

# ATMOSPHERIC DEPOSITION OF TOXICS TO THE GREAT LAKES:

## INTEGRATING SCIENCE AND POLICY



A Report By  
The Delta Institute



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# 1



## INTRODUCTION

### I Project Origins

Toxic contamination from anthropogenic (human) sources has been the subject of scientific research in the Great Lakes region for three decades. Over the years, environmental regulations have been successful in reducing direct discharges of contaminants into the Lakes, particularly from point sources such as factories and wastewater treatment plants. Indirect inputs of toxic contaminants, including atmospheric deposition and agricultural and urban runoff, have proven more difficult to control. As reductions continue to be made in both point and nonpoint sources, atmospheric inputs take on greater significance and account for an increasing portion of the total inputs to the Lakes.

The process of how contaminants travel in the atmosphere and the fate of those contaminants has become a subject of significant scientific research. As more research is conducted and more is understood about the relative importance of atmospheric deposition compared to other pathways of contamination, the effectiveness of federal and state environmental policies is called into question. Sources of contamination deposited via the atmosphere can be very difficult to identify. Contaminants react in the environment, and cycle between air, water and land in different ways. Further, some contaminants travel great distances in the atmosphere, meaning that a source of contamination may be hundreds or thousands of miles from the affected environment. No single governmental jurisdiction and no single set of government regulations can solve this problem.

Much of the research on atmospheric deposition derives from mandates in the Great Lakes Water Quality Agreement, an agreement between the United States and Canada that calls for the virtual elimination of contaminants of concern to the Great Lakes. In 1987, Annex 15 was added to the Great Lakes Water Quality Agreement, requiring the U.S. and Canadian governments to “conduct research, surveillance and monitoring and implement pollution control measures for the purpose of reducing atmospheric deposition of toxics substances, particularly persistent bioaccumulative toxic substances (PBTs), to the Great Lakes basin” (IJC, 1994). Annex 15 triggered significant research on how contaminants move in the atmosphere:

- A network of monitoring stations has been installed throughout the Great Lakes, called the Integrated Air Deposition Network, to monitor for the presence of toxics in the air.
- An aggressive mass balance study has been conducted on Lake Michigan to understand the inputs and outputs of contaminants including atmospheric deposition.
- Process research is taking place to understand how contaminants are deposited into the Lakes and how they cycle between air and water within the Great Lakes system.
- Scientific models have been developed to help predict the source and fate of different contaminants in the atmosphere, and to help evaluate the impact of policy decisions.

This research shows clearly that, even as total inputs decline, atmospheric deposition continues to account for a significant percentage of toxic contamination to the Great Lakes:

*Scientists report, for example, that atmospheric deposition is the major contributor of mercury to the Great Lakes. For Lake Michigan, approximately 80 percent of the mercury comes from atmospheric deposition. Localized sources, such as Chicago, contribute approximately 30 percent of the total regional atmospheric loading to the lake (Mason and Sullivan, 1997).*

*High levels of polychlorinated biphenyls (PCBs) are found in the atmosphere, particularly in urban/industrial centers. There is a seasonal plume of PCBs in the Chicago area that increases atmospheric deposition of PCBs for many miles out into Lake Michigan in the warmer seasons (Franz et al., 1998). The Great Lakes are also a source of PCB contamination into the atmosphere due to PCBs in the water and sediments that volatilize back into the atmosphere (Hornbuckle et al., 1995; Offenberg and Baker, 1997).*

*A significant portion of the dioxin and furans in the Great Lakes comes from the atmosphere. Half of the total deposition of dioxin comes from sources 300 to 1,500 miles from the center of the Lakes (Commoner et al., 1996).*

*Although most of the pesticides of concern in the Great Lakes are banned or restricted in the U.S., many are still in use in other countries, such as DDT, chlordane, lindane, and toxaphene. Atrazine, a pesticide in use in the Great Lakes region, is showing much greater persistence in the cold lake waters than in tributary streams, where the highest loadings occur (Rygwelski et al., 1999). It is currently a contaminant of concern for Lake Superior, with 95 percent coming from atmospheric deposition, the majority of which originates hundreds, even thousands, of miles away (Rygwelski et al., 1999; Schottler and Eisenreich, 1997).*

The science suggests that in order to meet Great Lakes water quality goals more aggressive efforts will have to be made to address atmospheric sources. This will be particularly challenging given the phenomena of long-range transport and the trans-jurisdictional aspect of atmospheric deposition. The Great Lakes community working alone will not be able to address this problem.

In 1999, the Delta Institute launched a project called *Atmospheric Deposition of Toxics: Integrating Science and Policy*. The intent of the project was to take stock of the research on atmospheric deposition of toxics in the Great Lakes and the implications of the research. Leading scientists were brought together with government policy experts, environmentalists, and industry representatives to discuss the research, the ability to respond with existing policy tools, and the overall issues that need to be considered in order to effectively address the difficult issue of atmospheric deposition of toxics.

Through the project's two workshops, it became apparent that current research confirms the pervasive problem of atmospheric deposition but that there is little practical experience in using the scientific tools to craft solid policy strategies targeted to source areas and source sectors. The workshops made it clear that information on atmospheric deposition of toxics largely rests within the realm of universities and government research organizations and that the public and policy practitioners have less access to and understanding of the issue. The phenomenon of long-range transport of air toxics also highlights the necessity for simultaneous local, regional, and national response strategies, and the need to increase involvement in international discussions on the use of toxics.

The Delta Institute workshops were not a consensus process and the information presented here does not necessarily represent the positions or conclusions of individual participants. Instead it summarizes the information that was presented at the workshops: outlining recent scientific research, U.S. federal and state programs and applicable international programs that address atmospheric deposition. Finally, the report presents recommendations drawn from the workshop discussions that together offer suggestions to further integrate science and policy, gain practical experience in using science tools, and increase international attention to the issue.

## II Emergence of the Air Deposition Issue

The issue of atmospheric deposition of toxic contaminants emerged slowly for environmental management agencies and the public, and still is not generally perceived as requiring urgent action. Following is a summary of significant stages in the evolution of attention to this environmental problem.

- 1962 - Publication of Rachel Carson's book *Silent Spring* informs public at large of dangers of indiscriminate use of DDT (Carson, 1969).
- 1968 - Regulatory hearing in Wisconsin calls international attention to link between DDT and disappearance of eagles, leading to first bans on use of DDT in Great Lake states (Dunlap, 1982).
- 1969 - Clean Air Act passed, with focus on reduction of criteria air quality pollutants, not including toxic contaminants (P.L. 91-604).
- 1971 - Discovery of PCBs in fish tissues during monitoring for DDT in northern Lake Michigan dismissed by the Environmental Protection Agency (EPA) as "just a Great Lakes problem" (Murphy and Rzesutko, 1977).
- 1972 - Great Lakes Water Quality Agreement (GLWQA) between Canada and the U.S. focuses on reduction of phosphorus loadings, with little mention of toxic contaminants. The International Joint Commission (IJC) is given oversight responsibilities for reporting to the governments on progress toward achievement of agreement objectives (IJC, 1972).  
  
Research reveals significant loadings of phosphorus by air deposition into Lake Michigan (Eisenreich et al., 1977).  
  
Clean Water Act passed, with emphasis on reduction of direct or "end of pipe" discharges (P.L. 82-500).  
  
National ban adopted on most uses of DDT (Dunlap, 1982).
- 1975 - Discovery of PCBs in lake trout in an interior lake on remote Isle Royale in northern Lake Superior turns scientific attention to air deposition as a source. Research reveals damage to wildlife health by presence of toxic contaminants in the food chain. National conference on PCBs in Chicago confirms potential threats to human health (Swain, 1978).
- 1976 - Toxic Substances Control Act passed, focusing on PCBs (P.L. 94-469).
- 1977 - Revised clean Air Act includes new authority for EPA to control toxic contaminant emissions, but results in little action (P.L. 91-604).  
  
Monsanto stops production of PCBs (Botts and Muldoon, 1977).
- 1978 - Revisited GLWQA adopted with call for "an ecosystem approach to management" and "virtual elimination" of toxic contamination (UN/ECE, 1979).
- 1979 - Convention on Long-Range Transboundary Air Pollution, developed by United Nations Economic Commission for Europe and signed by 34 countries, reflects international focus on acid rain rather than air transport of toxic contaminants (UN/ECE, 1979).  
  
PCB manufacture and most uses banned in final rule by U.S. EPA (U.S. EPA, 1999g).
- 1980 - Long-range transport of contaminants is confirmed by discovery of toxaphene, a pesticide used mainly in deep South and far West, in fish on Isle Royale (Hoff, 1996).
- 1984 - First national news coverage of atmospheric deposition occurs when Associated Press picks up story on "Toxic Fallout" from environmental advocacy newsletter in Chicago (Botts, 1994).
- 1985 - Report by Royal Society of Canada and National Research Council on the GLWQA confirm human health dangers of toxic contaminants in the Great Lakes region (National Research Council, 1985).
- 1986 - Ongoing Great Lakes research continues to reveal that PCBs can cycle between water, the atmosphere, and lake sediments (Mackay, 1982).

- 1987 - New protocol in GLWQA allows the governments to address issues more independently from the IJC (IJC, 1994).
- Ongoing research confirms deposition in the Great Lakes of DDT transported in the atmosphere from Mexico and Central America (Sweet, 1992).
- 1989 - *Great Lakes, Great Legacy?* presented to biennial meeting of IJC; documents threats to wildlife and humans and helps fuel increased activism for toxics control (Colburn et al., 1990). EPA Administrator William Reilly announces that EPA will use Great Lakes experience to develop an integrated approach to policy, based on ecological integrity rather than media-by-media pollution control (Reilly, 1990).
- International Air Deposition Network (IADN) is established to monitor loadings of toxic contaminants, with only one station in each Great Lake due to funding limitations (U.S. EPA, 1998b).
- 1990 - Clean Air Act is revised, establishing Great Waters Program and expanding EPA authority to control emissions of toxic contaminants (P.L. 101-549).
- Great Lakes Critical Programs Act sets up Remedial Action Plan and Lakewide Management Plan Processes (P.L. 101-380).
- 1991 - Lake Michigan Urban Air Toxics Study (LMUATS) takes advantage of concurrent study's collection of meteorological data to do intensive monitoring of air toxics (Keeler, 1994).
- 1993 - The Great Lakes National Program Office of EPA plans Lake Michigan Mass Balance Study to quantify loadings of four contaminants from all sources, including air deposition (U.S. EPA, 1997c).
- 1994 - North American Free Trade Agreement provides for creation of the Commission for Environmental Cooperation (CEC) for North America (CEC, 1997).
- 1995 - CEC calls for Sound Management of Chemicals initiative in North America, to include North American Regional Action Plans for specific substances (CEC, 1998).
- 1996 - United Nations Environmental Program initiates discussion of a binding global agreement on Persistent Organic Pollutants (POPs) (UNEP, 1999).
- 1997 - Binational Toxics Strategy is announced by U.S. EPA and Environment Canada to achieve the virtual elimination goal of the GLWQA (BTS, 1997).
- IJC International Air Quality Advisory Board considers challenges and complexities of dealing with air deposition and transport of toxic contaminants into the Great Lakes (IJC, 1998).
- 1998 - Preliminary draft is developed for POPs (UNEP, 1999).
- CEC teams up with the World Health Organization to help Mexico develop alternatives means of control of malaria in order to reduce or stop use of DDT (CEC, 1998).
- EPA launches the Persistent Bioaccumulative Toxic initiative, to seek "multimedia control" of toxic contaminants (U.S. EPA, 1998f).
- 1999 - National Research Council reports on growing scientific evidence that certain organic chemicals are "hormonally active" and may be affecting endocrine systems of wildlife and humans (National Research Council, 1999).
- 2000 - POPs agreement is said to be nearing completion.

# 2



## CURRENT SCIENTIFIC UNDERSTANDING

An understanding of atmospheric deposition requires knowledge in a variety of fields including atmospheric chemistry, meteorology, environmental engineering, and chemical engineering. Since the field is so complex, scientists working to understand atmospheric deposition often concentrate on a single process or part of a process. Field experiments investigating this topic are often difficult to interpret due to uncontrolled conditions, such as wind, humidity, temperature, water movement, and chemical concentrations. Lab scale experiments are used to provide insights into the details of a process, however, extrapolating those results to the real world can be difficult. In spite of these obstacles, significant advances in the understanding of the deposition process have been made in recent years.

This chapter begins with an introduction to atmospheric deposition processes, long-range transport and chemical cycling. An overview of the recent studies and monitoring/modeling efforts of the Great Lakes region provides insight into our current understanding of atmospheric deposition. More detailed information and research on selected chemicals of concern highlights atmospheric deposition as a significant pathway of pollution in the Great Lakes.

Atmospheric deposition refers to the removal of pollutants from the air to soil, water and other surfaces. Deposition to waterbodies can occur directly to the surface or indirectly, when material deposited to the land surface enters a waterbody through runoff. The three major processes in atmospheric deposition are wet deposition, dry deposition, and air-water exchange.

### **WET DEPOSITION**

Wet deposition refers to the incorporation of both gases and particles into all types of precipitation: rain, fog or snow. Pollutants may be removed from air by wet deposition through three main mechanisms:

1. Small particles can serve as cloud condensation nuclei and become entrapped in raindrops;
2. Particles can be incorporated into falling raindrops by a variety of mechanisms depending on their size, referred to as particle scavenging;
3. Gaseous pollutants can be dissolved into cloud droplets and falling rain or snow.

Trace metals and semi-volatile organic chemicals (chemicals that can exist either as a gas or associated with particles) can become associated with rain either by being dissolved in the raindrop or by being incorporated as particles. From an ecological perspective, the dissolved form is of greatest interest because it may be more readily available for bioconcentration in tissues.

The rate of removal by wet deposition depends on properties of the pollutants - solubility, vapor pressure, and the size of the particles - as well as on properties of the rain - the size of the raindrops and intensity of the rainfall. Although it is the easiest of the three depositional processes to measure, many scientific uncertainties about the wet deposition process remain, such as the process of incorporation of particles into precipitation droplets and the role of particle size.

### **DRY PARTICLE DEPOSITION**

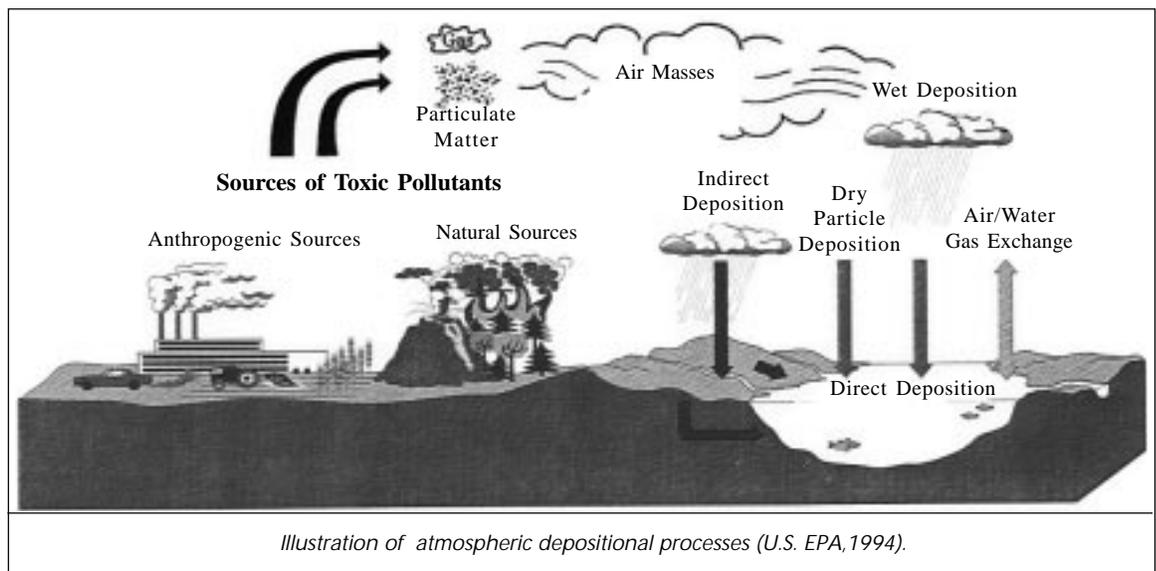
Dry particle deposition is broadly defined as the transport of particles and the contaminants associated with them onto surfaces. In general, the amount of contaminants deposited depends on concentrations in the air mass. The relationship is complex, however, depending on such physical factors as wind speed, the area of the receiving surface and whether that surface is water or land, and the properties of the contaminant, such as reactivity and the size of the particle with which it is associated.

Although progress has been made in recent years in understanding dry deposition, there are no universally accepted methods to directly measure or calculate dry deposition. Commonly, dry deposition to waterbodies is estimated using measured airborne particle concentrations, and a modeled or estimated dry deposition velocity.

## AIR-WATER EXCHANGE

Air-water exchange refers to the transfer of chemicals between the gas phase in the air and the dissolved phase in the water (across the air-water interface). Net volatilization occurs when a chemical's activity is higher in the water than the air. Net absorption of gases occurs when a chemical's activity in the air exceeds the activity in the water. Both volatilization and gas absorption occur simultaneously and the net result is determined by factors that include wind speed, wave intensity, temperature, water chemistry, and the physical properties of the chemical compound.

Recent studies suggest that the air-water exchange of semi-volatile organic chemicals (SVOCs) is important for large aquatic systems such as the Great Lakes, the Mediterranean Sea, and the world's oceans. The large surface areas of these bodies make them vulnerable to greater absorption from the atmosphere and also allow them to easily volatilize back into the air (U.S. EPA, 1998h).



## CHEMICAL CYCLING AND LONG-RANGE TRANSPORT

The cycling of chemicals between the air, water, and soil is especially important for SVOCs, such as PCBs, and for certain trace metals, such as mercury. In the atmosphere these contaminants can co-exist in both the gas and particle phases and may cycle between the atmosphere and the earth's surface many times in the course of being transported long distances. This phenomenon of repeated cycling between deposition and reemission is called the "grasshopper effect."

Long-range transport, with repeated deposition to land or water, and re-volatilization to the atmosphere has been shown to occur in response to seasonal temperature changes and depends in part on the volatility of the compound, its persistence, molecular weight, and concentration. Warmer conditions generally favor net movement into the atmosphere and deposition occurs more readily in areas of colder temperatures.

The extent to which pollutants reach a Great Lake from outside the watershed is difficult to predict and depends on many factors including the physical and chemical properties of the pollutants and meteorological conditions. The significance of long-range transport of toxic contaminants can be best illustrated by the presence of persistent PCBs in the Arctic snowpack and food chain, hundreds or thousands of miles from any possible source.

This section provides an overview of recent and ongoing studies performed around the Great Lakes. These studies are intended to assess the significance of atmospheric deposition to the Great Lakes and to monitor for particular chemicals of concern. Some of the following studies were required through treaties or legislative acts. These studies are responsible for most of our knowledge about deposition to the region. A few key findings are highlighted in each overview. More results are included in with the overview of each chemical, in section III of this chapter.

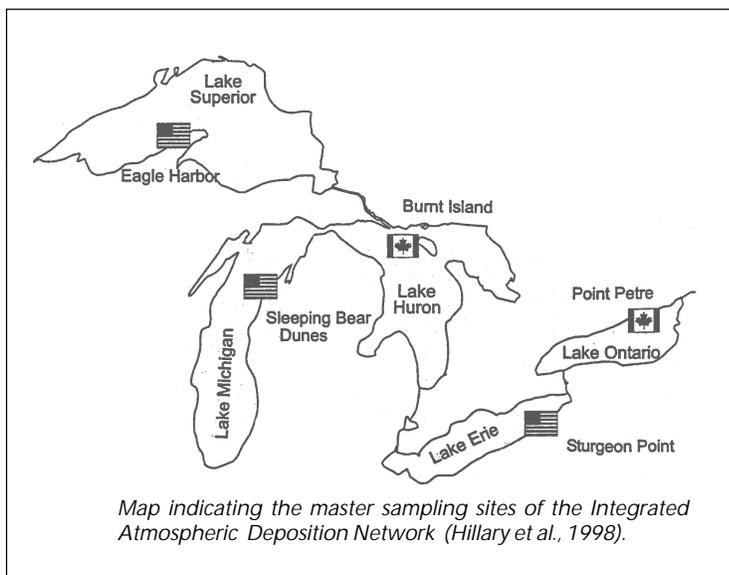
### INTEGRATED ATMOSPHERIC DEPOSITION NETWORK (IADN)

IADN is a joint U.S. and Canadian program, required under Annex 15 of the Great Lakes Water Quality Agreement. Launched in 1990, it is designed to assess the relative importance of atmospheric deposition to the Great Lakes and to provide information on pollutant sources. Under IADN, trends in pollutant concentrations in air and precipitation are assessed, and loading estimates to the Great Lakes are made every two years.

One master monitoring station on each lake measures air, rain and particles for a suite of chemicals. Each lake also has satellite stations, some of which measure only a subset of IADN pollutants. IADN monitors for: PCBs; polycyclic aromatic hydrocarbons (PAHs); pesticides including lindane, dieldrin, endosulfan, and DDT; and trace metals including lead, arsenic and cadmium.

Results from IADN demonstrate the importance of the atmosphere both as a source (via precipitation, gas absorption and dry deposition) and as a sink (via volatilization from water and terrestrial sources) for contaminants. In addition, IADN results have demonstrated for the first time that air concentrations of PCBs and other persistent organochlorines are declining significantly in the Great Lakes region. Back trajectory modeling (coupling air mass movements with pollutant concentrations) using IADN data has shown the importance of sources within the basin for metals and PAHs and more distant sources for toxaphene and DDT (U.S. EPA, 1998b).

IADN has been instrumental in documenting the importance of atmospheric deposition in the Great Lakes region. The long record of high quality measurements provides the data necessary to determine how concentrations and lake loading are changing over time, to begin to locate sources of pollutants, and to calibrate models in order to evaluate the effect of control strategies on concentrations and loadings.



## **LAKE MICHIGAN URBAN AIR TOXICS STUDY (LMUATS)**

During the summer of 1991, an air toxics monitoring program was carried out in the lower Lake Michigan area. LMUATS took advantage of an intensive monitoring of meteorological conditions as part of the Lake Michigan Ozone Study, a collective project of the Lake Michigan states. This meteorological data allowed the study to examine dispersion of the contaminants studied from the urban center. LMUATS was a collaborative effort between the U.S. EPA and the University of Michigan.

For a full month, 12-hour atmospheric samples were collected at three land-based sites, and on selected days by airplane and from an offshore research vessel. Over 1200 samples measured levels of PCBs, PAHs, pesticides, and trace metals. The overall goals were: to evaluate sampling methods; to quantify local concentrations in the atmosphere; to compare levels over land and water; to differentiate contaminant levels in the urban plume from regional background levels; to identify sources of the target pollutants; and to estimate the rate of net deposition from the atmosphere into the Lake (Keeler, 1994).

The concentrations of vapor phase mercury, PAHs, PCBs were 3 to 125 times higher in Chicago than over the lake or downwind at the South Haven, Michigan site suggesting that local sources are important for these chemicals. The highest concentrations of pesticides were found at the background site in Kankakee, Illinois, probably because of current agricultural uses, but DDT and its derivatives were found primarily at Michigan sites in patterns suggesting that their sources were past rather than current uses. Analysis showed the influence of the steel industry on the levels of trace metals, especially at the Chicago site (Keeler, 1994).

## **ATMOSPHERIC EXCHANGE OVER LAKE AND OCEANS STUDY (AEOLOS)**

The AEOLOS project in 1994 and 1995 was designed to study atmospheric deposition to the Great Waters as defined in Section 112 of the 1990 Clean Air Act (the Great Waters include the Great Lakes as well as Chesapeake Bay and other important coastal estuaries). The work involved scientists from the Universities of Minnesota, Michigan, Maryland, Delaware, and the Illinois Institute of Technology.

The project had three objectives:

1. To determine the dry depositional fluxes of critical urban contaminants to southern Lake Michigan near Chicago and to the northern Chesapeake Bay near Baltimore (the amount of these contaminants entering or leaving a given area over a given time);
2. To measure the contributions from urban sources to concentrations in the atmosphere and eventually to the nearby waterbody through atmospheric deposition; and
3. To measure the air-water exchange of contaminants.

The AEOLOS project provided more detailed information about atmospheric deposition in the southern basin of Lake Michigan than the IADN measurements. To test the hypothesis that emissions of hazardous air pollutants from urban sources increase atmospheric deposition into adjacent waterbodies, air and water concentrations and wet and dry deposition were measured in the urban/industrial complexes of Greater Chicago and Baltimore, and over

southern Lake Michigan and northern Chesapeake Bay. This information was then used to calculate deposition rates.

AEOLOS offered a great deal of insight regarding the significance of urban areas as important sources for atmospheric deposition and the importance of both wet and dry deposition as key processes in urban contaminant loadings. In general, atmospheric concentrations were higher and more deposition occurred in both downtown Baltimore and downtown Chicago than away from these areas. When the wind was blowing away from the downtown sites, concentrations and deposition increased at the downwind sampling sites. The rates of dry deposition measured near Lake Michigan were greater than those traditionally estimated by mathematical modeling. Heavy duty diesel vehicles, light duty vehicles that use unleaded gasoline, and soil dust were identified as the major sources of coarse particles in the air and the dry particles deposited on land in Chicago. Other sources included lime kilns, coke ovens, aluminum foundries, furnaces, coal-fired power plants, paint spray booths, and municipal incineration (Caffrey et al., 1996; Caffrey et al., 1998; Franz et al., 1998; Paode et al., 1998; Zufal et al., 1998).

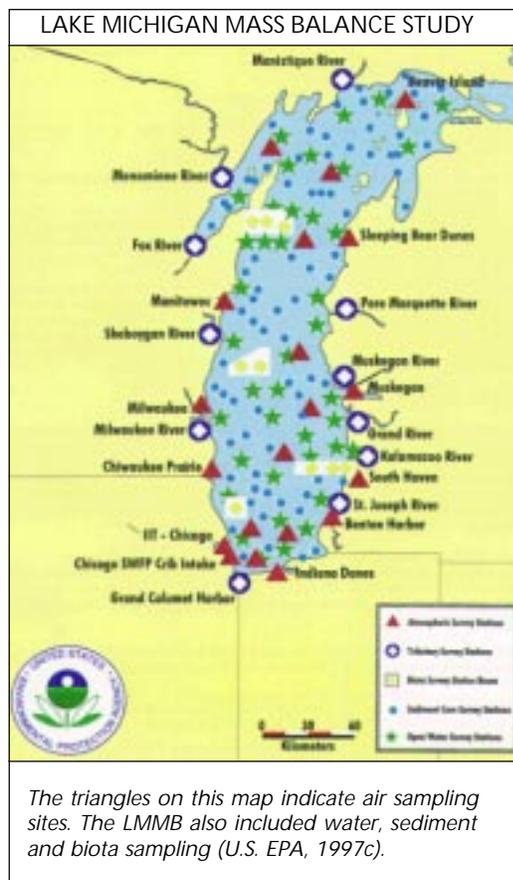
### LAKE MICHIGAN MASS BALANCE STUDY (LMMB)

This pioneering study, launched in 1994, was designed to collect information about the concentrations of contaminants in the environment, both in relation to their sources and to their effects in the ecosystem. The LMMB was based on the Green Bay/Fox River Mass Balance Study that began in 1987. Completed in 1992, the Green Bay pilot study tested the feasibility of using a mass balance approach to assess the sources and fates of toxic pollutants spreading throughout the Great Lakes food chain (Beltran and Richardson, 1993).

The primary goal of the LMMB is to develop a sound, scientific base of information to guide future toxics load reduction efforts for Lake Michigan at the State and Federal levels. The LMMB focuses on four chemicals: PCBs, trans-nonachlor (a component of chlordane), atrazine, and mercury. The four chemicals were selected from the contaminants of concern to Lake Michigan because they are representative of broad classes of pollutants with significance throughout the Great Lakes. Most are persistent in the environment and/or bioaccumulative in the food chain (U.S. EPA, 1997c).

The LMMB was designed to accomplish four specific objectives:

1. To identify relative loading rates of critical pollutants from major media (air, tributaries, sediment resuspension) to the Lake Michigan basin in order to better target future load reduction efforts.
2. To establish baselines against which to gauge progress in meeting reduction goals.
3. To predict benefits of specific load reduction scenarios for toxic substances and the time required to realize those benefits, in order to assist in choosing management strategies for Great Lakes toxic chemicals.



- To understand ecosystem dynamics in order to improve understanding of the processes governing contaminant cycling and contaminant availability within the food chain.

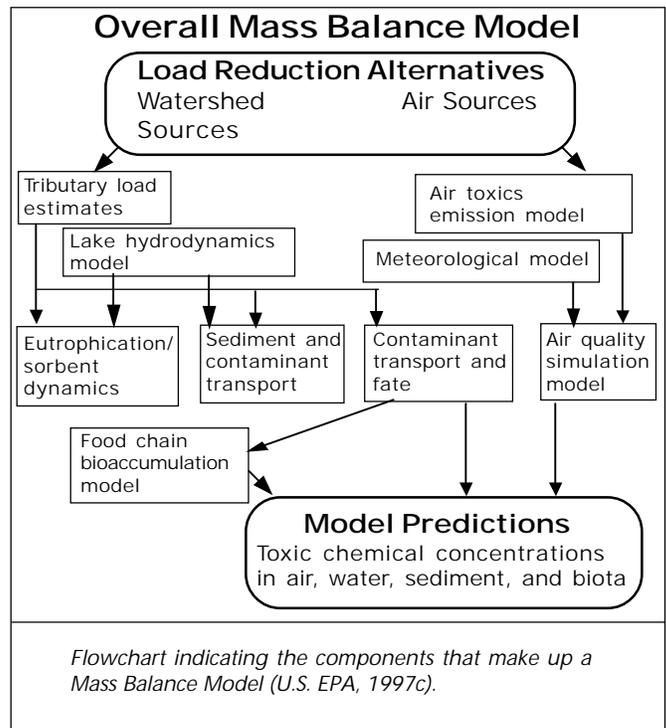
The mass balance approach employs the basic thermodynamic law governing conservation of mass. The model considers contaminant interactions with air, water and sediments, taking into account internal processes that may add or subtract mass. When modeling the behavior of a non-reacting dissolved substance such as chloride, in a simple system like a river flowing in one direction, the amount leaving the system should equal the amount entering. For reactive chemicals like PCBs engaged in complex systems such as the Great Lakes, a model must include many more parameters in order to provide desired results. These parameters include quantitative estimates of the mass of contaminants that enter and leave the system, predictions concerning concentrations of contaminants for points in time and space, and the means to

determine how much the inputs of a chemical must be reduced to reach a given concentration in the water, sediments or biota. Combined with costs associated with regulation of different sources, this information can be used to design optimal remedial strategies and to provide evidence that the economic investment of regulatory strategies will produce a definitive environmental benefit (Richardson et al., 1999).

The mass balance approach takes raw data collected through field monitoring and inputs it into mathematical models in order to determine how concentrations change in relation to loadings from the atmosphere and tributaries, and with that be able to estimate or predict quantitative results of policies and programs. Estimation of atmospheric deposition and air-water exchange of toxic contaminants is a significant concern for the LMMB, as is prioritizing further research, monitoring and modeling needs and quantifying the uncertainties associated with model predictions. Although study results are still being analyzed, they nevertheless provide the most comprehensive and complete information to date about concentrations and cycling of toxic chemicals in the Great Lakes.

#### MERCURY TOTAL MAXIMUM DAILY LOAD AIR DEPOSITION PILOT PROJECT

In 1999 U.S. EPA began a pilot project to investigate the relationship between air emissions of mercury and water quality impacts. The project, to be completed in the spring of 2000, is using a loadings model, a less comprehensive mass balance approach, to identify total maximum daily loadings (TMDLs), which include all inputs, including direct discharges, runoff, air depositional sources and sediment volatilization to a single waterbody. The project is a cooperative, voluntary effort with the States of Wisconsin and Florida, which will be conducted on Devil's Lake in Wisconsin and in a portion of the Florida Everglades.



The goal of the project is to examine methods for taking air sources into account when determining TMDLs. For each of the pilot waterbodies, the project will evaluate techniques for determining: 1) the amount of mercury reductions needed to meet water quality standards; 2) the relative contributions of mercury from various sources; and 3) the geographic extent of sources contributing mercury (U.S. EPA, 1999c).

On Devil's Lake the most recent version of the Dynamic Mercury Cycling Model (D-MCM) will be used. The D-MCM predicts the transport and fate of methylmercury, HgII, and elemental mercury in the water column, sediments, the atmosphere, the watershed, and a six-level food chain. On the atmospheric side, the Regulatory Modeling System for Aerosols and Deposition (REMSAD) will be used to determine the relative contribution of mercury to Devil's Lake from various sources and source categories, and the expected levels of mercury deposition under various mercury reduction scenarios. REMSAD provides wet and dry deposition rates for mercury over the United States on a variable grid size, with fine resolution over the Great Lakes region (U.S. EPA, 1999c).

The water and atmospheric models will be run concurrently, although there will be close coordination between the two modeling efforts. The Mercury Cycling Model (MCM) will assess how much reduction in mercury loadings is needed to meet water quality standards (i.e., fish tissue criteria). The MCM will also be run under various mercury loading scenarios to demonstrate the response of mercury levels in fish to changes in loadings, and how long it would take to achieve standards under different scenarios. The atmospheric model REMSAD will be run to determine baseline mercury deposition, as well as the effects of potential control strategies on mercury deposition. The results from the REMSAD runs will then be compared with the results of the Mercury Cycling Model, i.e., which control scenarios would be expected to result in meeting water quality standards within a specified timeframe (U.S. EPA, 1999c).

## **REGIONAL AND NATIONAL INVENTORIES**

Emissions inventories are essential to gain an understanding of the amount of pollutants emitted and where these pollutants are coming from.

The *Great Lakes Regional Air Toxic Emissions Inventory* was undertaken through an intergovernmental partnership involving the eight Great Lakes states, the province of Ontario, and U.S. EPA. The objective of this ongoing initiative is to present researchers and policy makers with detailed, basin wide data on the source and emission levels of 82 toxic contaminants. The inventory presents a compilation of the best available data for calendar year 1996 of point and area source toxic air emissions that have the potential to impact environmental quality in the Great Lakes basin. The project provides a strong foundation upon which to build national and binational strategies to reduce toxic air emissions affecting the Great Lakes (GLC, 1999).

The *National Toxics Inventory* (NTI) is a central repository of inventory data and estimated emissions of as many of the 188 hazardous air pollutants for as many source categories as possible, including mobile, area, and major source emissions data from county, regional, and national levels. This repository has been prepared as a tool for conducting the analyses required by the 1990 Clean Air Act, and to store and share data being generated through various EPA programs. Sources of data include not only Clean Air Act inventories, but also the Toxic Release Inventory database and sources being studied for regulatory purposes for Maximum Achievable Control Technology (U.S. EPA, 1999a).

### III Selected Chemicals of Concern

A comprehensive modeling approach is currently being used to develop information on the sources of chemicals being deposited in the Great Lakes region. An emissions inventory for the pollutant of interest is input into the model to simulate its transport throughout the United States and Canada. Geographically and temporally resolved emissions inventories are needed for any compound for which this analysis is to be performed (IJC, 1999).

This section describes several of the chemicals known to be impacting the Great Lakes through atmospheric deposition. These chemicals were selected for their significance to the region; many are persistent in the environment and all are known to impact the health of humans, wildlife and/or the ecosystem. These chemicals are also generally the most studied in the Great Lakes. It is from them that much of the understanding of atmospheric deposition, and especially of its importance to this region, has been reached. Many of these chemicals can be seen as representative of their chemical groups. The intent of this overview is to highlight recent research about the sources of these chemicals in the atmosphere and the ways in which they are entering the Great Lakes.

#### MERCURY

Mercury is released into the environment as a result of natural and anthropogenic activities. The amount of mercury mobilized and released into the biosphere has increased since the beginning of the industrial age. Most of the mercury in the atmosphere is elemental mercury vapor, which circulates in the atmosphere for up to a year and, hence, can be widely dispersed and transported thousands of miles from sources of emission. Most of the mercury in water, soil, sediments, plants and animals is in the form of inorganic mercury salts and organic forms of mercury (e.g., methylmercury). The inorganic form of mercury, when either bound to airborne particles or in a gaseous form, is readily removed from the atmosphere by precipitation and is also dry deposited.

Mercury transfers efficiently up the aquatic food chain, allowing it to bioaccumulate in the predatory organisms at the top. Nearly all of the mercury that accumulates in fish tissue is methylmercury. Inorganic mercury, which is less efficiently absorbed and more readily eliminated from the body than methylmercury, does not tend to bioaccumulate (U.S. EPA, 1997a). All forms of mercury are dangerous to the human nervous system and exposure can cause permanent fetus, kidney, and brain damage. Developmental problems have been shown to occur in children through exposure from mercury-contaminated fish eating mothers (ATSDR, 1999). The National Wildlife Foundation's (NWF) recent report *Clean the Rain* highlighted the problem of atmospheric deposition of mercury and the impact to the Great Lakes. In cities throughout the Great Lakes states the NWF reported elevated levels of mercury in the rain, in Detroit up to 65 times higher than EPA standards. In Chicago, levels are as high as 42 times, with a one-year average of 12 times, the level set by U.S. EPA as the human health standard (NWF, 1999b).

Wet deposition is the primary mechanism for transporting organic forms of mercury from the atmosphere to surface waters and land. Even after it deposits, mercury commonly is re-emitted into the atmosphere either as a gas or associated with particles, to be re-deposited elsewhere. As it cycles between the atmosphere, land, and water, mercury undergoes a series of

complex chemical and physical transformations, many of which are not completely understood (Mason et al., 1998; U.S. EPA, 1997a). In Lake Michigan, these cycles are much more similar to what occurs on the open ocean than on smaller freshwater lakes in the same region (Sullivan and Mason, 1998).

Estimates for annual mercury emissions decline from 242 tons in 1990 to 176 tons in 1995, with the biggest reductions coming from medical waste incinerators (Binational Toxics Strategy, 1999). Table 1 shows sources of mercury air emissions in the U.S. for these two years. One estimate of total annual global input from all sources including natural, anthropogenic and oceanic emissions is 5,500 tons, which would put U.S. source emissions in 1995 at around three percent of the total (U.S. EPA, 1997a). A computer simulation of long-range transport of mercury suggests that about one-third of U.S. anthropogenic emissions is deposited within the lower 48 states and the other two-thirds are transported into the global reservoir. The U.S. receives another 35 tons from the rest of the world. This simulation suggests that the U.S. is contributing three times the amount of mercury to the global atmosphere that it receives (U.S. EPA, 1997a).

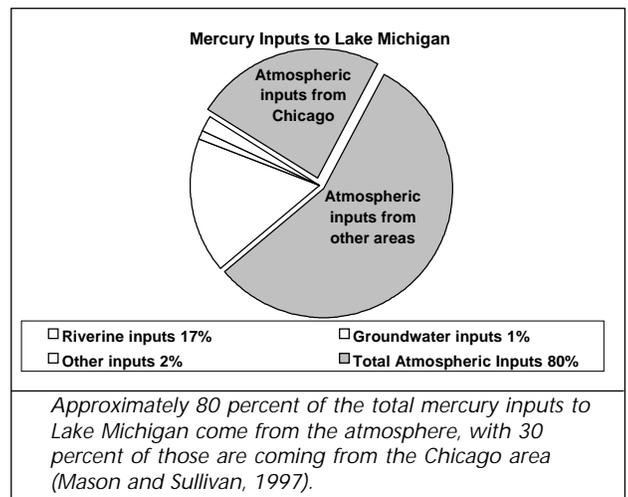
Source	1990	1995
Utility Boilers - Coal	51.0	51.6
Municipal Waste Combustors	41.7	29.6
Medical Waste Incinerators	50.2	16.0
Solid Waste Processing & Transport	32.0	16.0
Use of Steel Scrap	12.0	12.0
Chlorine Production	10.0	7.1
Hazardous Waste Incineration	5.7	7.1
Mobile Sources - Non-Road	6.8	6.8
Mobile Source - On-Road	5.0	5.0
Portland Cement (Non-Hazardous Waste)	4.0	4.0
Industrial Boilers	2.1	2.1
Other	22.0	19.3
<b>Total</b>	<b>242.5</b>	<b>176.6</b>

Table 1: U.S. Mercury Air Sources and Emissions Estimates in Tons (Binational Toxics Strategy, 1999)

Deposition rates of mercury are influenced by the location of sources, the form of mercury emitted, and the climate and meteorology, with higher deposition rates in humid areas. The southern Great Lakes area is predicted to have one of the highest rates of mercury deposition in the United States (U.S. EPA, 1997a).

Recent field studies illustrate that atmospheric deposition is the major contributor of mercury to the Great Lakes (Pirrone et al., 1998). Mercury accumulation rates in sediment cores from the Great Lakes showed significant increases (up to over 330-fold) from pre-industrial to modern times larger than those reported for small, remote lakes in the northeastern U.S., indicating sources other than natural inputs of mercury to the Great Lakes area (Pirrone et al., 1998). The atmospheric deposition flux of mercury is approximately seven to ten times higher in the Great Lakes region than in North America as a whole. (Flux is the mass in or out over some area during some time period.) This higher rate of flux in the Great Lakes is likely due to local and regional anthropogenic emissions (Pirrone et al., 1998).

LMUATS found that the median concentration of vapor phase mercury was four times higher on the south side of Chicago than over the lake or downwind at the South Haven, Michigan site. Particulate mercury levels were also five to fifteen times higher in Chicago than at downwind sites. These results suggest that local sources are primarily responsible for the high mercury levels in the air in Chicago (Keeler, 1994).



In preliminary results for the LMMB, it was found that localized urban sources, such as Chicago, contributed approximately 30 percent of the total atmospheric loading to the Lake. Atmospheric deposition from all areas contributed approximately 80 percent of the total mercury input to Lake Michigan. Riverine inputs accounted for approximately 17 percent of the total mercury and groundwater inputs were less than one percent. Because Lake Michigan is supersaturated with elemental mercury, there was a net outward flux of mercury from the lake through gas exchange (volatilization); however, mercury inputs through dry and wet deposition to Lake Michigan currently exceed outputs (Mason and Sullivan, 1997).

## **PAHS**

Polycyclic aromatic hydrocarbons (PAHs) are a category of SVOCs, some of which are suspected carcinogens. They are formed during the incomplete combustion of organic matter such as wood, coal, oil and gasoline. Major sources include residential heating sources, open burning, coke and aluminum production, and motor vehicle exhaust (Finlayson-Pitts and Pitts, 1986). PAHs undergo chemical and physical changes as they are transported through the atmosphere. They can be deposited by wet and dry deposition and also move from air to water by air-water exchange.

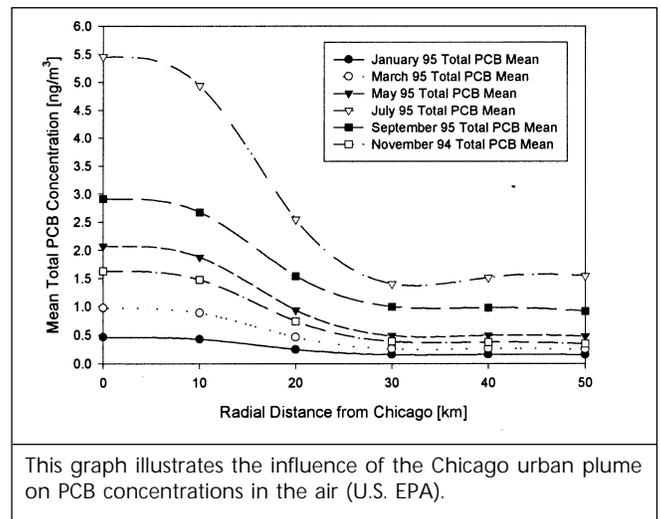
A study by Simcik et al. (1997) that focused on Chicago and the surrounding area concluded that the dominant source of PAHs is coke and steel production in the urban complex of Chicago, Illinois and Gary, Indiana. Christensen and Karls (1996) found a pattern of PAHs in Lake Michigan sediment indicating a significant contribution from wood-burning, and an increasing dominance of oil-burning sources (as opposed to coal-burning by coke and steel production), which is consistent with U.S. fuel consumption data. Christensen and Karls also found that PAH loadings at Green Bay, the Fox River, and the Kinnickinnic River in Wisconsin were strongly influenced by local industry, primarily coke production and coal gasification at the Milwaukee Solvay Coke Company which operated from 1900 to the 1970s. A study of the chemical composition of major PAH sources in the Chicago area in 1990-1991 found that the coke ovens of the steel industry and gasoline and diesel engines are the major sources of PAHs in the region's air (Khalili et al., 1995).

Air-water exchange is the dominant depositional process for most lower-molecular weight PAHs. The deposition of most of these compounds into the Great Lakes is about balanced by their volatilization from the Lakes (Hillary et al., 1998). PAH concentrations in the air have been found to be generally an order of magnitude higher at urban monitoring sites than at rural or over-lake sites. Levels at some monitoring locations did indicate that long-range transport was occurring (Simcik et al., 1997; Keeler, 1994).

## **PCBs**

PCBs are a class of highly toxic, persistent and bioaccumulative chemical compounds. PCBs are considered possible carcinogens and have been associated with a variety of conditions in animals including thyroid gland disorders and reproductive problems. In humans, nervous system disorders have been observed in newborns whose mothers were exposed to PCBs through PCB contaminated fish (ATSDR, 1999).

PCBs were produced in the United States from 1927 to 1977 for insulating and cooling electrical equipment. The Monsanto Company, the sole U.S. maker, stopped production in 1977, and new manufacturing and some uses were banned in 1979 as part of the 1976 Toxic Substances Control Act (U.S. EPA, 1999g). It has been estimated that 282 million pounds of PCBs, or one fifth of the total amount produced, were still in use in older commercial and industrial equipment, such as transformers and capacitors, at the end of 1988. Remediation of sites with high concentrations of PCBs is occurring but concern continues about possible release into the environment from, for example, contaminated sediments during their removal (U.S. EPA, 1997b).



Results from LMUATS reported PCB levels in the atmosphere at the Chicago site to be about three times higher than at the other sites in the lower Lake Michigan area. The over-water sites near Chicago were lower than city samples but higher than other site samples (Keeler, 1994). Studies as a part of AOLEOS reported many major findings regarding PCB concentrations in the Chicago and southern Lake Michigan region. Total concentrations of PCBs in Chicago precipitation were two to three orders of magnitude higher than the background concentrations of PCBs elsewhere in the Lake Michigan region. The higher PCB levels in the rain meant that more PCBs from the Chicago area were getting into the atmosphere than from remote locations. The “urban plume” from the Chicago area appeared to increase atmospheric deposition of PCBs for many miles out into the lake as precipitation falling into southern Lake Michigan had levels up to 400 times higher than the measured background. PCB concentrations in the water of southern Lake Michigan were elevated when the winds come from the south-southwest, the urban and industrial region of Chicago and Northwest Indiana. Total PCB concentrations in southern Lake Michigan have declined ten fold over the past 14 years, a decline of 17 to 30 percent per year (Franz et al., 1998; Offenburg and Baker, 1997; Simcik et al., 1997; Simcik et al., 1998; Zhang et al., 1999).

PCB concentrations measured during IADN and LMMB studies were used to determine that, in Chicago, gas-phase PCB concentrations are controlled by short-range transport but, at remote sites, these concentrations are controlled by long-range transport. Gas-phase PCB concentrations near Lake Michigan, Lake Erie, and in Chicago decreased between 1991 and 1997. Gas-phase PCB concentration near Lake Superior showed no general trend over this period (Simcik et al., 1998).



According to the LMMB, atmospheric inputs of PCBs to Lake Michigan are an important pathway, accounting for over four times the loading levels

coming from the water sources. On a local scale, however, tributary inputs may be important indications that sediment clean-ups are still needed, but on a lakewide scale atmospheric inputs are highly significant.

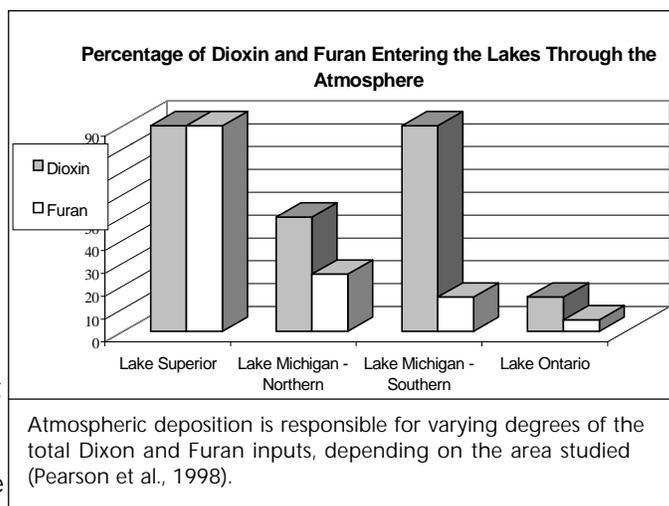
The LMMB reports inputs by dry and wet deposition to be roughly equal, with the net gas input (via air-water exchange) about an order of magnitude higher. Measurements for Lake Michigan reported significant variations in inputs of PCBs by dry deposition, ranging from 65 kg/yr, using data from the more remote IADN site, to 1,100 kg/yr, estimated as part of the urban Chicago-area AEOLUS study (U.S. EPA, 1999f; Franz et al., 1998). While recent studies point to the relative importance air-water exchange and dry deposition there are still many uncertainties in the measurement of depositional processes and in estimating atmospheric loadings of PCBs to the Lakes. The IADN study concluded that PCBs in the lake water and air were approximately in equilibrium, which would allow water PCB concentrations to be tracked through air measurements (Hillery et al., 1998). Other studies have demonstrated that the atmosphere and Lake Michigan are both sources and sinks for PCBs (Hornbuckle et al., 1995; Offenberg and Baker, 1997). Factors that require better understanding include seasonal variations of gas exchange, dry deposition rates, locational variations in these processes, and comparisons between over-land and over-lake measurements.

### DIOXIN AND FURANS

Polychlorinated dibenzo-p-dioxins (PCDD; dioxins) and polychlorinated dibenzofurans (PCDF; furans) are byproducts of combustion. These SVOCs enter the environment primarily as a result of waste incineration, including backyard burn barrels, and various industrial manufacturing processes. Dioxins and furans are soluble in fat, will bioaccumulate through the food chain and caused fish advisories in the Great Lakes region.

A recent study that examined three sediment samples for dioxins and furans, one from the Housatonic River in Connecticut, one from Lake Huron and one from the Baltic Sea, found that dry and wet deposition, coal-fired power plant emissions, municipal incinerators, and manufacturing processes that produce pentachlorophenols contributed significantly to the dioxin/furan sediment levels (Su and Christensen, 1997). The study found that both local sources and long-range transport were important to dioxin/furan loadings to the waterbodies. Recent sediment core studies found that currently the dominant source in Lake Superior of dioxin and furan is the atmosphere. Conversely, atmospheric contributions were much less important in Lake Ontario and varied, from north to south, in Lake Michigan (Pearson et al., 1998).

The flux of dioxin/furan increases from Lake Superior, to Lake Huron, to Lake Michigan, to Lake Erie, to Lake Ontario, following the pattern of industrialization around the Lakes. Waterborne inputs of dioxin/furan to Lake Superior, Lake Michigan, and Lake Huron play a lesser role than air deposition. In Lake Erie and Lake Ontario, the waterborne inputs are uncertain because of the difficulty in quantifying discharges to and from inter-lake channels (Cohen et al., 1995).



To help explain and understand variations in loadings and accumulations within and between the Great Lakes, the Hybrid Single Particle Lagrangian Integrated Trajectory (HYSPLIT)/Transfer Coefficient computer program was used to determine the amount of dioxin and furan emitted from identified sources to air and water that enters the Great Lakes. The model was run using 1993 source and emissions data from 1,329 identified sources in the U.S. and Canada (Cohen et al., 1995). Half of the cumulative dioxin deposition comes from sources about 300 miles (480 km)

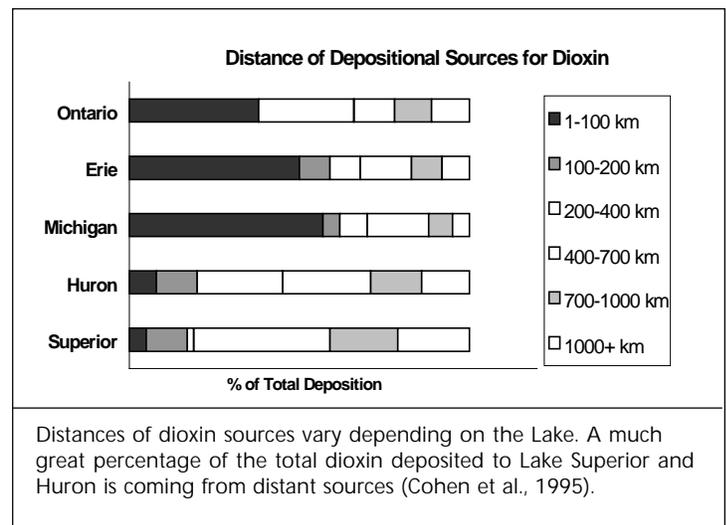
or less from the center of the Lakes. The remaining half of the total deposition comes from sources as far as 1,500 miles (2,400 km) away (Commoner et al., 1996). This chart shows the proportion of deposition for each Lake that arises from within a given range. The majority of deposition to Lakes Erie, Michigan and Ontario comes from sources within 400 km from each Lake. For Lake Superior, however, transport of dioxin from outside the region is relatively more important, the majority from sources 400 to 1000 km away, since there are few immediately adjacent upwind sources. This finding is also applicable to Lake Huron (Cohen et al., 1995; Cohen et al., 1997).

## PESTICIDES AND HERBICIDES

Although most of the pesticides of concern in the Great Lakes are banned or use-restricted, many are still in current use in other countries. Therefore, long-range transport may be a significant source leading to current levels in the Great Lakes. The LMUAT study found the highest concentrations of pesticides at a background site in Kankakee, Illinois, probably because of current agricultural uses, but DDT and its derivatives were found primarily at Michigan sites in patterns suggesting that their sources were past rather than current uses (Keeler, 1994). Some recent studies on pesticides and herbicides focus on the role of atmospheric transport, from both historic and current sources, in the contamination of waterbodies and biota. A few of the recent findings are highlighted below.

Volatilization is the more significant depositional process for many pesticides in the Great Lakes. For example, for dieldrin and DDE (a metabolite or breakdown product of DDT) the net atmospheric loading is negative, indicating that net losses by volatilization are greater than inputs by all other depositional processes (Hillery et al., 1998). Virtual elimination dates, ranging from about 2010 for *p,p'*-DDT to about 2060 for hexachlorobenzene, were estimated from pesticides in the atmosphere as a part of IADN. These estimates provide support for regulatory controls on pesticides (Cortes et al., 1998; Cortes et al., 1999).

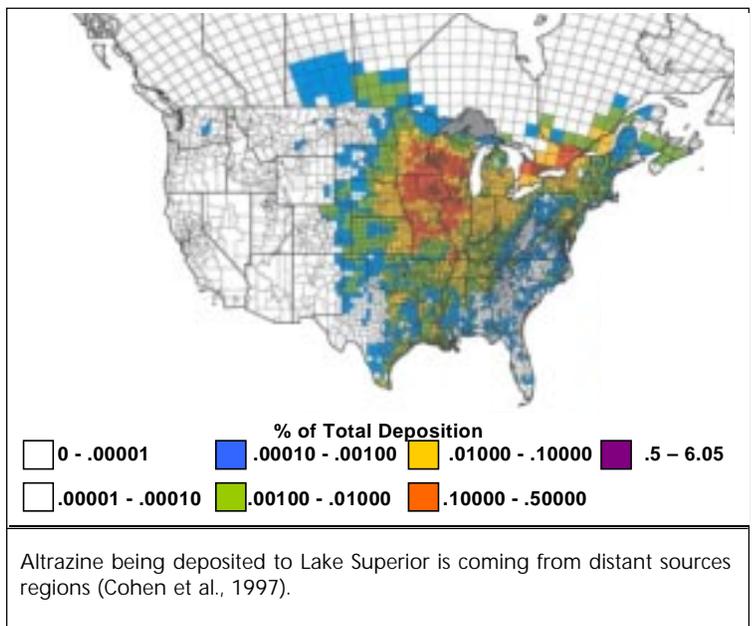
Lindane is an organochlorine insecticide with strong potential for long-range transport. It is still in fairly widespread use around the world, although most uses were restricted in the U.S. in 1983. Wet and dry deposition of lindane appears to be fairly uniform across all the Lakes. Gaseous lindane generally seems to be in equilibrium in Lakes Erie and Ontario, while gas absorption is the dominant mechanism in air-water exchange for Lakes



Superior and Michigan. The net gas transfer of lindane for Lake Michigan is into the Lake in the winter and spring and out of the Lake in the summer and fall. This is a common pattern for air-water exchange of pesticides (Achman et al., 1992; Hoff et al., 1996; McConnell et al., 1992; Ridal et al., 1996).

Chlordane, which was restricted in 1973 for use as a termiticide and was banned in 1988, was used primarily as a pesticide for corn crops (Aigner et al. 1998). Chlordane is associated with nervous and digestive system disorders and liver problems in both humans and animals (ATSDR, 1999). Using data collected from IADN, the half-life of chlordane was estimated and a decrease in concentration over time was found only near Lakes Michigan, Erie and Ontario (Cortes et al., 1998). Gas phase concentrations of chlordane on Lake Superior do not exhibit a decreasing trend, as has been seen with several other banned pesticides. A minimum virtual elimination date for chlordane in the Great Lakes regional atmosphere has been estimated between the year 2010 and 2030 (Cortes et al., 1998).

Atrazine is one of the primary herbicides in use in the Great Lakes watershed and was the single-most used herbicide among corn and soybean crops in 1991. It is also used to control weeds on residential lawns and sod farms. EPA considers atrazine a possible carcinogen (U.S. EPA, 1998j). Precipitation concentrations for atrazine have remained constant over the past five years, consistent with the steady sales of atrazine during that time (Miller et al., 2000). A study done between the years 1991 and 1995 found increasing atrazine concentrations in the waters of Lake Michigan, demonstrating a much greater persistence than had been



measured on agricultural fields (Rygwelski et al., 1999). Atmospheric inputs account for 30 percent or less of the total load to Lakes Erie, Ontario, Huron and Michigan, where runoff and tributary loadings may be more significant, and for 95 percent of the inputs to Lake Superior (Rygwelski et al., 1999; Schottler and Eisenreich, 1997).

Toxaphene, a semi-volatile organic compound, is a mixture of polychlorinated bornanes and bornenes. It was used as an insecticide in the U.S. (principally in the southern U.S.) and Canada from the mid-1940's until it was banned in 1982. It was reported in lake trout from Siskiwit Lake on Isle Royale in Lake Superior (Swackhamer and Hites, 1988) leading to speculation that its principal path to the Great Lakes was via long-range transport from the southern U.S. (Hoff et al., 1993).

According to the Department of Health and Human Services toxaphene is a probable carcinogen. Exposure to toxaphene can also cause kidney, nervous system and lung damage (ATSDR, 1999). Toxaphene concentrations declined in fish from 1982 to 1992 in all of the Lakes except Lake Superior where they have remained constant (Glassmeyer et al., 1997). Recent modeling work

## IV Conclusions

suggests that the colder temperatures and lower sedimentation rates in Lake Superior are responsible for toxaphene's high water concentrations and that there is no evidence of non-atmospheric sources to that lake. The model does suggest, however, that there were non-atmospheric sources to Lake Michigan (Pearson et al., 1997; Swackhamer et al., 1999).

Atmospheric deposition is a complex phenomenon that is responsible for a significant fraction of the chemical inputs to the Great Lakes. The impact of long-range transport, and of atmospheric deposition in general, depends to a large degree on the chemical properties of the compound of interest. The relative importance of wet deposition, dry deposition and air-water exchange also varies from compound to compound. For chemicals typically associated with urban-industrial areas (PCBs, PAHs, dioxin and furan, mercury and many other trace metals) it appears that urban centers, such as the greater Chicago area, are responsible for much of the deposition to the Lakes. For pesticides and other chemicals used in agriculture, rural sources are of greater importance. Out-of-basin and long-range sources generally have a more significant impact on Lake Superior, with varying impacts on the other Lakes depending on the chemicals being considered.

The recent HYSPLIT model results, mapping sources to the Great Lakes from the U.S. and Canada, reinforce the need for a continental, systematic, and sustained approach to improved annual or biennial estimations of emissions. For successful application of models to all substances of concern in the Great Lakes, more accessible and comprehensive emission information, including the removal, where necessary, of current inventory confidentiality restrictions, is essential. Systematic measurements of ambient air, precipitation and water concentrations must be extended to provide information on long-term trends of contaminant loadings to and concentrations in Great Lakes waters. These changes and additions to, and extensions of, data collection would facilitate development, evaluation and validation of models, as well as help determine trends in deposition reductions and help demonstrate progress achieved by control strategies (IJC, 1999).

Scientists have identified a great number of specific research needs relating to atmospheric deposition, including:

- Determination of physical-chemical constants, deposition velocities, air-water and air-soil interactions, mass transfer coefficients for air-water exchange, air-particle partitioning and atmospheric degradation pathways and mechanisms.
- Collection of open water measurements to obtain water concentration data for air-water exchange calculations, the impact of discrete plumes on the Lakes, and over-water turbulence structure measurements for deposition modeling.
- Development of new techniques for direct air-water exchange measurements.
- Measurement of complete particle size distributions, including how they change over time and space.
- Exploration of the fate of deposited compounds in the water column.

In order to guide new scientific research and modeling efforts, it is necessary to clarify and prioritize the specific questions that have the most urgent policy implication.

Continued research, monitoring and modeling, building on prior efforts, is important to support new national and international initiatives to prevent and control long-range transport and deposition. Open communication regarding policy initiatives and research findings is needed to avoid a long lag-time between scientific recognition of a problem and responsive action through policy changes. Current understanding of the importance of atmospheric deposition and long-range transport as sources for chemicals of concern in the Great Lakes makes the strengthening of scientific research efforts and policy initiatives crucial.

# 3



## U.S. POLICY TOOLS

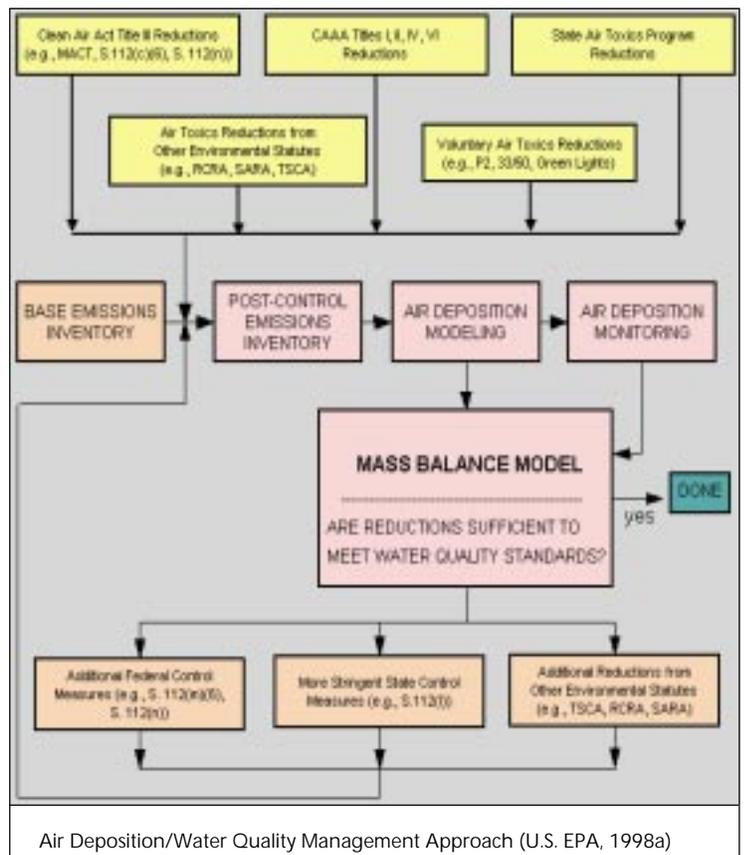
This chapter summarizes a range of federal regulatory programs that provide authorities to either directly or indirectly reduce emissions, restrict product use, and increase our understanding of or remove from the environment contaminants of concern. None of the many federal laws and regulations alone provides a magic bullet for solving a problem as complex as the virtual elimination of atmospheric deposition of contaminants of concern to the Great Lakes. Because many of the federal programs focus on a select list of pollutants, and often in a single media (e.g. air, water or land), additional state authorities, voluntary clean up programs, and research and coordinating initiatives are also considered.

## Air Deposition/ Water Quality Management Approach

U.S. EPA is working to develop an Air-Water Interface Action Plan, intended to consolidate the Agency's efforts to understand and address atmospheric deposition nationwide, including the Great Waters and other State-identified impaired waterbodies. The action plan is intended to target State-identified impaired waterbodies, to examine what rules or activities are in place that address impairment caused by air deposition, and to determine what additional actions are necessary to address impairment caused by air deposition. To date, management in U.S. EPA Region 5's Office of Air Resources and Office of Water have held two meetings with Great Lakes environmental groups to discuss various components of the action plan including the Total Maximum Daily Load program, upcoming Maximum Achievable Control Technology standards, the Residual Risk program, the Urban Air Toxics Strategy, and air toxics monitoring. A draft plan is being developed for external review.

The approach outlined in the flowchart below is an initial effort to look at the effects of air deposition on water quality. It was intended to clarify the spectrum of agency programs and to help begin to evaluate what need there is, if any, to act upon additional authorities or to revisit existing programs to ensure that emission reductions are adequate to achieve water quality objectives (U.S. EPA, 1999a).

At the highest level, the major federal regulatory and voluntary programs, as well as state programs, are listed. Federal regulatory programs include the Clean Water Act (CWA) and Clean Air Act (CAA), as well as others that provide specific authorities and mandates to address pollutants of concern, such as the Resource Conservation and Recovery Act (RCRA), which deals with treatment and disposal of uncontrolled hazardous waste; the Superfund Amendments and Reauthorization Act (SARA), which addresses the clean-up of hazardous waste sites; and the Toxic Substances Control Act (TSCA), which regulates use and sale of toxic substances. This level includes specific provisions of the Clean Air Act anticipated to be most effective in addressing pollutants of concern. State air toxics programs and voluntary reduction programs are also included.



The second level charts a process for evaluating the effectiveness of these tools, including building emission inventories and models, and maintaining monitoring programs. The evaluative process is strengthened by implementation of the programs listed above. For example, as standards for major sources of hazardous air pollutants are developed and carried out under the Clean Air Act, additional data collected through compliance testing and emissions data from high-performing sources will lead to better emission inventories.

Coordinating this work with enhanced modeling tools developed through

Great Lakes research efforts, such as the Lake Michigan Mass Balance Study, should allow policy makers to identify which additional authorities – if any – should be called upon. This final step identifies several specific mandates that provide such authorities, such as the Great Waters Program (CAA section 112(m)), Utility Air Toxics Study (CAA section 112(n)), other statutes (RCRA, SARA and TSCA), and state control measures (U.S. EPA, 1998a).

Such an overview of the air and water programs and policy options conveys the numerous, and somewhat scattered, efforts to address deposition of toxics to the Great Lakes. But in order to truly understand and solve this problem, an even wider array of federal programs and policy options must be taken into account. Many federal laws, not specifically addressing the problem of toxic contamination, could and should play an important role in improving the inventories of contaminants of concern and reducing their use or adverse effects on the environment. These include the Emergency Planning and Community Right to Know Act (EPCRA), the Federal Insecticide, Fungicide and Rodenticide Act, the Pollution Prevention Act, and the National Environmental Policy Act. Many federal agencies beyond EPA could also play a role in reducing air deposition of toxic contaminants, including the departments of Energy, Transportation, Commerce, Agriculture and Defense, the U.S. Geological Survey, and the Federal Aviation Administration.

Following is a summary of federal regulatory programs, additional coordinating initiatives and state programs, dealing most directly with atmospheric deposition of toxic contaminants.

Two federal laws are considered to have the most potential for addressing the problem of deposition of pollutants to the Great Lakes: the Clean Air Act and the Clean Water Act. Although each act is complex and entails an ongoing process of interpretation, rulemaking and regulation, the following discussion highlights specific provisions that either directly address deposition or regulate sources contributing to the problem. In addition, several other laws, regulating either sources of air pollution or problematic pollutants, are discussed.

### **CLEAN AIR ACT**

Congress enacted the Clean Air Act “to protect and enhance the quality of the Nation’s air resources” by controlling criteria pollutants, hazardous air pollutants, acid deposition precursors and ozone depleting substances. There are numerous provisions of the Clean Air Act that pertain to air toxics, some with specific emphasis on sources of pollutants critical to addressing the problem of deposition of toxics to the Great Lakes (P.L. 101-549, 1990).

Under section 112(b), 189 pollutants were listed as hazardous air pollutants (HAPs) when Congress amended the Clean Air Act in 1990. Since then, only one substance has been removed from the list. It is important to note, however, that EPA was given the authority to add additional air pollutants to this list when: “emissions, ambient concentrations, bioaccumulation or deposition are known to cause or may reasonably be anticipated to cause adverse effects to human health or adverse environmental effects” [section 112(b)3]. This section of the Clean Air Act addresses the emission of HAPs from stationary sources, defined as any structure or facility that emits or may emit an air pollutant. The specific programs listed below are all stemming from section 112 of the Clean Air Act (P.L. 101-549, 1990).

## **1 MAXIMUM ACHIEVABLE CONTROL TECHNOLOGY STANDARDS (MACT)**

Frustrated by the slow pace and the resources required to reduce HAP emissions through health based standards for toxics, Congress mandated that new standards be established based upon state-of-the art "technology." Technology is defined in the Act to be "measures, processes, methods, systems or techniques" including "process changes, substitution of materials or other modifications" and "design, equipment, work practice, or operational standards (including requirements for operator training or certification)" [section 112(d)2].

Under the MACT program, emission limits are to be set by determining the technology employed by the average of the best performing 12 percent of facilities in each category. MACT standards are intended to impact major sources of hazardous air pollutants. A major source is one that emits more than 10 tons per year of a single pollutant or 25 tons per year of any combination of pollutants. Under section 112(a)1 of the Act, U.S. EPA may choose to establish a lesser quantity or different criteria for a major source, "on the basis of the potency of the air pollutant, persistence, potential for bioaccumulation, other characteristics of the air pollutant, or other relevant factors" (P.L. 101-549, 1990). For example, U.S. EPA could include smaller sources in MACT rulemaking if the pollutant(s) emitted from the facility are of special concern to or were being deposited to the Great Lakes. The first Great Waters report recommended that EPA take such actions (U.S. EPA, 1994).

As a first step in implementing these standards, EPA listed and categorized the 175 types of facilities, or source categories, subject to MACT rulemaking. The Act then required that EPA establish numerical emission standards for all source categories by the year 2000. Both new and existing major sources must comply with MACT standards. A new source of a toxic pollutant is a stationary source built (or rebuilt) after the Agency first created an emission standard for that source category. All other sources are existing sources.

U.S. EPA was also instructed to consider energy, health concerns other than those stemming from air quality, and the environment in setting these standards. The Agency has promulgated standards for the first 47 of the now 147 source categories and must review and revise each standard at least every eight years (U.S. EPA. 1997d). In addition, under Section 112, the U.S. EPA must ensure that the MACT standards as set are providing an ample margin of safety. If not, additional controls are to be developed as are necessary to reduce the remaining risks.

## **2 RESIDUAL RISK**

In order to ensure that MACT standards are protective of public health after they are implemented, Congress created the residual risk program, under section 112(f) of the Clean Air Act. The residual risk program provides a powerful basis to address air toxics, in that it allows leeway for stricter standards directed towards specific source categories or in a specific geographical range.

The residual risk program requires U.S. EPA to set stricter standards for sources of known, probable or possible human carcinogens if lifetime cancer risks for the most exposed individuals exceed one in a million. This allows U.S. EPA to prevent adverse human and environmental effects that may remain after the adoption of technology-based standards. These reviews

are required no later than ten years after promulgation of each applicable MACT standard, with additional standards to be promulgated for a given source category within eight years, if they are required to protect human health. U.S. EPA has recently launched this program and is beginning the residual risk assessments for about twelve emission standards including coke ovens, perchloroethylene dry cleaners and secondary lead smelters. The due dates for these initial residual risk standards, if necessary, range from 2001 - 2003 (U.S. EPA, 1999h).

### **3 SPECIAL POLLUTANTS PROGRAM**

Section 112(c)6 of the Clean Air Act requires that U.S. EPA identify source categories that account for at least 90 percent of the emissions of seven specific pollutants, all of which are found in the Great Lakes, and ensure that those sources are covered by MACT rules by the year 2000.

The seven pollutants are:

- alkyl lead compounds,
- polycyclic organic matter (POM),
- mercury,
- hexachlorobenzene,
- PCBs,
- furans and
- dioxin.

In 1998 EPA issued the list of additional source categories, which included open burning of scrap tires (for POM) and specific types of gasoline distribution and storage (for lead). EPA may revise these analyses in the future as improved emissions information becomes available (U.S. EPA, 1998g).

### **4 URBAN AIR TOXICS STRATEGY**

Under Sections 112(c)3 and 112(k) of the Clean Air Act, the U.S. EPA is required to identify categories and subcategories of sources of at least 30 HAPs in urban areas that present the greatest threat to human health. The Clean Air Act also requires the Agency to ensure that sources that make up 90 percent or more of the total emissions, including area sources, are regulated by November 15, 2000. Finally, the Agency is required to develop a national strategy to reduce the incidence of cancer attributable to these HAPs by at least 75 percent. In response to these requirements, the Agency proposed a draft strategy in 1998 and issued the final Integrated Urban Air Toxics Strategy on July 6, 1999 (U.S. EPA, 1998c; U.S. EPA, 1999d).

The Strategy has four key components:

- 1) Regulations addressing sources of air toxics at both the national and local level;
- 2) Initiatives at both the national and local level to address specific pollutants (e.g., mercury) and to identify and address specific community risks (e.g., through pilot projects);
- 3) Air toxics assessments (including expanded air toxics monitoring and modeling) to identify areas of concern, to prioritize efforts to reduce risks, and to track progress; and
- 4) Education and outreach efforts to inform stakeholders about the Strategy and to get input into designing programs to implement it.

The Strategy specifies three major goals: 1) reduce by 75 percent the risk of cancer associated with air toxics from both large and small industrial/commercial sources; 2) substantially reduce non-cancer health risks (e.g., birth defects and reproductive effects) associated with air toxics from small industrial/commercial sources; and 3) address disproportionate impacts of air toxics hazards across urban areas, such as those in areas known as “hot spots,” and minority and low-income communities in urban areas (U.S. EPA, 1999d).

The Strategy offers several critical opportunities to address ongoing issues related to the deposition of toxics to the Great Lakes. First, the Strategy has targeted several pollutants not because they pose unacceptable risks from ambient (air) exposures, but because these pollutants are PBTs that have been identified as problematic because of deposition to waterbodies. The pollutants include mercury and other metals, dioxins, furans, PCBs and hexachlorobenzene. Second, the Strategy has listed several new source categories that have been identified as sources of Binational Toxics Strategy pollutants, including “Stage I” gasoline distribution facilities, mercury cell chlor-alkali plants, and small inorganic and organic chemical manufacturers. And finally, the Strategy has committed the Agency to an ongoing process of public outreach to ensure that program implementation addresses a range of issues raised by a diversity of stakeholders. The issues include establishing an adequate research and monitoring network to track progress in implementing the Strategy, developing pilot projects in several urban areas – including Great Lakes communities, and developing rules and strategies that also reduce critical pollutants of concern from mobile sources (U.S. EPA, 1999d).

## **5 SPECIAL PROGRAMS**

Several special programs required under this section of the Clean Air Act are especially relevant to the problem of deposition of air pollutants to the Great Lakes. Under Section 112(n), the Agency was required put in place an Electric Utility Study examining the health hazards from HAPs from electric utility steam generating units and the control strategies that may be appropriate (U.S. EPA, 2000). As a follow-up to this study reported to Congress in February 1998, EPA has exercised authority granted under section 114 to collect data on the amounts and types of mercury generated by these facilities (U.S. EPA, 1997a).

Also required under Section 112(n) was a comprehensive report on the adverse health effects of mercury from all sources, as well as possible controls for this substance. The Mercury Study report was completed in December 1997, but EPA reserved the right to consider additional regulations after further review of the effectiveness of ongoing MACT rules (U.S. EPA, 1998i).

Solid waste incineration units have also been singled out for regulation, with specific focus on cadmium, mercury and dioxins and furans. Already, MACT standards for municipal and medical waste combustors have been developed and are currently being implemented. These standards have significantly reduced emissions of mercury and dioxins from municipal waste combustion, and full implementation of the rule for medical waste incinerators may achieve additional significant reductions. MACT standards for other solid waste combustion units – including industrial and commercial non-hazardous waste incinerators, crematories and industrial boilers – are required by 2000, with full implementation by 2003.

## **6 GREAT WATERS PROGRAM**

The Great Waters Program offers one of the most promising, although under-utilized, tools in federal law for addressing out-of-basin sources of toxic air pollution. This program also affords a unique opportunity to bridge intra- and inter-agency gaps for types of pollutants, such as pesticides, over which various agencies have jurisdiction.

In the Clean Air Act Amendments of 1990 Congress added sections 112(m)5 and 6, requiring a two-step program for the "Great Waters," specifically identified as the Great Lakes, as well as Lake Champlain, Chesapeake Bay and other coastal waters. The first step required U.S. EPA to provide a biennial report to Congress containing the following information:

1. Quantification of atmospheric deposition to the Great Waters.
2. Assessment of the environmental and public health effects of such pollution.
3. Identification of the sources of the pollutants deposited.
4. Examination of whether the contributions cause, in whole or part, violations of environmental standards.
5. Description of any revisions of requirements, standards and limitations necessary to protect public and environmental health.

The second step requires U.S. EPA to determine the adequacy of existing regulations and programs for controlling toxic air contaminants and to propose necessary changes. This stage of the Great Waters program stipulates that there must be scientific analysis of cause-and-effects links in the depositional process, in order to support requirements for substantial pollutant reductions, and provides the authority to develop new or additional controls if current controls are deemed inadequate. This stage of the program provides a regulatory foundation for addressing loadings by long-range transport.

Although recognizing "serious or widespread environmental effects" are occurring "from indirect exposure pathways, associated with atmospheric deposition to the Great Lakes," U.S. EPA declared its authority to be adequate in the Second Great Waters Report and appears to be poised to do likewise in the forthcoming third, and final, report required. While the Agency has suggested that it intends to continue to produce such reports, it has not yet described how or when it plans to achieve the Great Waters charge of ending widespread harm to human health and the environment from atmospheric deposition (U.S. EPA, 1997b; U.S. EPA, 1999f).

## **7 ADDITIONAL AUTHORITIES OF RELEVANCE UNDER THE CLEAR AIR ACT**

The above authorities from section 112 of the Clean Air Act, commonly referred to as Title III, are often considered the primary regulatory tools for reducing critical toxic air pollutants with the potential to be deposited to the Great Lakes. Nonetheless, other non-toxic air pollution programs under that Act have achieved substantial toxic emission reductions and have the potential to reduce these emissions further.

Other specific provisions of the Clean Air Act that provide a means of addressing deposition of toxics to the Great Lakes include sections 115 and 114. Section 115 provides U.S. EPA with the authority to address air pollution emitted within our borders that impacts other countries. The problem must be recognized by a report from "a duly recognized international agency"

(P.L. 101-549, 1990). If the Agency concurs with the findings, it may require the state(s) responsible for the pollution to take appropriate actions. Section 114 of the Clean Air Act increases our understanding of the sources contributing to the deposition of toxics to the Great Lakes. This section provides U.S. EPA with the authority to require sources of air pollutants to test and monitor for pollutants of concern. This authority can be used not only to ensure compliance with existing rules and standards but also to develop new rules. Recently, the Agency utilized this authority to require testing of mercury content of fuel and emissions at electric utilities.

Additionally, in Section 103 of the Clean Air Act Congress established a framework for U.S. EPA to conduct the research required to better understand – and appropriately regulate – complex problems such as deposition of air pollutants to waterbodies. Specific provisions of this section include mandates to:

- 1) Establish a national monitoring network that assesses deposition;
- 2) Establish and coordinate several interagency task forces to coordinate and leverage federal resources for necessary research activities;
- 3) Establish an ecosystem oriented research program that evaluates and improves modeling and monitoring systems and networks;
- 4) Identify and fill critical data gaps related to emission inventories and monitoring; and
- 5) Develop and implement a plan for fulfilling its research obligations in conjunction with other federal ecological and air pollution research efforts.

Although Congress clearly recognized that addressing deposition of air pollutants would require a significant amount of new and well-coordinated research activity, the mandates of this section have been largely forgotten in the annual appropriation process.

Title I of the Clean Air Act provides for the setting and reaching of National Ambient Air Quality Standards (NAAQS) throughout the United States. Most urban areas in the Great Lakes Region have been, are currently, or will be considered nonattainment areas for NAAQS standards for ozone or particulate matter. Under Section 107(d), a nonattainment area is “any area that does not meet (or that contributes to ambient air quality in a nearby area that does not meet)” NAAQS standards (P.L. 101-549, 1990). Developing and implementing attainment plans and demonstrating maintenance under these standards require extensive emission inventories, modeling tools and monitoring networks. For ozone nonattainment areas, emission reductions will be targeted to some pollutants of concern such as PAHs and benzene compounds. For ozone, fine particulates and regional haze, many strategies will be developed to reduce oxides of nitrogen (NO<sub>x</sub>) emissions, generally coming from sources where collateral reductions will be seen in mercury and other HAPs critical to the Great Lakes.

Significant reductions of toxics also could be achieved through holistic strategies developed under Title II of the Clean Air Act, that sets emission standards for mobile sources: cars, trucks and aircraft. Already, the reformulated gasoline program has resulted in significant ambient reductions of benzene compounds and PAHs in the Gary-Chicago-Milwaukee corridor. Additionally, EPA could address the contribution of mobile sources (including diesel engines) to inventories of mercury, dioxins, benzene

compounds, and other toxic contaminants that pose a significant risk to human health. Section 202(l)1 mandates a study to examine the need for and feasibility of promulgating additional regulations to control these emissions for motor vehicles and motor vehicle fuels.

Programs mandated under Title IV of the Clean Air Act, *Acid Deposition Control*, are targeted to power generating sources. Concurrent reductions in mercury and other pollutants of concern may be achieved through Title IV efforts to reduce NOx and Sulfur Dioxide in these major source contributors.

Title V of the Clean Air Act, *Permits*, presents other opportunities. Some reductions in emissions of critical pollutants will surely occur from new emission standards, rigorous public and regulatory review of permit applications, and enhanced enforcement and monitoring. Additional knowledge and reductions could be achieved from pollution prevention opportunities identified through state and federal permitting programs, supplemental enforcement projects, and enhanced monitoring requirements.

Finally, Title IV of the Clean Air Act, *Stratospheric Ozone Protection*, will also result in reductions of many toxic air pollutants, particularly chlorine based compounds.

#### **CLEAN WATER ACT – TOTAL MAXIMUM DAILY LOAD (TMDL)**

Under section 303(d) of the Clean Water Act, states must list all waterways where water quality standards are not being met and, for each, prepare a Total Maximum Daily Load (TMDL) to achieve the standards (P.L 82-500). For a TMDL, the maximum amount of pollutants that would allow water quality standards to be met must be apportioned among all sources, including air, land runoff, sediment, and direct discharges.

Potential benefits of TMDLs include:

- Application to all sources, whether point or nonpoint, including runoff and air.
- Necessary coordination by air and water quality divisions within agencies.
- Accountability for effects of pollutants from air deposition on water quality, fisheries and other components of an aquatic ecosystem.
- Provision of a framework for cooperation, but also enforceability for achievement of results.
- Requirement for a built in "margin of safety" for unanticipated future pollution.

States have the primary responsibility for developing TMDLs but lack authority to control out-of-state sources that contribute to in-state water pollution.

U.S. EPA is proposing a lakewide TMDL strategy for the Great Lakes that will be incorporated into the Lake Michigan and Lake Superior Lakewide Management Plans in 2000. The strategy will include a determination of sources, including atmospheric deposition; the determination of loads from the sources; the determination of the maximum load that will not violate water quality standards; an allocation of the load to various sources; and an implementation plan. U.S. EPA has indicated that this process could take 15 years to implement (U.S. EPA, 1999c).

## **COMPREHENSIVE ENVIRONMENTAL RESPONSE, COMPENSATION, AND LIABILITY ACT (CERCLA)**

CERCLA, enacted by U.S. EPA in 1980, was responding to releases and threatened releases of hazardous substances from waste disposal sites. Releases may include volatilization into air from sediment or surface sources. The “Superfund” was established by this act, which was amended in 1986 by the Superfund Amendments and Reauthorization Act (SARA). Hazardous substances covered by these two acts included all pollutants, wastes and substances also regulated under the Clean Air Act, the Clean Water Act, RCRA, and TSCA.

## **EMERGENCY PLANNING AND COMMUNITY RIGHT-TO-KNOW ACT (EPCRA)**

This 1986 Act is also referred to as Title III of SARA. EPCRA required local and state-level governments to develop plans to prevent, prepare for and respond to chemical accidents. EPCRA also established the Toxics Release Inventory (TRI). The TRI requires covered facilities to report annual releases and EPA to maintain a public database of the information reported.

The TRI originally required manufacturing facilities, with ten or more full-time employees, that manufacture, process, or otherwise use more than threshold amounts of listed toxic chemicals or chemical categories to report their annual releases to the environment. Under the TRI, covered facilities that manufacture or process over 25,000 pounds of the approximately 600 listed chemicals and 28 chemical categories (such as mercury compounds), or otherwise use more than 10,000 pounds of any listed chemical or category, are required to report their annual environmental releases. The TRI was expanded under the Pollution Prevention Act of 1990 to require facilities to report on recycling, energy recovery, on-site treatment, and pollution prevention/source reduction activities as well.

U.S. EPA’s increasing concern about persistent, bioaccumulative toxics – particularly those deposited to the Great Lakes – has resulted in two significant revisions to the TRI program. In May 1997, the Agency extended the reporting requirements to an additional seven industry groups including mining, petroleum and chemical distribution, and electric generating facilities. In October 1999, the Agency reduced reporting thresholds for 18 chemicals, added seven new chemicals, and eliminated some exemptions. These recent changes, the 1997 inventory and other information regarding the TRI program can be accessed at <http://www.epa.gov/opptintr/tri/>.

## **RESOURCE CONSERVATION AND RECOVERY ACT (RCRA)**

Congress enacted RCRA in 1976 due to concern over the “disposal of solid and hazardous waste in or on the land without careful planning and management.” RCRA was amended by the Hazardous and Solid Waste Amendments of 1984. RCRA set standards for the reduction or elimination of hazardous waste generation and the treatment, storage, or disposal of waste that had already been generated “so as to minimize the present and future threat to human health and the environment.” The Agency oversees the proper management of non-hazardous solid waste and also the national “cradle-to-grave” management system used to track and control hazardous wastes, established by RCRA. Although entirely a land-based program, RCRA could be an important part of controlling or preventing sources of fugitive emissions.

## TOXIC SUBSTANCES CONTROL ACT (TSCA)

This 1976 Act gives EPA the authority to regulate and control existing and new chemical substances and mixtures that pose a risk to human health or the environment. Two of four amendments address toxic pollutants.

Under Title I, *Control of Toxic Substances*, EPA can regulate the manufacture, processing, use, distribution in commerce, and disposal of chemical substances and mixtures and, if necessary, limit, prohibit, or ban chemical substances and mixtures that pose imminent hazards to human health or the environment. PCBs are presumed to pose such risks, and EPA is given the authority to prohibit the manufacture, processing, use, or distribution in commerce of any PCBs. Under Title I, EPA must compile and maintain an inventory of over 60,000 chemical substances, including those identified as priority pollutants under the Binational Toxics Strategy.

Under Title IV, *Lead Exposure Reduction (1992)*, EPA is required to promulgate final regulations governing lead-based paint activities, and to identify dangerous levels of lead in order to classify hazards in lead-based paint, and lead-contaminated dust and soil (P.L. 94-469).

The U.S. EPA already has in place several programs to promote binational, federal and state coordination for management of toxic air contaminants.

## BINATIONAL TOXICS STRATEGY (BTS)

In 1997, the United States and Canada signed the Binational Toxics Strategy (BTS) to fulfill the Great Lakes Water Quality Agreement's ultimate goals of zero discharge and virtual elimination (BTS, 1998). The BTS represents a collaborative effort of the U.S. and Canadian environmental agencies, Great Lakes states, Province of Ontario, tribes and First Nations, and Great Lakes Basin stakeholders to restore the health of the Great Lakes waters.

The BTS identified a dozen "Level 1" priority pollutants for virtual elimination. As part of their efforts to control Level 1 substances, the BTS set a challenge to cut in half national air emissions and releases of mercury to Great Lakes waters by 2006. Additional substance-specific challenges set by the BTS are listed in Table 2. Ten more "Level 2" substances are identified as targets for reduction or elimination through pollution prevention and other supported government programs (BTS, 1997).

Level I pollutants	Challenges under the BTS
Aldrin/dieldrin Chlordane DDT (DDD & DDE) Mirex Octachlorostyrene Toxaphene	In U.S. <ul style="list-style-type: none"> <li>Confirmation of discontinued use or release from sources that enter the Great Lakes Basin.</li> </ul> In Canada <ul style="list-style-type: none"> <li>Confirmation of discontinued use, generation or release from Ontario sources that enter the Great Lakes.</li> </ul>
Benzo(a)pyrene and Hexachlorobenzene	In U.S. <ul style="list-style-type: none"> <li>Reduction in releases that are within or have the potential to enter the Great Lakes Basin.</li> </ul> In Canada <ul style="list-style-type: none"> <li>90 percent reduction in releases from Great Lakes Basin sources.</li> </ul>
Alkyl-lead	In U.S. <ul style="list-style-type: none"> <li>Confirmation of discontinued use in automotive gasoline.</li> <li>Support reductions from other sources.</li> </ul> In Canada <ul style="list-style-type: none"> <li>90 percent reduction in use, generation or release.</li> </ul>
Mercury and its compounds	In U.S. <ul style="list-style-type: none"> <li>50 percent reduction in deliberate use.</li> <li>50 percent reduction in release from human sources.</li> </ul> In Canada <ul style="list-style-type: none"> <li>90 percent reduction in the release, and where warranted the use, from human sources in the Great Lakes Basin.</li> </ul>
PCBs	90 percent reduction of high-level PCBs used in electrical equipment and proper disposal (U.S.) or destruction (Canada).
Dioxins and furans	In U.S. <ul style="list-style-type: none"> <li>75 percent reduction in total releases</li> </ul> In Canada <ul style="list-style-type: none"> <li>90 percent reduction from Great Lakes Basin sources</li> </ul>

Table 2: Reduction or elimination challenges set under the Binational Toxics Strategy for Level I pollutants (BTS, 1997).

Atmospheric inputs are addressed specifically in the BTS as a challenge to the two countries to assess atmospheric inputs of the Strategy substances into the Lakes, toward the goal of clarifying the contribution and significance of long-range sources. If long-range transport is confirmed as a contributing factor in the Great Lakes, the governments have committed to work, through the BTS and other international frameworks, to reduce releases of these substances. As part of this commitment, U.S. EPA and Environment Canada agreed to coordinate to identify sources and collaborate on emissions control programs, to maintain monitoring stations, to continue to research atmospheric deposition, and to conduct an assessment of long-range transport from world-wide sources (BTS, 1997).

In early 1999, U.S. EPA Administrator Carol Browner confirmed a commitment to the BTS when she advised all EPA program offices to incorporate BTS goals and workplans into their core programs and recommitted the Agency to virtually eliminate toxic substances that build up in the Great Lakes food chain (GLU, 1999).

### **PERSISTENT BIOACCUMULATIVE TOXICS STRATEGY (PBT STRATEGY)**

In its PBT Strategy, the U.S. EPA strives to better integrate its statutory authorities and divisions at the national and regional levels in a multi-media approach to controlling toxic contaminants that move easily among air, water, and land (U.S. EPA, 1998e). The strategy focuses primarily on the "Level I" or "priority" pollutants listed in the BTS.

The PBT strategy has four elements:

1. Develop and implement national action plans for the priority pollutants using all available tools, including pollution prevention, to reduce risk;
2. Screen and select more priority PBT pollutants;
3. Prevent new PBT pollutants from entering commerce; and
4. Assess progress by linking actions to environmental results, as in the new national "action plan" for mercury reduction.

The PBT Strategy is linked with the BTS by selecting substances in addition to those in "Level I" and providing a basis for BTS implementation decisions on "Level II" substances (U.S. EPA, 1998e). While the BTS scope is national for air but regional for water, the PBT Strategy coverage is national for all media. In addition, the BTS highlights innovations by stakeholders and the PBT coordinates research on new technologies. The PBT also builds on the BTS use and release tracking data and aligns progress tracking more closely with measures of human and ecological effects.

The Agency created the PBT Strategy partly to advance in areas where the BTS was not yet progressing. However, the goal of the PBT is not virtual elimination. In contrast, U.S. EPA has framed PBT's primary goal as the reduction of risk. The strategy appears to rely on voluntary measures and focuses more on developing plans than on implementing actual control or management programs.

## **U.S. EPA'S MERCURY ACTION PLAN**

Since announcing its PBT strategy in 1998, U.S. EPA has committed to establishing an integrated action plan for each of the targeted PBTs of concern. The first, and the only, action plan thus far has been proposed for mercury (U.S. EPA, 1999e). This plan offers a multimedia approach based upon an analysis of current regulations, initiatives and programs that manage and control mercury. Based upon this review of Agency options, ten key action items were proposed:

1. Promulgate air regulations.
2. Link air emissions to water quality impacts to prioritize control actions.
3. Revise mercury water quality criteria.
4. Pursue voluntary reductions in industrial use and releases.
5. Reduce reporting threshold for mercury releases under EPCRA.
6. Develop disposal options for hazardous wastes containing mercury.
7. Give high priority to mercury in international efforts.
8. Develop a mercury research/monitoring strategy and implement an EPA mercury research/monitoring plan.
9. Develop options for addressing the mercury problem of abandoned mines.
10. Support regional, state and local actions to reduce mercury.

Since proposing this plan, several key actions have been implemented. These include lowering the reporting threshold for mercury, including additional sources in the reporting requirement, drafting a mercury research strategy, and signing voluntary agreements with several source sectors (U.S. EPA, 1999e).

## **LAKEWIDE MANAGEMENT PLANS**

The Great Lakes Water Quality Agreement, Annex 2, calls on the United States and Canada to develop Lakewide Management Plans (LaMPs) for each of the Great Lakes. LaMPs are intended to identify critical pollutants and develop plans for reducing them in order to restore beneficial uses to the lakes. The lists of critical pollutants vary from LaMP to LaMP as do the strategies for addressing them.

## **33/50 PROGRAM**

This was a voluntary partnership launched in 1988 between U.S. EPA and 1,300 companies required to report toxic chemical releases, targeting 17 chemicals reported to TRI. Using the 1988 TRI data as a baseline, the program sought to achieve a 33 percent national reduction in releases and transfers by 1992 and a 50 percent reduction by 1995. Companies were asked to make their own goals, with some sources pledging a 100 percent decrease in releases and transfers for the 17 chemicals they reported to TRI. EPA encouraged companies to meet these commitments through pollution prevention whenever possible (U.S. EPA, 1999b).

The 1995 goal translated to a reduction of 750 million pounds from the nearly 1.5 billion pounds reported to TRI for the 17 chemicals in 1988. The goal was surpassed, with the national releases and transfers actually declining by 824 million pounds (55 percent). The program ended in 1996 but the trend continued for the 1996 TRI data. In general, companies enrolled in the 33/50 program reduced emissions at faster rates than other companies, and with greater reliance on source reductions (U.S. EPA, 1999b).

While most U.S. laws and regulations apply to major sources of air pollution, U.S. EPA has delegated enforcement and implementation authority to the states. Along with these authorities, EPA usually gives grants to the states to carry out implementation and enforcement activities. Federal rules do not preclude states from electing to establish more protective rules or regulating additional sources that may not be covered by federal programs. While this discretionary authority is often severely restricted by state legislation, unique regulatory, voluntary and research initiatives have been initiated in the Great Lakes states that could play a critical role in increasing the knowledge base and activities needed to reduce the deposition of toxics to the Great Lakes.

## **REGULATORY PROGRAMS**

As with federal laws, numerous state statutes, covering various media, pollutants and sources, address the release into the environment of pollutants of concern. These regulations target hazardous materials handling and disposal, waste disposal and planning, contaminated sites, water quality, wetlands, pesticides and air pollution. The following discussion focuses on activities related specifically to air pollution and deposition to the Lakes.

### **1 CLEAN AIR ACT STATE IMPLEMENTATION PLANS**

Many provisions of the Clean Air Act require that states submit State Implementation Plans (SIPs) to the U.S. EPA for review and approval. Some provisions of the Act, such as requirements for nonattainment areas, entail numerous submittals. Other provisions are more straightforward, calling for plans demonstrating that legal authority and resources are in place to allow state enforcement of federal programs such as the MACT standards. All these submittals, however, allow for public and Agency review and ensure that a defined set of requirements is federally enforceable.

The U.S. EPA sets NAAQS standards to protect human health for the criteria pollutants. States have leeway to decide how to control local pollution sources to meet the federal standards or to meet stricter state standards. The means of control are specified in individually tailored SIPs that are subject to federal review and approval. SIPs can include monitoring plans, emissions data, enforceable emission limitations, and schedules and required resources for attaining compliance with the standards (U.S. EPA, 1998d).

SIPs for nonattainment areas must include provisions for (1) application of reasonably available control technology (RACT) for existing sources, (2) plans for incremental reduction in air emissions, (3) an inventory of current emissions, (4) permit limits for new and modified sources, and (5) contingency measures. A state that fails to submit a SIP or to correct a deficient SIP by a specified deadline is subject to sanctions. Conditional approval of a SIP can be granted if the deficiencies are minor and corrected within a year (U.S. EPA, 1998d).

Collaborative efforts have grown out of SIP requirements in the Northeastern U.S. and Lake Michigan states. In the Lake Michigan area, ozone nonattainment SIPs have presented an opportunity for states to collaboratively develop programs and leverage resources. For example, the requirement for a photochemical assessment monitoring system network (PAMS) was jointly developed and submitted by the states of Michigan, Indiana, Illinois and Wisconsin. This program is a model example of how states can work together to address regional air quality problems. The resulting PAMS network serves the needs of a multi-state severe nonattainment area for ozone and includes a monitor in a downwind state not subject to the PAMS requirement.

Downwind states and other local units of government can also petition U.S. EPA for additional SIP requirements. The Clean Air Act in sections 110 and 126 allows U.S. EPA to force other states or sources to reduce pollution that is transported and interferes with local efforts to attain air quality standards.

## **2 STATE AIR TOXIC RULES AND PROPOSALS**

State specific regulations addressing air toxics can be promulgated by the states or states can regulate air toxic emissions through enforcement and implementation of federal rules, regulations and permits. The Great Lakes states rely primarily on federal regulations but some states have additional regulations. For example, Illinois EPA is developing an inventory of HAPs for the purpose of exploring the need to develop additional state rules and has incorporated a list of chemicals known to be problematic to the Great Lakes/ Great Waters, as well as pollutants identified in the Clean Air Act, into the state list of "toxic air contaminants."

Both Michigan and Wisconsin have state air toxics regulations with similar benefits and shortcomings in relation to addressing the problem of deposition of toxics to the Great Lakes. Benefits include a more comprehensive list of pollutants than covered individually by any federal environmental statute, the potential to reduce or regulate emissions from a greater number of sources, the opportunity to collect data from individual sources, a higher level of pollution control for some facilities, and a potentially more dynamic means of modifying permissible emission limits than available through federal programs. The major shortcomings of these programs include case-by-case permitting (as opposed to permitting based upon total emissions for the airshed) and establishing individual pollutant limits that do not consider chemical interactions or cumulative effects. Still, similar programs in all of the Great Lake states may prove critical to both building the inventories required and controlling emissions necessary to fully address the problem of deposition of air toxics to the Great Lakes.

## **VOLUNTARY PROGRAMS AND INITIATIVES**

The Great Lakes states have acknowledged, "that the atmosphere is a significant source of the total balance of pollutants entering the Great Lakes system" (Council of Great Lakes Governors, 1986). This concern has led to several initiatives recently launched by these states. U.S. EPA's Mercury Action Plan has pledged to support several state initiatives, including task forces and innovative local and regional efforts to address the deposition of mercury to waterbodies. Additional representative state initiatives to address other contaminants are presented below.

## 1 MERCURY REDUCTION GOALS

Several of the Great Lakes States have initiated mercury reduction programs. Minnesota's program has been highlighted as one of the innovative state programs. Wisconsin proposed its own strategy after acting as a participant in Minnesota's task force. Michigan's mercury pollution prevention program offers an example of a state-led voluntary initiative.

In its effort to set mercury reduction goals, Minnesota established and actively supported a mercury task force. This group represented a broad range of stakeholders and even sought input and participation from neighboring states. The group began its work by conducting an extensive inventory of sources and then explored options for reducing emissions, issuing a set of recommendations on reduction goals. The state of Minnesota has set a goal to reduce mercury contamination by reducing the release of mercury into the air and water of the state by 60 percent from 1990 levels by December 31, 2000, and by 70 percent from 1990 levels by December 31, 2005. The goal applies to the statewide total of releases from existing and new sources of mercury.

Minnesota has a parallel effort under development in the state, an emission "cap and trade" program, which is considered to be innovative and integral to achieving the State's mercury goals. A proposal to establish a program for major sources, including utilities, non-utility boilers and chlor-alkali facilities, has been introduced into the last two legislative sessions.

While contributing to the ongoing dialogue in Minnesota, Wisconsin parties have also proposed their own state program. The Wisconsin Department of Natural Resources (WDNR) recently proposed a *Recommended Strategy for Mercury Reductions to the Atmosphere in Wisconsin*. The strategy calls for the establishment of a mercury cap, trading, banking and offset program that would achieve a 20 percent reduction in air emissions by 2005, a 35 percent reduction by 2010 and a 50 percent reduction by 2015. The 35 percent and 50 percent reduction goals would be reassessed in 2005, taking into consideration new scientific and technology developments, including the regional TMDL, and caps would be adjusted if appropriate. The baseline, from which total and individual source annual mercury emission caps would be calculated, is the average annual emissions of mercury over the three year period preceding establishment of the mercury cap program. Four strategy elements are included: 1) a mercury cap and trade program, 2) development of a state-wide TMDL, 3) establishment of a Mercury Reduction Fund and 4) promotion of regional and national actions to address the problem of mercury being transported into Wisconsin. This strategy recognizes the need for both local action and new regional and national efforts to address the problem of toxics deposited to waterbodies in the region (Wisconsin Department of Natural Resources, 1999).

In the mid-90's, Michigan established a task force to study and make recommendations to address mercury emissions. The effort was launched to address concerns about the number of inland lakes subject to fish consumption advisories and the recognition that the primary source of mercury contamination was air deposition. The effort resulted in the 1996 report of the Mercury Pollution Prevention Task Force, chaired by Michigan Department of Environmental Quality, and several subsequent voluntary initiatives to reduce emissions. These efforts targeted the auto industry, dental offices and on-site usage of mercury containing devices at Detroit Edison and Consumers Energy.

## **2 "CLEAN SWEEP" PROGRAMS**

Another program that several Great Lakes states have implemented is the "Clean Sweep" collection program. These voluntary programs are offered on a periodic basis to collect hazardous household and commercial products. State Departments of Agriculture have demonstrated success in targeting agriculture facilities and collecting banned or problematic materials that could have otherwise been improperly disposed of, which could result in contamination and/or volatilization of problematic pollutants, such as mirex and mercury.

Another "Clean Sweep" program was targeted to small businesses and local governments in Cook County Illinois in 1999. While aiming to collect both PCB and mercury containing wastes and materials, the program also made public education of local officials a priority. In addition to environmental agencies' sponsorship, this program benefited from additional support from the business community and electric utilities.

## **3 SPECIAL TOXICS PROGRAMS**

As with any program that regulates toxics based upon risk due to ambient exposures, risk assessment and assumptions play a critical role in determining emission limitations. In order to build in an additional level of protection for pollutants with high-risk uncertainty factors, Wisconsin's air toxics program has established a "watch list" of pollutants of concern. Facilities that emit these pollutants are then targeted for special attention and technical assistance under the state's pollution prevention program. Although no Great Lakes pollutants of concern are on the watch list, the concept offers an innovative model for addressing pollutants that are problematic to the Great Lakes. A similar strategy based upon Level I & II substances, or total exposure models, could be developed that is voluntary in nature, achieves significant reductions in emissions and is within bounds of legislative restrictions.

## **RESEARCH EFFORTS AND STATE PARTNERSHIPS**

Just as the number of voluntary and proposed initiatives reflects a concern about critical pollutants at the state level, so too does the commitment of scarce state resources to research activities reflect an acknowledgement that additional understanding must be gained and new strategies developed to address the problem of air toxics. Likewise, the working relationships among the Lake Michigan States have evolved through efforts to leverage resources and develop regional (multi-state) solutions to air quality problems. While major research efforts specific to deposition of toxics are extensively discussed in Chapter 2, several other research, modeling or monitoring activities are discussed below.

## **1 CHICAGO CUMULATIVE RISK INITIATIVE**

The Chicago Cumulative Risk Initiative (CCRI) is a unique partnership between U.S. EPA Region 5, EPA Headquarters, Illinois EPA, Cook County Department of Environmental Control, Chicago Department of Environment, Illinois Department of Health, Indiana Department of Environmental Management, Indiana Department of Public Health, Argonne National Laboratories, and community groups within Cook County, Illinois, and Lake County, Indiana.

The project is divided into four phases. Phase I involved the development of a loading profile, which summarized all available emissions and environmental data in all media for the two counties. Phase II consisted of a workshop to educate and involve the community. Currently phase III is under way. This crucial phase in the project involves developing cumulative risk methodology for air media by carrying out a hazards screening study. Phase IV will entail toxics reduction implementation projects. It is expected that many different organizations will be able to use the information collected in all phases of the project to improve the ability to address urban environmental pollution.

## **2 AIR MONITORING PROGRAMS**

Both Michigan and Indiana have dedicated new resources to monitoring of toxic contaminants. Michigan has responded to recent findings of unusual ambient levels of DDT in the Muskegon area by launching a monitoring program to identify the source(s) of continuing emission of this banned substance. Similarly, Indiana recently expanded its air toxic monitoring program. The state is currently using mobile monitors to collect data for the purpose of designing a permit network in the Lake Michigan region. These efforts could significantly contribute to a better understanding of ambient levels, transport and sources of pollutants of concern. In addition, urban air toxics monitoring programs are being undertaken in several cities in the Great Lakes region, including Detroit and Cleveland, in partnerships with industry, citizens and county, state and federal agencies.

## **3 LAKE MICHIGAN AIR DIRECTORS CONSORTIUM**

The Lake Michigan Air Directors Consortium (LADCO) was established in 1990 by the states of Illinois, Indiana, Michigan, and Wisconsin. LADCO provides technical assessments for and assistance to its member states on air quality and provides a forum for its member states to discuss air quality issues. LADCO's major pollutants of concern are ozone, fine particulate matter and their precursors; however, problems related to other pollutants such as toxics would be assessed at the direction of the member states. LADCO's primary geographic focus is the area encompassed by its member states and any areas that affect air quality in its member states. LADCO's goals are achieved through work in three areas: photochemical modeling, emissions modeling, and coordination of ozone and particulate monitoring in the Lake Michigan area (LADCO, 1999).

This overview of federal, state and regional efforts shows that there are numerous tools to address a spectrum of pollutants in many media – land, sediments, water and air. It also demonstrates that policy makers and regulators at the federal and state levels have acknowledged that toxic pollutants are a problem in the Great Lakes and atmospheric deposition continues to contribute to this problem. With the possible exception of mercury initiatives, however, none of these efforts or regulatory authorities has resulted in an integrated, multimedia strategy for either achieving committed goals such as virtual elimination or defining reductions in emissions necessary to reverse the cycle of continued deposition of toxics to the Great Lakes.

Much of the criticism for the lack of comprehensive, multimedia strategies for addressing pollutants of concern has been focused on the inconsistencies of lists of pollutants established in environmental statutes (Dernbach, 1997). Some BTS Level I and II pollutants are not even considered by critical federal and state environmental regulations. While some of the inconsistencies can be attributed to the uniqueness of specific pollutants to individual media or sources, this disjointed defining of what are the critical pollutants is problematic.

Regulated businesses often complain of increased compliance costs and uncertainties associated with a “pollutant *du jour*” approach to control. A recent example is the complaints voiced by some electric utilities that the proposed rules to address NO<sub>x</sub> emissions would confound opportunities to simultaneously address mercury emissions.

In addition, narrowly focused research and regulatory efforts forgo important opportunities to develop more cost effective, comprehensive emission reduction strategies. While the ozone planning efforts of LADCO serve as an example of the benefits of leveraging state resources to develop state-of-the-art modeling tools, establish emission inventories, and conduct technical and policy analyses, even more could have been accomplished by simultaneously targeting critical air toxics in with the ozone efforts.

Despite the policy shortcomings for atmospheric deposition, this review of state and federal efforts offers some valuable lessons. Collectively the states have demonstrated a willingness to develop a spectrum of innovative programs that either increases understanding about transport and deposition of toxics or seeks to reduce emissions of pollutants of concern. Despite differences in state political and regulatory environments, many of these efforts could be rolled out to neighboring states. Using the Lake Michigan region as an example, each of the four states has developed an expertise in, and appreciation of, the regional nature of air pollution. Each has recognized that toxics being deposited into the Lake is a continuing threat to a critical resource and has committed to developing solutions for the problem of atmospheric transport and deposition of toxics to the Great Lakes.

# 4



## MAJOR INTERNATIONAL FORUMS FOR AIR DEPOSITION AND TRANSPORT ISSUES

As has been made clear throughout this report, toxic contaminants can travel great distances through the atmosphere, ignoring political boundaries. Although the United States has more to do in its efforts to reduce and eliminate air toxics, if the problem is to truly be solved it must be with the cooperation and coordination of both neighboring and distant nations. Currently toxic contamination and its transport via the atmosphere are being addressed in several international forums, some of which have more direct impact upon the Great Lakes region.

This chapter describes some of the major international forums where reduction of use or elimination of toxic contaminants is being sought. While many more non-governmental or smaller consortium efforts exist, the forums presented here are the major efforts that include air depositional issues.

The International Joint Commission's (IJC) oversight of the implementation of the Great Lakes Water Quality Agreement between Canada and the United States provided the context from which the Great Lakes community emerged. The IJC is a binational commission that has regulatory authority only over certain water level and flow matters. Since the GLWQA was first signed in 1972, the IJC's primary function has been to advise the governments about progress, new problems and emerging issues. The agreement's additional requirement, that the IJC provide information to the public, led to expansion of efforts to encourage public involvement, especially in the 1970s and 1980s (Botts and Muldoon, 1997).

In developing reports to the federal governments, the IJC depends on advisory boards, covering both scientific and research issues and regulatory programs of the federal, state and provincial governments, and on results of public participation activities. Scientists, all levels of government agency staff, and leaders of nongovernmental environmental organizations exchange information as they participated in the IJC's advisory boards, work groups and task forces on specific topics and issues. As research uncovered ways to deal with known problems and revealed new ones, including toxic contamination, environmental organizations joined the IJC in informing the general public in the Great Lakes basin. With public concern leading to calls for action by governments, environmental groups also worked with state legislators and members of Congress as well as agency staffs to secure funding and develop regulatory measures.

The result of the expansion of political power by the Great Lakes community is that several of the current major legislative actions and policies concerned with toxic contaminants, in both the U.S. and Canada, originated as initiatives for the Great Lakes. Examples include the expansion of the section on toxic contaminants in the 1990 Clean Air Act and the Great Waters program requiring reports to Congress on actions to implement controls and reduction of use (Botts and Muldoon, 1997).

In the past, the IJC has not sought to deal directly with the contributions of long-range transport to atmospheric deposition of contaminants because the jurisdiction of the GLWQA is limited to the watershed. In addition, until recently, the governments of Canada and the U.S. limited the role of the IJC to investigating issues of water quality. For example, the only function of the IJC under an agreement on acid rain was to hold an annual public hearing and report its results to the governments (IJC, 1991).

Currently the International Air Quality Advisory Board (IAQAB) of the IJC is engaged in the study and modeling of atmospheric deposition to the Great Lakes. This effort has supported the development and demonstration of a powerful and efficient methodology for identifying specific sources and source regions of selected persistent toxic air emissions which are deposited in the Great Lakes. As a result of its recent research, the IAQAB is recommending that the IJC actively advocate, to the U.S. and Canadian governments, the coordinated reexamination of current control programs and identification of additional actions necessary to address the goals contained in the GLWQA and the associated BTS, in order to reduce inputs of persistent toxic substances (IJC, 1998; IJC, 1999).

The trilateral Commission on Environmental Cooperation for North America (CEC) was established under a side agreement to the North American Free Trade Agreement (NAFTA) that was adopted by the United States, Canada and Mexico in 1994. Its creation was a response to widespread concerns about potential environmental degradation that could result from trade liberalization.

The CEC is not required to limit its attention to issues directly related to immediate trade activities but sets its own agenda to consider threats to environmental and human health of continental significance. The agency has three principal components: 1) a council of the highest level environmental officials from each country has the primary responsibility for governance; 2) a joint secretariat for the commission is located in Montreal, Quebec; and 3) a Joint Public Advisory Committee (JPAC) includes five members from each country. CEC efforts to engage environmental groups in its affairs have had limited success in the United States. The agency and its activities are largely unknown to the general public (Botts and Muldoon, 1997).

The major focus of the CEC on persistent, bioaccumulative chemicals, including air deposition and long-range transport, began with a 1995 resolution that called for Sound Management of Chemicals in North America. Borrowing from processes of the GLWQA, the efforts include development of North American Remedial Action Plans for several substances (thus far mercury, chlordane, DDT and PCBs). Specific goals include virtual elimination of PCBs in the environment. The goal for DDT is elimination of illegal uses and gradual reduction of use for malaria control. For chlordane, the goal is the phasing out of use, and for mercury, the minimization and ultimate prevention of releases into the environment from human uses (CEC, 1998; CEC, 1999).

The CEC's related project on Continental Pollutant Pathways addresses the problem of long-range transport through the atmosphere of toxic contaminants across national boundaries. Andrew Hamilton, chief scientist for the Secretariat and former chief scientist for the Canadian office of the IJC, instigated a scientific panel to consider sources, pathways and effects of air pollution. Its conclusions reinforced the need for "an effective collaborative mechanism (or mechanisms) with the authority, expertise and motivation. . .to ensure that the continental pathway issue becomes, and remains, a significant trinational priority" (CEC, 1997).

The question remains how to translate these goals and plans into concrete action. The CEC must contend with great distances and even more differences in population size, economic capacity, language and culture among its members than the IJC. In one example, the CEC was assisted by the World Health Organization in its efforts to promote alternatives to DDT for malaria control, in Mexico in recognition of that country's special needs.

Like the IJC, the CEC has no regulatory authority and depends on action by the national governments for implementation. Government action, especially in democracies, depends on the political will of citizens. The CEC has instituted various ways to provide funding support for nongovernmental participation in its activities, with little outcome in the United States. Very few participants from the U.S. took advantage of available travel funds to attend the June 1999 annual meeting of the Council and the Joint Public Advisory Committee in Banff National Park in Canada. As under the GLWQA, ultimately results of CEC initiatives will depend on political will developed through engagement of environmental groups and the public as well as scientists and government agency staffs.

### III Persistent Organic Pollutants (POPs) Negotiations

When the 34 members of the United Nations Economic Commission for Europe (UN/ECE) signed the Convention on Long Range Transboundary Air Pollution in 1979, they focused on acid rain (UN/ECE, 1979). The Convention had been drafted after scientists demonstrated the link between sulphur emissions in continental Europe and the acidification of Scandinavian lakes and after studies confirmed that air pollutants could travel several thousand kilometers before deposition and damage occurred.

The Convention was the first internationally legally binding instrument to deal with problems of air pollution on a broad regional basis. Many extensions to the original convention have been made or are underway, including additional protocols on sulphur, nitrogen oxides, heavy metals and ground-level ozone. Besides laying down the general principles of international cooperation for air pollution abatement, the Convention set up an institutional framework associating research and policy. A mapping program and five cooperative programs for assessing and monitoring the effects of air pollution are now in operation (UN/ECE, 1998).

Now this broad international agreement provides the framework for development of a binding global agreement on Persistent Organic Pollutants (POPs). This global effort to control POPs was launched in 1996 by the United Nations Environmental Program (UNEP) and progress appears to be underway. Negotiations on a preliminary draft began in Montreal in 1998 and continued with two sessions in 1999, in Nairobi, where 103 countries were represented, and later in Geneva, Switzerland. Another session took place in Bonn, Germany, in March 2000, and the final negotiations are scheduled for November 2000 in South Africa (UNEP, 1999).

The three categories of listed substances in the POPs negotiations are pesticides, industrial chemicals and unintended but harmful byproducts. The pesticides include aldrin, chlordane, DDT, dieldrin, endrin, heptachlor, hexachlorobenzene, Mirex and toxaphene. The industrial chemicals are hexachlorobenzene and PCBs. The byproducts are dioxins and furans (UNEP, 1999).

Like the CEC initiatives, the prospective POPs accord relies heavily on information exchange but has even greater challenges in dealing with differences in economic capacity and knowledge, especially between the developing countries and the industrial nations. Developing countries are on the receiving end of the most severe and widespread contamination from POPs.

Much of the discussion in the ongoing meetings has been about the unequal capacity of the participating nations to act, similar to the international discussions on climate change. With toxic contaminants, as with reduction of greenhouse emissions, developing countries, participating in the POPs negotiations, generally do not feel that they should bear the burden of correcting problems resulting from technological developments in wealthier industrial nations (Weinberg, 1998).

In Africa, Asia and Eastern Europe as well as Mexico and Central America, pesticides are still seen as a means to prevent disease and increase food production. At the end of March 1999, an inventory of global capacity for disposing of PCBs was released as a step toward virtual elimination of this persistent, bioaccumulative toxic substance but there was no provision to pay disposal costs in countries where day-to-day human survival is the principal issue.

## IV Conclusions

Although the prospective POPs accord is referred to as “a legally binding instrument,” as with other international accords, actual implementation will depend on the legal authority and economic capacity within each of the parties that agree to it (UN/ECE, 1998). Signing of the accord commits the political leadership of each country to seek the authority needed to achieve the accord’s objectives. Again, the ultimate result will likely depend directly on support of citizens and on leadership by environmental organizations and agencies. Public education and information, as well as organizing citizen participations, will play a crucial role in influencing individual governments.

An International POPs Elimination Network (IPEN) has been established to promote information exchange among nongovernmental organizations (NGOs) in countries involved in the POPs negotiations. The IPEN network has been expanding rapidly since its inception and includes NGOs from at least 53 countries (IPEN, 1999).

The forums highlighted above in no way encompass the wealth of work and interest on this issue in the international arena. Many nongovernmental organizations are actively working to address toxic contaminants in air and water and smaller regional efforts address specific contaminants as the need arises. What is essential for success in achieving common environmental objectives across international boundaries is a sense of community that links action at the local level to leadership by national governments. Whether this vital context can be created is uncertain in the current binational, continental and global efforts to reduce use or eliminate toxic contaminants in the environment. While nongovernmental participation is increasing in some forums, the great distances and cultural divides make it difficult to maintain communication between global environmental communities, scientists and governmental staff working on the issues or actions being considered. Most importantly, among the public at large there is little of the awareness that might pressure governments to take action.

There is overlapping agreement in all these forums that reduction or elimination of use is needed for toxic organic chemicals and some heavy metals that tend to persist in the environment and bioaccumulate in living tissue. There is also substantial but not universal agreement on specific substances or compounds that require action. The thirteen chemicals included in POPs, in addition to a few heavy metals, make up the CEC’s list.

All of the substances on the POPs list were identified in the 1978 amendment to the GLWQA as “Hazardous Polluting Substances” that are known to have toxic effects on aquatic or animal life (IJC, 1978). Most of them are on the IJC list of 11 substances of most concern, developed in the 1980s to help prioritize actions. Since 1992, the IJC has several times recommended to the governments of Canada and the United States that use of these 11 substances of concern be “sunsetting,” that is, phased out. The recommendations have also urged that industrial processes should be altered to eliminate production of hexachlorobenzene, dioxins and furans as by-products.

In spite of the general international agreement on target substances, there is greater disconnect between the lists in various U.S. domestic laws, as described in the previous chapter. More harmony would be needed in U.S. regulations and laws to facilitate fulfillment of international obligations under a new POPs protocol and to achieve North American objectives under the CEC's Sound Management of Chemicals initiative.

The common issue for all international programs is how to achieve implementation at every level of jurisdiction, from local municipalities to states and provinces, to entire countries. Scientists, NGOs, industry and business leaders, government agencies and the public will all have to participate in order to build worldwide recognition of this issue. A global sense of community based on agreement to reduce and eliminate use of persistent, bioaccumulative toxic contaminants from the environment will ultimately eliminate air deposition and long-range transport.



## ISSUES AND RECOMMENDATIONS

The Delta Institute held two workshops on *Atmospheric Deposition of Toxics to the Great Lakes: Integrating Science and Policy* that provided an opportunity for scientists, state and federal agencies, environmental organizations, and industry to talk together about atmospheric deposition, both what is known through research to date and options for addressing the problem. The first workshop, held in May 1999, took stock of recent research. The second workshop, held in October 1999, focused on a set of issues that were prompted by research results:

- Setting priorities for research that are consistent with policy needs;
- Developing a mechanism to collate, integrate, and make research results available;
- Working through a case study that uses research results to create a policy strategy for reducing atmospheric deposition of toxics;
- Creating a coordinated national policy strategy for atmospheric deposition; and
- Working internationally to raise attention around the issue and advocate for coordinated international efforts.

Some general conclusions emerged from the workshops: The research cannot yet directly correlate a deposition event with a specific source, but process research and modeling for particular contaminants can point to source areas and source sectors. The research to date has been conducted in a piecemeal approach, leaving some specific questions important to policy makers unanswered. Nevertheless, enough research has been conducted to show that atmospheric deposition has to be addressed in order to meet water quality goals in the Great Lakes and to protect future generations from the accumulation of toxic contaminants in the ecosystem.

From the policy perspective, the long-range transport phenomenon presents significant challenges. It means that the Great Lakes region cannot address its contamination problems by only working within regional boundaries. Thus, the Great Lakes region has a direct stake in both national and international policies and programs that are intended to control or eliminate the use of toxic contaminants. Because the geographic scales are so large, it's hard to know where to begin – which of all the state, federal and international programs and policies should be emphasized? How can we know what policy initiatives will actually work? Overall, how can this work be manageable and effective?

Participants in the workshops helped to think through the issues and form recommendations for moving forward. The recommendations below reflect the ideas and input from workshop participants as well as other research conducted by the Delta Institute. The recommendations constitute a set of actions that, taken together, will create more momentum for action on atmospheric deposition regionally, locally, and internationally. In order to implement these actions, scientists, government, environmentalists, and industry will have to work together and coordinate to the greatest extent possible. The Delta Institute hopes that this document and the workshop recommendations will stimulate additional research, policy development, and advocacy, and that efforts to further integrate science and policy for the issue of atmospheric deposition will continue.

Investments in long-term monitoring, research into depositional processes, and modeling infrastructure have yielded important information that can be used to support policy responses to atmospheric deposition of toxic contaminants to the Great Lakes. In order to guide new scientific research and modeling efforts, it is necessary to clarify and prioritize the specific questions that have the most urgent policy implications. Decision is also needed as to the degree of scientific certainty required to substantiate policy action.

## RECOMMENDATIONS

- Review monitoring networks to determine where there is a need and/or opportunity to expand and integrate programs to better address national and North American air deposition issues. Evaluate the number and location of monitoring sites and the compounds monitored in the Integrated Atmospheric Deposition Network (IADN) and other monitoring networks to determine if enough data is being collected to evaluate local and regional response strategies. Identify where additional monitoring sites should be located, in order to assess pollutant loadings from urban areas.
- Investigate levels and transport pathways of substances of concern, such as trace metals, mercury, endocrine disruptors, and chemicals of potential emerging concern, such as alkyl-phenols, chlorinated paraffins, and brominated flame retardants, to see if they merit routine monitoring.

- Focus additional modeling resources on improving the Great Lakes Regional Air Toxics Emissions Inventory and the National Toxics Inventory, as well as a global inventory of current uses of the manufactured toxic, persistent, bioaccumulative chemicals of concern. Use newer monitoring techniques, land-use maps and Geographic Information System (GIS) technology to develop improved inventories, including smaller sources, area sources, natural emissions from the tree canopy, or re-emissions from soils due to past uses.
- Use receptor-modeling techniques to develop and incorporate better and more current source fingerprints and to help determine specific source data.
- Encourage industry to aid in developing better emission inventories and source fingerprints. Strategies to be considered include the exemption of participating industries from enforcement action for previous releases discovered by new source monitoring.

### **FIRST STEPS**

- Use existing Great Lakes policy committees and commissions to refine the policy questions around atmospheric deposition. The Integration Workgroup of BTS, the IJC and the CEC could consider these questions jointly and provide results to the scientific community to inform research needs.
- Convene scientists from existing Great Lakes scientific organizations, such as the International Association of Great Lakes Research (IAGLR), to prioritize research to respond to resulting policy questions. Summarize and make the results available to the Great Lakes scientific and policy communities and to funding agencies.

Open communication regarding policy initiatives and research findings is needed to avoid a long lag-time between scientific recognition of a problem and responsive action through policy changes.

### **RECOMMENDATIONS**

- Utilize science and policy forums, or if necessary create a new forum, to collate existing research, identify research gaps, and integrate research results into policy-making. Such a forum or entity could:
  - Increase communication between researchers, policy-makers, environmental organizations, the regulated community and the public.
  - Help prioritize research funding from a policy perspective.
  - Bring together research and monitoring tools, provide technical support for policymaking, and assist implementation of Lakewide Management Plans.
  - Consider how to apply studies and models that have been developed for one lake to other Great Lakes, such as the Lake Michigan Mass Balance Study.
  - Be a source of integrated research information to environmental organizations, industry, communities, and elected officials and assist in developing broad-based support for both the research and responses to it.

- Directly link government requests for proposals for air deposition research to applicable programmatic goals.
- Require primary investigators of government-funded research relating to the Great Lakes to give briefings to EPA employees and the public to help disseminate information about research findings.

#### **FIRST STEP**

- Conduct an implementation study through U.S. EPA's Great Lakes Program Office (GLNPO) to evaluate whether existing institutions could house such a forum, or whether creation of a new institution is necessary.
  - The study would determine how the entity would function, what the potential is for long-term financial support and how to balance any affiliation with federal programs with an inclusive stakeholder process.
  - Existing entities which could be considered include, but are not limited to, GLNPO, the Sea Grant Network, the CEC, IAGLR, the Council of Great Lakes Research Managers, the Northeast Midwest Institute, the Great Lakes Commission, IJC's Air Quality Board, the BTS, and the National Academy of Sciences.

The best way to understand how existing policy tools can most appropriately be used is to work through a regional strategy around a lake basin. Strategies developed for a specific region using real data will help establish policies for all the Great Lakes and will inform national policy-making on atmospheric deposition.

#### **RECOMMENDATIONS**

- Launch a policy development project that will result in a strategy for addressing atmospheric deposition using Lake Michigan as a test case region. The resulting strategy should articulate how data and models resulting from recent and on-going atmospheric deposition research in the Great Lakes can be used to support regulatory and non-regulatory approaches for reducing air emissions of Great Lakes pollutants. The strategy should contain specific recommendations for government and industry and will identify the certainties and uncertainties of scientific models and data and, as a result, show how to practically use available scientific tools to better identify sources areas and source sectors that should be targeted for reductions.
- The strategies and recommendations should be developed with the input of state agencies, GLNPO, leading scientists, environmental organizations, and interested Lake Michigan industry. These recommendations would help inform state activities related to air toxics. Further, the recommendations would identify the extent to which national and international programs must be relied on to reduce atmospheric deposition. The recommendations would help to inform national and international policy initiatives and could be incorporated into other Great Lakes Lakewide Management Plans.

**IV  
A National  
Strategy  
Linked to  
International  
Goals**

**FIRST STEP**

- Solicit the involvement and support of the IJC's Science Advisory Board and International Air Quality Advisory Board to assist in the effort as well as a Great Lakes foundation to provide funding support.

Achieving both domestic and international control of atmospheric deposition and long-range transport of toxic contaminants depends on a strong national strategy to coordinate efforts across all environmental media. Currently no single agency has the authority or capacity to address the multiplicity of sources and media interaction, making interagency coordination essential. Implementation of international goals requires an innovative, resourceful and definitive domestic program to serve as an example.

**RECOMMENDATION**

- Develop a national interagency multimedia strategy.
  - Use the next Great Waters report to Congress to develop a U.S. action agenda, linking agency efforts and building national consensus as to the depth and implications of the problem of air deposition of toxics.
  - Use the mandate of the Clean Air Act to protect human health to promote coordinated action by all federal agencies.
  - Clarify the relationship between the Great Waters program, the Urban Air Toxics Strategy, the Persistent Bioaccumulative Toxics Strategy and the Binational Toxics Strategy within EPA and in relation to other federal programs.
  - Highlight creative and voluntary local, state and regional examples in air toxics controls.
  - Solicit support from stakeholder groups for an interagency approach to control of air deposition of toxics.

**FIRST STEP**

- EPA officials with responsibility for the Great Waters and PBT programs should take the lead in developing a national integrated strategy concerning air deposition of toxic contaminants.

**V  
Global  
Community**

Experience in the Great Lakes demonstrates that the political will needed to provoke action by national governments depends on public demand for implementation. A strong sense of community, to push for and support government commitment, depends on information exchange between scientists, government agencies and nongovernmental leaders. The International POPs Elimination Network (IPEN) has been developed around the negotiations for the legally binding convention on Persistent Organic Pollutants (POPs) under the United Nations Environmental Program (UNEP). This network provides a foundation for additional efforts to create a lasting sense of community and build the political will for action, in North America or as a link between international regions.

## RECOMMENDATIONS

- Organize information exchange programs to build a more complete, lasting and inclusive community and network of nongovernmental organizations and other stakeholders around the world.
  - Use internet communications and new information technology to reduce costs and expand reach.
  - Support national and international Right-To-Know and any measures nationally or internationally which result in more comprehensive and useful public information on toxic releases.
  - Integrate information about air deposition and toxics into mainstream news media.
- Use this network to increase stakeholder participation in a range of governmental efforts.
  - Work with the CEC to encourage greater stakeholder participation in the Sound Management of Chemicals program.
  - Include all stakeholders in public meetings leading up to treaty negotiations. Emphasize alternative and effective pollution control techniques and local innovative efforts in air toxics control as important aspects of agreements forged.
  - Assist UNEP to inform and educate governments about toxic contaminants, local and long-range deposition issues, and appropriate controls.
  - Encourage innovative programs within the U.S. to provide assistance to reduce toxic contaminants in other countries, such as: Department of Commerce efforts at technology exchange, sister city exchanges, and technical assistance by U.S. Agency for International Development (USAID) for pollution prevention.

## FIRST STEPS

- Do a scoping study to explore the opportunities for building a lasting international network of NGOs, agencies and initiatives working on transboundary air toxics issues and the potential for using this network to promote effective policy and action for reducing the impacts of air deposition.
- Strengthen the international community by working with the CEC to foster more participation by nongovernmental groups in Canada, the U.S. and Mexico in the ongoing Sound Management of Chemicals program for North America.

## APPENDIX: WORKSHOP PARTICIPANTS

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