INTRODUCTION

Human Health, the Great Lakes, and Environmental Pollution: A 1994 Perspective

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The Great Lakes constitute the largest body of surface freshwater on earth and are one of the planet's most valuable natural resources. Home to roughly 36 million people, the Great Lakes basin is a major industrial and agricultural region of North America. The Canadian portion of the basin contains one-third of the Canadian population and half of all the manufacturing activity in Canada.

The health and integrity of the Great Lakes ecosystem has been the subject of much public and scientific interest and debate over the past 25 years. In the early 1970s, scientists, provincial and state governments, and Great Lakes communities began to express serious concerns about the integrity of the Great Lakes ecosystem and the potential harmful effects of toxic chemicals present in the Great Lakes. By the mid-1980s, over 800 distinct chemical substances from a variety of industrial, agricultural and municipal sources had been identified in the Great Lakes basin, of which only 40 to 50% were well known (1). Of these, the International Joint Commission on Great Lakes Water Quality targeted 11 of the most persistent toxic substances as critical contaminants (2): polychlorinated biphenyls (PCBs), dioxins, and furans; the organochlorine pesticides dichlorodiphenyl trichloroethane (DDT), toxaphene, mirex, dieldrin, and hexachlorobenzene (HCB); the heavy metals methylmercury and alkylated lead; and benzo[α]pyrene, a member of a class of substances known as polycyclic aromatic hydrocarbons (PAHs).

Since the early 1970s, monitoring data have shown the presence of these waterborne toxic chemicals in the sediments and biota (plants, fish, wildlife) of the Great Lakes, the latter through the processes of bioaccumulation and bioconcentration. An important consequence of these developments is a heightened awareness and a growing public and scientific concern over the past 25 years about how and to what extent the health of wildlife and humans in the Great Lakes basin may be affected by exposure to environmental contaminants. Since the signing of the 1978 binational Great Lakes Water Quality Agreement—in which Canada and the United States agreed to the virtual elimination of all persistent toxic substances from the Great Lakes—programs have been put into place to reduce or eliminate inputs of environmental contaminants to the Lakes and to study the potential health effects of exposure to them. While there is dissent over the adequacy of the rate at which contaminant levels in Great Lakes sediments and biota are declining, it is certain that levels of all 11 critical pollutants have dropped significantly since the early 1970s, some by over 90% (3).

The Great Lakes Health Effects Program

The Great Lakes Health Effects Program (GLHEP) is a Canadian Department of Health Initiative that was established in 1989 in response to health issues addressed in the 1987 protocol to the Canada–United States Great Lakes Water Quality Agreement. Phase I of this multidisciplinary program covered a 5-year period (1989–1994) and was allocated funding of $20 million. It combined research and action in partnership with the Canadian public and communities of the Great Lakes basin and with agencies in Canada and the United States to reduce the risk to human health from contaminants present in the Great Lakes.

GLHEP’s mission statement “to protect human health in the Great Lakes basin from the effects of exposure to environmental contaminants” gave rise to three majors goals: to determine the nature, magnitude, and extent of effects on human health associated with exposure to contaminants (chemical, microbiological, radiological) from all sources of pollution in the Great Lakes basin; to develop and implement strategies to reduce or eliminate risks to human health related to pollution in the Great Lakes basin; and to increase communication and consultation among agencies and the public and to provide timely, useful information to foster understanding and appropriate action on health and environmental issues.

These goals led to over 50 projects that were meshed with the public’s priorities and with scientific realities. Projects and related activities included: a) surveillance projects, which entailed developing a sampling strategy and analyzing contaminant levels in human tissues and in the food, air, water, and soil; b) objectives and remedial measures, which involved formulating binational objectives and Remedial Action Plans, working to reduce levels of contaminants to which we are exposed, and examining the health implications of eating Great Lakes fish; c) toxicologic research that focused on the effects of persistent chemicals, including mixtures, on human tissues, molecular and biochemical processes, fetal and child development, reproduction, the immune system, and respiratory health; d) epidemiologic research that identified high-risk populations and investigated the impact of the Great Lakes environment on their health;
and e) public consultation with various public groups and the provision of health advice to communities and individuals throughout the Great Lakes basin.

**Exposure Levels**

Data on chemical concentrations in sediment cores indicate that the major loadings of persistent toxic chemicals to the Great Lakes took place between the 1950s and the early 1970s, with peak concentrations occurring in the mid-1970s (1). Ambient concentrations of most toxic inorganic and organic chemicals have since declined and are significantly lower than they were 15 to 20 years ago, due in part to the bans or restrictions on their manufacture and use (e.g., PCBs and mirex). The levels of most chemical contaminants are now below the levels indicated in the objectives of the 1978 Canada–U.S. Great Lakes Water Quality Agreement. Concentrations in fish and bird species (e.g., spottail shiners, lake trout, herring gulls) have also declined on a lake-wide basis. However, while the levels of these contaminants in Great Lakes biota are lower than in 1975, many have not been decreasing significantly since the mid-1980s. Some persistent contaminants (e.g., dioxins, PCBs, mercury) are still at unacceptably high concentrations in some fish species (1).

GLHEP-supported research involving measurements of organochlorine chemicals in human adipose tissue, breast milk, and blood has confirmed that humans in the Great Lakes basin are exposed to persistent toxic chemicals through the air we breathe, the water we drink, and the food we eat. The latter accounts for approximately 80 to 90% of human exposure to most persistent organochlorine contaminants (4). This proportion may be even higher for consumers of large quantities of Great Lakes fish or wildlife in which these contaminants can readily bioaccumulate.

Over the years, tissue levels of some of the most prevalent contaminants (e.g., PCBs, HCB, dioxins) in Great Lakes basin residents have been shown to be similar to those in people living elsewhere. More recently, an analysis of 497 human breast milk samples from donors from across Canada in 1992 has revealed that, compared to earlier similar surveys in Canada, concentrations of most PCB and organochlorine pesticide residues in breast milk have declined and are lower than those recently reported in European countries (5). Minor regional differences were detected, with mean population residues being slightly but not significantly higher in the Great Lakes basin compared to the rest of Canada. Concentrations of PCBs, DDT, and HCB were higher in those who consumed more than 100 g of fish weekly. Higher than average exposures have been observed more generally in those who consume relatively large amounts of contaminated fish or wildlife, such as Native people, sportsmen, and their families. In the future, human tissue residue levels are likely to decrease slowly if continued efforts are made to reduce discharges to the environment and to clean up contaminated areas.

**Health Effects**

The GLHEP has used a weight of evidence approach to assess the human health effects of exposure to environmental contaminants in the Great Lakes basin. This approach considers all quality scientific data on adverse health effects, i.e., from studies on a range of wildlife species, toxicologic studies on laboratory animals, and human epidemiologic studies of acute accidental or chronic occupational exposures. These data have proved useful in hazard identification and in weighing the potential for adverse health effects in human populations in the Great Lakes region.

Monitoring of various fish, bird, and mammalian species in the Great Lakes basin during the 1970s provided the first alert of adverse health effects due to exposure to chemical contaminants. A wide range of effects were observed between the mid-1970s and mid-1980s, including reproductive failure and population declines in mink, lake trout, bald eagles, snapping turtles, double-crested cormorants, herring gulls, and common terns; congenital malformations were observed in the latter four species, as well as various biochemical changes in the latter three (4).

Laboratory animal studies and human epidemiologic studies of accidental and occupational exposures have demonstrated that high concentrations of certain heavy metals and persistent chlorinated contaminants can cause a range of adverse health effects in humans (4). The potential exists for similar effects from exposure to the lower levels of contaminants found in the Great Lakes basin. These effects are relatively subtle and difficult to demonstrate because they are confounded by lifestyle factors (e.g., smoking, alcohol use). While recent data do not indicate that exposure of the general population in the basin is higher than elsewhere in North America, additional epidemiologic studies have helped to identify several subpopulations who are at higher risk of adverse health effects because of their greater exposure to Great Lakes contaminants or their increased susceptibility. In addition to consumers of large amounts of contaminated Great Lakes sport fish or wildlife, people living in large or industrial urban areas, the elderly, the sick, young children, pregnant women, the developing fetus, and newborns/infants of mothers who consumed contaminated Great Lakes fish have been identified as subpopulations at higher risk for health effects. These health effects include exaggerated respiratory disease, immune system impairment, neurologic developmental delays, psychosocial disorders, reproductive anomalies, and possibly others.

These adverse health effects are discussed in the series of topic papers appearing in this volume. The papers combine original research and reviews that reflect some of the accomplishments of the first 5 years of the GLHEP. The findings from these studies indicate that adverse reproductive, developmental, and immunologic effects, among others, may potentially result from exposure to Great Lakes contaminants, particularly in those belonging to the higher risk groups mentioned above. Among the key points outlined in this series of papers:

- Developments in research on biomarkers indicate that, at present, the majority of biomarkers of effect and susceptibility (e.g., enzyme induction) are currently limited in their use because they are nonspecific and can apply to a variety of environmental contaminants. More research should focus on developing biomarkers that are more sensitive and specific to particular chemical exposures.
- At present there is inadequate human evidence in Great Lakes populations to conclude that environmental contaminants adversely affect reproductive function at the levels currently measured in tissues of the general population. Animal studies provide evidence which suggests that most persistent chemical contaminants have the potential to adversely affect reproduction.
- There is limited epidemiologic evidence that consumption of Great Lakes fish contaminated with mixtures of PCBs, methylmercury, and other persistent contaminants can affect reproductive outcomes such as birthweight, length of baby, and head circumference.
- Both retrospective and prospective epidemiologic studies have shown that
environmental exposure to lead in utero or during childhood results in deficits in intelligence quotient (IQ) and in distractibility, inattention, and other developmental and neurobehavioral problems, even at levels considered normal in industrialized countries.

- Laboratory animal (monkey, rodent) data and limited human epidemiologic data on the effects of methylmercury and PCBs on neurologic development indicate that consumption of highly contaminated Great Lakes fish represents a hazard to the developing fetus.

- Low-dose exposures of animals (below, but not very much below those measured in humans) have been found to result in adverse effects on growth and sexual development and the development of genitalia.

- Limited data from epidemiologic studies suggest an association between human exposure to Great Lakes contaminants and clinical signs of immune dysfunction. Laboratory animal studies show that many of the persistent Great Lakes contaminants are immunotoxic but no-effect levels have not been established.

- There is limited epidemiologic evidence to indicate that some drinking-water sources with Great Lakes origin are associated with increases in the incidence of several types of cancer in humans. These drinking-water sources currently have elevated levels of alpha-heptachlorocyclohexane (α-HCH), nickel, and trihalomethanes. However, the epidemiologic evidence is not of sufficient strength to link the presence of these animal and human carcinogens with the elevated cancer incidences. It should also be noted that socioeconomic status and lifestyle factors are comparatively more significant contributors to increased cancer incidence.

- The total number of predicted fatalities over the lifetime of the current Great Lakes basin population of 36 million that could be theoretically attributable to a 50-year exposure to natural background radiation is of the order of $2.4 \times 10^5$. In comparison, the total number of predicted fatalities theoretically attributable to radioactive fallout from all nuclear weapons tests to date would be approximately 3400, while corresponding estimates due to 50-year exposure to current fuel cycle effluent from nuclear facilities based on environmental models and actual radio nuclide emission rates are of the order of 140. These are hypothetical values based on conservative exposure models and show that the impact from artificial sources of radiation are small compared to the effects of natural background radiation.

- In addition to the research findings discussed in these papers, the GLHEP has funded further research on the respiratory effects of airborne contaminants in the Great Lakes basin and on health effects associated with microbial contaminants.

### A New Era

Reductions in chemical contaminants such as dichlorodiphenyl dichloroethane (DDE) and PCBs have resulted in dramatic improvements in reproductive success and significant increases in the populations of cormorants, gulls, terns, herons, and other predatory birds in the Great Lakes basin. Even the bald eagle has returned to nest in the lower Lakes (4).

These successes must be tempered by new realities. We are entering a new era in which further reduction is more complex and problematic. For example, long-range atmospheric transport and deposition of several persistent chemicals is now a relatively greater source of input to the Great Lakes than are traditional point sources.

Long-range atmospheric transport is a global problem not resolvable by any one country acting alone. Local air pollution is also a growing problem for health and well-being. While the levels of many routinely measured airborne pollutants have decreased over the years, sulfate and ground-level ozone concentrations continue to rise in many large urban areas of the basin (3). Recently, a linear, non-threshold relationship has been established between increased ozone and sulfate levels and increased hospital admissions, especially of people predisposed to respiratory disease such as asthma (6). International progress to control these pollutants is urgently needed.

### Evolving Issues

The ways by which we measure health are changing. Traditional health outcomes such as cancer and birth defects, which are well recorded, are comparatively insensitive indicators of the effects of long-term, low-level exposure to environmental contaminants. Increased interest in and attention to the more subtle potential health effects of chronic low-level exposures to mixtures of chemicals are evident in current and future research directions. These include the study of effects associated with hormone alteration, stimulation or mimicry, genital development, endometriosis, sperm abnormalities, subclinical immune dysfunction, respiratory effects, neurobehavioral and child development, and psychosocial health. People’s perceptions of their health and the effects on social structures and functions are as significant as clinically demonstrated disease conditions. The findings presented in the series of topic papers that follow form the basis for further study of these evolving issues and serve as a valuable contribution to ongoing research on the human health impact of environmental contaminants in the Great Lakes basin.

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