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# Winds of Chance: The Effects of Air Pollution on the Great Lakes

International Air Quality Advisory Board

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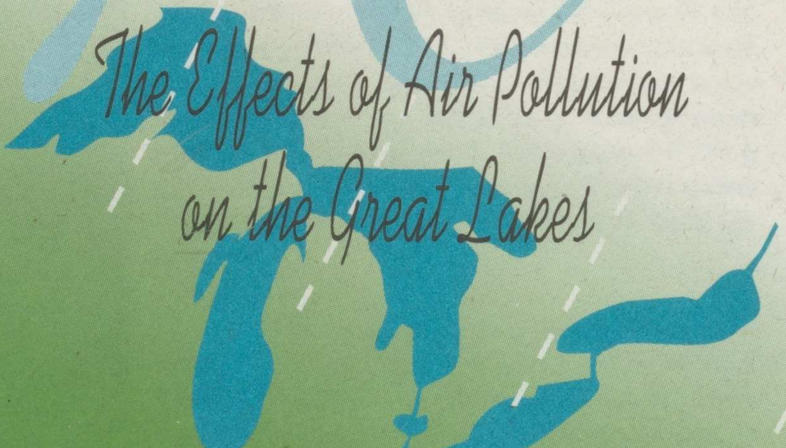
## The Effects of Air Pollution on the Great Lakes



International Air Quality Advisory Board

International Joint Commission
Canada and United States

The Parties, in cooperation with State and Provincial Governments, shall conduct research, surveillance and monitoring and implement pollution control measures for the purpose of reducing atmospheric deposition of toxic substances, particularly persistent toxic substances, to the Great Lakes Basin Ecosystem."

Annex 15
Canada - United States
Great Lakes Water Quality Agreement, 1987

*August 1992*

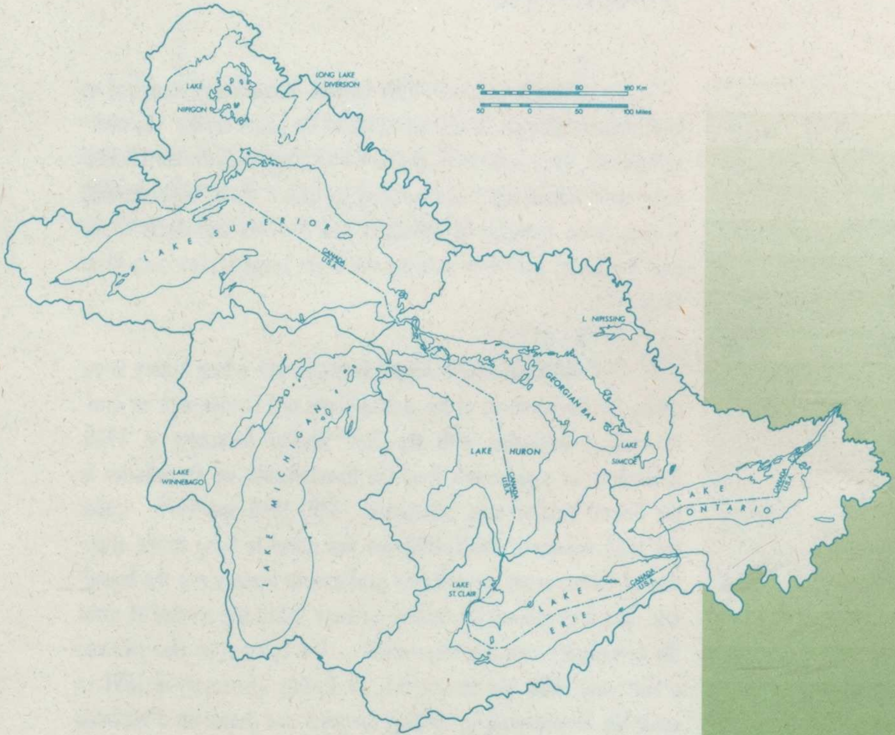
*Copies also available in French*

# Foreword

Airborne pollutants have become increasingly recognized as important contributors to contamination of the Great Lakes. The International Air Quality Advisory Board, an advisory body to the International Joint Commission, is attempting to gain a better understanding of long range transport of pollutants and how this contributes to the total burden of pollutants entering the Great Lakes-St. Lawrence River basin.

The International Joint Commission has a long history in assisting the Governments of the United States and Canada with air quality matters beginning with the Trail Smelter Reference in 1928. References, or assignments from the Governments, on air pollution in the Detroit-Windsor area followed in 1949, 1966 and 1975. Under the 1966 Reference, the Commission was asked to bring to the attention of Governments air pollution problems in areas along the boundary. The International Air Quality Advisory Board was created to assist the Commission with this responsibility. The Commission also received a Reference under the Canada-U.S. Air Quality Agreement of 1991 to assist the Governments by inviting comment and preparing a synthesis of views on the biennial reports of the governments' Air Quality Committee.

The growing awareness of the relationships between air and water pollution has increasingly drawn the Commission into the field of atmospheric studies. In its role of assessing and evaluating Governments' progress under the Great Lakes Water Quality Agreement, the Commission tracks progress in controlling atmospheric emissions of toxic substances that contribute to pollution of the Great Lakes. The International Air Quality Advisory Board and the advisory bodies established under the Great Lakes Water Quality Agreement - the Water Quality Board and Science Advisory Board - assist the Commission in this work.




*The Great Lakes Drainage Basin*

# Winds Of Chance

For many years scientists studying pollution in the Great Lakes have been perplexed by a number of questions:

- Some Great Lakes fish contain toxaphene, a pesticide used almost exclusively on cotton crops in the southern United States. How did it get to the Great Lakes, hundreds of miles away?
- DDT, the dangerous pesticide that has been virtually banned in the United States and Canada since 1972, is still turning up in samples of Great Lakes water. Is it possible the pesticide comes from hundreds and perhaps even thousands of miles away, from countries south of the Rio Grande — where DDT is still legally used?
- In tiny Siskiwit Lake, located on Isle Royale in the northwest part of Lake Superior, a variety of toxic chemicals have been found in the water, sediment and fish. How could the chemicals have gotten to this isolated spot?

Slowly, as research has continued, answers have emerged. Scientists have found that toxic substances are being carried hundreds of miles by winds and deposited in places far from their source. For the Great Lakes, this means that some of the toxics in the water, fish and soils are not necessarily from nearby sources.

It has become evident that even though pollution control programs around the lakes may be effective, controlling pollution from faraway sources is a different sort of challenge. DDT might be outlawed in one country, for example, but its use in other countries may cause pollution many miles away and still pose a serious threat to citizens who thought their governments had "solved" the problem.

Determining the exact source of airborne pollution is very difficult. Unlike a river's course, which is clearly established, air movements are less predictable. Weather conditions, wind speed and wind direction vary, changing where airborne pollutants end up.

Scientists on both sides of the Great Lakes — in the United States and Canada — are working together to get a better understanding of how long-range transport of air pollution works. Some of this research is carried out by the International Air Quality Advisory Board, an advisory body to the International Joint Commission.

# The "Airshed" Concept

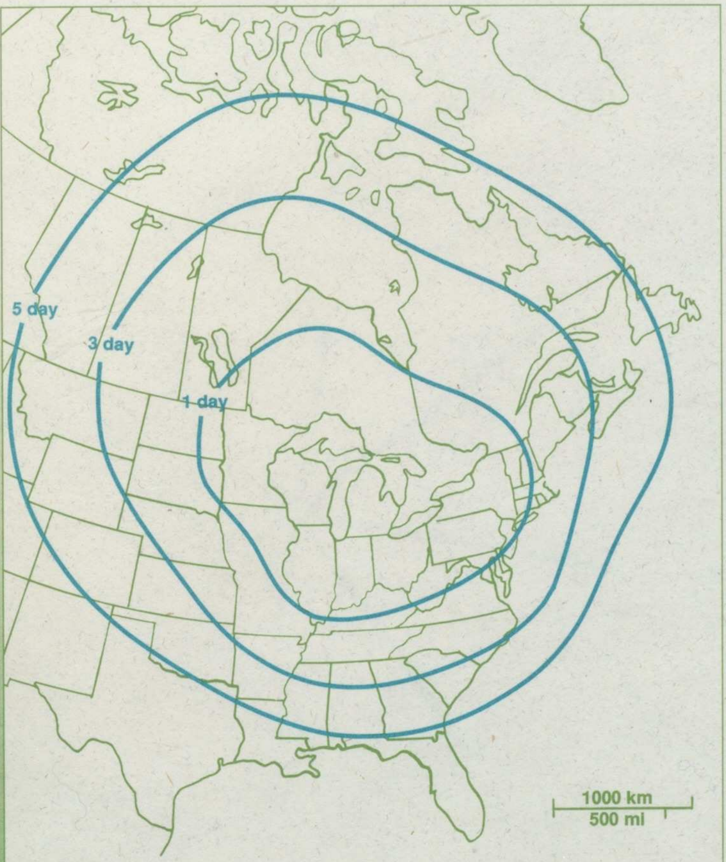
A major activity of the International Air Quality Advisory Board is charting air movement patterns and determining how airborne toxic substances end up where they do. The scientists working with the Board have developed the concept of an "atmospheric region of influence (AROI)" — or "airshed," to use a simpler term — to help them understand what happens.

The concept of an "airshed" is similar to that of a "watershed": both apply to the movements of fluids (air or water) over great distances. However, there are important differences.

- With an airshed, there are no fixed geographical boundaries. Instead, its area is defined in terms of a given travel time of the air and of the probability that the air arriving at a certain place has come from a specified area.
- Various sites within a relatively small area might have different airsheds.

The aspect of time is particularly important. That's because different pollutants stay in the air longer than others. Those that stay longer may eventually be dispersed over a much wider area than those that fall to the earth more quickly. For example, large particle pollutants such as dust, fly-ash and soot that have long been associated with urban and industrial areas, tend to settle quickly. They have atmospheric lifespans of only a few hours at most, and typically their impact is confined to areas near the source of the emissions. Other pollutants, however, have lifespans of many years. Some of the more familiar are chlorofluorocarbons, which remain in the atmosphere and stratosphere for long periods, damaging the earth's protective ozone shield. These pollutants are slowly dispersed over vast distances, making the atmosphere of the entire planet their "airshed."

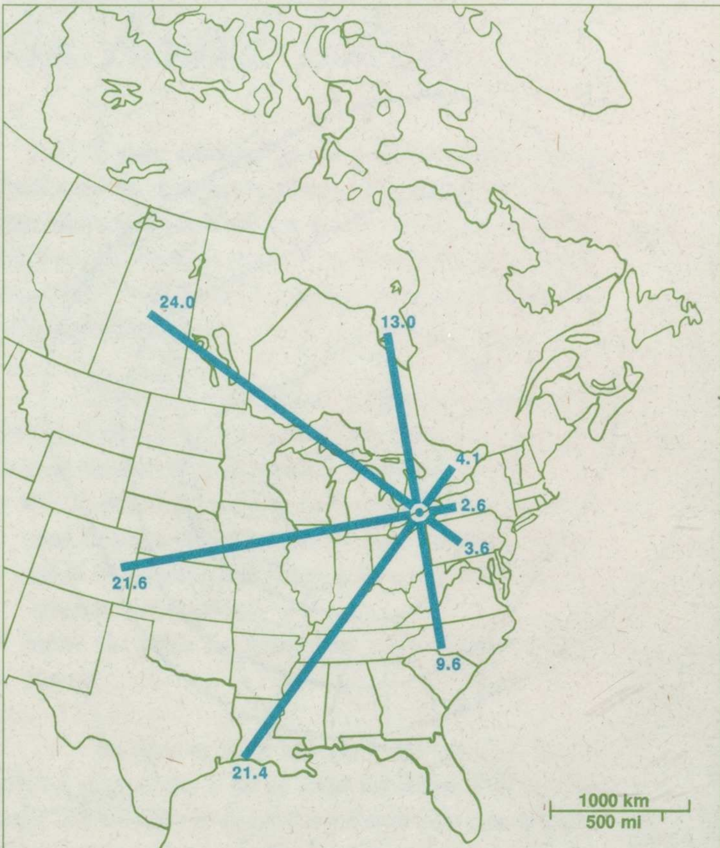
The atmospheric lifespans of toxic chemicals affecting the Great Lakes are usually in the median range, from several days to a few weeks. But even with what might seem a short lifespan, the pollutants can be transported hundreds of miles in the atmosphere to the Great Lakes as well as other areas. Their emission source might be far from the lakes. Tracking the pollutants and controlling their emissions is difficult.




*Lines indicate the median location of airborne contaminants originating 1,3 and 5 days before their arrival in the Great Lakes hydrological basin.*
*Source: International Air Quality Advisory Board, 1988.*

## Atmospheric Regions of Influence for the Great Lakes Basin

The atmospheric region of influence which affects the Great Lakes basin is large, encompassing nearly all of Canada and the United States. This means that air pollution created almost anywhere in either country has the potential of ending up in the Great Lakes.




*The "trajectory wind-rose" indicating the frequency with which air masses arrive at Long Point from each directional sector.*
*Source: International Air Quality Advisory Board, 1988.*

## Wind Direction Patterns

While winds primarily arrive in the Great Lakes basin from the west, they can come from almost anywhere, even from the east. This is very important as strategies to reduce and eliminate the atmospheric deposition of pollutants to the Great Lakes basin are developed and put into place.

# Tracking Airborne Pollutants

Scientists typically use what is called a "mass-balance model" to track the movement of pollutants through the environment. The model calculates the amount of a pollutant entering a designated area, the amount retained or transformed and the amount that leaves the area.

For airborne pollution the model is complicated. Pollutants are emitted in particle or vapor form. Carried by the wind, they reach a surface or are washed out of the atmosphere by rain or snow. What happens to the pollutants when they reach a surface is influenced by the individual characteristics of each chemical or compound in the pollutants, as well as by the characteristics of the surface and the prevailing weather conditions. The texture of a surface, for example, might cause one reaction to occur; or, in other cases, the pollutants may be changed into quite different substances.

From the perspective of the Great Lakes, it is seldom possible or practical to measure directly the amount of a pollutant deposited from the atmosphere (the "loading") onto the surface of a body of water. The calculation of "load" must be made indirectly, combining field and laboratory observations with theoretical modeling, and "loadings" for each chemical or compound must be calculated separately.

The upshot is that an enormous amount of data is required to make even moderately reliable estimates about the "loading" of just one chemical to one lake.

For the past five years, climatologists at Environment Canada's Atmospheric Environment Service have been developing a method for determining the source of airborne pollutants deposited at any designated point. The method involves using map overlays that show industrial and urban pollution sources, the median distance air masses travel during a given time to the designated point, and typical wind directions at the point. When this information is correlated with the average atmospheric lifespan of a particular chemical or compound, it is possible to estimate the relative impact of emissions from one source area on a selected "receiving" point.

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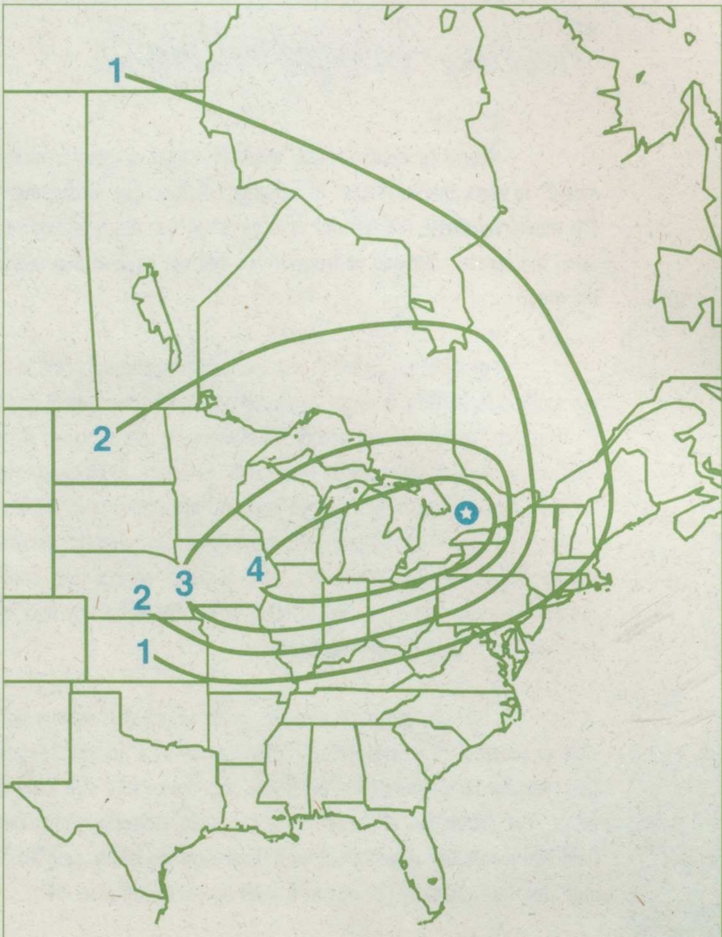



*Isopleths of annual concentration contribution from pollution sources located along each isopleth for an example receptor located in southern Ontario.*
*Source: International Air Quality Advisory Board, 1988.*

## Annual Concentrations from Pollution Sources

Using mathematical models to simulate the fate and transport of atmospheric pollutants, sources located at great distances from the Great Lakes have been found to have the potential to impact air and water quality in the basin.

Fairly complete information on atmospheric behaviour and longevity is available for some chemicals — sulfur dioxide, for example — but for many other toxic chemicals there is little information. Among the many toxic chemicals or compounds causing concern in the Great Lakes region, sufficient data exist for only four to estimate their effect on the lakes. These are: benzo(a)pyrene, DDT, lead and PCBs.

Despite this lack of information, the existing data show the magnitude of the airborne pollution problem. In the upper Great Lakes, where fewer toxics come from direct discharges or from rivers flowing into the lakes, atmospheric transport of toxic pollutants has a very big effect.

- In Lake Superior up to 90 percent of the new PCBs added to the lake come from the air.
- Most DDT enters Lake Superior the same way, and for benzo(a)pyrene and lead, atmospheric transport has an important effect even in the lower lakes.

## How Serious Is the Problem?

The threat to an individual's health from pollutants traveling hundreds of miles may seem remote. How can a particle small enough to be airborne for so long pose any danger?

The answer lies in the "behaviour" of the particles as they travel through the air. Particles "look" for company, often picking up other particles and effectively accumulating more and more pollutants the longer they stay airborne. (As an example of this phenomenon, consider what happens when baking soda is placed in a refrigerator to pick up odors: the particles of baking soda in the box do a good job of absorbing odors and other particles released by stored food, effectively taking smells "away" — although they still remain in some form.) Small particles have a particularly high surface-area-to-weight ratio, meaning they have greater potential to pick up other particles.

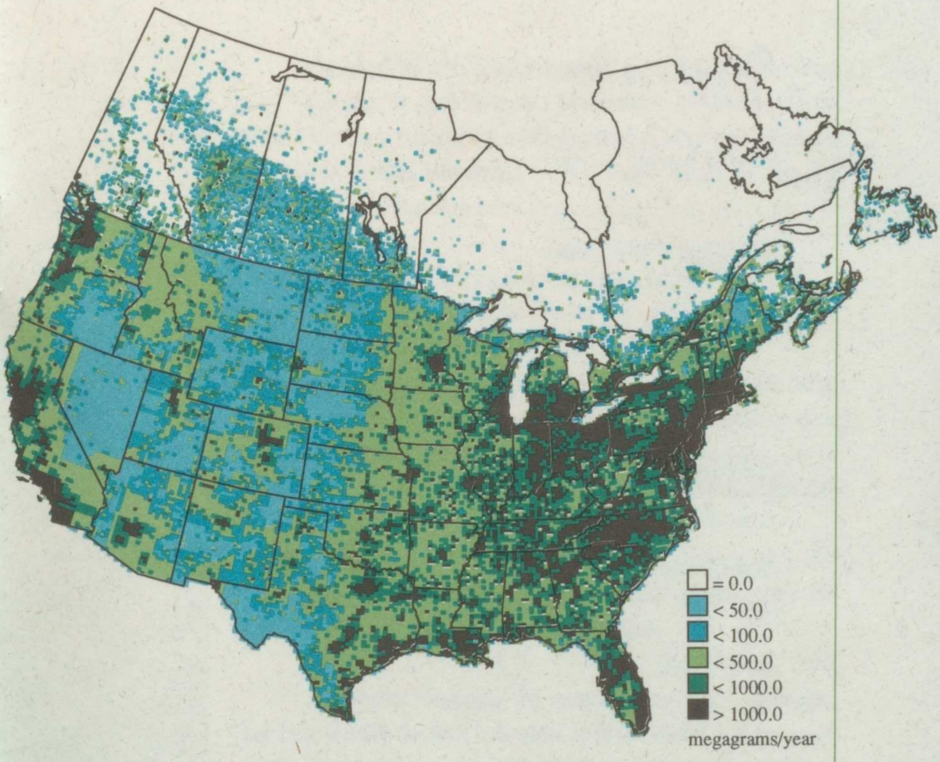
Thus, airborne particles, when finally deposited, bring a complex combination of pollutants to the surface they land on. They may be a major source of many contaminants.

- In 1990, in its Fifth Biennial Report on Great Lakes Water Quality, the International Joint Commission said "there is a threat to the health of our children emanating from our exposure to persistent toxic substances, even at very low ambient [general] levels.".
- A February 1992 report of the International Joint Commission on air quality in the Detroit-Windsor/Port Huron-Sarnia Region concluded that "Sufficient information exists on airborne toxic chemicals in the region to conclude that there is a significant public health issue which requires the immediate implementation of additional air emission abatement and preventive measures".

The Great Lakes can be thought of as giant pollution collectors. Pollutants from city sewer systems, industries and farms are carried into the lakes by groundwater, rivers, direct discharges and the air. Much of that pollution — such as phosphorus, which can harm fish by causing algae to bloom and lake oxygen to be depleted — can be controlled, largely because the sources are identifiable. But toxic pollutants are more formidable.

- Many toxics don't break down easily. They are only slightly soluble in water, and they can accumulate in sediments and take many years to dissolve.
- If the toxics are taken in by animals, however, they are soluble in lipid (fat) cells, and they tend to accumulate as they move up the food chain. Often, concentrations in the body tissue of fish and wildlife can be 10,000 to 100,000 times greater than concentrations in the surrounding water.
- Since 1950, at least 16 species of wildlife in the Great Lakes region have been affected, at one time or another, by reproductive problems or declining populations. In every case, high concentrations of toxics were found in the animals' tissue.

The message is that we should be very concerned about toxics and should continue working towards a more complete understanding of how they enter and move around in our environment. Further research into the concept of airsheds will broaden our knowledge of how toxics put into the air hundreds of miles away have an important effect on the Great Lakes region.




*Plot of volatile organic compound (VOC) emissions for 1985 showing detail for lower emission density ranges. Source: Acid Deposition: State of Science and Technology, Report 1, National Acid Precipitation Assessment Program.*

## Density of Volatile Organic Compound Emissions

VOCs are an important class of pollutants to control. They combine with oxides of nitrogen to form ground level ozone, an important transboundary air pollutant. Further, some VOCs are of concern directly because they are toxic air pollutants.

## *Atmospheric Deposition of Pollutants in the Great Lakes**

(percentage of total inputs)

| | PCBs | Benzo (a) pyrene |
|---|---|---|
| *Lake Superior* | 90 | 96 |
| *Lake Huron* | 78 | 80 |
| *Lake Michigan* | 58 | 86 |
| *Lake Erie* | 13 | 79 |
| *Lake Ontario* | 7 | 72 |

*Summary Report of the Workshop on Great Lakes Atmospheric Deposition, International Joint Commission, Windsor, Ontario, October 1987.

# What's Ahead?

In keeping with their commitment in Annex 15 of the Great Lakes Water Quality Agreement, the Governments of Canada and the United States are establishing an "Integrated Atmospheric Deposition Network" to develop information on how certain toxics get into the Great Lakes and where they come from.

The network will be in full operation by 1995:

- One "master" research and monitoring site on each lake has been set up jointly by Canada and the United States.
- Data gathered from experiments will be used in planning and building an expanded network of up to 20 "satellite" monitoring sites. Additional stations might be necessary for special projects, such as proposed mass balance studies for Lake Michigan and a demonstration program for Lake Superior.
- Together, the "master" and "satellite" sites will create an integrated monitoring system that will provide estimates, updated every two years, of airborne pollutants entering the lakes.

Scientists designing the network face many challenges. They must identify the toxic substances to be monitored and design an appropiate monitoring network to allow calculations to be made of where the pollutants come from. In addition, they must keep a watch for new environmental problems by monitoring other toxic compounds.

The development of a comprehensive and consistent monitoring network is critical to achieving the goals of the Great Lakes Water Quality Agreement of 1978. The Agreement's overall objective is prohibiting the discharge into the lakes of toxic amounts of any substance and "virtually eliminating" the discharge of all persistent toxic substances. Meeting this objective requires effective surveillance of the transport of pollutants by air as well as by water.

"We often hear that many Lake Superior pollutants, and about 90 percent of some pollutants, enter via air transport . . . We would like to know about air deposition to Lake Superior so any future recommendation will be based on good science."

*Gordon Durnil, 1991*
*Chairman, United States Section*
*International Joint Commission*

"Atmospheric emissions of varied toxic substances have been shown to have a definite impact on human health. We, as citizens, must deal with this crucial problem."

*Claude Lanthier, 1992*
*Chairman, Canadian Section*
*International Joint Commission*