario

1:00 p.m. Session Chair: Dr. Chris DeRosa

4. **Exposures of Great Lakes Populations and Surrogates of Exposure**

1:00 p.m. **Canadian Surveys of Fisheaters**
Dr. Donald Cole, University of Toronto, Ontario

1:30 p.m. **United States Surveys of Fisheaters**
Dr. Henry Anderson, University of Wisconsin, Madison, Wisconsin

2:00 p.m. **Ojibwa Health Study**
Dr. John Dellinger, University of Wisconsin, Milwaukee, Wisconsin

2:30 p.m. **Break**

3:00 p.m. **Mercury Concentrations in Fish in Canadian Areas of Concern**
Dr. Michael Weis, University of Windsor, Windsor, Ontario

3:30 p.m. **Review of Historic and Recent Mercury Concentrations in Great Lakes Sediments**
Dr. Ronald Rossmann, U.S. EPA, Grosse Isle, Michigan

4:00 p.m. Session Chair: Dr. Chris DeRosa

5. **Epizootiology**

4:00 p.m. **Evaluating Common Loon Mercury Exposure and Toxicity Risk in the Great Lakes Basin and Canadian Maritimes**
Dr. Michael Meyer, Wisconsin Department of Natural Resources, Rhinelander, Wisconsin

4:30 p.m. **Facilitated Discussion**
Dr. Donna Mergler

5:00-6:30 p.m. **Cash Bar and Poster Session**

Thursday, February 27, 2003

9:00 a.m. Session Chair: Dr. David Carpenter

6. **Epidemiological and Clinical Challenges to Diagnosis of the Effects of Mercury**

9:00 a.m. **Early Neurotoxic Effects of Mercury Exposure through Fish Consumption from the Great Lakes and the Saint-Lawrence**
Dr. Donna Mergler, Université du Québec à Montréal, Québec

9:30 a.m. **Examining Potential Indicators of Neurological Effects of Mercury in Communities**
Michael Gilbertson, International Joint Commission, Windsor

10:00 a.m. **Break**

10:30 p.m. **Exposure Assessment Imprecision and Criteria for Outcome Measures**
Dr. Philippe Grandjean, University of South Denmark, Odense, Denmark

11:00 a.m. **Subtle Neurological Effects on Populations: Epidemiological and Clinical Perspectives**
Dr. David Bellinger, Harvard Medical School, Boston, Massachusetts

11:30 a.m. **Facilitated Discussion**
Dr. David Carpenter

Noon **Lunch**

12:30 pm. **Session Chair: Glen Fox**

7. **Lunchtime Keynote Address**
Linking Science with Science
Dr. David Lean, University of Ottawa, Ottawa, Ontario

1:00 pm. **Session Chair: Dr. Donna Mergler**

8. **Toxicological Effects of Mercury and Nutritional Benefits of Eating Fish**

1:00 pm. **U.S. EPA's Risk Assessment for Methylmercury: Sources of Uncertainty**
Dr. Deborah Rice, U.S. Environmental Protection Agency
Washington, D.C.

1:30 p.m. **Benefits of Fish Consumption**
Dr. Laurie Chan, Centre for Indigenous Peoples, McGill University
Ste. Anne-de-Bellevue, Québec

2:00 p.m. **Mercury Risk Assessment: Balancing Toxicity with the Nutritional Benefits of Eating Fish**
Dr. Kathryn Mahaffey, U.S. Environmental Protection Agency,
Washington, D.C.

2:30 p.m. **Discussion**
Dr. David Carpenter

2:45 p.m. 9. **Wrap-up: Improved Understanding of the Health Effects of Mercury: Policy, Science and Research Needs**
Dr. Milton Clark

3:45 p.m. **Adjournment**
Dr. David Carpenter and Glen Fox

AN ECOSYSTEM APPROACH TO THE HEALTH EFFECTS OF MERCURY IN THE GREAT LAKES BASIN

Abstracts of Presentations

1. KEYNOTE ADDRESS

1.1 An Ecosystem Approach to Environmental Mercury

Mark Lucotte, University of Quebec, Montreal, PQ

The Collaborative Mercury Research Network (COMERN) addresses the urgent need for the development of a framework enabling researchers, political stakeholders, responsible industries and communities concerned by the mercury (Hg) question to evolve toward an interdisciplinary association capable of synergistically combining our knowledge on Hg into an original synthesis. We are developing a complex index representative of the specific vulnerability of a given ecosystem to Hg bioaccumulation in the biota and subsequent transfer to humans through food consumption. This index includes two concepts: (1) the sensitivity of the ecosystem to Hg bioaccumulation, induced and influenced by factors such as Hg loadings, the different transport and methylation processes, and human activities like watershed management and fishing intensity; (2) the adaptability of the ecosystem, an evaluation of its resilience, or its capacity to recover and/or to cope with the contamination, taking into account the social and political resources within the communities impacted. The integration of both dimensions of the vulnerability index is contributing to reformulate the fairly static concept of critical loads into a more dynamic assessment of the Hg issue in Canada. This initiative aims at leading to cost-effective environmental and health-related decisions by local communities as well as by politicians. COMERN's members are presently working to apply this approach to four distinct case studies representative of the large spectra of both Hg contamination and Hg exposure through fish and seafood consumption in Canada, i.e. sports fishers of lakes of the boreal forest, commercial fishers of the industrialized region of the St Lawrence River, first nation communities in Labrador and seafood consumers of the Bay of Fundy.

2. CURRENT AND HISTORIC SOURCES, POOLS AND SINKS OF MERCURY

2.1 Modeling the Atmospheric Transport and Deposition of Mercury to the Great Lakes

Mark Cohen, National Oceanic and Atmospheric Administration,
Silver Springs, MD

Mercury contamination of the Great Lakes remains a serious environmental concern, and atmospheric deposition is a significant loading pathway. However, information regarding the relative importance of different sources and source regions has not generally been available. This study has been designed to attempt to provide such information. The NOAA HYSPLIT model has been modified to simulate the fate and transport of mercury emitted to the air from sources in the United States and Canada. The entire year 1996 has been simulated so that representative estimates can be made despite the inherently episodic nature of source-receptor relationships.

A U.S. emissions inventory from the U.S. EPA and a comparable Canadian inventory developed by Environment Canada have been used as input. When lacking, speciation information has been added to the inventory, to develop reasonable estimates for emissions of elemental mercury, reactive gaseous mercury, and particulate mercury. Meteorological data computed by an external model (e.g., NCEPs NGM model) are used to drive the dispersion simulation. The model simulates the dispersion, chemical transformation, and wet and dry deposition of emitted mercury compounds. The modeling analysis is evaluated by comparison against available ambient monitoring data. Data from several locations within the modeling domain are available, primarily for mercury in wet deposition (e.g., the Mercury Deposition Network). The simulation results show relatively good agreement with measurements.

The overall deposition to each of the Great Lakes has been estimated for 1996, arising from sources in the U.S. and Canada. In addition, information about the relative magnitude of the contributions to atmospheric deposition from different source categories and source regions has been developed. Maps showing the geographical distribution of contributions to deposition have been prepared for each Great Lake. Estimates of the uncertainty in the simulations have also been made, based on a number of sensitivity analyses.

2.2 Assessing Inventories to Understand the Impacts of Mercury Emissions to Aquatic, Terrestrial and Atmospheric Ecosystems.

Luke Trip, SENES Consulting, Ottawa and
David Niemi, Environment Canada

North American pollutant release and transfer registries (PRTRs) have been continuously developing with an eye to understanding source/receptor relationships and ensuring that the polluter pay principle is applied to the appropriate parties. An area of emissions inventories quantification that is poorly understood and the subject of concern is the contribution of aquatic and terrestrial sources of mercury contamination to the Great Lakes Basin. A considerable amount of data may be available on the atmospheric component of mercury emissions to the Basin; however, much of this information is not derived from direct measurements. An even greater challenge is to determine the quantity of mercury and its bioavailability emanating from land based sources and from aquatic media. This paper will attempt to describe the interplay among the sources and receptors of mercury, and provide a quantitative assessment of current Canadian contributions of mercury as a contaminant to the Great Lakes.

2.3 **United States Inventory**: **Opportunities to Prevent Environmental Releases of Mercury**

Frank Anscombe, U.S. Environmental Protection Agency, Chicago, IL

A natural constituent of the earth's makeup (0.5 ppm), traces of mercury are contained in vegetation, fossil fuels, water, minerals, and soil. Relying on such fundamental inputs, most forms of productive human endeavor inevitably encounter some mercury. Since mercury has the highest vapor pressure among metals, these encounters often produce air emissions.

A mass balance accounting for mercury within inputs to and outputs from an industrial process is integral to sound scientific understanding of mercury releases. This will be illustrated by the example of mercury losses from the mercury-cell chlor-alkali sector. During the past five years, U.S. chlor-alkali factories have achieved strong voluntary progress in curbing losses of mercury. Reasons for this progress will be discussed. A useful tool of industrial ecology, mass accounting can provide insights into other poorly characterized sources.

Mercury vapor is not visible to the human eye under normal light, nor can we discern it via sense of smell. Computer-age vapor analyzers offer industries and environmental agencies alike a quantum leap forward in the power to identify preventable mercury sources. This is especially true for non-combustion area (non-stack) sources.

There are also discharges of mercury to water. Dental practices, for instance, are increasingly adopting ways to curtail loss of mercury in wastewaters. In addition, some historic accumulations of mercury in the Great Lakes region will be mentioned.

Through the ages, natural processes like sedimentation and formation of fossil fuels have sequestered mercury from our Biosphere. Some well-intentioned policies have the effect of discouraging return of mercury to the earth, whence it came. Some measures move it between the earth's compartments, moving mercury from soils to air, increasing bioavailability.

There are natural processes that transform mercury into a potent poison, methylmercury, taken up by aquatic food webs. More happily, there are simultaneous natural processes that demethylate mercury, acting as a natural defense mechanism against the ruinous levels reached during poisonings in Japan (Minamata, Niigata), owing to man-made methylmercury.

In general, mercury levels in the United States seem to have decreased during the past three decades. Yet the world's growing appetite for energy could inflate global emissions. So could use of mercury by small-scale gold and silver miners in many developing countries, since they burn off copious quantities. Given mercury's long range dispersion via the atmosphere, world sources could countervail encouraging U.S. trends. It is only by better characterizing sources that human ingenuity is then empowered to consider their amenability to prevention.

3. LUNCHTIME KEYNOTE ADDRESS

3.1 State of the Science: Environmental Transport, Distribution and Fate of Mercury

Don Mackay, Trent University, Peterborough, ON

Mercury presents the ultimate challenge to the environmental scientist. It has numerous natural and anthropogenic sources. It is a truly "multi-media" contaminant which ignores international boundaries. It can switch between elemental, inorganic and organic species, each with its own partitioning tendencies between environmental media. Analysis of these species is problematic because of low levels and species instabilities. It displays unusual behaviour in the atmosphere in cold climates in the early spring. It bioaccumulates, but not by the same mechanism as the well studied organic contaminants such as PCBs. It biomagnifies in food chains resulting in high exposure to humans and wildlife. It has all the attributes of a high priority pollutant; Persistence, Bioaccumulation, Toxicity and Potential for Long Range Transport. These attributes and processes are reviewed briefly. It is argued that whereas we have successfully probed many of the detailed processes, we have not devoted adequate effort to establishing the complete "big picture" of ecosystem-wide sources, transport, transformation, biouptake and effects. The scientific community has failed to generate and convey this ecosystem approach to policy makers. Until this is accomplished policies aimed at reducing adverse effects will, at the best be haphazard and at the worst, wasteful and ineffective. Suggestions are made for a purposeful path forward, which it is hoped, will be articulated by this Workshop.

4. EXPOSURES OF GREAT LAKES POPULATIONS AND SURROGATES OF EXPOSURE

4.1 Canadian Surveys of Fisheaters

Donald Cole, University of Toronto, Toronto, ON

Concern over mercury levels among sport fish eaters led us to recruit 86 frequent consumers of Great Lakes (GL) fish, via shore surveys and community contacts. Participants ate an annual median of 88 GL meals in the past year, with Asian-Canadians consuming more total fish meals (women median of 213; men, 223) compared to Euro-Canadians (women, 131; men 137.5). Eight Vietnamese women had total blood mercury levels above the study reporting guideline for women of reproductive age of 10 μg/L. The highest value of 25.98 μg/L (above the Health Canada tolerable level of 20 μ/L) included a considerable inorganic contribution. Four men with levels ranging from 15.5 to 19 μg/L may have had contributory occupational exposures. Overall, the median total blood mercury level was 4.2 μg/L (mean 5.8, standard deviation 5.4). Correlations between blood mercury and Great Lakes fish consumption were moderate and significant among Euro-Canadians but low among Asian-Canadians, perhaps due to consumption of purchased imported fish. Blood Hg levels were higher than those found in earlier Ontario angler studies but lower than those found in other studies of St. Lawrence River fish consumers and substantially lower than those found in Inuit women of reproductive age consuming high amounts of seafood. Given the nutritional and social benefits of fish consumption, prudent species and location choices should continue to be advised.

4.2 **United States Surveys of Fisheaters**

Henry Anderson, University of Wisconsin, Madison, WI

In 1970 the Wisconsin Conservation Bulletin reported the growing threat to the environment posed by mercury. An aggressive sport fish monitoring program launched in Wisconsin, other Great Lakes States and Canada documented the extent of the environmental impact. Levels of methylmercury in fish tissue alarmed the public health community resulting in the issuing of sport fish consumption advisories, which, now 30 years later remain in place. Human health research efforts in the Great Lakes region and public perception of risk has shifted from mercury and been eclipsed by the focus on lipophilic chemicals such as polychlorinated biphenyl (PCB) and other halogenated hydrocarbon contamination found in Great Lakes salmonids. Despite the shift in attention, mercury remains responsible for the largest number of sport fish consumption advisories.

Until source control and environmental remediation efforts can complete the reduction of the environmental burden of mercury and PCB below levels of concern, sport fish consumption advisories will remain the primary means of reducing human exposure. Thus, assuring and assessing the effectiveness of such advisories is paramount. In 1993-94, using random telephone survey techniques we interviewed 8,306 adults in the 8 Great Lakes states to evaluate sport fish consumption and PCB advisory awareness. We found that women, minorities and those with less than a high school education were not being reached effectively. In 2001 we conducted a 12-state random telephone survey of 3,015 women of childbearing age specifically focusing upon fish consumption and mercury. Sport fish consumption in the past year varied between 13-43%. Advisory awareness among those reporting sport fish consumption ranged from 5-43%. Women confused PCB issues with those of mercury. Detailed results of the 12-state mercury survey will be presented.

4.3 **Ojibwa Health Study**

John Dellinger, University of Wisconsin, Milwaukee, WI

The Ojibwa Health Study has concluded 10 years of data collection and exposure assessment. Approximately 800 participants (10-times the original Red Cliff study) from Ojibwa tribes of Wisconsin, Michigan and Minnesota completed fish consumption and environmental risk perception questionnaires. Approximately two-thirds provided hair and/or blood samples for mercury and polychlorinated biphenyls (PCBs).

Partnership and funding was provided to three tribal organizations: Great Lakes Indian Fish and Wildlife Commission (GLIFWC), Great Lakes Inter-Tribal Council (GLITC), and Intertribal Fisheries Assessment Program (ITFAP). Fish were collected and contaminants analyzed for numerous tribal reports, professional environmental journal articles, and used to design and produce tribal-specific GIS maps by GLIFWC. The data are critical for assisting tribal members in minimizing their exposures to harmful contaminants in their diets. These maps are currently available at www.glifwc.org for six Wisconsin tribes who regularly harvest walleye.

The collaboration with GLITC helped spur the initial growth of their EpiCenter, an epidemiology resource project. The Ojibwa Health Study required baseline chronic disease and reproductive health data for each tribe. To determine the health impacts (if any) of pollutants on cancer, diabetes, reproduction, it is necessary to know the recent trends in key indicators, for examples; cancer mortality ratios and birth gender ratios. GLITC provided each participating tribe in Wisconsin and Michigan with a health profile for their tribe. The GLITC EpiCenter now prepares Community Health Profiles biannually for more than a dozen reservations.

In 2002 all PCB and mercury hair and blood results were received from the Centers for Disease Control and University of Nevada-Las Vegas, respectively. Currently those data are receiving detailed review with medical and scientific specialists. The highest concentrations in tribal participants were 18.6 ppb total PCBs and 11.8 ppb total blood mercury. Ninety percent of the participants had less than 3.8 ppb total PCBs and 2.6 ppb total blood mercury. Compared to other studies of subsistence fishing populations these exposures are only moderately elevated and not high enough to warrant widespread restrictions to diets. Furthermore, the benefits of eating a fish diet must be continually emphasized. Fish is lower fat, provides more omega-3 and other nutrients compared with alternative protein sources. However, sport fishermen and their families who consume larger and more contaminated fish should abide by their state fish consumption advisories to minimize their health risks.

4.4 Mercury Concentrations in Great Lakes Fish in Canadian Areas of Concern

Michael Weis, University of Windsor, Windsor, ON

The primary route of human exposure to methylmercury is from the consumption of fish. In the Great Lakes basin there are several subpopulations that are heavily dependent on fish for nutrition. There are few direct measurements of exposure of these subpopulations to methylmercury on which to base risk assessments. An alternative strategy is to use concentrations in fish as a surrogate measure of likely exposure. The extensive database on concentrations of mercury in fish, compiled by Environment Canada, has been used to rank likely exposures of the subpopulations in the 17 Canadian Areas of Concern. Statistical methods have been used to separate the effects of interspecific variation in mercury concentrations, the effect of age of the fish, and the year in which the fish were sampled as an approach to providing an index of the methylmercury concentration in fish at the various sites.

4.5 Review of Historical and Recent Mercury Concentrations in Great Lakes Sediments

Ronald Rossmann, United States Environmental Protection Agency, Grosse Ile, MI

Sediments of the Great Lakes have been impacted by inputs of mercury to the lakes. The first measurements of mercury concentrations in Great Lakes sediments were for samples collected in 1968 for Lake Ontario; 1969 for Lake Huron; 1969-1970 for southern Lake Michigan; 1970 for Lake St. Clair; 1971 for Lake Erie; 1973 for Lake Superior, the North Channel, and Georgian Bay; and 1975 for all of Lake Michigan. These first whole-lake data sets were collected in response to the identification of a mercury problem in fish taken from Lake St. Clair in 1969. After 1975, there was a hiatus in analysis of sediments for mercury. With mercury being elevated to a world issue, more recent collections were made. The most recent collection dates for sediments measured for mercury are 1994-1996 for Lake Michigan, 1997-1998 for Lake Ontario and Lake Erie, 2000 for Lake Superior and Lake St. Clair, and 2002 for Lake Huron. Sediments from all lakes were analyzed for total mercury. In addition, Lake Michigan sediments were analyzed for methyl mercury. Total mercury concentrations in the most recently collected surficial sediments increase in the order Lake Michigan (78 ppb, excluding Green Bay) < Lake Superior (88 ppb)< Lake Erie (190 ppb) < Lake St. Clair (200 ppb) < Green Bay (360 ppb) < Lake Ontario (590 ppb). For each of these lakes, total mercury concentrations in surficial sediments have decreased during the last 30 years. These decreases in Lakes Superior, Michigan, and Erie are confirmed with cores that document decreasing mercury concentrations toward the sediment surface from a subsurface maximum. This abstract does not necessarily reflect EPA policy.

5. EPIZOOTIOLOGY

5.1 Evaluating Common Loon Mercury Exposure and Toxicity Risk in the Great Lakes Basin and Canadian Maritimes

Michael Meyer, Wisconsin Department of Natural Resources,
Rhinelander, WI

Neil Burgess, Canadian Wildlife Service, Environment Canada,
Mount Pearl, Newfoundland

Common loons (*Gavia immer*) are at the greatest risk of mercury (Hg) exposure among wildlife species on inland (non-marine) North American aquatic systems as they are high trophic level, long-lived, obligate piscivores and are thought to be sensitive to the toxic effects of Hg. Blood, eggs, and feathers of loons collected in the Canadian Maritimes and New England averaged higher in Hg content than did samples collected from loons in the Great Lakes states. Samples collected from loons nesting in Alaska were consistently lower in Hg content than samples collected in the Great Lakes, New England, or Canadian Maritimes. In the Great Lakes basin and the Canadian Maritimes, highest Hg concentrations were found in tissue samples collected from loons nesting on low pH, low alkalinity lakes. The highest loon Hg exposure levels measured in the Great Lakes basin were in loons captured on acidic lakes in northern Wisconsin.

Higher mean egg Hg concentrations and log-transformed adult male and female blood and feather Hg concentrations, chick blood Hg concentrations, and fish Hg concentrations were found in Nova Scotia and New Brunswick than in northern Wisconsin. The lakes on which loons were sampled in the Canadian Martimes were more acidic on average than lakes at which loons were captured in Wisconsin. Adult male and female body masses were higher in the Canadian Maritimes. In both regions, female blood Hg concentrations strongly correlated with those of eggs from the same territory and loon tissue Hg concentrations often correlated with those of prey samples collected from the same lake.

Common loon productivity (7-year average) on lakes in Wisconsin was positively correlated with lake pH and adult male body mass, but negatively correlated with fish and chick blood Hg content. Field studies conducted in Wisconsin 1995-1996 showed adult provisioning efficiency (prey items offered chicks per unit effort) declined as lake pH declined and biomass intake per unit chick body mass increased with lake pH, which resulted in lower cumulative biomass intake by chicks on the most acidic lakes (pH<5.5). Although Hg concentration of the 3 major prey species was negatively related to lake pH and positively to blood Hg level of chicks at a lake, total Hg consumption was not related to lake acidity. By fledging, cumulative Hg uptake by loon chicks was highest on moderately acidic lakes (pH 5.5-6.3) because both Hg concentration and biomass consumption remained relatively high. Both chick survival and number of chicks produced as well as food intake declined with declining lake pH, suggesting that loon chick survival is more closely related to prey availability than Hg exposure in the northern Wisconsin lakes we studied. Complicating this interpretation was the finding that adult foraging efficiency was negatively correlated with adult blood Hg content and mean 7 year productivity was negatively related to loon chick blood and fish Hg content. Because of the confounded nature of these field findings, WDNR and USGS are conducting laboratory dose-response experiments to determine the level of Hg exposure associated with negative effects on growing loon chicks.

Analysis of loon blood and feather samples collected from re-captured adult loons in Wisconsin from 1992 to 2000 revealed a decline in overall body burdens of mercury in common loons for this region. The interval between sampling individual loons spanned 2 to 8 years, a sufficient length of time to observe a change in tissue Hg concentrations. Loon chick blood Hg levels declined by 4.9% annually for chicks

sampled on 33 lakes during the period of 1992 to 2000. Other scientists documented this rate of decline in surface water total Hg concentrations and yellow perch Hg concentrations on lakes within our study area during the same time period. This is the first evidence we are aware of showing a recent regional annual decrease in common loon Hg exposure.

6. EPIDEMIOLOGICAL AND CLINICAL CHALLENGES TO DIAGNOSIS OF THE EFFECTS OF MERCURY

6.1 Early Neurotoxic Effects of Mercury Exposure through Fish Consumption from the Great Lakes and the Saint-Lawrence

Donna Mergler PhD, CINBIOSE, Université du Québec à Montréal, PQ

Although much concern has been expressed over the years about the contamination of freshwater fish in the Great Lakes and the St. Lawrence River and very many studies have revealed high mercury concentrations in the carnivorous fish, surprisingly few studies have examined the health effects of exposure to this toxic substance in human fish-eating communities. The neurotoxic properties of methylmercury are well documented through animal research and studies of the Japan and Iraq disasters, which left thousands of persons with a debilitating neurological disease. From these studies, we learned that the fetus is particularly sensitive to exposure and even in the absence of symptoms in the mother, the exposed fetus can suffer from neurodevelopmental retardation. Delayed neurotoxicity has been documented in animal studies and as the Japanese population around the Minamata Bay ages, new cases of the disease are emerging and the population presents higher prevalences of signs and symptoms of neurological disorders compared to others. At much lower levels of mercury contamination, studies are currently being carried out on the effects of *in utero* exposure to methylmercury through fish consumption on children's neurodevelopment in the Faroes Islands and the Seychelles. At low levels of exposure, dose related deficits in neurophysiological functions and/or neurobehavioral performance have been reported in children from the Amazon region, the Faroes, and the Inuits of Northern Canada and in adults who consume fresh-water fish on a regular basis in the Brazilian Amazon. The sum of these studies suggest that (i) mercury neurotoxicity in humans is on a continuum with lower exposures associated with subtle nervous system changes in the absence of clinical manifestations; (ii) there is differential vulnerablity to methylmercury exposure throughout the life span; (iii) other factors, such as diet and other contaminants, may influence positively or negatively, the effects of mercury. The studies that have been carried out on human populations in the Great Lakes and St. Lawrence region will be examined here from the perspective of these premises.

6.2 Examining Potential Indicators of Neurological Effects of Mercury in Communities

Michael Gilbertson, International Joint Commission, Windsor, ON

In communities in Japan and Iraq, past perinatal exposures of infants to methylmercury have resulted in increased incidences of neurological deficits, including mental retardation, seizures and symptoms resembling cerebral palsy. Males seem to be more susceptible to the neurological effects of perinatal exposure to methylmercury than females. In the Great Lakes basin, mercury has been extensively used, particularly in chloralkali plants, resulting in widespread sediment contamination. The estimated financial resources that would be required for remedial action are substantial and pose the question whether present deposits

are causing harm. Data on hospitalization rates for cerebral palsy, compiled by Health Canada, were used for the 17 Canadian Areas of Concern as an index of the effects of community exposures to methylmercury. There are several limitations to this approach including issues of data, statistics and other etiological factors. Hospitalization of males at three of the five locations associated with former mercury chloralkali plants will be discussed. Elevated rates of male hospitalization occurred at other locations not associated with industrial mercury sources indicating a need to reconsider the reliability of this index and to search for other possible mercury sources or other causes of the observed health effects.

6.3 Exposure Assessment Imprecision and Criteria for Outcome Measures

Philippe Grandjean, University of South Denmark, Odense, Denmark

Exposure misclassification is a major obstacle when developing dose-response relationships for risk assessment. Random error results in underestimation of the risk. We have used data from a prospective study of a Faroese birth cohort to determine the imprecision of biomarkers of methylmercury exposure and the resulting underestimation of exposure-associated effects.

We measured the mercury concentrations in cord blood and in maternal hair (sampled at the time of parturition). The laboratory imprecision on both chemical analyses was thought to be below 5% (coefficient of variation, CV). However, using factor analysis and structural equation analysis, the calculated total imprecisions much exceeded the known laboratory variations: The CV was about 30% for the cord-blood concentration and almost twice that much for the maternal hair concentration. The questionnaire response was an even more imprecise predictor of the joint exposure variable.

Sensitivity analyses showed that the imprecision-adjusted impact on nervous system function for each increment of mercury concentration in cord blood increased only by about 15%. However, the highest exposure in this study was about 1,000-fold higher than the lowest, thus limiting the impact of the measurement error.

These findings illustrate that measurement error may be greatly underestimated if judged solely from laboratory quality data. Although sensitivity analyses may provide adjustment for this factor, they are only meaningful if they include measurement errors of a realistic magnitude.

In contrast, standard statistical analysis assumes that the outcome measures are associated with a random error function. Nonetheless, their sensitivity in studies of developmental neurotoxicology will depend on their ability to distinguish between performances that differ only slightly and may be considered within the normal range. Thus, both 'floor' effects and 'ceiling' effects should be avoided. Computer-assisted tests may be advantageous, because they provide a greater separation of responses. Likewise, neurophysiological tests, which do not depend on the subject's cooperation would have certain advantages over tests where motivation may be a confounder. Preferably, the tests should be administered by a qualified health professional, since trained technicians may in some cases be less likely to provide valid data.

The validity of outcome tests may be assessed from their dependence upon known covariates, such as age, sex, and maternal intelligence. Thus, the ideal test battery would be known to be sensitive to neurotoxicant exposures, known to reflect brain functions and brain structures that are likely to be affected by the particular exposure in question, and in the actual study shows dependence upon relevant covariates.

Such criteria deserve to be included in the planning and execution of future studies. Comparisons between studies and meta analyses of results from different studies should also take into account these issues.

6.4 Subtle Neurological Effects on Populations: Epidemiological and Clinical Perspectives

David Bellinger, Harvard Medical School, Boston, MA

In the framework of the National Research Council biomarker model, the neurobehavioral correlates of population exposures to neurotoxicants are generally indicators of "altered function" rather than of "clinical disease." Although some advocate limiting concern to endpoints that correspond to clinical disease, this is likely to result in exposure standards that are not sufficiently protective. A corollary of the prevention paradox is that a small shift in the central tendency of a distribution might have little significance for most individuals in the population but, as has been shown for many chronic diseases, produce a sizeable increase in the prevalence of individuals who meet diagnostic criteria. Furthermore, many neurobehavioral diagnoses are phenomenological, and a neurotoxicant might cause a unique pattern of deficits to which a label has not, by convention, been assigned. Poor performance on a neurobehavioral test does not necessarily map clearly onto the underlying behavioral or neural substrate. Given our generally poor understanding of brain-behavior relationships, the absence of such linkages should not necessarily reduce confidence in neurobehavioral endpoints. The issues involved in using neurobehavioral endpoints in risk analyses differ little from those one faces in using more familiar chronic disease endpoints.

7. LUNCHTIME KEYNOTE ADDRESS

7.1 Linking Science with Science

David Lean, Department of Biology, University of Ottawa, Ottawa, ON

While the need to link science with government policy is widely recognized, the prerequisite to link scientists with other scientists has never been adequately achieved. If we are to provide a synthesis of information, we need a template for integration of existing knowledge. Our concerns about mercury in the environment relate principally to human health but we usually start with mercury sources and work our way up to humans instead of the other way round. There are indeed review papers which attempt to integrate some of the over 50,000 papers on mercury but too often they remain in a discipline framework (otherwise they would never be published). To give some examples, I will attempt to provide some critical gaps in our knowledge of the relative contribution of mercury emissions from human activity and natural sources. I will then comment on existing efforts to determine mercury deposition rates. Since we know that only a small fraction of the mercury passing over a particular area is deposited, some of the chemical reactions that control deposition will be explored. While far less effort is made to measure volatilization rates, it seems that these two processes are of similar magnitude. Making the distinction between natural and re-volatilization of industrial emissions is difficult. With the net contribution of deposition lower than previously thought, the role of natural rock weathering cannot be discounted entirely. Almost all of our research efforts have focused on total mercury but only methyl mercury accumulates in food chains and it is by far the most toxic form. Conditions which lead to methyl mercury formation instead of re-volatilization of recently deposited mercury are discussed and some direction provided for predicting mercury accumulation in small fish. Small fish rather than sport fish are not as influenced by biomagnification processes and are the food source for large fish, wildlife, birds and humans. Finally, the overriding concern of whether or not mercury levels in fish will diminish with reduced mercury emissions is explored.

8. TOXICOLOGICAL EFFECTS OF MERCURY AND NUTRITIONAL BENEFITS OF EATING FISH

8.1 U.S. EPA's Risk Assessment for Methylmercury: Sources of Uncertainty

Deborah Rice, U.S. Environmental Protection Agency, Washington, DC

As part of its mandate, the US Environmental Protection Agency (EPA) assesses the hazard to human health associated with specific environmental contaminants. Such an assessment may include development of a reference dose (RfD), which is an estimate of a daily exposure to the human population that is likely to be without an appreciable risk of deleterious effects during a lifetime. The current reference dose is based on a National Research Council (NRC) assessment of the health effects of methylmercury. The NRC performed quantitative analysis of three epidemiological longitudinal studies assessing neuropsychological effects in children associated with *in utero* exposure to methylmercury: the Seychelles Islands, the Faroe Islands, and New Zealand studies. Benchmark dose (BMD) analysis was performed for a number of endpoints from all three studies, yielding the body burdens associated with a defined increase in abnormal performance. EPA derived RfDs for each of a number of the BMDs modeled by the NRC, including several endpoints from the Faroe Islands and New Zealand studies, as well as an integrative analysis of all three studies. EPA used a one-compartment pharmacokinetic model to derive a daily intake of mercury associated with each BMDL (i.e. the lower limit of the 95 percent confidence interval of the BMD). Most endpoints yielded an RfD of 0.10 μg/kg/day, including an uncertainty factor (UF) of 10 for human pharmacokinetic and pharmacodynamic variability. However, EPA assumed the ratio of cord to maternal blood was 1:1 in its pharmacokinetic model. Recent analysis reveals that it is about 1.7:1.0; consequently, the RfD should be lowered correspondingly. Other areas that could affect the RfD are quantitative analyses of cardiovascular effects in adult males, quantification of variability of pharmacokinetic parameters, and data on the neuropsychological effects of *in utero* methylmercury exposure from additional ongoing studies.

8.2 Benefits of Fish Consumption

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Fish consumption and fish oil have been found to lower the risk of coronary heart disease (CVD) in patients with preexisting CVD as well as in healthy individuals. New information about how n-3 fatty acids affect cardiac function (including antiarrhythmic effects), hemodynamics (cardiac mechanics), and arterial endothelial function have helped clarify potential mechanisms of action. N-3 fatty acids also play an important role as structural membrane lipids, particularly in nerve tissue and the retina and are precursors to eicosanoids. The Food and Nutrition Board of the Institute of Medicine has recently defined the Adequate Intake levels for alpha-linolenic acid as 1.6 and 1.1 g/day for men and women, respectively. The American Heart Association (AHA) issued a statement in November, 2002 suggesting that patients with cardiovascular disease should increase their consumption of eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA) to about 1 gram/day or at least 2 servings of fish per week. In addition, protection against certain cancers as well as diabetes type 2, and severe neurological disease is currently an active area of research. We will also discuss the socio-economic benefits particularly among aboriginal populations.

8.3 **Mercury Risk Assessment: Balancing Toxicity with the Nutritional Benefits of Fish Consumption.**

Kathryn R. Mahaffey, Pesticides and Toxic Substances,
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Consumption of finfish, shellfish, and marine mammals is the source of virtually all human exposure to methylmercury. Data from the National Health and Nutrition Examination Survey for the years 1999 and 2000 indicate that approximately 8 percent of women of childbearing age have blood mercury concentrations greater than 5.8 μg/L, which is the blood mercury concentration associated with US EPA's Reference Dose (RfD) for methylmercury. This RfD, developed in 2000, is based on protecting the developing fetal nervous system from adverse neurological effects of *in utero* exposure to methylmercury. Recent data from Europe and Israel (Guallar et al., 2002) confirm earlier observations from Eastern Finland (Salonen et al., 2000) that methylmercury exposures increase the risk of coronary heart disease among adult men. An additional report (Yoshizawa et al., 2002) describing adult males in medically related health professional occupations identified a trend toward increased risk of coronary heart disease with increased fish consumption when subjects with occupational exposure to inorganic mercury (i.e., dentists) were analyzed separately from the subjects with predominantly methylmercury exposure from diet.

Although fish may become contaminated with methylmercury and other persistent bioaccumulative toxic substances, fish provide a number of nutrients which may not be plentiful from other dietary sources. Intakes of fish or fish oils (containing long-chain n-3 polyunsaturated fatty acids, also termed omega-3-fatty acids) provide nutrients that are especially important for the developing nervous system. In addition, fatty fish or fish oil supplements have been shown in some clinical trials to reduce mortality after myocardial infarction.

Assessment of the concentrations of methylmercury in fish, shellfish, and marine mammals indicate that mercury concentrations are highest in higher trophic level, piscivorous species. The concentrations of long-chain n-3 polyunsaturated fatty acids are more closely associated with the percent fat in the species of fish and shellfish. Both concentrations of methylmercury and fatty acids vary widely across fish species. Assessment of published literature indicates there is a weak association between the mercury concentrations and the fatty acid composition of fish. This discussion will consider fish consumption patterns and their impact on consumption of both methylmercury and long-chain n-3 polyunsaturated fatty acids as identified in NHANES 1999 and 2000 data.

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POSTER ABSTRACTS

• CORRELATION BETWEEN ENVIRONMENTAL PCBs AND MERCURY CONCENTRATIONS AND AGE-STANDARDIZED DISEASE MORBIDITY AND MORTALITY RATES FOR THE 17 CANADIAN GREAT LAKES AREAS OF CONCERN

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Both PCBs (polychlorinated biphenyls) and methyl mercury have been implicated as possible confounding factors in a number of neuro-endocrine disease states. In an attempt to assess whether exposure to these semi-ubiquitous pollutants may have implications for public health, we assessed whether PCB and mercury monitoring data could be correlated using statistical analyses with public health indicators in the same region. Age-standardized health statistics, including morbidity as hospitalization, and mortality, were obtained from the Health Canada databases for the 17 Areas of Concern (AOCs) as identified by the International Joint Commission. The concentrations of PCBs in the water, suspended sediments, and bottom sediments, and mercury concentrations in the bottom sediments in the Great Lakes were obtained from several published reports. Statistical analyses, including simple, stepwise, and multiple variate regressions, were performed using SAS. We found that PCB concentrations in the water, suspended sediments, and bottom sediments, and mercury concentrations in bottom sediments at the seventeen Canadian Great Lakes Areas of Concern (AOCs) were significantly correlated with health problems affecting the immune, endocrine, reproductive, and neurological systems. These correlations tended to be more significant (lower p and greater r squared values) for the PCBs in water data because the monitoring data was more accurate and more complete, while the PCBs in sediment and suspended sediment and the mercury data was estimated from contaminant maps, and was therefore a less accurate indicator of potential exposure (i.e. was one extra step removed as an indicator of potential exposure). We believe that the exposure indicator to public health indicator correlations will improve in accuracy and sensitivity once more complete and higher resolution monitoring data is available for analysis.

• MINK AND OTTER AS SENTINELS OF MERCURY CONTAMINATION IN THE CANADIAN GREAT LAKES BASIN

Pamela A. Martin, Canadian Wildlife Service, Environment, Burlington, ON

Mink (*Mustela vison*) and river otters (*Lutra canadensis*) are top mammalian carnivores in the aquatic ecosystem of the Great Lakes, and as such can accumulate relatively high concentrations of persistent contaminants, including mercury. Mercury concentrations in organ tissues of these mammals are approximately one order of magnitude greater than those found in prey fish species, suggesting them as appropriate sentinels of Hg contamination in the aquatic environment. Until recently, sampling of mink and otter for total Hg levels in Ontario has concentrated on areas in the central regions of the province on the Precambrian Shield, where the elevated acidity of the region was suspected to make Hg more available to aquatic biota. Mean concentrations of mink liver samples from the 1980s from this region ranged from 0.56 $\mu g/g$ wet wt in Sudbury to 2.55 $\mu g/g$ in the English River. Otter samples from the 1980s and 1990s from central Ontario also did not exceed 3.5 $\mu g/g$ wet wt. In the early 1980s, mink and otter liver samples from the Winnipeg River system, feeding into Lake Superior, both

approached 4 $\mu g/g$. In 2000, liver Hg levels were analyzed from mink trapped around the lower Great Lakes basin. Concentrations of animals from the St. Lawrence River Area of Concern near Cornwall were significantly higher than those from animals trapped near Lake Erie and Lake St. Clair, with mean liver levels approaching 5 $\mu g/g$, and two individual animals exceeding 10 $\mu g/g$ total Hg. Nevertheless, all levels were well below those associated with toxicity as determined from laboratory tests or in wild animals found suffering from Hg poisoning, generally >25 $\mu g/g$. Although otter are more completely piscivorous than are mink, it is generally concluded that mink make a better bioindicator for local mercury contamination given there greater distribution throughout the Great Lakes basin and their smaller home range. There appears to be little difference in the ability of the two species to accumulate mercury; however otter appear to be better able to break down the harmful methyl mercury into organic mercury than mink, possibly making mink more susceptible to its accumulation and poisoning.

• EAGLES AS INDICATORS OF MERCURY EXPOSURE IN THE GREAT LAKES REGION

Amy S. Roe[1], Jennifer M. Wing[1], Dennis Bush[2], David A. Best[3], James G. Sikarskie[4], and William W. Bowerman[1]. [1] Department of Environmental Toxicology, Clemson University, Pendleton, South Carolina [2] Department of Environmental Quality, East Lansing, Michigan . [3] U.S. Fish and Wildlife Service, East Lansing, Michigan. [4] Department of Small Animal Clinical Sciences, Michigan State University, East Lansing, Michigan.

The bald eagle (*Haliaeetus leucocephalus*) is a tertiary predator of aquatic ecosystems. Testing of tissue samples of eagles integrates the exposure potential of bioaccumulative substances and has been proposed as a means of monitoring water quality and ecosystem health. We report here the results from years 1-2 of a multi-year study using feathers of nestling bald eagles to measure exposure to mercury through food chain transfer in the Great Lakes Region. During normal banding activities, feathers were collected from nestling eagles that were between 5 and 10 weeks of age. We compared sub-population concentrations from interior portions of the Upper (UP) and Lower (LP) Peninsulas, and Lakes Michigan and Huron (LMH), Lake Superior (LS), Michigan, and Voyageurs National Park (VNP), Minnesota. Significant differences in mercury were found within the UP and LMH sub-populations between 1999 and 2000. In comparison to concentrations in nestling feathers collected from 1985-89 and 1999-2000 in these same regions, only concentrations at VNP showed a statistically significant decrease between the two time periods. It is notable that the breeding areas in which the highest Hg concentrations were measured often were located near inland impoundments. During the active nesting and chick-rearing period, it is likely that the adults feed primarily from these nearby impoundments. Specifically, breeding areas near impoundments with Hg concentrations greater than 15 $\mu g/g$ include AL-02j (16.67 $\mu g/g$) which is located on Bamfield Pond; MM-08a (17.46 $\mu g/g$) which is located on Peterson Pond; and MN-06e (17.50) which is on Tippy Dam. For the 2000 samples, there are a total of 16 breeding areas on impoundments with Hg concentrations ranging from 6.75-17.50 $\mu g/g$ Hg. Among these impoundment breeding areas, 2 are part of the Saginaw National Resources Damage Assessment (NRDA), AR-02b (13.60 $\mu g/g$) Big Charity Island and BY-03c (4.33 $\mu g/g$) Nayanquing Point. Along with the breeding areas from the Saginaw NRDA, 6 breeding areas in Delta county are a part of the Green Bay NRDA. Concentrations of Hg range from 5.70 – 13.35 $\mu g/g$. The Deer Lake breeding area in Marquette County (MQ-09) is the one territory sampled in 1999 and 2000 that is associated with a known site of Hg contamination. Deer Lake, an International Joint Commission designated Area of Concern for Hg contamination, is a mesotrophic-eutrophic impoundment of the Carp River. It was contaminated historically with Hg by analytical laboratories conducting ore analysis. Two nestlings sampled at the Deer Lake breeding area in 1999 had high Hg concentrations in their feathers (16.2 and 17.2 $\mu g/g$). The nestling sampled at the Deer Lake breeding area in 2000 also had high Hg concentrations in the feathers (16.22 $\mu g/g$). Based on the proximity of the breeding area to Deer Lake, it is presumed that the adults are feeding on fish from Deer Lake and providing those

fish to the nestling eaglet. This study had shown that mercury concentrations have not changed dramatically in the Great Lakes higher trophic level food web over the past decade. However, due to the relative ease of sampling and analysis, monitoring of mercury levels within the Great Lakes using nestling bald eagles should continue. This would allow for the monitoring of long term spatial and temporal mercury trends. This information could be useful to environmental policy makers who are concerned with wildlife and human health risks of mercury.

• MERCURY LEVELS IN COLONIAL WATERBIRDS NESTING ON THE GREAT LAKES (1973-2002)

Cynthia Pekarik, Carolyn Matkovich, Chip Weseloh, Canadian Wildlife Service, Burlington, ON

As part of the Great Lakes egg contaminants monitoring program, the Canadian Wildlife Service has monitored (total) mercury levels in several species of colonial water birds. Data accumulated for Herring Gulls (*Larus argentatus*), Great Black-backed Gulls (*Larus marinus*) and Black-crowned Night-Herons (*Nycticorax nycticorax*) were sufficient for inter-species comparisons and trend analysis. In 2000, for eggs collected at four colonies located in Lakes Huron, Erie and Ontario and the Niagara River, levels in Black-crowned Night-Herons were 30% higher than in Herring Gulls (0.21 and 0.16 $\mu g/g$ wet weight, respectively) ($p = 0.28$). In 2001, at two colonies in eastern Lake Ontario, levels were three times greater in Great Black-backed Gulls (0.64 $\mu g/g$) than they were in Herring Gulls (0.21 $\mu g/g$) ($p<0.0001$). Temporal trend analysis was conducted for Herring Gull eggs from fifteen colonies throughout the Great Lakes, samples were collected since the early 1970s (eight sites) and early 1980s (seven sites). In 2002, values ranged from 0.08 to 0.21 $\mu g/g$ (wet weight), levels were lowest in Eastern Lake Erie and highest in Eastern Lake Ontario. Results indicated significant declining trends at eleven colonies and non-significant declines at an additional three sites. Significant declines occurred at all sites sampled on Lakes Ontario, Erie, Superior, the Niagara and Detroit Rivers and at two sites on Lake Huron, non-significant declines occurred at both sites on Lake Michigan and on the St. Lawrence River. A non-significant increasing trend was observed at Saginaw Bay, Lake Huron.

• REGIONAL MODELING OF FISH TISSUE CONTAMINATION

Tamara Saltman, U.S. EPA, Washington, DC

Models that estimate mercury contamination in fish tissue have historically been used only for a single lake. Working with TetraTech we have developed a Monte Carlo approach that allows us to estimate changes in fish tissue concentrations due to changes in lake mercury loads over broad regions of the U.S. The poster will explain the methods used and present the results of the analysis to date.

• NATURAL MERCURY LEVELS IN GREAT LAKES FISH

Dennis Leonard, Detroit Edison, Detroit Michigan

The Binational Toxics Strategy, implementing the Great Lakes Water Quality Agreement, strives to achieve natural levels of pollutants that are naturally occurring. Mercury concentrations in fish in various bays and tributaries to the Great Lakes were historically high and in some instances elevated mercury concentrations were even found in the main basins of the Great Lakes. Mercury levels is fish have since declined in some portions of the Great Lakes, notably the St. Clair River, Lake St. Clair, the Detroit River and Lake

Erie. Analyses of mercury concentrations in portions of the Great Lakes indicate that mercury levels in fish, in certain open waters of the lakes, are approaching natural levels. (Request is being made to the Ontario Ministry of Environment for permission to use their data on mercury levels in Great lakes fish including analyses of museum specimens). Information on mercury deposition to the Great Lakes and the non-linear relationship between mercury loading and subsequent mercury levels in fish also support the contention that mercury levels in the main basins of the Great Lakes are approaching natural levels. This information is important, since the Binational Toxics Strategy defines "virtual elimination" of natural occurring substances as the attainment of natural levels in Great Lakes and only requires the reduction of man made releases of naturally occurring substances where warranted.

• AN HISTORICAL VIEW OF MERCURY: LAKE SUPERIOR PERSPECTIVE

Jim Bailey, EcoSuperior; Kory Groetsch, Great Lakes Indian Fish and Wildlife Commission; Steve Hopkins, US Environmental Protection Agency; Paul Jordan, Ontario Ministry of Environment; Nancy Larson, Wisconsin Department of Natural Resources; Carri Lohse-Hanson, Minnesota Pollution Control Agency; Victor Oriecuia, Ontario Ministry of Environment; Darrell Piekarz, Environment Canada; Sarah Walsh, Michigan Department of Environmental Quality.

Mercury is one of nine chemicals targeted for zero discharge and zero emission in the Lake Superior watershed by the 1991 Binational Program to Restore and Protect the Lake Superior Basin. This zero discharge goal was incorporated into the Lake Superior Lakewide Management Plan (LaMP) and the Lake Superior LaMP has progressed through Stages 1 (Problem Identification), 2 (Reduction Schedule) and 3 (Implementation) for mercury. While the level of mercury in Lake Superior fish is a useful indicator of trends and the goal of unlimited consumption, measuring sources of mercury from within the basin is equally important for measuring progress towards the zero discharge and zero emission goal. As part of the LaMP, the jurisdictions surrounding Lake Superior have developed a use tree of mercury sources, estimated loading from a variety of sectors in the basin and engaged in mercury reduction activities that range from jurisdictions' involvement in national and international mercury reduction programs to very specific efforts to reduce the use of mercury products in the watershed.

• ACCOUNTING FOR 40% OF CANADA'S MERCURY EMISSIONS: THE USE AND FATE OF MERCURY-CONTAINING PRODUCTS

Leah Hagreen, Executive Director, Mercury Recovery Fund, Toronto, ON

As major industrial emitters of mercury come under control, the significance of products as a source of mercury to the environment has received increasing attention. Mercury containing products such as thermostats and vehicle switches contribute as much as 40% of Canada's total mercury emissions per year, but collection programs are not in place to prevent these releases and virtually no legislation exists to prevent further use of mercury in these products. There exists an opportunity in Canada to reduce mercury emissions using a pollution prevention approach through a combination of reduced use and the implementation of recovery programs for products before they are disposed of and the mercury released.

The intent of this poster is to address the increasing significance of mercury use in products as a source of mercury pollution, and examine management options for these sources in Canada. The poster will examine the use and fate of mercury in products, and explore management options to deal with both the use and disposal of the products. The poster will draw upon examples of management options from Canada, Europe and the United States, identify current collection programs, and recommend policies to prevent future releases of mercury from products.

- ASSESSMENT OF THE POTENTIAL FOR MERCURY BIOMAGNIFICATION FROM SEDIMENT IN THE ST. LAWRENCE RIVER (CORNWALL) AREA OF CONCERN

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Elevated concentrations of mercury exist in sediments of the St. Lawrence River at Cornwall. To assess the bioavailability of this mercury and its potential for biomagnification, mercury concentrations were determined in sediment and 3 benthic invertebrate taxa (midges, snails, amphipods) sampled from 22 contaminated and 12 reference sites. Regression analyses showed concentration of total mercury in sediment to be strongly predictive of total mercury in invertebrates. Sediment methyl mercury was weakly predictive of invertebrate methyl mercury levels. Concentrations of mercury in representative consumers of benthic invertebrates and their predators (white sucker, yellow perch, walleye, great blue heron, mink) were predicted using screening-level trophic transfer models. With the highest biomagnification factors obtained from a review of pre-existing studies and maximum mercury-exposure assumptions, total and methyl mercury concentrations in perch and walleye at almost all sites were predicted to exceed tissue residue guidelines for the protection of fish-consuming wildlife and humans. For white sucker, this outcome existed only for total mercury. Results suggest that under "worst-case" exposure and trophic transfer scenarios mercury could bioaccumulate in receptors to levels that are not protective of adverse effects. However, the likelihood of realizing this degree of mercury biomagnification is not clear due to uncertainties associated with predicting receptor mercury concentrations.

- **DEVELOPMENT OF MERCURY SPECIATION, FATE AND BIOACCUMULATION MODEL**

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Fate models are a key precursor for targeting emission reductions, understanding the connection between emissions and exposure, and drafting reasonable remediation options. Fate models can also be used to assist with human and ecological risk assessments by estimating the concentrations to which receptors are exposed and how this might change under different scenarios. We have developed a mathematical fate and transport model that generates the concentrations, mass and rate of movements of mercury species in environmental media. The steady-state version of "BIOTRANSPEC", a mathematically linked BIOtic, fugacity/aquivalence multispecies TRANsport model, and aqueous equilibrium SPECiation model, has been developed in order to improve estimates of the fate and biotic uptake of mercury in aquatic systems. BIOTRANSPEC couples the kinetics and aquatic speciation model MINEQL+ with our fugacity/aquivalence model that allows consideration of multiple, interconverting species of mercury. The kinetics module calculates the net production of organic mercury (MeHg) using site-specific rate constants. The speciation model estimates the concentrations and distribution of mercury species that occur as inorganic (Hg^{+2} and Hg^{0}) and organic mercury (MeHg) species in dissolved, colloidal and particulate phases. In order to accurately estimate the fate of mercury, we have integrated methylation kinetics, speciation and fate models with a simple model of biotic uptake since fish are an important sink for methyl mercury. We illustrate the use of the model through its application to several aquatic systems.

• MERCURY IN TRIBUTARY AND LAKEBED SEDIMENTS OF THE LOWER GREAT LAKES

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A spatial overview of mercury concentrations in sediments, incorporating both lakebed and tributary sites, has been collated for the lower Great Lakes, including the St. Clair River – Lake St. Clair - Detroit River corridor. The data suggest that Canadian tributaries do not generally represent significant sources of mercury to the Great Lakes, but local sources may be indicated. The highest mercury concentrations are observed in open lake depositional areas. The mercury concentrations observed in these 1997-2002 measurements represent a 40% and 70% decline in mercury concentrations over the past 30 years for Lakes Erie and Ontario bed sediments, respectively.

• GREAT LAKES BINATIONAL TOXICS STRATEGY: MERCURY CHALLENGE UPDATE

Edwin R. Smith, U.S. Environmental Protection Agency, Chicago, IL

Canadian and United States efforts to reduce mercury loadings to the Great Lakes Basin under the Great Lakes Binational Toxics Strategy have met with considerable success. Canadian mercury releases have been reduced by 78% since 1988, and nationally, US use and emissions have been reduced by 50% and 40% respectively. General trends of mercury in Great Lakes Rainbow Smelt and in herring gull eggs indicate that concentrations in the Basin are declining.

• FISH SENSE: COMMON SENSE ADVICE FOR DOCTORS AND PATIENTS ABOUT FISH CONSUMPTION

David Wallinga, MD, MPA, Institute for Agriculture & Trade Policy, Minneapolis, MN

Fish can be nutritious, heart-protective, and a source of omega-3 fats beneficial to early brain development. But fish also are vulnerable to contamination by toxic industrial pollutants that persist in the environment and accumulate in fish fat or muscle tissue. These include not only mercury, but also polychlorinated biphenyls (PCBs), and dioxins. Individuals and their health care providers must consider possible health impacts and exert precaution in choosing and eating fish.

Since pollutants can vary by geography, by fish species, and the health impacts can vary by the age and health status of the consumer, advice to fish consumers must be finely nuanced and reflect all relevant issues beyond simply mercury levels. Part of common sense advice to patients should be information about non-contaminated, non-fish sources of beneficial fats, including, for example, seed and oils from flax and other grains, omega-3 fat supplements, and eggs from chickens fed flax, algae or other relatively rich sources of omega-3 fats.