**Biological Markers of Human Exposure to Persistent Chemicals**
Indicator #4177

**Overall Assessment**

Status: **Mixed**
Trend: **Undetermined**
Primary Factors Determining Status and Trend: **At present, no routine Great Lakes human biomonitoring programs exist to monitor biological markers of human exposure to persistent chemicals. Individual epidemiological studies have been conducted or are on going in the Great Lakes to monitor specific populations. For this reason, the status is mixed and no trends can be determined regarding biological markers of human exposure.**

**Lake-by-Lake Assessment** No lake by lake assessments can be determined for this indicator. Instead, a list of ongoing research funded by ATSDR's Great Lakes Human Health Effects Research Program is provided according to the institution conducting the research.

**Lake Superior**

Status: Mixed
Trend: Undetermined
Primary Factors Determining Status and Trend: No ATSDR studies are currently being funded by any institution in the Lake Superior basin. However, basin wide studies do incorporate Lake Superior information.

**Lake Michigan**

Status: Mixed
Trend: Undetermined
Primary Factors Determining Status and Trend:
- Health Effects of PCB Exposure from Contaminated Fish (Susan L. Schantz, PhD University of Illinois at Urbana-Champaign)
- Organo-chlorides and Sex Steroids in two Michigan Cohorts (Janet Osuch, M.D., Michigan State University)
- A Pilot Program to Educate Vulnerable Populations about Fish Advisories in Upper Peninsula of Michigan (Rick Haverkate, MPH, Inter-Tribal Council of Michigan, Inc.

**Lake Huron**

Status: Mixed
Trend: Undetermined
Primary Factors Determining Status and Trend: No ATSDR studies are currently being funded by any institution in the Lake Huron basin. However, basin wide studies do incorporate Lake Huron information.

**Lake Erie**

Status: Mixed
Trend: Undetermined
Primary Factors Determining: No ATSDR studies are currently being funded by any institution in the Lake Erie basin. However, basin wide studies do incorporate Lake Erie

Status and Trend information.

**Lake Ontario**

| | |
|---|---|
| Status: | Mixed |
| Trend: | Undetermined |
| Primary Factors Determining Status and Trend | • Neuropsychological and Thyroid Effects of PDBEs (Edward Fitzgerald, PhD, State University of New York at Albany)<br>• PCB Congener and Metabolite Patterns in Adult Mohawks: Biomarkers of Exposure and Individual Toxicokinetics (Anthony DeCaprio, PhD State University of New York at Albany)<br>• Neurobehavioral Effects of Environmental Toxics - Oswego Children's Study: Prenatal PCB Exposure and Cognitive Development (Paul Stewart, PhD., State University of New York at Oswego) |

**Purpose**

•To assess the levels of persistent toxic substances such as methyl mercury, polychlorinated biphenyls (PCBs), and dichlorodiphenyl dichloroethenes (DDEs) in the human tissue of citizens of the Great Lakes basin; and

•To infer the efficacy of policies and technology to reduce these persistent bioaccumulating toxic chemicals in the Great Lakes ecosystem.

**Ecosystem Objective**

Citizens of the Great Lakes basin should be safe from exposure to harmful bioaccumulating toxic chemicals found in the environment. Data on the status and trends of these chemicals should be gathered to help understand how human health is affected by multimedia exposure and the interactive effects of toxic substances. Collection of such data supports the requirement of the Great Lakes Water Quality Agreement Annex 1 (Specific Objectives), Annex 12 (Persistent Toxic Substances), and Annex 17 (Research and Development).

**State of the Ecosystem**

***Women and Infant Child Study***

Data presented for this indicator are solely based upon one biomonitoring study that Wisconsin Department of Public Health (WiDPH) conducted in the basin. However, information on previous biomonitoring studies has been collected and is highlighted as a way to support the results of the WiDPH study and to illustrate previous and other ongoing efforts.

In the study conducted by WiDPH, the level of bioaccumulating toxic chemicals was analyzed in women of childbearing age 18 – 45 years of age. Hair and blood samples were collected from women who visited one of six participating Women Infant and Child (WIC) clinics located along Lake Michigan and Lake Superior. Levels of mercury were measured in hair samples, and mercury, PCBs, and DDEs were measured in blood serum. Awareness of fish consumption advisories was assessed through a survey.

There was greater awareness of fish consumption advisories in households in which someone fished compared to those in which no one did (Figure 1), and there was greater awareness of advisories from individuals with at least a high school education compared to those with only some high school or less education (Figure 2). More women in the 36-45 age category were aware of advisories than those of other ages, but there was less than 50% awareness in all age classes (Figure 3). More Asian women were aware of advisories that those of other races, and Hispanic women were least aware of the advisories (Figure 4).

Sixty-five hair samples were analyzed for mercury levels. The average mercury concentration in hair from fish-eating women was greater than that from non-fish eaters, ranging from 128% increase in women who ate few fish meals to 443% increase in those who ate several meals of sport-caught fish (Table 1).

Five samples of blood were drawn and analyzed for PCBs, DDEs and mercury levels. Although the small sample precludes definitive findings, the woman consuming the most fish (at least 1 sport-caught fish meal per week) had the highest concentration of DDE and the only positive finding of PCB in her serum. The woman consuming the fewest fish per year (6 – 18 fish meals) had the lowest concentration of DDE in her serum, and no PCBs were detected (Table 2).

***Effects on Aboriginals of the Great Lakes (EAGLE) Project***
A similar study was conducted by a partnership between the Assembly of First Nations, Health Canada and First Nations in the Great Lakes basin between 1990 and 2000 to examine the effects of contaminants on the health of the Great Lakes Aboriginal population. The Contaminants in Human Tissues Program (CHT), a major component of the EAGLE Project, identified three main goals: To determine the levels of environmental contaminants in the tissues of First Nations people in the Great Lakes basin; To correlate these levels with freshwater fish and wild game consumption; and, To provide information and advice to First Nations people on the levels of environmental contaminants found in their tissues.

The EAGLE project also analyzed hair samples for levels of mercury and blood serum for levels of PCBs and DDEs. A survey was also used to identify frequency of fish and wildlife consumption. However, the EAGLE project analyzed both male and female voluntary participants from 26 First Nations in the Great Lakes basin. The participants were volunteers, not selected on a random basis, and the project did not specifically target only fish eaters.

Key findings of the study included:
•Males consumed more fish than females and carried greater contaminant levels;
•No significant relationship was found between total fish or wild game consumption and the contaminant levels in the body;
•Levels of mercury in hair from First Nations people in the Canadian portion of the Great Lakes basin suggest the levels have decreased since 1970;
•PCBs and DDE were the most frequently appearing contaminants in the serum samples;
•Increased age of participants correlated with increased contaminant concentrations;
•Mean levels of PCBs reported in the EAGLE CHT Program were lower than or within the similar range of PCBs in fish-eaters in other Canadian health studies (Great Lakes, Lake Michigan, and St. Lawrence);
•Most people have levels of contaminants that were within Health Canada’s guidelines for PCBs in serum and mercury in hair;
•Levels of DDE were similar to levels found in other Canadian health studies; and
•There was little difference between serum levels of DDE in male and female participants.

***ATSDR-sponsored Studies***

The Agency for Toxic Substances and Disease Registry (ATSDR) and the U.S. Environmental Protection Agency (USEPA) established the Great Lakes Human Health Effects Research Program through legislative mandate in September 1992 to "assess the adverse effects of water pollutants in the Great Lakes system on the health of persons in the Great Lakes States" (ATSDR, http://www.atsdr.cdc.gov/grtlakes/historical-background.html). This program assesses critical pollutants of concern, identifies vulnerable and sensitive populations, prioritizes areas of research, and funds research projects. Results from several recent Great Lakes biomonitoring research projects are summarized here.

Data collected from 1980 to 1995 from Great Lakes sport fish eaters showed a decline in serum PCB levels from a mean of 24 parts per billion (ppb) in 1980 to 12 ppb in 1995. This decline was associated with an 83% decrease in the number of fish meals consumed (Tee et al. 2003).

A large number of infants (2716) born between 1986 and 1991 to participants of the New York State Angler Cohort Study were studied with respect to duration of maternal consumption of contaminated fish and potential effects on gestational age and birth size. The data indicated no significant correlations gestational age or birth size in these infants and their mother's lifetime consumption of fish. The researchers noted that biological determinants such as parity, and placental infarction and maternal smoking were significant determinants of birth size (Buck et al. 2003).

The relationship between prenatal exposure to PCBs and methylmercury and performance on the McCarthy Scales of Children's Abilities was assessed in 212 children. Negative associations between prenatal exposure to methylmercury and McCarthy performance were found in subjects with higher levels of prenatal PCB exposure at 38 months. However, no relationship between PCBs and methylmercury and McCarthy performance was observed when the children were reassessed at 54 months. These results partially replicated the findings of others and suggest that functional recovery may occur. The researchers concluded that the interaction between PCBs and methylmercury can not be considered conclusive until it has been replicated in subsequent investigations (Steward et al. 2003b).

Response inhibition in preschool children exposed parentally to PCBs may be due to incomplete development of their nervous system. One hundred and eighty-nine children in the Oswego study were tested using a continuous performance test. The researchers measured the splenium of the corpus callosum, a pathway in the brain implicated in the regulation of response inhibition, in these children by magnetic resonance imaging. The results indicated the smaller the splenium, the larger the association between PCBs and the increased number of errors the children made on the continuous performance test. The researchers suggest if the association between PCBs and response inhibition is indeed causal, then children with suboptimal development of the splenium may be particularly vulnerable to these effects (Stewart et al. 2003a).

Long term consumption of fish, even at low levels, contributes significantly to body burden levels (Bloom et al. 2005).

•American Indians were assessed for their exposure to PCBs via fish consumption by analysis of blood samples and the Caffeine Breath Test (CBT). Serum levels of PCB congers #153, #170 and #180 were significantly correlated with CBT values. CBT values may be a marker for early biological effects of exposure to PCBs (Fitzgerald et al. 2005).

•Maternal exposure via fish consumption to dichlorodiphenyl dichloroethylene (DDE) and PCBs indicated that only DDE was associated with reduced birth weight in infants (Weisskopf et al. 2005).

•The association between maternal fish consumption and the risk of major birth defects among infants was assessed in the New York State Angler Cohort Study. The results indicated mothers who consumed 2 or more fish meals per month had a significantly elevated risk for male children being born with a birth defect (males: Odds Ratio = 3.01, in comparison to female children: Odds Ratio = 0.73) (Mendola et al. 2005).

**Pressures**

Contaminants of emerging concern, such as certain brominated flame-retardants, are increasing in the environment and may have negative health impacts. According to a recent study conducted by Environment Canada, worldwide exposure to polybrominated diphenyl ethers (PBDEs, penta) is highest in North America with lesser amounts in Europe and Asia. Food consumption is a significant vector for PBDE exposure in addition to other sources. The survey analyzed PBDE concentration in human milk by region in Canada in 1992 and in 2002 and showed a tenfold increase in concentration in Ontario (Ryan 2004).

The health effects of contaminants such as endocrine disruptors are somewhat understood. However, there is little known about the synergistic or additive effects of bioaccumulating toxic chemicals. Additional information about toxicity and interactions of a larger suite of chemicals, with special attention paid to how bioaccumulating toxic chemicals work in concert, is needed to better assess threats to human health from contaminants in the Great Lakes basin ecosystem. ATSDR has developed 5 interaction toxicological profiles for mixtures of Volatile Organic Compounds, metals, pesticides and for contaminants found in breast milk and fish.

**Management Implications**

There have been many small-scale studies regarding human biomarkers and bioaccumulating toxic chemicals. However, to this date, there have been no large-scale or basin-wide studies that can provide a larger picture of the issues facing the citizens of the basin. It is important that those in management positions in Federal, State, Provincial, and Tribal governments and universities foster cooperation and collaboration to identify gaps in existing biomonitoring data and to implement larger, basin-wide monitoring efforts. A Great Lakes environmental health tracking program, similar to the Center for Disease Control (CDC) Environmental Health Tracking Program, should be established by key Great Lakes partners.

**Comments from the author(s)**

A region-specific biomonitoring program, similar to the CDC's National Health and Nutrition Examination Survey (NHANES) project could provide needed biomonitoring information and fill in data gaps.

It is important that additional studies assessing the levels of bioaccumulative toxic chemicals through biomarkers be conducted on a much larger scale throughout the basin. In order to build up on the WIC study it would be important for a question about fish consumption from restaurants be included in future surveys. Because all states have WIC clinics, or something similar, the WiDPH monitoring tool could be implemented basin-wide.

In the future, ATSDR's Great Lakes Human Health Effects Research Program plans to continue to provide research findings to public health officials to improve their ability to assess and evaluate chemical exposure in vulnerable populations. ATSDR also plans to focus on research priorities of children's health, endocrine disruptors, mixtures, surveillance, and identification of biomarkers, i.e., exposure, effect, and susceptibility. In addition, the program will use established cohorts to monitor changes in body burdens of persistent toxic substances and specified health outcomes, and develop and evaluate new health promotion strategies and risk communication tools.

**Acknowledgments**
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**List of Tables**



**List of Figures**

**Last updated**
SOLEC 2006

| Fish meals/3 months Sport-caught (Y/N) | Min (UG/G) | Ave (UG/G) | Max (UG/G) | N | Ave no. fish meals |
|---|---|---|---|---|---|
| 0 | 0.00 | 0.07 | 0.24 | 14 | 0 |
| 1-9 (N) | 0.04 | 0.16 | 0.59 | 28 | 2.3 |
| 1-9 (Y) | 0.03 | 0.30 | 0.99 | 7 | 2.4 |
| 10+ (N) | 0.04 | 0.33 | 1.23 | 7 | 12.8 |
| 10+ (Y) | 0.09 | 0.38 | 1.53 | 9 | 8.11 |

**Table 1**. Concentration of mercury in hair samples from women who consumed sport-caught or not sport-caught fish during the previous three months.
Source: Wisconsin Department of Health and Family Services

| ID | Fish Meals | PCB | DDE | Mercury |
|---|---|---|---|---|
| 100 Sheb | Commercial = 1/week<br>Sport Caught = none | 0.0 | 0.34 | <5 mcg/L |
| 100 Sup | Commercial = 5/month<br>Sport Caught = 30/year | 0.0 | 0.40 | <5 mcg/L |
| 100A GB | Commercial =<6/Year<br>Sport Caught = 6-12/Year | 0.0 | 0.25 | <5 mcg/L |
| 105 GB | Commercial = 1/week<br>Sport Caught = 1/week | 0.4 | 1.20 | <5 mcg/L |
| 101A GB | Commercial = 4/month<br>Sport Caught = 2/month | 0.0 | 0.49 | <5 mcg/L |

**Table 2**. Number of fish meals consumed and concentration of PCBs, DDE and mercury in blood serum of 5 women who participated in the WIC study.
Source: Wisconsin Department of Health and Family Services

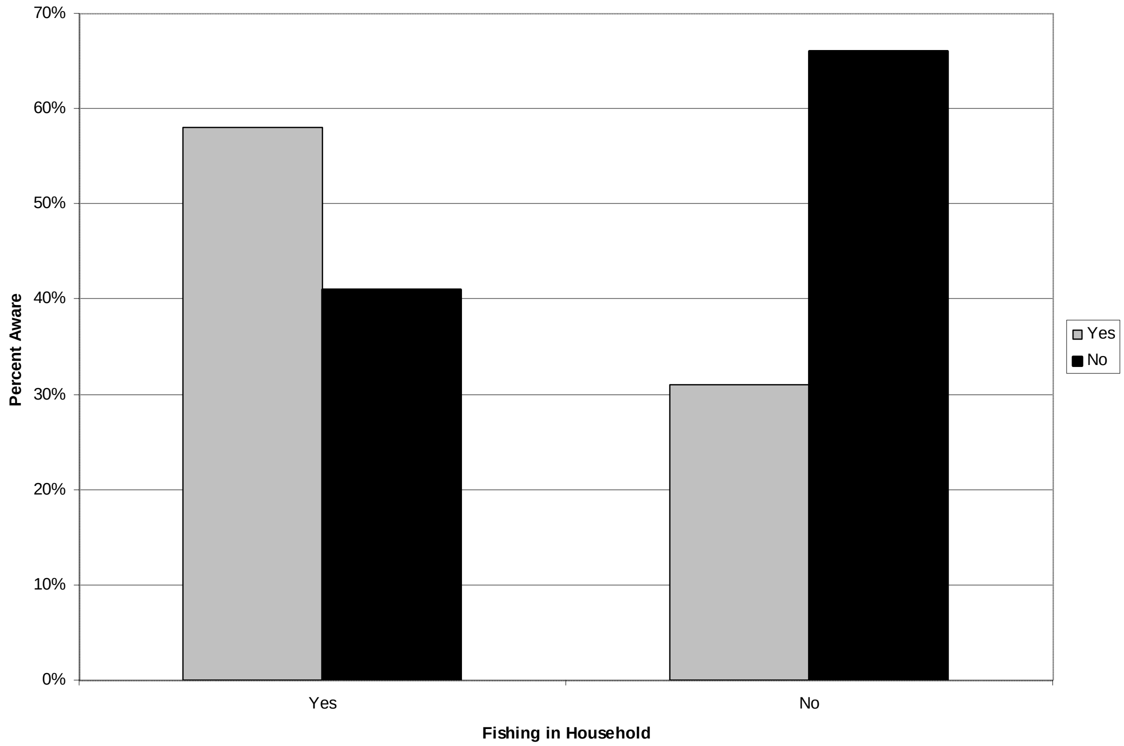


**Figure 1**. Percent of responders to the survey who are (red) or are not (yellow) aware of fish consumption advisories and who do (yes) or do not (no) have someone in the household who fishes**.**
Source: Wisconsin Department of Health and Family Services

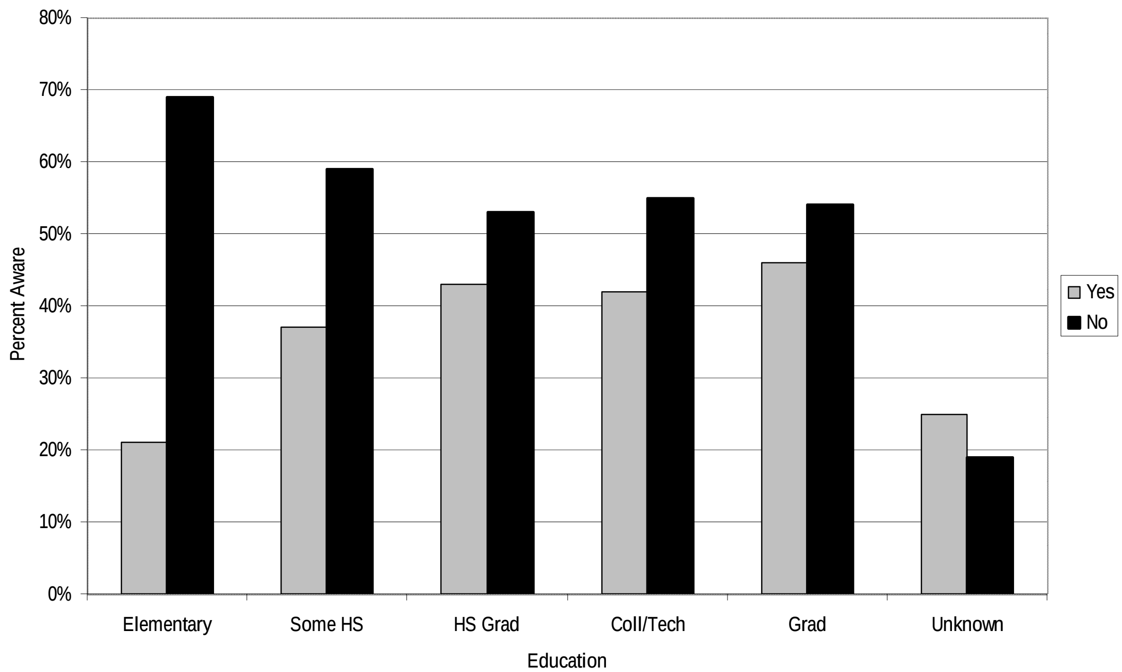


**Figure 2**. Percent of responders to the survey who are (red) or are not (yellow) aware of fish consumption advisories according to level of education.
Source: Wisconsin Department of Health and Family Services

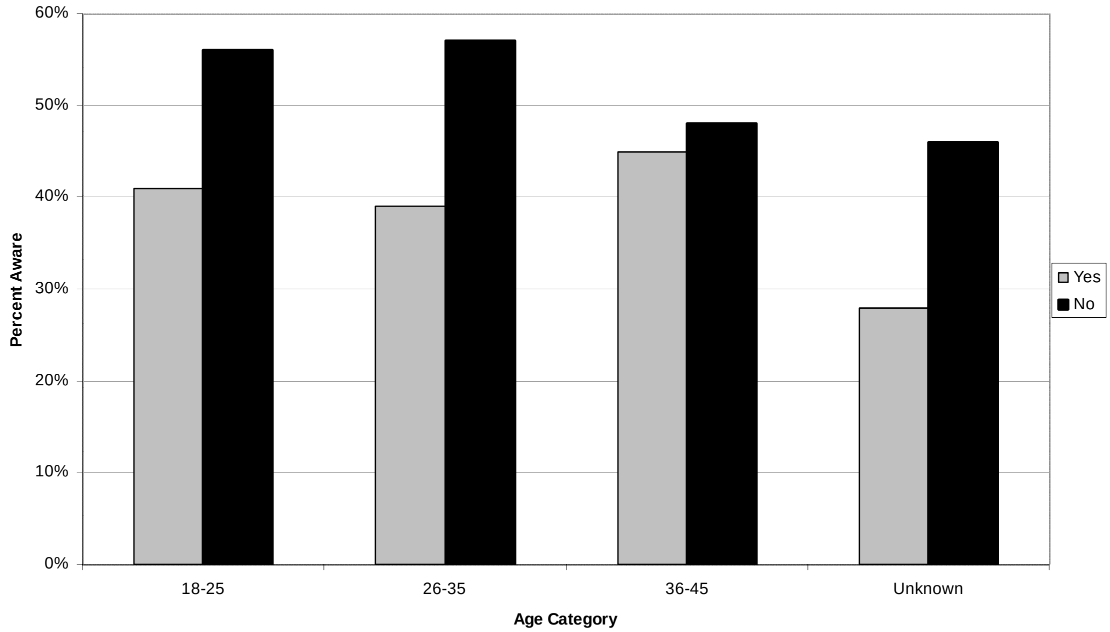


**Figure 3**. Percent of responders to the survey who are (red) or are not (yellow) aware of fish consumption advisories according to age group.
Source: Wisconsin Department of Health and Family Service

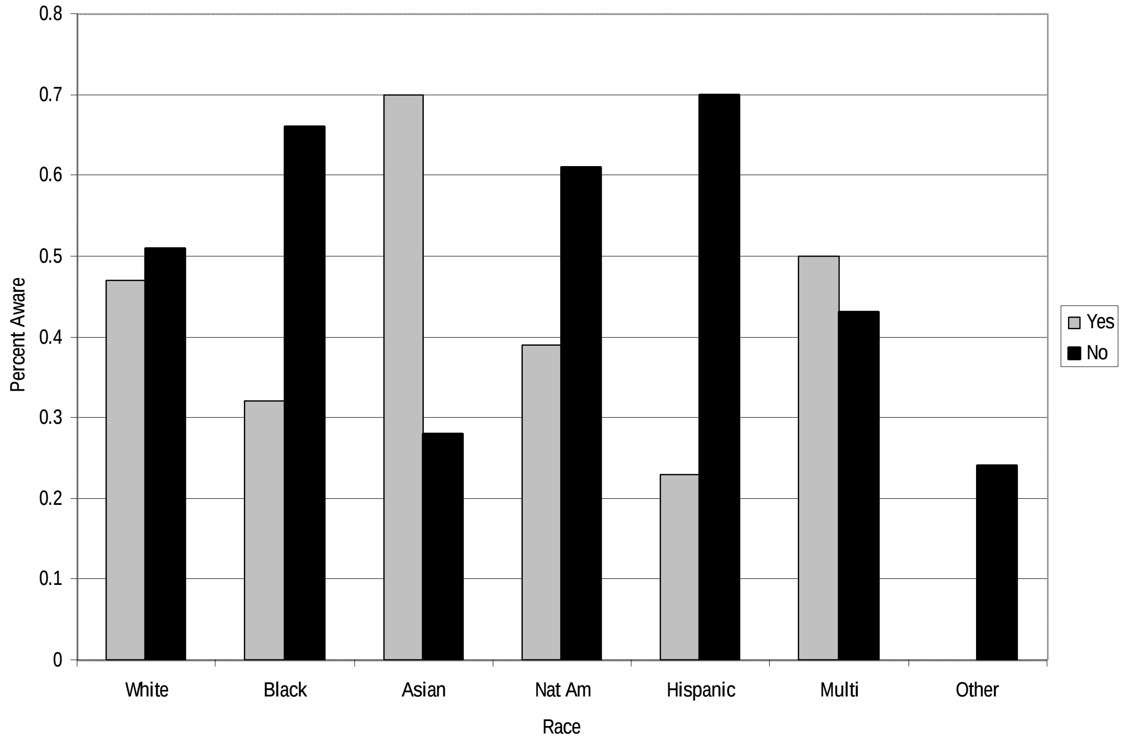


**Figure 4**. Percent of responders to the survey who are (red) or are not (yellow) aware of fish consumption advisories according to race.
Source: Wisconsin Department of Health and Family Service

## Beach Advisories, Postings and Closures
Indicator #4200

*Previous beach reports for the Canadian side included inland beach data. All data for inland beaches has been removed for this 2006 report, which has skewed the results of the doughnut for previous years.

### Overall Assessment

Status: **Mixed**

Trend: **Static**

Primary Factors Determining Status and Trend: While there's been an increase in monitoring and in the number of beaches reporting, the percentage of beaches open during beach season over the last 8 years remains constant in the U.S. – at roughly 70% and slightly declining conditions at 52% in Canada (see Figure 1). The percentage of beaches posted more than 10% of the beach season averaged 13% in the U.S. and 38% in Canada since 2000. The significant difference in the number of open beaches in the U.S. and Canada may be due to the difference in posting criteria. The Ontario standard is a geometric mean of 100 *E. coli* colony-forming units per 100ml of water, while in the U.S., beaches are typically posted using a single sample maximum of 235 *E. coli* cfu per 100ml.

### Lake-by-Lake Assessment
### Lake Superior

Status: Good

Trend: Undetermined (due to vast increase in number of reported beaches)

Primary Factors Determining Status and Trend: During 2004 and 2005, 90% or more of Lake Superior beaches (green & blue - Figure 2a) were open more than 95% of the time in the U.S. This meets the key objective of the 2002 U.S. Great Lakes Strategy goal: By 2010, 90% of monitored, high priority Great Lakes beaches will meet bacteria standards more than 95% of the swimming season. In Canada, during 2005, 5 of 9 beaches were open more than 95% of the time (green & blue - Figure 2b).

### Lake Michigan

Status: Fair

Trend: Undetermined (due to vast increase in number of reported beaches)

Primary Factors Determining Status and Trend: Since 2000, on average, 77% of Lake Michigan beaches were open more than 95% of the time (green & blue - Figure 3). Increased monitoring has resulted in approximately twice as many postings since 2000 (yellow & red – Figure 3). Several groups are collaborating to identify and remediate sources of beach contamination in Lake Michigan.

### Lake Huron

Status: Good

Trend: U.S.: Static; Canada: Undetermined

Primary Factors: Since 1998, on average, 94% of U.S. Lake Huron beaches are open more

| | |
|---|---|
| Determining Status and Trend | than 95% of the beach season. This meets the key objective of the 2002 U.S. Great Lakes Strategy goal. However, in Ontario, an average of 49% of Lake Huron beaches were open more than 95% during 1999 through 2005 beach seasons (green & blue – Figures 4a & 4b). |

**Lake Erie**

| | |
|---|---|
| Status: | Fair |
| Trend: | Undetermined |
| Primary Factors Determining Status and Trend | From 1998 to 2005, on average, 76% of U.S. Lake Erie beaches were open more than 95% of the beach season. From 1999 through 2005, in Ontario, an average of 55% of Lake Erie beaches were open more than 95% of the beach seasons (green & blue - Figures 5a & 5b). Contamination source identification work is being conducted at Lake Erie beaches. |

**Lake Ontario**

| | |
|---|---|
| Status: | Fair |
| Trend: | Undetermined |
| Primary Factors Determining Status and Trend | From 1998 to 2005, on average, 84% of Lake Ontario beaches in the U.S. were open more than 95% of the beach season. From 1999 through 2005, in Ontario, an average of 46% of Lake Ontario beaches were open more than 95% of the beach season (green & blue - Figures 6a & 6b). |

**Purpose**

Assess the number of health-related swimming posting days for freshwater recreational areas (beaches) in the Great Lakes basin.

**Ecosystem Objective**

Waters used for recreational activities involving body contact should be substantially free from pathogens that may harm human health, including bacteria, parasites, and viruses. As the surrogate indicator, *E. coli* levels should not exceed national, state or provincial standards set for recreational waters. This indicator supports Annexes 1, 2 and 13 of the Great Lakes Water Quality Agreement (United States and Canada 1978).

**State of the Ecosystem**

<u>Background</u>

A health-related posting day is one that is based upon elevated levels of *E. coli*, or other indicator organisms, as reported by county or municipal health departments in the Great Lakes basin. *E. coli* and other indicator organisms are measured in order to infer potential harm to human health through body contact with nearshore recreational waters because they act as indicators for potential pathogens.

The Ontario provincial standard is 100 *E. coli* cfu per 100 mL, based on the geometric mean of a minimum of one sample per week from each sampling site (minimum of 5 sampling sites per beach) (Ministry of Health 1998). It is recommended by the Ontario Ministry of Health and Long-Term Care that beaches of 1000 metres of length or greater require one sampling site per 200 metres. In some cases local Health Units in Ontario have implemented a more frequent sampling procedure than is outlined by the provincial government. When *E. coli* levels exceed the limit, the beach is posted as unsafe for the health of bathers. Each beach in Ontario has a different swimming season length, although the average swimming season for Ontario beaches begins in early June and continues until the first weekend in September. The difference in the swimming season length may skew the final result of the % of beaches posted throughout the season

The bacteria criteria recommendations for *E. coli* from the U.S. Environmental Protection Agency (USEPA) are a single sample maximum value of 235 cfu per 100 ml. For enterococci, another indicator bacterium, USEPA's recommendations are a single sample maximum value of 62/100 ml (USEPA 1986). When levels of these indicator organisms exceed water quality standards, swimming at beaches is prohibited or advisories are issued to inform beachgoers that it may not be safe to swim.

One of the most important factors in nearshore recreational water quality determination is that indicator bacterial counts are at a level that is safe for bathers. Recreational waters may become contaminated with animal and human feces from sources and conditions such as combined sewer overflows (CSOs) and sanitary sewer overflows (SSOs), malfunctioning septic systems and poor livestock management practices. This pollutant input can become further emphasized in certain areas after heavy rains. The trends provided by this indicator will aid in beach management and in the prediction of episodes of poor water quality. In addition, states, provinces, and municipalities are continuing to identify point and non-point sources of pollution at their beaches, which will determine why beach areas are becoming impaired. As some sources of contamination are identified, improved remediation measures can be taken to reduce the number of postings at beaches.

Status of Great Lakes Beach Advisories, Postings and Closures

Figure 1, shows that as the frequency of monitoring and reporting increases in the U.S. and Canada, more postings are also observed, especially after 1999. In fact, both countries experienced an approximate percentage doubling of beaches that had postings for more than 10% of the season in 2000 due to increases in monitoring and reporting. The number of U.S. beaches being included in the monitoring and reporting program in 2005 has expanded significantly (more than double since 2002) due to funding from USEPA through the BEACH Act, however, the percentage of U.S. beaches open all season and the percentage of beaches posted more than 10% of the season in 2005 are virtually unchanged when compared to 2000-2004.

While the number of beaches reporting in 2004 and 2005 in Canada decreased, the number of postings each swimming season is fairly constant at about 49% over the last 8 years, excluding 2002 and 2003 (Figure 1). Although, Lakes Ontario, Huron, and Erie have not met the key objective of the Great Lakes Strategy 2002, there are measures being taken to improve the beaches on these lakes. A new version of the Guideline for Canadian Recreational Water Quality will be out this year, focusing on implementing measures to reduce the risk of contamination (Robertson, 2006). Beach surveys, barriers, and preventive weather measures are some of the actions that will be taken to assist in improving beach quality for the Canadian Great Lakes.

U.S. beaches in Lakes Superior and Huron are meeting the key objective of the U.S. Great Lakes Strategy 2002 (http://www.epa.gov/glnpo/gls/index.html). The Great Lakes Strategy envisions that all Great Lakes beaches will be swimmable and sets a goal that by 2010, 90% of monitored, high priority Great Lakes beaches will meet bacteria standards more than 95% of the swimming season (Figures 2a & 4a - except for Lake Huron in 2002). To help meet this goal, USEPA will build local capacity in monitoring, assessment and information dissemination to help beach managers and public health officials comply with USEPA's National Beach Guidance (USEPA 2002b) at 95% of high priority coastal beaches.

Further analysis of the data may show seasonal and local trends in recreational water quality. It has been observed in the Great Lakes basin that unless contaminant sources are removed or new sources introduced, beach sample results contain similar bacteria levels after events with similar meteorological conditions (primarily wind direction and volume and duration of rainfall). If episodes of poor recreational water quality can be associated with specific events (such as meteorological events of a certain threshold), then forecasting for episodes of elevated bacterial counts may become more accurate.

**Pressures**

Future pressures: There may be new indicators and new detection methods available through current research efforts occurring binationally in both public and private sectors and academia. Although currently a concern in recreational waters, viruses and parasites are difficult to isolate and quantify, and feasible measurement techniques have yet to be developed. Comparisons of the frequency of beach postings are typically limited due to the use of different water quality criteria in different localities. In the U.S., all coastal states (including those along the Great Lakes) have criteria as protective as USEPA's recommended bacteriological criteria (use of *E. coli* or enterococci indicators) applied to their coastal waters. Conditions required to post Ontario beaches as unsafe have become more standardized due to the 1998 Beach Management Protocol, but the conditions required to remove the postings remain variable.

Current pressures: Additional point and non-point source pollution at coastal areas due to population growth and increased land use may result in additional beach postings, particularly during wet weather conditions. In addition, due to the nature of the laboratory analysis, each set of beach water samples requires an average of one to two days before the results are communicated to the beach manager. Therefore, a lag time in posting exists in addition to the lifting of any restrictions from the beach when safe levels are again reached. The delay in developing a rapid test protocol for *E. coli* is lending support to advanced models to predict when to post beaches.

**Management Implications**

Continued BEACH Act funding for beach monitoring and notification programs should be encouraged as well as funding for beach water contaminant source identification and remediation, rapid test methods research, and development of predictive models.

In Canada, a partnership between Environment Canada (Ontario Region) and the Ontario Ministry of Health and Long-Term Care have created the Seasonal Water Monitoring and Reporting System (SWMRS). This web-based application will provide local Health Units with a tool to manage beach sampling data, as well as link to the meteorological data archives of

Environment Canada. The result will be a system that potentially can be evolved to have some predictive modeling capability.

**Comments from the author(s)**

Wet weather sources of pollution have the potential to carry pathogenic organisms to waters used for recreation and contaminate them beyond the point of safe use. There is a need to begin identifying beach water contamination sources and implement remediation measures to reduce contaminant loading.

Many municipalities are in the process of developing long-term control plans that will result in the selection of CSO controls to meet water quality standards. The City of Toronto has an advanced Wet Weather Flow Management Master Plan, which could serve as a model to other urban areas. Information on this initiative can be obtained at: http://www.city.toronto.on.ca/wes/techservices/involved/wws/wwfmmp/index.htm.

Environment Canada (Ontario Region), in conjunction with the Ontario Ministry of Health and Long-Term Care and other potential partners, will work to implement the SWMRS reporting system. Future work will include a predictive modeling capability as well as improving the interface for public use. The system, once running, will help identify areas of chronic beach postings and, as a result, will aid in improved targeting of programs to address the sources of bacterial contamination.

Creating wetlands around rivers, or areas that are wet weather sources of pollution, may help lower the levels of bacteria that cause beaches to be posted. The wetland area may reduce high bacterial levels that are typical after storm events by detaining and treating water in surface areas rather than releasing the bacteria-rich waters into the local lakes and recreational areas. Studies by the Lake Michigan Ecological Research Station show that wetlands could lower bacterial levels at state park beaches, but more work is needed (Mitchell 2002).

Variability in the data from year to year may result due to changing seasonal weather conditions, the process of monitoring and variations in reporting, and may not be solely attributable to actual increases or decreases in levels of microbial contaminants. At this time, most of the beaches in the Great Lakes basin are monitored and have quality public notification programs in place. In addition, state beach managers are submitting their beach monitoring and advisory/closure data to the USEPA annually. The state of Michigan has an online site (http://www.glin.net/beachcast) where beach monitoring data is posted by Michigan beach managers. In Ontario, the SWMRS program will increase the efficiency and accuracy of the data collection and reporting.

To ensure accurate and timely posting of Great Lake beaches, methods must be developed to deliver quicker results that focus not just on indicator organism levels but on water quality in general. This issue is being addressed. The BEACH Act requires EPA to initiate studies for use in developing appropriate and effective indicators for improving detection in a timely manner in Coastal Recreation Waters. In connection with this requirement, the USEPA and the Centers for Disease Control and Prevention are conducting the National Epidemiological and Environmental Assessment of Recreation Waters study at various coastal freshwater and marine beaches across the country to evaluate new rapid and specific indicators of recreational water quality and to determine their relationships to health effects. Until new indicators are available, predictive models and/or the experience of knowledgeable environmental or public health officers (who regularly collect the samples) can be used on both sides of the border. Each method takes a variety of factors into account, such as amount of rainfall, cloud coverage, wind (direction and speed), current, point and non-point source pollution inputs, and the presence of wildlife, to predict whether it is likely that *E. coli* levels will likely exceed established limits in recreational waters.

**Acknowledgments**
Authors: Tracie Greenberg, Environment Canada Intern, Ontario Region, Burlington, ON;
David Rockwell, U.S. Environmental Protection Agency, Great Lakes National Program Office, Chicago, IL;
Holiday Wirick, U.S. Environmental Protection Agency, Region 5, Water Division, Chicago, IL;

**Data Sources**
Canadian data obtained from Ontario Health Units along the Great Lakes.

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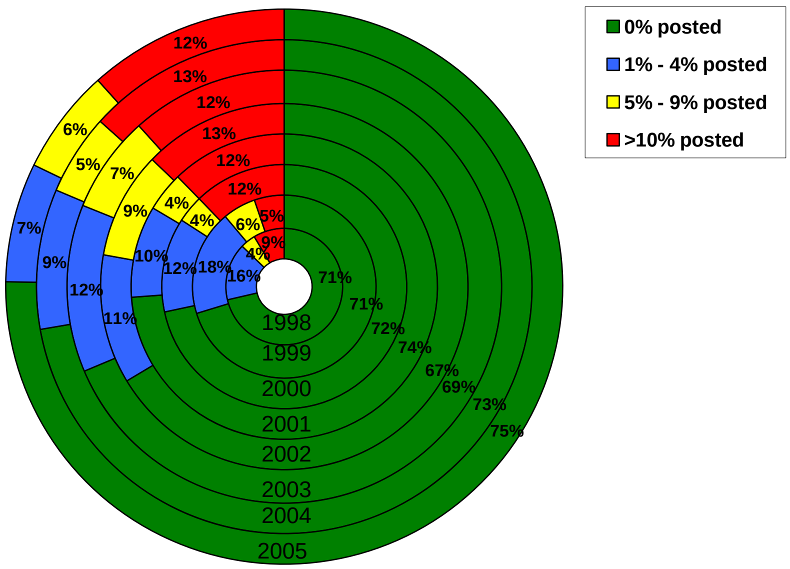
**List of Figures**



**Last updated**
SOLEC 2006

**Proportion of U.S. Great Lake Basin Beaches with Postings for the 1998 - 2005 Bathing Seasons**




**Number of Great Lake Basin Beaches reported**

| Canada | | U.S. |
|---|---|---|
| 194 | 2005 | 892 |
| 161 | 2004 | 787 |
| 270 | 2003 | 649 * |
| 272 | 2002 | 381 |
| 304 | 2001 | 304 |
| 293 | 2000 | 333 |
| 238 | 1999 | 320 |
| 218 | 1998 | 303 |

* Data Source NRDC

**Proportion of Canadian Great Lakes Beaches with Beach Postings for the 1998-2005 Bathing Season**

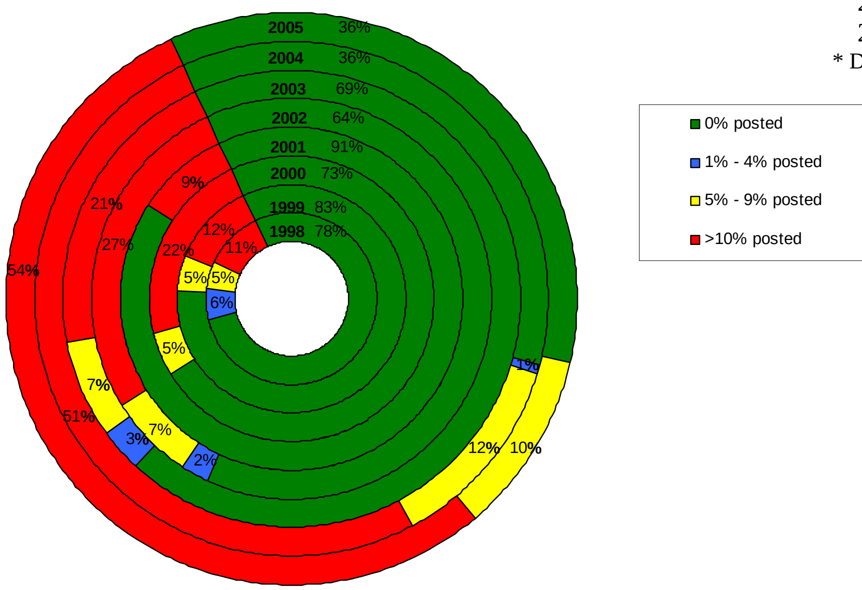
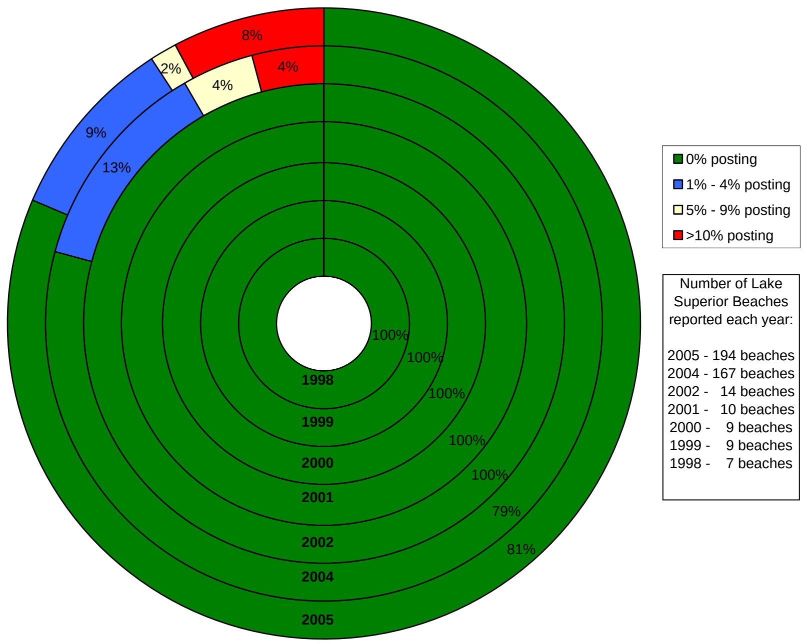



**Figure 1**. Proportion of Great Lakes beaches with postings in the United States and Canada for the 1998-2005 bathing seasons.
Source: U.S. data: U.S. Environmental Protection Agency, Great Lakes National Programs Office and the National Resource Defense Council for 2003; Canadian data compiled by Environment Canada from Ontario Health Units

**Proportion of U.S. Lake Superior Beaches with Beach Postings for the 1998-2005 Bathing Seasons**




**Lake Superior - Canada**

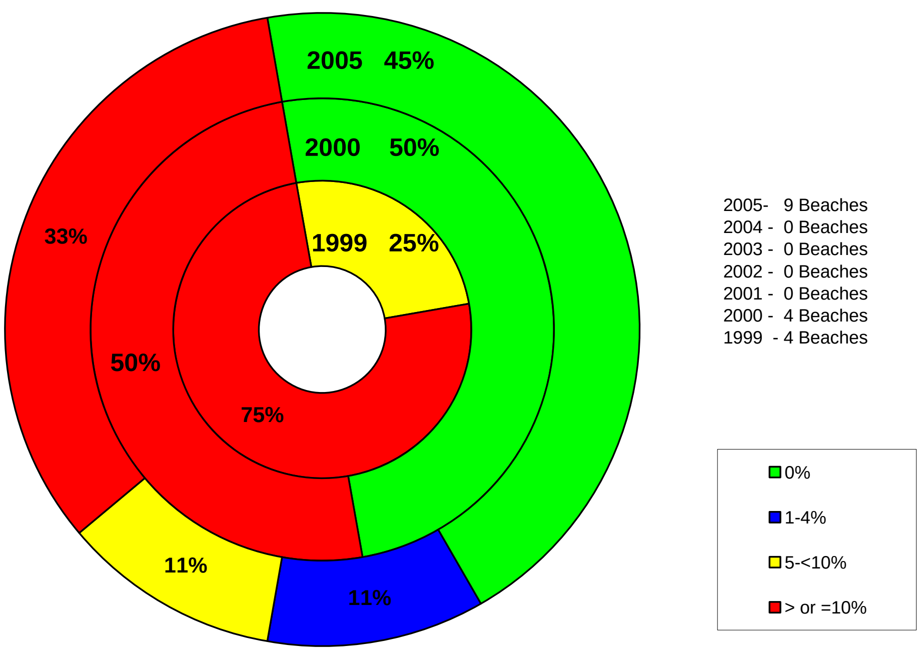



**Figure 2**. Proportion of Great Lakes beaches with postings for Lake Superior.
Source: U.S. data: U.S. Environmental Protection Agency, Great Lakes National Programs Office and the National Resource Defense Council for 2003; Canadian data compiled by Environment Canada from Ontario Health Units

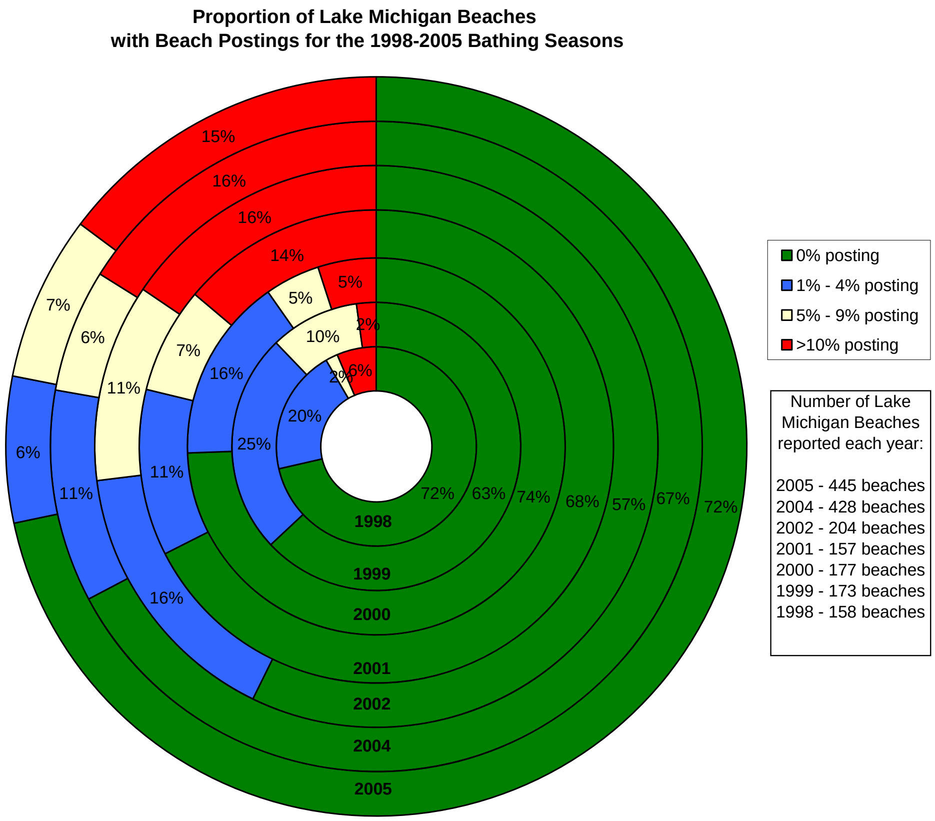
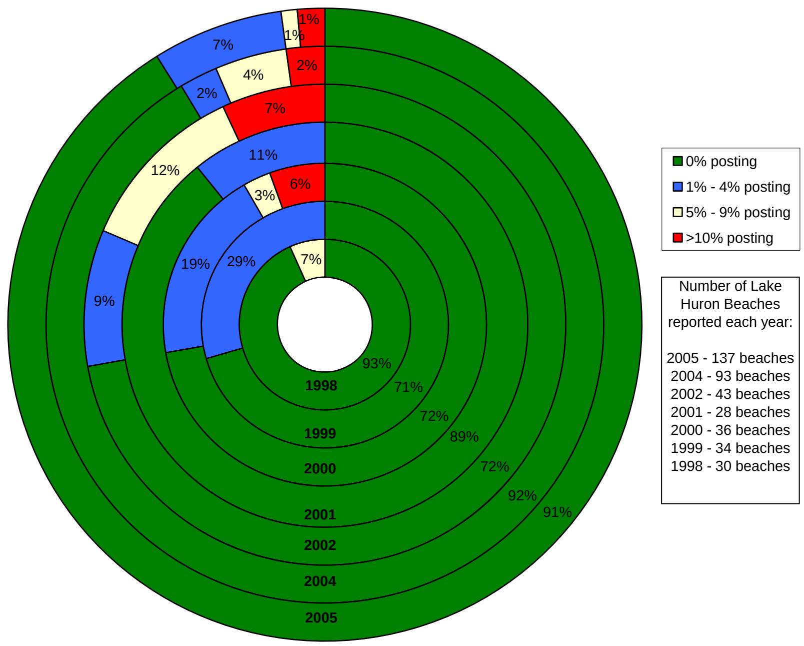



**Figure 3**. Proportion of Great Lakes beaches with postings for Lake Michigan.
Source: U.S. data: U.S. Environmental Protection Agency, Great Lakes National Programs Office and the National Resource Defense Council for 2003

**Proportion of Lake Huron Beaches**
**with Beach Postings for the 1998-2005 Bathing Seasons**




**Lake Huron - Canada**

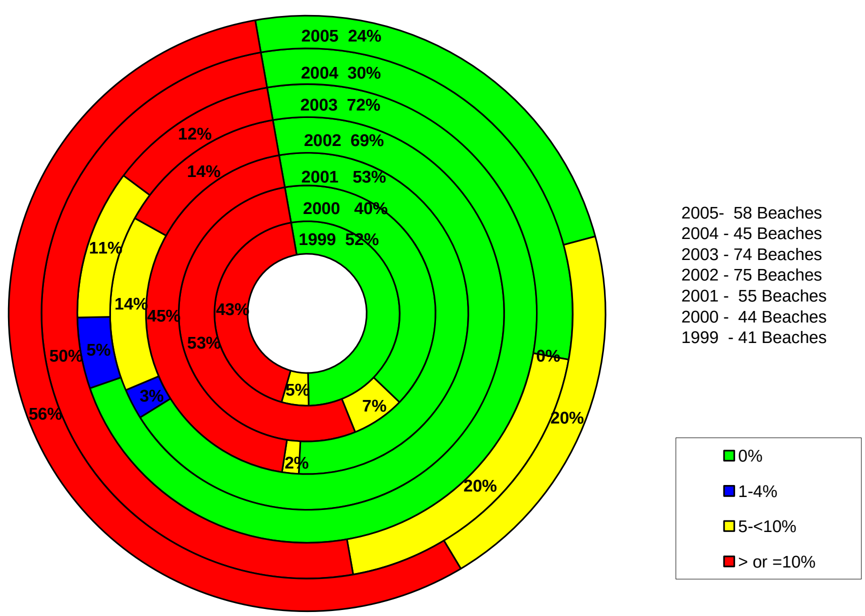
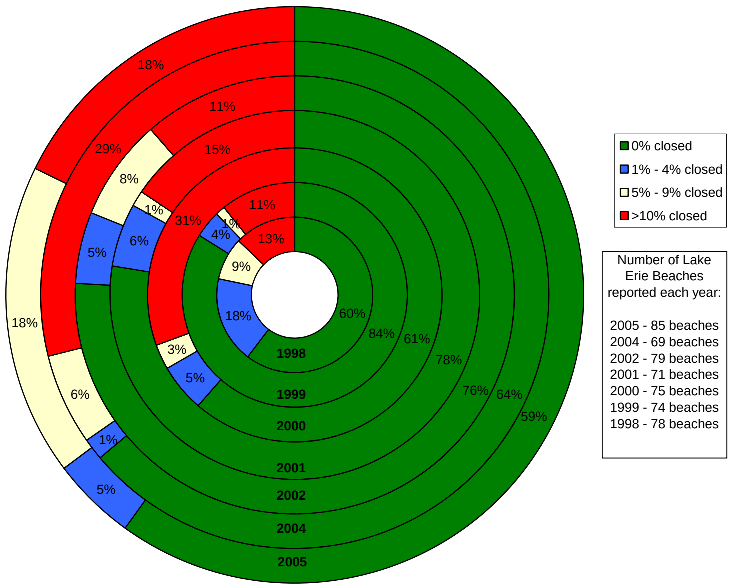



**Figure 4**. Proportion of Great Lakes beaches with postings for Lake Huron.
Source: U.S. data: U.S. Environmental Protection Agency, Great Lakes National Programs Office and the National Resource Defense Council for 2003; Canadian data compiled by Environment Canada from Ontario Health Units

**Proportion of Lake Erie Beaches with Beach Advisories for the 1998-2005 Bathing Seasons**




**Lake Erie - Canada**

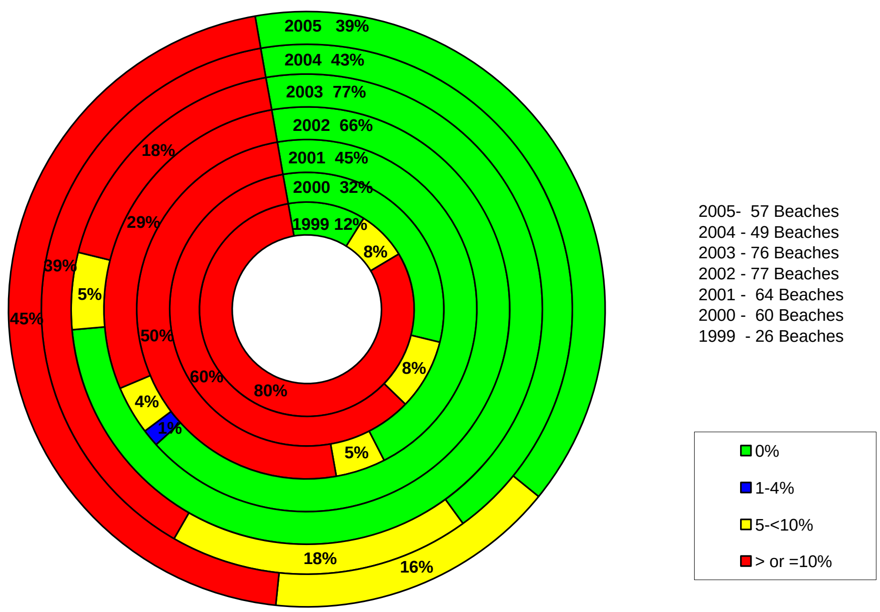
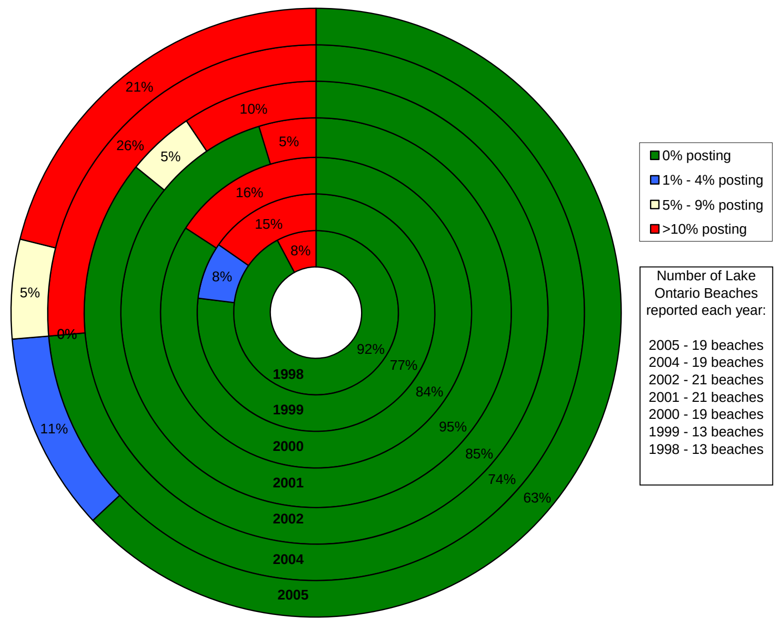



**Figure 5**. Proportion of Great Lakes beaches with postings for Lake Erie.
Source: U.S. data: U.S. Environmental Protection Agency, Great Lakes National Programs Office and the National Resource Defense Council for 2003; Canadian data compiled by Environment Canada from Ontario Health Units

Proportion of Lake Ontario Beaches
with Beach Postings for the 1998-2005 Bathing Seasons




Lake Ontario - Canada

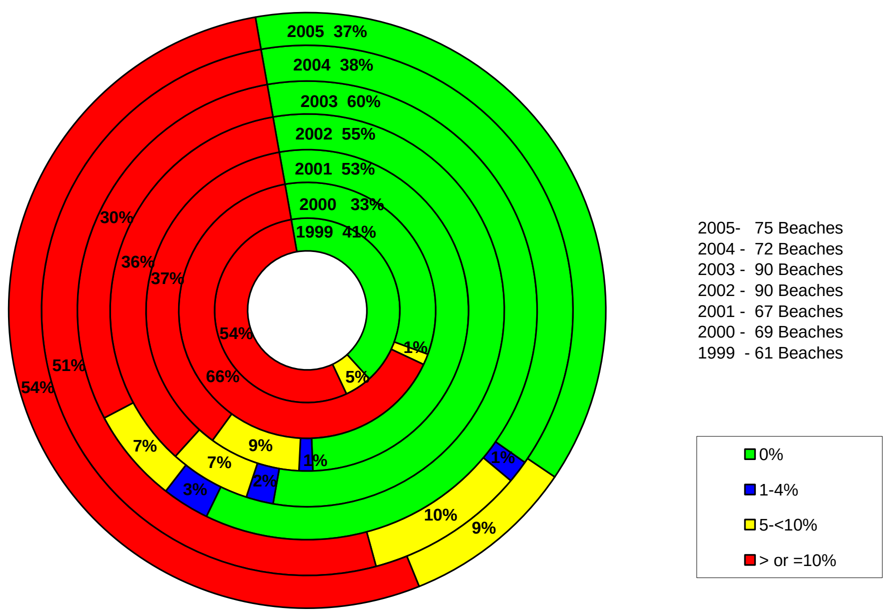



**Figure 6**. Proportion of Great Lakes beaches with postings for Lake Ontario.
Note: The Ontario standard is 100 *E. coli* colony-forming units per 100ml of water, while the U.S. standard is a single sample maximum of 235 *E. coli* cfu per 100ml.
Source: U.S. data: U.S. Environmental Protection Agency, Great Lakes National Programs Office and the National Resource Defense Council for 2003; Canadian data compiled by Environment Canada from Ontario Health Units

## Contaminants in Sport Fish

Indicator #4201

**Overall Assessment**

Status: **Mixed**

Trend: **Improving**

Primary Factors Determining Status and Trend: **The Great Lakes Fish Monitoring Program (GLNPO) and the Sport Fish Contaminant Monitoring Program (Ontario Ministry of the Environment, OMOE) have been monitoring contaminant levels in Great Lakes fish for over three decades. To demonstrate trends in organic contaminant levels, average-size (60cm) lake trout were chosen by OMOE as the representative fish species due to their presence in all of the Great Lakes, their potential for exploitation by anglers and their high accumulation rates for organic contaminants. To demonstrate trends in mercury levels, average-size (45cm) walleye were chosen by OMOE due to high mercury accumulation rates. The GLNPO program was not designed to determine trends in levels of contaminants in sport fish, and it relies on individual Great Lakes States and Tribes to issue consumption advice. Rather, the GLNPO program can compare mean concentration levels to a set standard, the Protocol for a Uniform Great Lakes Sport Fish Consumption Advisory, by year. Other important differences between the GLNPO and OMOE programs include composite analysis versus individual analysis, skin on versus skin off, and whole fillet analysis versus dorsal plug analysis respectively. For this reason, only general comparisons between GLNPO and OMOE data should be made.**

**Lake-by-Lake Assessment** EPA – GLNPOs data can not be used for statistical trend analysis. Any trend discussions in the lake assessments below are based on OMOE data.

Contaminant concentrations for both EPA – GLNPO and OMOE can be compared to meal category advice. OMOE calculates its own advice and EPA – G LNPO compares its contaminant concentrations to the Protocol for a Uniform Great Lakes Sport Fish Consumption Advisory categories.

**Lake Superior**

Status: Mixed

Trend: Improving

Primary Factors Determining Status and Trend: PCB concentrations in Lake Superior lake trout have declined considerably over the period of record. In the late 1970s, PCB concentrations exceeded the current OMOE "do not eat" consumption limit. Since 1990, concentrations have generally fluctuated between 0.153 and 0.610 ppm, which would permit the consumption of 2 to 4 meals per month. Current EPA – GLNPO concentrations range between the one meal per week and the one meal per month categories.

Mercury levels in 45cm walleye from Lake Superior have ranged from 0.62 to 0.30 ppm between 1973 and 2002. With the exception of a maximum level reached in 1989 (0.84 ppm), levels of mercury in walleye have declined over the last few decades. In the last 5 years of the period of record, levels of mercury in 45cm walleye have been around 0.30 ppm, permitting the consumption of 4 meals per month for the sensitive population. These mercury levels are similar to those found in fish from other Ontario lakes and rivers.

Toxaphene has historically been high in fish from Lake Superior due to atmospheric deposition. In 60cm lake trout from Lake Superior, toxaphene has ranged from 0.810 to 0.214 ppm between 1984 and 2003. In 1993, levels of toxaphene in lake trout exceeded 1 ppm. The most current concentration is below the consumption limits and does not result in any fish consumption advisories.

**Lake Michigan**

Status: Mixed

Trend: Improving

Primary Factors Determining Status and Trend: EPA – GLNPO data can be used to discern general trends from Lake Michigan data due to multiple collection sites. These data display a general decline in PCB concentrations in coho and chinook salmon fillets. No OMOE samples were collected from Lake Michigan. Current EPA – GLNPO concentrations fall into the one meal per month category.

**Lake Huron**

Status: Mixed

Trend: Improving

Primary Factors Determining Status and Trend: PCB levels in Lake Huron OMOE lake trout declined substantially between 1976 and 2004. In 1976 concentrations exceeded 4ppm, well above the “do not eat” consumption limit of 1.22ppm for the general population. Current PCB concentrations in 60cm lake trout slightly exceed 0.153 ppm, allowing for the safe consumption of a maximum of 4 meals per month. Current EPA – GLNPO concentrations range between the one meal per week and the one meal per month categories.

Mercury levels in 45cm walleye from Lake Huron have ranged from 0.48 to 0.16 ppm between 1976 and 2004. With the exception of a maximum level reached in 1984 (0.59 ppm), there has been a general decline over the last few decades. During the last decade, levels of mercury have remained below the first level of consumption restriction (0.26ppm) for the sensitive population.

**Lake Erie**

Status: Mixed

Trend: Improving

| | |
|---|---|
| Primary Factors Determining Status and Trend | Trend data are sparse for Lake Erie as lake trout are less abundant in this lake. PCB levels in OMOE fish declined between 1984 and 2003. Nevertheless, PCB concentrations in 60 cm lake trout currently restrict consumption to 2 meals per month for the general population. The sensitive population is advised not to consume these fish. Current EPA – GLNPO concentrations range between the one meal per week and the one meal per month categories.<br><br>Mercury levels in 45cm walleye have declined considerably over the period of record, from 0.76 ppm in 1970 to 0.18 ppm in 2004. Over the past two decades, levels of mercury have remained between 0.10 and 0.20 ppm, and do not restrict consumption of 45cm walleye. |

**Lake Ontario**

| | |
|---|---|
| Status: | Mixed |
| Trend: | Improving |
| Primary Factors Determining Status and Trend | Historically, the highest concentrations of PCBs have been found in Lake Ontario. From the late 1970s to 1999, PCBs in 60 cm OMOE lake trout from Lake Ontario were at or near the "do not eat" consumption limit. Substantially lower concentrations have been found in the most recent samples in 2002 and 2004, and the current levels would permit consumption of 2 meals per month. Current EPA – GLNPO concentrations fall into the one meal per week category.<br><br>Mercury levels in 45cm walleye have fluctuated between 0.23 and 0.17 ppm between 1975 and 2005. There has been no major decline in mercury concentrations in walleye, however, maximum levels have only reached 0.32ppm. Over the past 3 years, mercury concentrations in 45cm walleye have remained below the first level of consumption restriction for the sensitive population.<br><br>High levels of mirex have been found in fish from Lake Ontario and it has historically been a source of fish consumption restrictions. Levels of mirex in 60cm lake trout from Lake Ontario have declined significantly from 0.302 to 0.036 ppm between 1978 and 2004, with a maximum of 0.387 ppm reached in 1985. The current concentration of mirex no longer restricts consumption of 60cm lake trout. Photomirex is a breakdown product of mirex, which also bioaccumulates in fish and has historically caused consumption restrictions in some Lake Ontario species. Levels in 60cm lake trout have declined from 0.044 to 0.015 ppm between 1994 and 2004. |

Advice for the Protocol for a Uniform Great Lakes Sport Fish Consumption Advisory was calculated for sensitive populations based on a weight of evidence of non-cancer developmental effects. The general population is advised to follow the same advice based on potential cancer risk. Health Canada does not consider PCBs (especially environmental levels) to be carcinogens. Therefore, non-cancer endpoints were used to calculate the Tolerable Daily Intakes (TDI) for PCBs. This TDI was applied more-or-less equally to both sensitive and general populations. For mercury, Health Canada and US states assign separate TDIs or RfDs for the general and sensitive populations.

**Purpose**

•To assess potential human exposure to persistent bioaccumulative toxic (PBT) contaminants through consumption of popular sport species;
•To assess the levels of PBT contaminants in Great Lakes sport fish; and
•To identify trends over time of PBT contaminants in Great Lakes sport fish or in fish consumption advisories.

In addition to an indicator of human health, contaminants in fish are an important indicator of contaminant levels in an aquatic ecosystem because of the bioaccumulation of organochlorine chemicals in their tissues. Contaminants that are often undetectable in water can be detected in fish.

**Ecosystem Objective**

Great Lakes sport fish should be safe to eat and concentrations of toxic contaminants in sport fish should not pose a risk to human health. Unlimited consumption of all Great Lakes sport fish should be available to all citizens of the Great Lakes basin.

Annex 2 of the Great Lakes Water Quality Agreement (United States and Canada 1987) requires Lakewide Management Plans (LaMPs) to define "…the threat to human health posed by critical pollutants… including their contribution to the impairment of beneficial uses." Both the Protocol for a Uniform Great Lakes Sport Fish Consumption Advisory and the Guide to Eating Ontario Sport Fish are used to assess the status of the ecosystem by comparing contaminant concentrations to consumption advice.

**State of the Ecosystem**

Program History

Both the United States and Canada (Ontario) collect and analyze sport fish to determine contaminant concentrations, relate those concentrations to health protection values and develop consumption advice to protect human health. For U.S.-caught sport fish, the Protocol for a Uniform Great Lakes Sport Fish Consumption Advisory for PCBs is used as a standardized fish advisory benchmark for this indicator, and it is applied to historical U.S. Environmental Protection Agency (USEPA) Great Lakes National Program Office (GLNPO) data to track trends in fish consumption advice. Individual Great Lakes States and Tribes issue specific consumption advice for how much fish and which fish are safe to eat for a wide variety of contaminants. GLNPO salmon fillet data are used to demonstrate this indicator. Due to gaps and variability in GLNPO salmon fillet data, statistically significant trends are difficult to discern. For Canadian-caught sport fish, Health Canada sets Tolerable Daily Intakes (TDI) for certain contaminants of concern, including PCBs, mercury, dioxins (including dioxins, furans and dioxin-like PCBs), mirex, photomirex, toxaphene and chlordane. TDIs are defined as the quantity of a chemical that can be consumed on a daily basis, for a lifetime, with reasonable assurance that one's health will not be threatened, and they are used in the calculation of sport fish consumption limits which are listed in the Guide to Eating Ontario Sport Fish.

The GLWQA, first signed in 1972 and renewed in 1978, expresses the commitment of Canada and the United States to restore and maintain the chemical, physical and biological integrity of the Great Lakes basin ecosystem.

Contaminants in Great Lakes Sport Fish
Since the 1970s, there have been declines in the levels of many PBT chemicals in the Great Lakes basin due to bans on the use and/or production of harmful substances and restrictions on emissions. However, because of their ability to bioaccumulate and persist in the environment, PBT chemicals continue to be a significant concern. Historically, PCBs have been the contaminant that most frequently limited the consumption of Great Lakes sport fish. In some areas, dioxins, toxaphene (Lake Superior) or mirex/photomirex (Lake Ontario) have been the consumption-limiting contaminant. Recently Health Canada has revised downward its TDIs for PCBs and dioxins, which has increased the frequency of consumption restrictions caused by PCBs and dioxins and decreased the frequency for toxaphene and mirex/photomirex.

Illustration note - Please note that differing species (coho salmon and lake trout) and units (ppm and ppb) are presented in the accompanying graphs. Typically lake trout have higher contaminant concentrations than coho salmon.

**Pressures**
Organochlorine contaminant levels in fish in the Great Lakes are generally decreasing. As these contaminants continue to decline, mercury will become a more important contaminant of concern in Great Lakes fish.

Concentrations of PBT contaminants such as PCBs have declined in lake trout throughout the Great Lakes basin. However, concentrations still exceed current consumption limits. Regular monitoring must continue in the Great Lakes basin to maintain trend data. In many areas of the Great Lakes, dioxins (including dioxins, furans and dioxin-like PCBs) are now the consumption-limiting contaminant and need to be monitored more frequently. The focus should also turn to PBT contaminants of emerging concern, such as brominated flame retardants, before their concentrations in sport fish reach levels that may affect human health.

Consumption advisories and PCB concentrations in coho salmon (U.S. program)
State and tribal governments provide information to consumers regarding consumption of sport caught fish. Neither the guidance nor advice of a state or tribal government is regulatory. However, some states use the federal commercial fish guidelines for the acceptable level of contaminants when giving advice for eating sport-caught fish. Consumption advice offered by most agencies is based on human health risk. This approach involves interpretation of studies on health effects from exposure to contaminants. Each state or tribe is responsible for developing fish consumption advisories for protecting the public from pollutants in fish and tailoring this advice to meet the health needs of its citizens. As a result, the advice from different states and tribal programs is sometimes somewhat different for the same lake and species within that lake.

Additional information about the toxicity of a larger suite of chemicals is needed. The health effects of multiple contaminants, including endocrine disruptors, also need to be addressed.

**Management Implications**
Health risk communication is a crucial component to the protection and promotion of human health in the Great Lakes. Enhanced partnerships between states and tribes involved in the issuing of fish consumption advice and USEPA headquarters will improve U.S. commercial and non-commercial fish advisory coordination. In Canada, acceptable partnerships exist between the federal and provincial agencies responsible for providing fish consumption advice to the public.

At present, PCBs and Chlordane are the only PBT chemicals that have uniform fish advisory protocols across the U.S. Great Lakes basin, mercury is being drafted. There is a need to establish additional uniform PBT advisories in order to limit confusion of the public that results from issuing varying advisories for the same species of sport fish across the basin.

In order to best protect human health, increased monitoring and reduction of PBT chemicals need to be made a priority. In particular, monitoring of contaminant levels in environmental media and biomonitoring of human tissues need to be addressed, as well as assessments of frequency and type of fish consumed. This is of particular concern in sensitive populations because contaminant levels in some fish are higher than in others. In addition, improved understanding of the potential negative health effects from exposure to PBT chemicals is needed.

In March, 2004, the U.S. Food and Drug Administration and the USEPA jointly released a consumer advisory on methylmercury in fish. The joint advisory advises women who may become pregnant, pregnant women, nursing mothers, and young children to avoid eating some types of fish and to eat fish and shellfish that are lower in mercury. While this is a step forward toward uniform advice regarding safe fish consumption, the national advisory is not consistent with some Great Lakes State's advisories. Cooperation among National, State, and Tribal governments to develop and distribute the same message regarding safe fish consumption needs to continue. Health Canada has had a similar advisory since 1999.

**Comments from the author(s)**
Support is needed for the States from the Great Lakes National Program Office (GLNPO) and U.S. Environmental Protection Agency (USEPA) headquarters to help facilitate a meeting to review risk assessment protocols.

Evaluation of historical long term fish contaminant monitoring data sets, which were assembled by several jurisdictions for different purposes, need to be more effectively utilized. Relationships need to be developed that allow for comparison and combined use of existing data from the various sampling programs. These data could be used in expanding this indicator to other contaminants and species and for supplementing the data used in this illustration.

Coordination of future monitoring would greatly assist the comparison of fish contaminants data among federal, provincial, state and tribal jurisdictions.

Agreement is needed on U.S. fish advisory health benchmarks for the contaminants that cause fish advisories in the Great Lakes. Suggested starting points are: The Great Lakes Protocol for PCBs and Chlordane and USEPA's reference dose for mercury. Ontario remains consistent with Health Canada's TDIs throughout the province.

**Acknowledgments**
Authors: Elizabeth Murphy, U.S. Environmental Protection Agency, Great Lakes National Program Office;
Jackie Fisher, U.S. Environmental Protection Agency, Great Lakes National Program Office;
Emily Awad, Sport Fish Contaminant Monitoring Program, Ontario Ministry of Environment, Etobicoke, ON;
Alan Hayton, Sport Fish Contaminant Monitoring Program, Ontario Ministry of Environment, Etobicoke, ON; and

**Data Sources**
Elizabeth Murphy, U.S. Environmental Protection Agency, Great Lakes National Program Office, murphy.elizabeth@epa.gov.

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Ontario Ministry of the Environment (OMOE). 2005. Guide to Eating Ontario Sport Fish 2005-2006. http://www.ene.gov.on.ca/envision/guide/index.htm, last accessed July 19, 2006.

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U.S. Environmental Protection Agency. 2004. Consumption Advice, Joint Federal Advisory for Mercury in Fish. http://www.epa.gov/waterscience/fishadvice/advice.html, last accessed May 24, 2004.

**Data**
Great Lakes Fish Monitoring Program, Great Lakes National Program Office;
Sport Fish Contaminant Monitoring Program, Ontario Ministry of Environment;
Minnesota DNR salmon fillet data for Lake Superior.

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Table 2. Uniform Great Lakes Sport Fish Consumption Advisory.
Source: Great Lakes Sport Fish Advisory Task Force, 1993.

Table 3. Consumption limits used for the *Guide to Eating Ontario Sport Fish* (based on Health Canada TDIs).
Source: Ontario Ministry of the Environment

**Last updated**
SOLEC 2006

| Lake | Contaminants that Fish Advisories are based on in Canada and the United States |
|---|---|
| Superior | Dioxin, PCBs, toxaphene, mercury, chlordane |
| Huron | Dioxin, PCBs, toxaphene, mercury, chlordane |
| Michigan | PCBs, mercury, dioxin, chlordane |
| Erie | PCBs, dioxin, mercury |
| Ontario | PCBs, dioxin, mercury, mirex, toxaphene |

**Table 1**. Contaminants on which the fish advisories are based on by lake for Canada and the United States.
Source: Compiled by U.S. Environmental Protection Agency (USEPA) Great Lakes National Program Office

| **Consumption Advice Groups** | **Concentration of PCBs (ppm)** | **Concentration of Mercury (ppm)**** | **Concentration of Chlordane (ppm)***** |
|---|---|---|---|
| Sensitive* and General | | | |
| Unrestricted Consumption | 0 – 0.05 | 0 <= 0.05 | 0 - 0.15 |
| 2 meals/ week | NA | > 0.05 <= 0.11 | NA |
| 1 meal/ week | 0.06 – 0.2 | > 0.11 <= 0.22 | 0.16 - 0.65 |
| 1 meal/ month | 0.21 – 1.0 | > .22 <= 0.95 | 0.66 - 2.82 |
| 6 meals/ year | 1.1 – 1.9 | NA | 2.83 - 5.62 |
| Do not eat | >1.9 | > 0.95 | > 5.62 |

* Women of childbearing age and children under 15
**Draft Protocol for Mercury-based Fish Consumption Advice
***Discussion Paper for Chlordane HPV

**Table 2**. Uniform Great Lakes Sport Fish Consumption Advisory.
Source: Great Lakes Sport Fish Advisory Task Force, 1993

| Advised meals per month | | Concentration of PCBs (ppm) |
|---|---|---|
| Sensitive* | General | |
| 8 | 8 | < 0.153 |
| 4 | 4 | 0.153 – 0.305 |
| Do not eat | 2 | 0.305 – 0.610 |
| Do not eat | 1 | 0.610 – 1.22 |
| Do not eat | Do not eat | >1.22 |

* Women of childbearing age and children under 15

**Table 3**. Consumption limits used for the *Guide to Eating Ontario Sport Fish* (based on Health Canada TDIs).
Source: Ontario Ministry of the Environment

**Air Quality**
Indicator #4202

**Overall Assessment**

Status: **Mixed**
Trend: **Improving**

**Purpose**

•To monitor the air quality in the Great Lakes ecosystem; and
•To infer the potential impact of air quality on human health in the Great Lakes basin.

**Ecosystem Objective**

Air should be safe to breathe. Air quality in the Great Lakes ecosystem should be protected in areas where it is relatively good, and improved in areas where it is degraded. This is consistent with ecosystem objectives being adopted by certain lakewide management plans, including Lake Superior, in fulfillment of Annex 2 of the Great Lakes Water Quality Agreement (GLWQA). This indicator also supports Annexes 1, 13, and 15.

**State of the Ecosystem**

Overall, there has been significant progress in improving air quality in the Great Lakes basin. For several substances of interest, both emissions and ambient concentrations have decreased over the last ten years or more. However, progress has not been uniform and differences in weather from one year to the next complicate analysis of ambient trends. Ozone and fine particulate matter can be particularly elevated during hot summers, and the trends are not consistent with those for related pollutants. Drought conditions result in more fugitive dust emissions from roads and fields, increasing the ambient levels of particulate matter.

In general, there has been significant progress with urban/local pollutants over the past decade or more, though somewhat less in recent years, with a few remaining problem districts. Ground-level ozone and fine particles remain a concern in the Great Lakes region, especially in the Detroit-Windsor region and extending northward to Sault St. Marie and eastward to Ottawa, the Lake Michigan basin, and the Buffalo-Niagara area. These pollutants continue to exceed the respective air quality criteria and standards at a number of monitoring locations in Southern Ontario and in the lower Great Lakes region in the U.S.

For the purposes of this discussion, the pollutants can be divided into urban (or local) and regional pollutants. For regional pollutants, transport is a significant issue, from hundreds of kilometers to the scale of the globe. Formation from other pollutants, both natural and man-made, can also be important. Unless otherwise stated, references to the U.S. or Canada in this discussion refer to nationwide averages.

**Urban/Local Pollutants**

Carbon Monoxide (CO)

*Ambient Concentrations:* In the U.S., CO levels for 2004 were the lowest recorded in the past 25 years. Ambient concentrations have decreased approximately 71% nationally from 1980 to 2004 and 42% nationally from 1993 to 2002. There are currently no nonattainment areas (areas where air quality standards are not met) in the U.S. for CO. In general, CO levels have decreased at the same rate in the Great Lakes region as the nation as a whole.

In Ontario, the composite average of the one-hour maximum CO concentration decreased by 82 percent from 1971 to 2004, while the composite average of the eight-hour maximum concentration decreased 87 percent. Since 1995, average CO concentrations have only decreased 16%. Ontario has not experienced an exceedence of the 1-hour and 8-hour criteria since 1991.

*Emissions:* In the U.S., nationwide emissions of CO have decreased 33% from 1990 to 2002, the most recent year for which aggregate National Emissions Inventory (NEI) estimates are available. The reductions in CO emissions are almost entirely due to decreased emissions from on-road mobile sources, which have occurred despite yearly increases in vehicle miles traveled. In general, CO emissions have decreased at the same rate in the Great Lakes region as the nation as a whole.

In Canada, anthropogenic emissions (not including open sources such as forest fires) have decreased nationally by about 22% between 1990 and 2002, with a 29% decline in Ontario over the same time period. These declines are mainly the result of more stringent transportation emission standards.

<u>Nitrogen Dioxide (NO2)</u>
*Ambient Concentrations:* In Ontario, ambient average NO2 concentrations have decreased 31 % from 1975 to 2004. Over the last decade (1995 to 2004), average NO2 concentrations declined 13%. The Ontario 1-hour and 24-hour air quality criterion for NO2 were not exceeded at any of Ontario's monitoring stations in 2004.

In the U.S., the annual mean concentrations decreased 37% from 1980 to 2004. NO2 levels in the Great Lakes region decreased at a slightly higher pace during this time period. An analysis of urban versus rural monitoring sites indicates that the declining trend seen nationwide and in the Great Lakes region can mostly be attributable to decreasing concentrations of NO2 in urban areas (similar results can be found in Ontario). There are currently no NO2 nonattainment areas in the U.S.

*Emissions:* In Canada, anthropogenic emissions (not including open sources such as forest fires) have increased nationally by about 5% between 1990 and 2002; however, emissions have decreased by about 11% in Ontario over the same time period. These declines are mainly the result of more stringent transportation emission standards.

In the U.S., emissions of NOx decreased by about 18% from 1990 to 2002. The downward trend can be attributed to emissions reductions at electric utilities and on-road mobile sources. Although nationwide NOx emissions have decreased, emissions from some source categories have increased including non-road engines. In general, NOx emissions have decreased at a slightly greater rate in the Great Lakes region as compared to the nation as a whole. (For more information on oxides of nitrogen, please refer to the Great Lakes Indicator Report #9000 Acid Rain.)

Sulfur Dioxide (SO2)

*Ambient Concentrations:* In the U.S., annual mean concentrations of SO2 decreased 54% from 1983 to 2002. From 1993 to 2002, annual mean concentrations of SO2 in the U.S. decreased 39%. The Great Lakes region experienced reducing trends on par with the national averages. Since the SOGL 2005 Report, the U.S. Environmental Protection Agency (USEPA) approved the redesignation of Lake County, Indiana, and Cuyahoga County, Ohio, to attainment areas. There are currently no nonattainment areas for SO2 in the Great Lakes region.

In Ontario, the average ambient SO2 concentrations improved 86% from 1971 to 2004, with a 17% improvement since 1995. Ontario did not experience any violations of the one-hour SO2 criterion (250 ppb), 24-hour criterion (100 ppb), or the annual criterion (20 ppb) in 2004.

*Emissions:* In the U.S., national SO2 emissions were reduced 33% from 1990 to 2002 mostly in response to regulations imposing cuts on coal-burning power plants. SO2 emissions in the Great Lakes region have decreased at a much greater rate than the national trend over this time period.

Canadian emissions decreased 29% nationwide from 1990 to 2002, but have remained relatively constant since 1995. Even with increasing economic activity, emissions remain about 29% below the target national emission cap. From 1990 to 2002, the emissions of SO2 in Ontario decreased 47%. These reductions mostly were the result of the Canada Acid Rain Program which primarily targeted major non-ferrous smelters and fossil fuel-burning power plants in the seven eastern-most provinces.

(For more information on sulfur dioxide, please refer to the Great Lakes Indicator Report #9000 Acid Rain.)

Lead

*Ambient Concentrations:* U.S. concentrations of lead decreased 97% from 1980 to 2004 with most of the reductions occurring during the 1980s and early 1990s. Lead levels in the Great Lakes region decreased at nearly the same rate as the national trend over this time. There are no nonattainment areas for lead in the Great Lakes region.

Based on historical data, lead concentrations at urban monitoring stations in Ontario have decreased over 95%.

*Emissions:* National lead emissions in the U.S. decreased 98% from 1980 to 1999 mostly as a result of regulatory efforts to reduce the content of lead in gasoline. The declines since 1990 have been from metals processing and waste management industries.

Similar improvements in Canada have followed with the usage of unleaded gasoline.

Total Reduced Sulfur (TRS)

*Ambient Concentrations:* This family of compounds is of concern in Canada due to odour problems in some communities, normally near industrial or pulp mill sources. Ontario did not experience any violations of the one-hour TRS criterion (27 ppb) in 2004.

*Emissions:* Hydrogen sulphide accounts for more than half of total reduced sulphur emissions. There is no requirement to report TRS emissions in the NPRI; however, there has been a requirement to report hydrogen sulphide emissions since 2000. Hydrogen sulphide emissions have increased about 47 percent from 2000 to 2003.

PM10

*Ambient Concentrations:* PM10 is the fraction of particles in the atmosphere with a diameter of 10 microns or smaller. Annual average PM10 concentrations in the U.S. have decreased 28% from 1990 to 2004. Annual average concentrations in the Great Lakes region have decreased at nearly the same rate as the national trend over this time. The national 24-hour PM10 concentration was 31% lower than the 1990 level. 24-hour average concentrations in the Great Lakes region have decreased at nearly the same rate as the national trend over this time. There are currently no nonattainment areas in the Great Lakes region. Since the SOGL 2003 report, the USEPA approved the redesignation of 2 areas in Cook County, Illinois, to attainment areas.

Canada does not have an ambient target for PM10. However, Ontario has an interim standard of 50 µg/m3 over a 24-hour sampling period to guide decision-making.

*Emissions:* In the U.S., national direct source man-made emissions decreased 29% from 1990 to 2002. The fuel combustion source category experienced the largest absolute decrease in emissions (422,000 tons and 35%), while the on-road vehicle sector experienced the largest relative decrease (183,000 tons and 47%). The Great Lakes region experienced reducing trends on par with the national averages.

In Canada, anthropogenic emissions (not including open sources such as road dust) have decreased nationally by about 15% between 1990 and 2002. However, total PM10 emissions including open sources such as road dust have actually increased by 34% in Canada over this time period. Ontario has experienced similar trends over this time period.

Air Toxics

This term captures a large number of pollutants that, based on the toxicity and likelihood for exposure, have the potential to harm human health (e.g. cancer causing) or adverse environmental and ecological effects. Some of these are of local importance, near to sources, while others may be transported over long distances. Monitoring is difficult and expensive, and usually limited in scope as such toxics are usually present only at trace levels. Recent efforts in Canada and the U.S. have focused on better characterization of ambient levels and minimizing emissions. In the U.S., the Clean Air Act targets a 75% reduction in cancer "incidence" and a "substantial" reduction in non-cancer risks. The Maximum Available Control Technology (MACT) program sets emissions standards on industrial sources to reduce emissions of air toxics. Once fully implemented, these standards will cut emissions of toxic air pollutants by nearly 1.36 million metric tons per year from 1990 levels.

In February 2006, EPA released the results of its national assessment of air toxics (NATA) using 1999 emissions. The purpose of the national-scale assessment is to identify and prioritize air toxics, emission source types and locations which are of greatest potential concern in terms of contributing to population risk. From a national perspective, benzene is the most significant air toxic for which cancer risk could be estimated, contributing 25 percent of the average individual cancer risk identified in this assessment. Based on EPA's national emissions inventory, the key sources for benzene are onroad (49%) and nonroad mobile sources (19%), and open burning, prescribed fires and wildfires (14%). EPA projects that onroad and nonroad mobile source benzene emissions will decrease by about 60% between 1999 and 2020, as a result of motor vehicle standards, fuel controls, standards for nonroad engines and equipment, and motor vehicle inspection and maintenance programs.

Of the 40 air toxics showing the potential for respiratory effects, acrolein is the most significant, contributing 91 percent of the nationwide average noncancer hazard identified in this assessment. Note that the health information and exposure data for acrolein include much more uncertainty than those for benzene. Based on the national emissions inventory, the key sources for acrolein are open burning, prescribed fires and wildfires (61%), onroad (14%) and nonroad (11%) mobile sources. The apparent dominance of acrolein as a noncancer "risk driver" in both the 1996 and 1999 national-scale assessment has led to efforts to develop an effective monitoring test method for this pollutant. EPA projects that acrolein emissions from on-road sources will be reduced by 53% between 1996 and 2020 as a result of existing motor vehicle standards and fuel controls. The assessment estimates that most people have a lifetime cancer risk between 1 and 25 in a million from air toxics. This means that out of one million people, between 1 and 25 people have increased likelihood of contracting cancer as a result of breathing air toxics from outdoor sources, if they were exposed to 1999 levels over the course of their lifetime. The assessment estimates that most urban locations have air toxics lifetime cancer risk greater than 25 in a million. Risk in transportation corridors and some other locations are greater than 50 in a million. In contrast, one out of every three Americans (330,000 in a million) will contract cancer during a lifetime, when all causes (including exposure to air toxics) are taken into account. Based on these results, the risk of contracting cancer is increased less than 1% due to inhalation of air toxics from outdoor sources.

In Canada, key toxics such as benzene, mercury, dioxins, and furans are the subject of ratified and proposed new standards, and voluntary reduction efforts.

*Ambient Concentrations:* A National Air Toxics Trend Site (NATTS) network was launched in the U.S. in 2003 to detect trends in high-risk air toxics such as benzene, formaldehyde, 1,3-butadiene, acrolein, and chromium. There are four NATTS monitoring sites in the Great Lakes region including Chicago, IL, Detroit, MI, Rochester, NY and Mayville, WI. Some ambient trends have also been found from existing monitoring networks. Average annual urban concentrations of benzene have decreased 60% in the U.S. from 1994 to 2004.

Manganese compounds are hazardous air pollutants of special concern in the Great Lakes region. They are emitted by iron and steel production plants, power plants, coke ovens, and many smaller metal processing facilities. Exposures to elevated concentrations of manganese are harmful to human health and have been associated with subtle neurological effects, such as slowed eye-hand coordination. The most recent NATA results identify manganese compounds as the largest contributor to neurological non-cancer health risk in the U.S. Modeled estimates of ambient manganese compounds in all 3222 U.S. counties show that among the 50 counties with the highest concentrations nation-wide, 20 are located in Region 5. The median average annual manganese concentration at 21 trend sites showed a 14.7% decline between 2000 and 2004. Additional years of data will be needed to confirm this apparent trend.

In Ontario, average annual urban concentrations of benzene, toluene, and xylene have decreased about 45%, 42%, and 50% respectively from 1995 to 2004.

*Emissions:* The Great Lakes Toxics Inventory is an ongoing initiative of the regulatory agencies in the eight Great Lakes States and the Province of Ontario. Emissions inventories have been developed for 1996, 1997, 1998, 1999, 2001, and 2002 but different approaches were used to develop these inventories making trend analysis difficult.

In Canada, emissions are also being tracked through the National Pollutant Release Inventory (NPRI). The NPRI includes information on some of the substances listed by the Accelerated Reduction/Elimination of Toxics (ARET) program. Significant voluntary reductions in toxic emissions have been reported through the ARET program.

In the U.S., emissions are also being tracked through the National Emissions Inventory (NEI) and the Toxics Release Inventory (TRI). NEI data indicate that national U.S. air toxic emissions have dropped approximately 42% between the 1990 and 2002, though emission estimates are subject to modification and the trends are different for different compounds. The 1999 NEI also showed that Region 5 had the highest manganese emissions of all EPA Regions, contributing 36.6% of all manganese compounds emitted nation-wide.

The TRI, which began in 1988, contains information on releases of nearly 650 chemicals and chemical categories from industries, including manufacturing, metal and coal mining, electric utilities, and commercial hazardous waste treatment, among others. Although the TRI has expanded and changed over the years, it is still possible to ascertain trends over time for core sets of toxics. The total reported air emissions of the TRI 1988 Core Chemicals (299 chemicals) in the eight Great Lakes states have decreased by about 78% from 1988 to 2004. According to the TRI manganese emissions from point sources declined between 1988 and 2003 both nationally (26.2%) and in Region 5 (36.7%). Year-to-year variability in manganese emissions is high, however, and recent emissions data (1996-2003) suggest a weaker trend: emissions dropped 7.6% and 12.4% nation-wide and in Region 5, respectively.

**Regional Pollutants**

<u>Ground-Level Ozone (O3)</u>
Ozone is generally considered a secondary pollutant, which forms from reactions of precursors (VOCs - volatile organic compounds and NOx - nitrogen oxides) in the presence of heat and sunlight. Ozone is a problem pollutant over broad areas of the Great Lakes region, except for the Lake Superior basin. Local onshore circulations around the Great Lakes can exacerbate the problem, as pollutants can remain trapped for days below the maritime/marine inversion (this forms when a layer of warm air moves to lie over colder marine air, thus trapping the colder air). Consistently high levels are found in provincial parks near Lakes Huron and Erie, and western Michigan is impacted by transport across Lake Michigan from Chicago.

*Ambient Concentrations*: In 2004, ozone levels in the U.S. showed continued improvement. National assessments find some uneven improvement in peak levels, but with indications that average levels may be increasing on a global scale. Ozone levels are still decreasing nationwide, but the rate of decrease for 8-hour ozone levels has slowed since 1990. The Great Lakes region has experienced smaller decreases than nationwide averages (Figure 1). Many of the improvements in ozone concentrations during these times have been a result of local emission reductions in urban areas.

To address the regional transport of ozone and ozone-forming pollutants in the eastern half of the country, the U.S. EPA developed a program to reduce regional NOx emissions called the NOx State Implementation Plan (SIP) Call in 2002. An analysis of 2002-2004 ozone data show that the NOx SIP Call achieved an additional 4 percent reduction in seasonal 8-hour ozone concentrations. It is important to note that weather conditions in 2004 were not conducive to ozone formation, and that ozone levels in 2005 and 2006 could be higher than in 2004 depending on weather conditions. The NOx SIP Call also appears to have caused a gradual decline in 8-hour daily maximum ozone concentrations (Figure 2).

Since the SOGL 2005 Indicator Report, the 1-hour ozone standard was revoked in the U.S. and all 6 nonattainment areas in the Great Lakes basin were reclassified. Now there are 28 areas covering 70 counties in the Great Lakes basin designated as nonattainment for the 8-hour ozone standard (Chicago-Gary-Lake Co, IL-IN metropolitan area; South Bend/Elkhart, IN; LaPorte County, IN; Fort Wayne, IN; Detroit-Ann Arbor metro area, MI; Flint metro area, MI; Grand Rapids metro area, MI; Muskegon County, MI; Allegan County, MI; Huron County, MI; Kalamazoo-Battle Creek metro area, MI; Lansing-East Lansing metro area, MI; Benton Harbor area, MI; Benzie County, MI; Cass County, MI; Mason County, MI; Jamestown, NY; Buffalo-Niagara Falls metro area, NY; Rochester metro area, NY; Jefferson County, NY; Toledo metro area, OH; Cleveland-Akron-Lorain metro area, OH; Erie, PA; Milwaukee-Racine metropolitan area, WI; Sheboygan County, WI; Manitowoc County, WI; Kewaunee County, WI; and Door County, WI).

In Ontario, ozone concentrations continued to exceed Ontario's Ambient Air Quality Criterion (AAQC). In 2004, 28 of the 37 ambient Air Quality Index (AQI) monitoring stations in Ontario recorded exceedences of the 1-hour ozone AAQC on at least one occasion. Although the ozone levels continue to exceed Ontario's AAQC, the 1-hour maximum ozone concentrations recorded in Ontario have, on average, decreased by 13% from 1980 to 2004. Over the past 10 years (1995 to 2004), the annual composite means of one-hour ozone maximum concentrations have decreased by about 4%. In fact, the year 2004 recorded the lowest one-hour ozone maximum (84 ppb) over the last 25 years. This is partly related to the lack of weather conditions conducive to formation of ground-level ozone in 2004; however, it also indicates that many of the efforts to curb emissions and improve the air quality in Ontario are working.

However, Ontario has experienced an overall increasing trend in seasonal mean ozone concentrations over the same 25-year period. The summer and winter seasonal ozone means have increased by approximately 25% and 44%, respectively (Figure 3). The increase of the summer mean is related to meteorological conditions and the transport of ozone and its precursors into Ontario, whereas the increase of the winter mean indicates an increase in background concentrations of ozone throughout Ontario. Similar increases in the background concentrations of ozone have been found in other parts of North America.

Although Ontario is not required to report on the new Canada-wide Standard (CWS) for ozone until 2006, data from 2002-2004 indicate that all but one monitoring site (Thunder Bay) in Ontario exceeded the ozone CWS of 65 ppb based on the 4$^{th}$ highest ozone eight-hour running average over three consecutive years.

*Emissions:* In the U.S., VOC emissions from anthropogenic sources decreased 32% from 1990 to 2002. The rate of reduction in the Great Lakes basin was slightly less than the national average. In 2002, VOC emissions from biogenic sources were estimated to determine the relative contribution of natural versus anthropogenic sources. It was estimated that biogenic emissions contributed approximately 71% of all VOC emissions in the country. NOx emissions in the U.S. have also decreased 18% from 1990 to 2002.

In Ontario, man-made VOC emissions have decreased about 27 percent from 1990 to 2002. The reductions are mostly attributable to the transportation and petroleum refining sectors. VOC emissions in all of Canada have decreased 22 % over the same time period. Canadian NOx emissions have increased nationally by about 5% between 1990 and 2002; however, emissions have decreased by about 11% in Ontario over the same time period.

$PM_{2.5}$

This fraction of particulate matter (diameter of 2.5 microns or less) is a health concern because it can penetrate deeply into the lung, in contrast to larger particles. $PM_{2.5}$ is primarily a secondary pollutant produced from both natural and man-made precursors (SO2, NOX, and ammonia).

*Ambient Concentrations:* A CWS for $PM_{2.5}$ of 30 µg/m3 was established in June 2000. Achievement of the standard is based on the 3-year average of the annual 98th percentiles of the daily, 24-hour (midnight to midnight) average concentrations. As $PM_{2.5}$ monitoring has only begun quite recently, there is not enough data to show any national long-term trends. Although Ontario is not required to meet the CWS for fine particulate matter until 2010 and begin reporting on progress towards meeting the new CWS until 2006, data from 2004 indicate that many areas in Ontario have recorded 98$^{th}$ percentile daily averages of $PM_{2.5}$ above 30 ug/m3 (Figure 4). In Ontario, during summer episodes, PM2.5 mainly consists of sulphate particles.

In the U.S., annual average $PM_{2.5}$ concentrations in 2004 were the lowest since nationwide monitoring began in 1999. The trend is based on measurements collected at 707 monitoring stations that have sufficient data to assess trends over that period. Concentrations in 2004 represent an 11% decrease since 1999. The Great Lakes region has experienced a slightly greater decline than the national average. In 2004, the average 24-hour $PM_{2.5}$ concentration was also 11% lower than the average 1999 level. 24-hour $PM_{2.5}$ concentrations in the Great Lakes region decreased at nearly the same rate as the national trend over this time. Despite some uncertainties, the reductions in PM2.5 concentrations in the Great Lakes region appear to be largely a result of emission reduction at sources that contribute to the formation of carbon-containing particles (Figure 5). Direct emissions of carbon-containing particles include motor vehicles and fuel combustion.

There are three areas in the Great Lakes region that are designated nonattainment for the PM2.5 standard (Chicago-Gary-Lake Co, IL-IN metropolitan area; Detroit-Ann Arbor, MI metro area; and the Cleveland-Akron-Lorain, OH metro area).

*Emissions:* In the U.S., direct emissions from anthropogenic sources decreased 27 percent nationally between 1990 and 2002; however, this decreasing trend does not account for the formation of secondary particles. The largest absolute reduction in PM2.5 emissions was seen in the fuel combustion source category (347,000 tons and 38%); while, the largest relative reduction in PM2.5 emissions was in the on-road vehicle category (175,000 tons and 54%).

In Canada, emissions (not including open sources such as road dust, construction operations, and forest fires) have decreased nationally by about 14% between 1990 and 2002. However, total PM2.5 emissions including open sources have increased by 6% in Canada over this time period. Ontario has experienced similar trends over this time period.

**Pressures**

Continued economic growth, population growth, and associated urban sprawl are threatening to offset emission reductions achieved by policies currently in place, through both increased energy consumption and vehicles miles traveled. The changing climate may affect the frequency of weather conditions conducive to high ambient concentrations of many pollutants. There is also increasing evidence of changes to the atmosphere as a whole. Continuing health research is both broadening the number of toxics, and producing evidence that existing standards should be lowered.

**Management Implications**

Major pollution reduction efforts continue in both U.S. and Canada. In Canada, new ambient standards for particulate matter and ozone have been endorsed, with a 2010 achievement date. This will involve updates at the Federal level and at the provincial level (the Clean Air Action Plan, and Ontario's Industry Emissions Reduction Plan). Toxics are also addressed at both levels. The Canadian Environmental Protection Act (CEPA) was recently amended.

In the U.S., new, more protective ambient air standards have been promulgated for ozone and particulate matter. MACT (Maximum Available Control Technology) standards continue to be promulgated for sources of toxic air pollution. USEPA has also begun looking at the risk remaining after emissions reductions for industrial sources take effect.

At the international level, Canada and the U.S. signed the Ozone Annex to the Air Quality Agreement in December 2000. The Ozone Annex commits both countries to reduce emissions of NOX and VOCs, the precursor pollutants to ground-level ozone, a major component of smog. This will help both countries attain their ozone air quality goals to protect human health and the environment. Canada estimates that total NOX reduction in the Canadian transboundary region will be between 35% and 39% of the 1990 levels by 2010. Under the Clean Air Action Plan, Ontario is also committed to reducing provincial emission of NOX and VOCs by 45% of 1990 levels by 2015, with interim targets of 25% by 2005.

The U.S. estimates that the total NOx reductions in the U.S. transboundary region will be 36% year-round by 2010 and 43% during the ozone season. Canada and the U.S. have also undertaken cooperative modeling, monitoring, and data analysis and developed a work plan to address transboundary PM issues. PM2.5 networks will continue to develop in both countries, to determine ambient levels, trends, and consequent reduction measures. Review of standards or objectives will continue to consider new information. Efforts to reduce toxic pollutants will also continue under North America Free Trade Agreement and through United Nations-Economic Commission for Europe protocols. The U.S. is continuing its deployment of a national air toxics monitoring network.

**Comments from the author(s)**
Updated 2005 emissions data from Canada's National Pollutant Release Inventory (NPRI) is expected to become available in the fall of 2006. Environment Canada is also expected to release a five-year comprehensive report on the progress towards the Canada-wide Standards (CWS) for PM and ozone in the fall of 2006.

These new data will be incorporated into the indicator report before finalization.

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Source: Figure 004-4. Ambient ozone concentrations, 1980-2004, by EPA region; 2007 Report on the Environment (ROE) Technical Document. http://www.epa.gov/indicators/, last accessed September 5, 2006.

Figure 2. Rural Seasonal Average 8-hour Maximum Ozone Concentrations by EPA Region, 1997-2004.
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Figure 3. Trend of Ozone Seasonal Means at Sites Across Ontario (1980-2004).
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Figure 4. $PM_{2.5}$ Levels at Selected Sites Across Ontario, $98^{th}$ Percentile PM2.5 Daily Average (2004).
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Figure 5. Trends of $PM_{2.5}$ and its chemical constituents in the Industrial Midwest of the U.S., 1999-2003.
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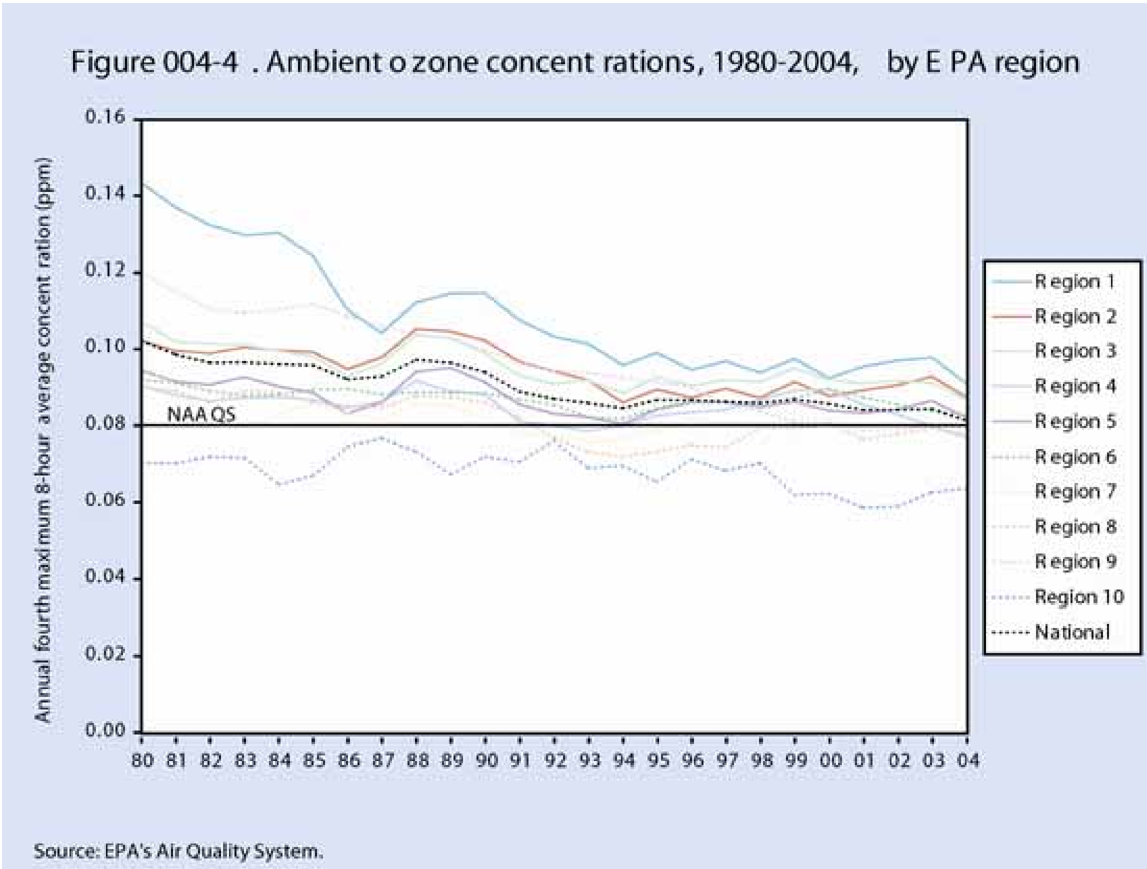


**Figure 1**. Trends in Fourth Highest Daily Maximum 8-hour ozone concentration (ppm) by EPA Region 1980-2004.
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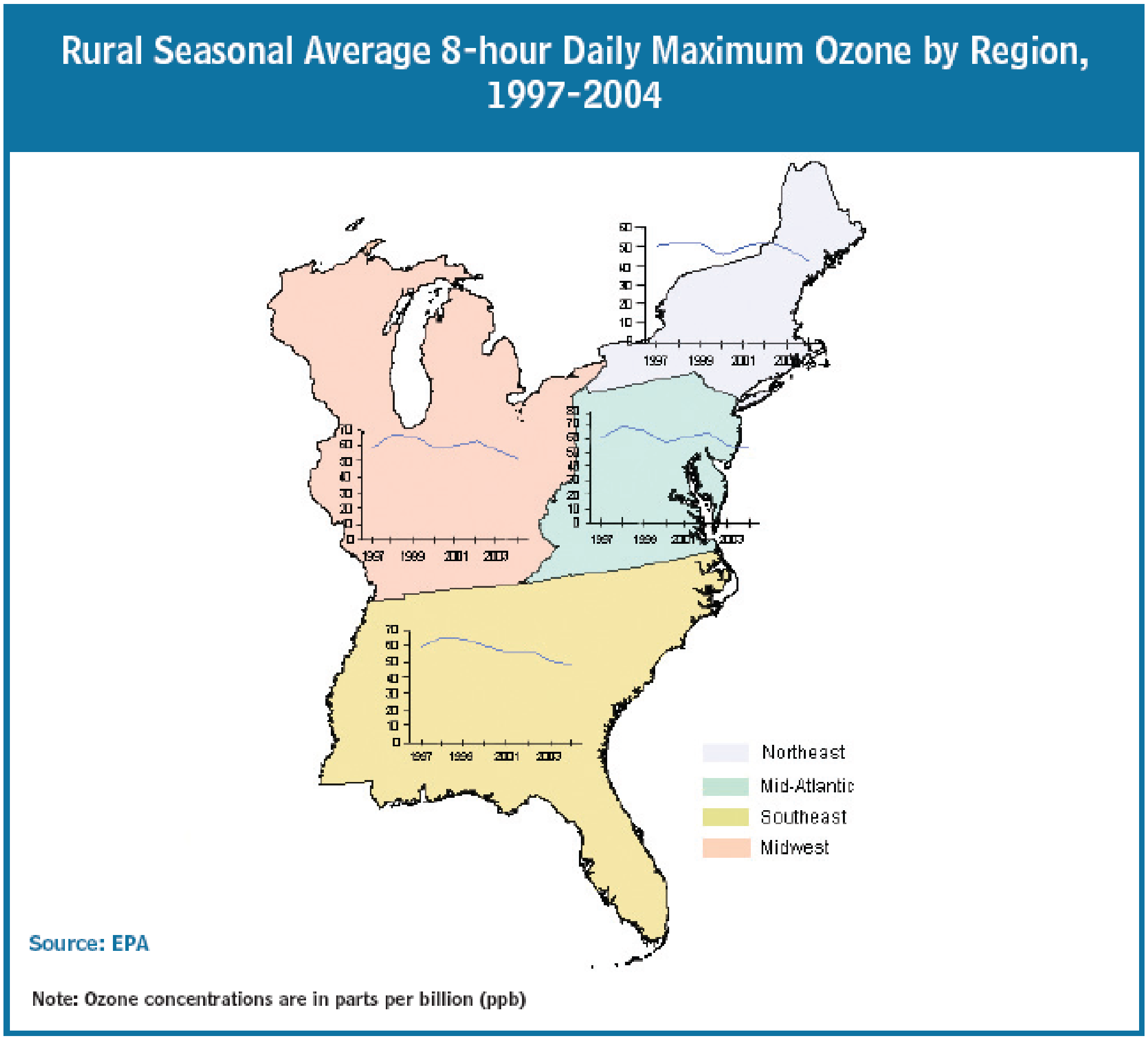


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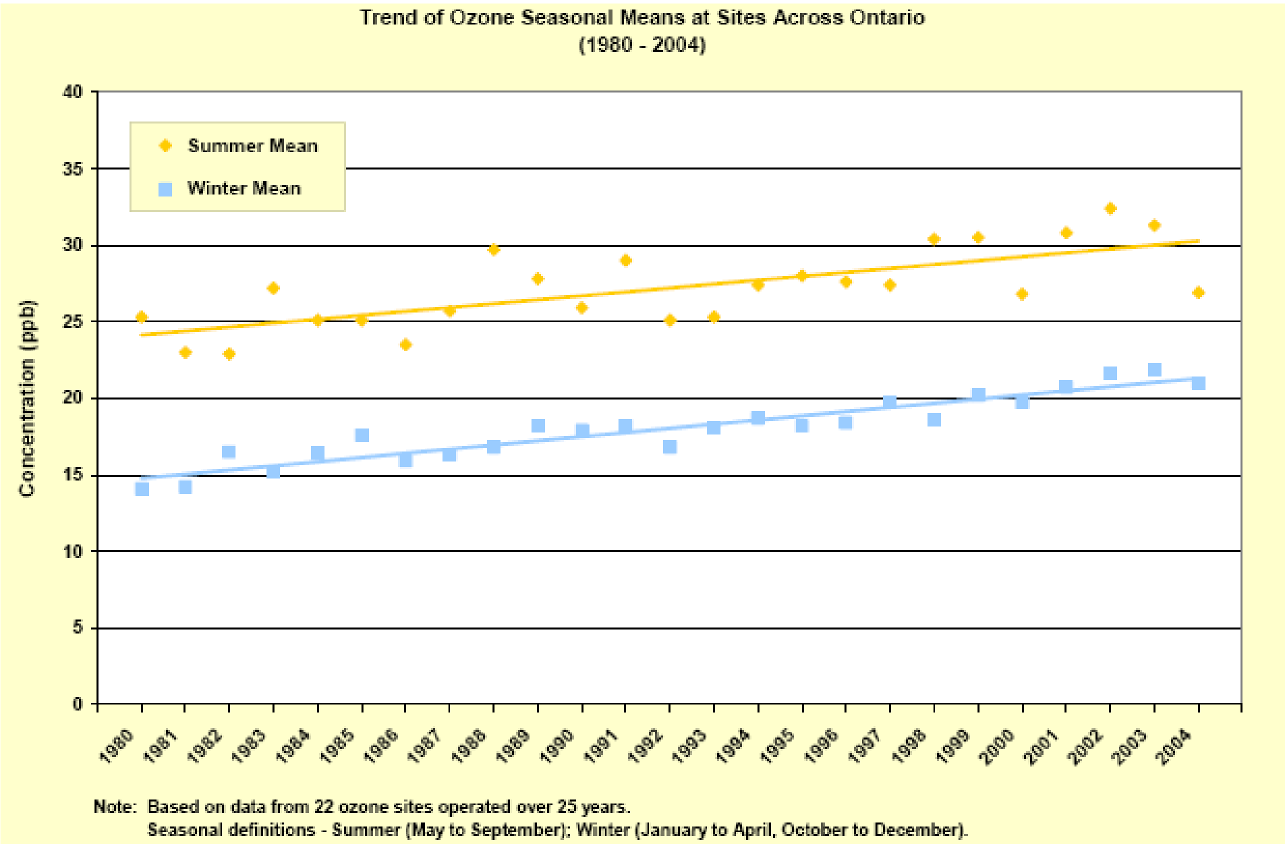


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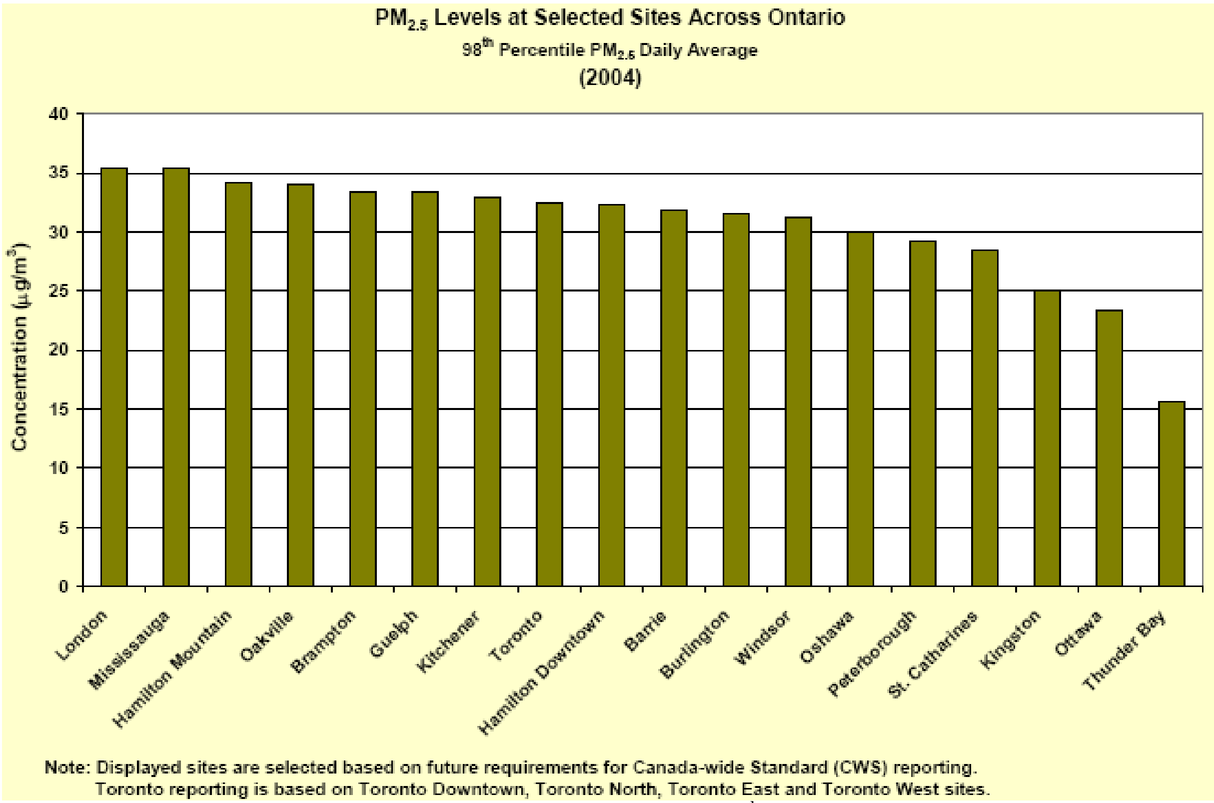


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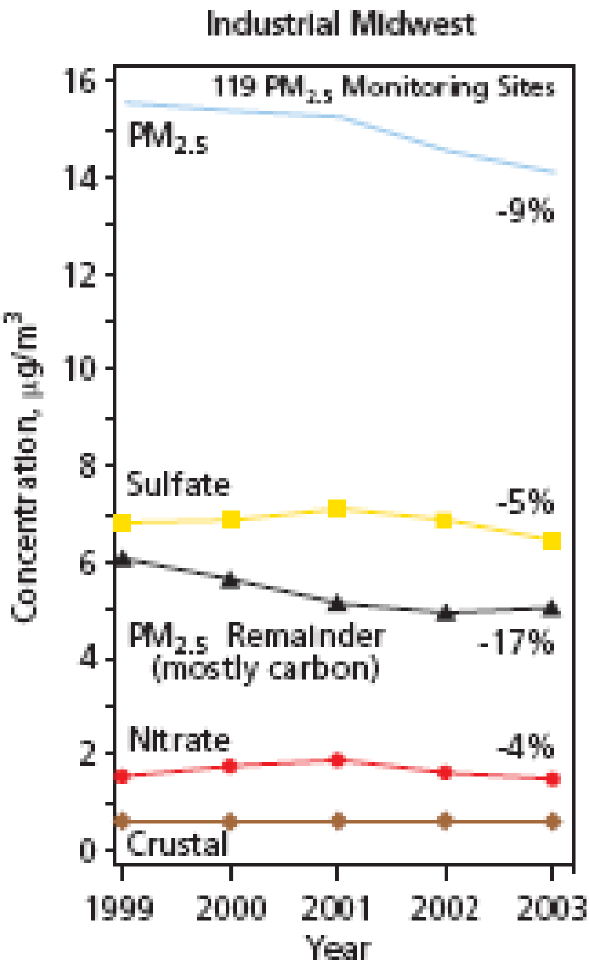


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