



Toxic Chemicals in Offshore Waters

Formerly Indicator #118

Overall Assessment

Status: Fair

Trend: Undetermined

Rationale: Concentrations of many compounds are still detectable, although they are at very low concentrations. The trends are mixed (and therefore “undetermined”). The majority of trends are favourable (declining concentrations) for the organochlorine compounds. For PAHs, the trends are mixed, and the trends for in-use pesticides indicate increasing concentrations or no change.

Lake-by-Lake Assessment

Lake Superior

Status: Fair

Trend: Unchanging

Rationale: Concentrations of some compounds are lowest in Lake Superior, but several persistent compounds that are delivered to Lake Superior by atmospheric deposition are found at higher concentrations compared to the other Great Lakes. The temporal changes are subtle and the overall trend is unchanging.

Lake Michigan

Status: Fair

Trend: Undetermined

Rationale: More limited information is available for Lake Michigan from the Great Lakes Surveillance Program. Temporal trends cannot be determined. Concentrations of most compounds are low, but some relatively elevated concentrations were observed at the most southern sampling station in 2006 compared to the rest of the lake.

Lake Huron

Status: Good

Trend: Unchanging

Rationale: The water quality in Lake Huron tends to reflect the inflows from Lake Michigan and Lake Superior. Higher concentrations of atmospherically-deposited substances that are observed in Lake Superior are not as apparent in Lake Huron, resulting in lower concentrations of these substances here. Long-term trends are subtle, indicating little to no change for most parameters.

Lake Erie

Status: Fair

Trend: Unchanging

Rationale: The highest concentrations of some parameters, such as mercury, are observed here. Within Lake Erie, higher concentrations are observed in the western basin. Data do not indicate significant change over time for most parameters with the exception of some currently used pesticides which are increasing.

Lake Ontario

Status: Fair

Trend: Unchanging

Rationale: The highest concentrations of some parameters, such as total PCBs and certain in-use pesticides, are

observed in Lake Ontario. With some exceptions, most trends are subtle, indicating little change over time.

Purpose

- To assess the concentration of priority toxic chemicals in offshore waters
- To infer the potential for impacts on the health of the Great Lakes aquatic ecosystem by comparison to criteria for the protection of aquatic life and human health
- To infer progress toward virtual elimination of toxic substances from the Great Lakes basin

Ecosystem Objective

The GLWQA and the Binational Strategy both state the virtual elimination of toxic substances to Great Lakes as an objective. Additionally, GLWQA General Objective (d) states that the Great Lakes should be free from materials entering the water as a result of human activity that will produce conditions that are toxic or harmful to human, animal, or aquatic life. This indicator supports Annexes 1, 11 and 12 of the GLWQA.

Ecological Condition

This indicator tracks whether concentrations of the IJC priority toxic chemicals are, as a group, decreasing, staying the same, or increasing in open waters over time. The chemicals of interest include, but are not limited to, PCBs, dieldrin, chlordane, DDT and metabolites, hexachlorobenzene and mercury. Monitoring for this indicator occurs during the three year periods between SOLEC. Sampling is conducted during spring, isothermal conditions, as maximum concentrations of many priority toxics have been reported during this time.

Endpoint

When concentrations of toxic chemicals associated with existing water quality criteria in the offshore waters of the Great Lakes are no longer measurable above naturally-occurring levels by current technology, or are below existing water quality criteria and show a declining trend. The endpoint will be achieved when 95-100% of the available data indicate concentration levels below criteria. Progress will be determined based on whether trends of the IJC priority toxic chemicals are positive (i.e., increasing pollutant concentrations) or negative (decreasing pollutant concentrations) and by the number of chemicals which reach the endpoint.

Background

Water quality samples for the analysis of toxics have been collected from the Great Lakes since the mid 1980s as part of Environment Canada's Great Lakes Surveillance Program. Ship-based monitoring cruises are conducted to measure water quality in each of the lakes upon which Canada borders. Measuring organic contaminants in water is challenging, and it requires special equipment, techniques and knowledge. In the first years of monitoring for organic contaminants, whole water samples were collected. Special studies, conducted between 1992 and 1995, recommended collecting surface, dissolved phase samples during the spring only (Williams et al., 2001). With the exception of some in-use pesticides, maximum concentrations were observed during the spring, and therefore represent the worst-case situation and can be used to determine compliance with water quality objectives.

Prior to 2004, samples for organic contaminants were centrifuged to separate the dissolved and particulate fractions, and the dissolved fraction was prepared for analysis immediately after collection, on board the ship, using a Goulden large volume extractor (Goulden and Anthony, 1985). Extracts were stored and returned to Environment Canada laboratory facilities in Burlington, Ontario, for analysis using gas chromatography/mass spectrometry. Since 2004, we have improved the technique and the 16 – 24 L samples are now stabilized in the field, and brought back to a specially constructed clean laboratory at Environment Canada for extraction. There appears to be less interference from extraneous contamination (presumably from ship-derived pollutants). Improvements in laboratory methods

have resulted in much better (i.e., lower) detection limits for many compounds including PAHs and some organochlorines. For some parameters, the improvements mean that we have greater confidence in the more recent data compared to those obtained before 2004, but this also means that longer-term trends are difficult to determine. For example, detection limits for many polycyclic aromatic hydrocarbons (PAHs) have greatly improved. Measurable concentrations of some PAHs are now reported in Great Lakes waters for the first time; this does not necessarily mean that they were previously absent, but rather our ability to detect them has improved.

The Canadian Council of Ministers of the Environment (CCME, 1999) has withdrawn the water quality guidelines for several of the organochlorine compounds (aldrin, chlordane, dieldrin, endrin, heptachlor and PCBs) and a water quality guideline is no longer recommended. Exposure to these compounds for aquatic organisms is primarily via sediment, soil and/or tissue, therefore assessment of environmental quality relative to sediment and fish tissue guidelines is instead recommended. Indeed, these compounds are relatively hydrophobic and are difficult to measure in surface waters. Because of those difficulties, and because of the short time period of higher quality data that is available for assessing trends, it may be more useful to assess longer term trends using sediments or fish as environmental quality indicators for these compounds.

Status

Lake Superior

Concentrations of most organic compounds are lowest in Lake Superior. This is likely because historic sources of most compounds were predominantly located in more industrial and agricultural regions. However, several compounds that are more susceptible to atmospheric transport and deposition are found at higher concentrations in the upper Great Lakes compared with the lower lakes. Compounds that are found at higher concentrations in Lake Superior include a-HCH, lindane, g-chlordane, a-endosulfan, endrin, and b-endosulfan (b-endosulfan was only found in trace quantities in Lake Superior). An example of the spatial distribution of one of these compounds, a-HCH, is shown using the most recent quality-assured data in Figure 1. No exceedences of Canadian federal water quality guidelines are observed for any parameter in Lake Superior.

Concentrations of most organochlorine compounds are below detection limits or declining, although data are insufficient in most cases to quantify the rate of decline. Concentrations of a few organochlorines appear to be unchanging, such as HCB, heptachlor epoxide and dieldrin, although the latter shows some indication of a more recent decline (2005-2008). Increases are observed for the in-use pesticides atrazine and possibly metolachlor. The overall temporal trend for toxics is therefore mixed.

The ecosystem objective has not been achieved in Lake Superior because detectable concentrations of many parameters are observed and some compounds are showing increasing trends.

Lake Michigan

Only limited information is available for Lake Michigan. Environment Canada does not conduct monitoring in Lake Michigan as it is located entirely within the United States. In 2006, however, as part of the Cooperative Monitoring and Science Initiative, some limited sampling for toxics in water was conducted. Data are also available from the USEPA for Lake Michigan from 1994 to 1997 and from the mid-2000s, and these are used for comparison purposes.

Samples were collected from six stations in Lake Michigan in 2006. Similar to Lakes Superior and Huron, concentrations of most compounds were low. However, certain compounds showed higher concentrations compared to the other Great Lakes, including dieldrin, heptachlor epoxide and a-chlordane. Although the Canadian water quality guidelines are not applicable to United States' waters, comparison with the benchmark CCME water quality

guideline indicated no exceedences. Within Lake Michigan, higher values of certain compounds (some PAHs, g-chlordane, a-endosulfan) were found at sites in the southern basin compared to more offshore locations.

Information about contaminants in the waters of Lake Michigan is available from the USEPA from sampling conducted during the 1990s and 2000s. These data can be used to help determine changes over time, although inter-laboratory differences make trend determinations more difficult. A comparison of total PCBs obtained by the two agencies, and a comparison of values obtained by Environment Canada in the other Great Lakes, indicates that our values determined from 2006 samples in Lake Michigan may be too low. Total PCBs determined by EPA in the 1990s and again from 2003 – 2005 indicate values are typically in the 110 to 170 pg/L range, which are higher than Environment Canada's measured whole-lake average of only 49 pg/L in 2006. Additional samples were collected by Environment Canada from Lake Michigan in 2010. Values of total PCBs appeared to be higher than in 2006, but blank values are currently being analyzed to assess the blank-corrected concentrations for comparison with the other lakes.

Lake Huron

With inflows from both Lake Superior and Lake Michigan, the water quality of Lake Huron tends to reflect these other two Great Lakes. North Channel waters tend to reflect the outflow from Lake Superior, with very low values of many compounds (such as PAHs and organochlorines such as dieldrin), but higher concentrations of compounds that are deposited from atmospheric sources in Lake Superior, such as a-HCH. The waters of Georgian Bay are similar to the main body of Lake Huron with respect to toxic chemicals (i.e., low concentrations). Slightly higher concentrations of some parameters (for example, HCB) have been observed in and near Saginaw Bay and the inflow from Lake Michigan, compared to the remainder of the lake.

The overall status for most toxic compounds is better in Lake Huron compared to the other Great Lakes. Temporal trends indicate little change over time. The ecosystem objective has not been achieved in Lake Huron because toxics are still measurable and because temporal trends are not demonstrating significant declines.

Lake Erie

The waters of Lake Erie have some of the highest concentrations of chemicals that are still in commercial use or that had historical sources in its basin or upstream in the St. Clair and Detroit Rivers. Within Lake Erie, water quality tends to be poorest in the western basin, and improves towards the east. For example, the highest concentrations of mercury in Great Lakes surface waters are observed in the western basin of Lake Erie. Although the maximum concentration of mercury (18.2 ng/L in 2009) approaches the CCME (1999) water quality guideline for inorganic mercury for the protection of freshwater aquatic life (26 ng/L), there have been no observed exceedances of the guideline to date. a-endosulfan is only consistently detectable in the western and central basins of Lake Erie; a-chlordane is only detected in the western basin of Lake Erie, in Lake Michigan and in Toronto harbour. The current use pesticides are found at highest concentrations in Lake Erie; contrary to most other parameters, concentrations tend to be higher in the central and eastern basins compared to the west. DDT and its metabolites are routinely detected only in the lower Great Lakes (lakes Erie and Ontario), likely due to historic usage in agriculture. The majority of the PAH compounds monitored are also found at highest concentrations in Lake Erie compared with the other lakes.

Concentrations of a-HCH have decreased over time, although the rate of decline appears to have slowed and recent measurements indicate higher concentrations in the western basin compared to other locations within Lake Erie. Similarly, concentrations of Lindane (g-HCH) appear to be lower since about 2000, with higher values found in the western basin compared to other sites. Other compounds, such as d-HCH, indicate no spatial or temporal trends.

The trends for PAH compounds are mixed. For example, phenanthrene concentrations indicate a possible decline since about 2000, but most others indicate no clear temporal trend. The current use pesticides atrazine and metolachlor both showed maximum values in 1998, but no clear trend over time.

The ecosystem objective has not been achieved in Lake Erie because many compounds are detectable and show higher concentrations compared to the other Great Lakes, and because declining trends are not generally observed.

Lake Ontario

Many compounds, particularly those resulting from historical use in industry and agriculture, are found at highest levels in the lower Great Lakes (Ontario and Erie). These compounds include hexachlorobenzene (HCB), lindane, dieldrin, DDT and its metabolites and some PAHs. The spatial distribution of HCB is shown in Figure 2. Higher values of total PCBs are observed in Lake Ontario and along the southern shore and western basin of Lake Erie compared to the upper Great Lakes. The monitored current-use pesticides (atrazine and metolachlor) are observed in higher concentrations in Lake Ontario. However, no CCME water quality exceedences are observed.

Because the highest concentrations of some compounds are observed here, and because the temporal trends are mixed, the ecosystem objective has not been achieved for Lake Ontario.

Total PCBs

Polychlorinated biphenyls (PCBs) are monitored as congeners and are summed to give total PCB concentrations. Field and laboratory methodologies have improved since we began measuring PCBs in Great Lakes waters, and the detection limits have lowered from 0.8 ng/L to 0.044 ng/L. Field and laboratory blanks have improved as well, but background, extraneous PCB contamination remains problematic. Total PCBs are detected in all Great Lakes waters, but concentrations are significantly higher in sample water than in field blanks only in Lake Ontario and in the western basin of Lake Erie.

Temporal trends are difficult to discern because of improved detection limits and extraneous contamination as measured by laboratory and field blanks. The best record exists for Lake Ontario, where toxics were measured on five occasions between 2004 and 2010. The data indicate values in the offshore have been relatively constant over this time period (~190 pg /L). Studies conducted by the USEPA in spring 1993 indicated similar values (range 110 – 190 pg /L), indicating no change over the past 15 years.

Despite the problems with determining the absolute values of total PCBs in lake water, the relative values indicate a spatial distribution of PCBs with higher levels in the lower Great Lakes compared with the upper Great Lakes, and higher values in the nearshore environment compared to the open lake. The most recent (2004-2008) quality-assured data indicate total (laboratory blank-corrected) PCBs in the open waters of Lake Ontario are approximately 190 pg/L. Concentrations at nearshore stations (where water depth is less than 50 m) have remained relatively constant at about 287 pg/L, and values in Toronto Harbour (395 pg /L) and Hamilton Harbour (2565 pg /L) are greater. In Lake Erie, concentrations are highest in the western basin (average 547 pg /L) and decline as the waters flow through the central basin (144 pg /L) to the east (116 pg /L). Values in the upper Great Lakes (Huron, Georgian Bay, Michigan and Superior) are lower, and range from 50 pg /L to about 124 pg/L.

Dieldrin

Dieldrin is detected throughout the Great Lakes. Lakewide average concentrations are highest in Lake Michigan (184 pg/L) and lowest in Lake Huron and Georgian Bay (63 to 85 ng/L). Concentrations in most lakes are declining. In Lake Ontario, the rate is about 6.6 pg/L yr ($p < 0.001$), resulting in a half-fold time of approximately 16

years (starting from 1992). In Lake Erie the rate is about 8.9 pg/L · yr ($p=0.04$) and in Lake Superior the rate is about 3.3 pg/L · yr ($p=0.078$). In Lake Huron, dieldrin appears to be increasing at a rate of 5.9 pg/L · yr ($p=0.056$) but the data are relatively sparse and the trend in Lake Michigan is unknown.

Lindane

Lindane (g-HCH) is detected in all of the Great Lakes. Concentrations are highest in Lake Superior and lowest in Lake Huron, Georgian Bay and Lake Michigan. The temporal trend (Figure 3) shows that lindane is declining in all the lakes (no temporal information is available for Lake Michigan). The use of lindane in the US and Canada started to be restricted in the 1970s and in 2007 its major uses were banned entirely with the exemption of its use for the treatment of head scabies and lice. The marked decline in the lakes reflects the success of usage restrictions. The high concentrations found in Lake Superior are likely due to atmospheric deposition and slower volatilization and breakdown at lower water temperatures.

Mercury

Mercury is a metal found in trace concentrations in the Great Lakes, but due to the processes of bioconcentration (accumulation within organisms) and bioaccumulation (accumulation within the food chain), even low water concentrations accumulate and adversely affect higher organisms. Mercury is responsible for the majority of the fish consumption advisories in the Great Lakes (Health Professionals Task Force, 2004). Total mercury has been measured in the Great Lakes using novel, ultra-clean techniques since 2003 (Dove et al., 2011). The record of total mercury on suspended sediments extends back to 1986 in the Niagara River. The modern data provides us with a spatial overview of surface water mercury concentrations (Figure 4) and the longer-term record provides a trend over time (Figure 5).

Currently, mercury concentrations tend to be highest in the western basin of Lake Erie, where higher turbidity levels and proximity to urban areas and probable historical sources likely contribute to elevated mercury levels. With the notable exception of Lake Erie, the nearshore areas of Lake Ontario also show higher concentrations of total mercury than the nearshore of the other lakes. Offshore concentrations throughout most of the Great Lakes are within a relatively narrow range from about 0.24 to 0.54 ng/L. Within this narrow range, the lowest concentrations are observed in Lake Huron and Georgian Bay (mean 0.24 and 0.3 ng/L, respectively), intermediate concentrations are observed in Lake Superior and Lake Ontario (mean ~0.35 ng/L), and higher concentrations are observed in Lake Michigan (0.49 ng/L) and the eastern basin (most representative of the offshore) of Lake Erie (0.54 ng/L) (Figure 4). The average concentration of total mercury in waters from the western basin of Lake Erie was 12.4 ng/L in 2009 (Dove et al., 2011).

Long-term concentrations of mercury appear to be declining. Figure 5 shows the concentration of total mercury in Niagara River waters, calculated from the concentration of mercury on suspended sediment, and the concentration of suspended sediment in the water. The equivalent water concentrations show considerable variability but the long-term trends are declining. Upstream at Fort Erie, the rate of decline has been 0.0061 ng/L · yr and downstream at Niagara-on-the-Lake the rate has been 0.015 ng/L · yr. For the time period 1986 to 2005, these rates translate to an approximate 18% decline at FE and a 30% decline at NOTL. The faster rate of decline downstream indicates that sources of mercury to the river are decreasing.

Currently-Used Pesticides

In-use pesticides are monitored only at selected stations and on selected cruises, mainly during the summer to reflect post-application concentrations. The monitored parameters include a suite of acid and neutral herbicides as well as organophosphorus pesticides. In-use pesticides are not as persistent nor as bioaccumulative as the other compounds

monitored here, and Canadian federal water quality guidelines instead reflect their potential for direct toxicity to aquatic organisms.

Most organophosphorus pesticides are not detected or only rarely detected at low concentrations in Great Lakes waters. However, several compounds are detected almost ubiquitously, including the herbicides atrazine and metolachlor. Despite their relatively low persistence, concentrations of these in-use pesticides are increasing or remaining stable in the lakes due to their continued use in agriculture and on urban lawns and gardens. The temporal trend of atrazine is shown in Figure 6, and indicates that concentrations are highest in lakes Ontario and Erie, where usage is greatest, and lowest in Lake Superior. An increasing trend is detected for each lake, ranging from a rate of 0.4 ng/L · yr in Lake Superior to 4.74 ng/L · yr in Lake Ontario. All concentrations are below the Canadian federal water quality guideline of 1800 ng/L; current open lake concentrations range from 6.3 ng/L in Lake Superior to 83.6 ng/L in Lake Ontario.

Chemicals Management Plan

The Canadian federal Chemicals Management Plan incorporates environmental monitoring into the assessment and management of compounds in commercial use in Canada. Surveillance has been conducted in selected lakes for compounds in commercial use that are more likely to be found in waters, such as perfluorinated compounds and some pharmaceuticals. The available data are currently being analyzed. In addition, work has been initiated in 2011 to screen for additional compounds in Great Lakes waters. This initiative will permit the qualitative and quantitative assessment of compounds that are not included in the targeted analytical suite currently monitored in the Great Lakes.

Linkages

Some pressure indicators such as industrial loadings, contamination in sediment, pesticides in tributaries, and the inland water quality index are also linked to this indicator since they assess the toxic chemicals which enter our waterways and can contribute to increased contamination levels in the Great Lakes. The reader is referred to the Contaminants in Whole Fish indicator to compare the available information.

Management Challenges/Opportunities

For over 40 years, the Great Lakes Surveillance Program has monitored water quality in the Great Lakes, and since approximately 1986, toxic contaminants have comprised an important component of that program. Knowledge of the concentration of toxics dissolved in Great Lakes waters is important for comparison with other measurements in water (e.g., tributaries and precipitation), for the assessment of bioaccumulation and bioconcentration behaviours and rates, and for the calculation of water-atmosphere fluxes in order to assess atmospheric deposition and volatilization of contaminants. The long-range atmospheric transport of contaminants remains an important concern, particularly to more northern Great Lakes.

Continued refinements of field and laboratory methods have both improved the quality of the sample results and reduced the resources required to conduct the program. Despite these improvements, measuring toxic contaminants in Great Lakes surface waters remains a challenging task. Concentrations of many substances are extremely low; in the part per quadrillion (1×10^{-15}) to part per trillion (1×10^{-12}) range. Routine monitoring for determining trends might be better accomplished, for some parameters, using sediment and fish samples. Contaminants in sediment can be used to indicate long-term changes in contaminant concentrations, as the settling of sediments represents a long-term sink for contaminants as they are gradually buried over time. Contaminants in fish are better indicative of the exposure of aquatic organisms to toxics in lake water and through their food chain. Because many of the legacy toxics are bioaccumulative and hydrophobic, higher concentrations can be measured in sediment and fish and these

STATE OF THE GREAT LAKES 2012 - DRAFT

media are more appropriate for assessing ecosystem health. It remains important, however, to continue periodic monitoring of Great Lakes waters to verify concentrations and trends. Monitoring water concentrations is important for assessing compounds that are soluble in water such as certain in-use pesticides, selected legacy toxics as well as many of the compounds of emerging concern.

Environment Canada is currently reviewing its programs and refinements are being considered. One proposal is to primarily use fish tissue measurements for tracking contaminant trends, supplemented with the periodic review of water column concentrations at selected offshore stations. Contaminants that are not bioaccumulative or that are of greater concern due to direct toxicity, such as some of the currently-used pesticides, are more appropriate for continued monitoring in Great Lakes waters.

Assessing Data Quality

Insert “x” under the statement that best corresponds with each data characteristic

Data Characteristics	Strongly Agree	Agree	Neutral or Unknown	Disagree	Strongly Disagree	Not Applicable
1. Data are documented, validated, or quality-assured by a recognized agency or organization	x					
2. Data are traceable to original sources	x					
3. The source of the data is a known, reliable and respected generator of data	x					
4. Geographic coverage and scale of data are appropriate to the Great Lakes basin	x					
5. Data obtained from sources within the U.S. are comparable to those from Canada						x
6. Uncertainty and variability in the data are documented and within acceptable limits for this indicator report			x			
Clarifying Notes: The comparability of organic contaminant data with other available information is currently being conducted. A full report on toxic contaminants in Great Lakes waters is in preparation. For some parameters, the comparison with other data sources and the quality assurance information indicates the data are robust. For other parameters, laboratory and field blank interference remain problematic and some uncertainty about absolute values remains.						

Acknowledgments

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Information Sources

All data from Great Lakes Surveillance Program, Water Quality Monitoring and Surveillance, Environment Canada,

Burlington, Ontario. GLSP-PSGL@ec.gc.ca

Supplementary data for Lake Michigan from Great Lakes National Program Office, United States Environmental Protection Agency, Chicago, Illinois.

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List of Figures

Figure 1. Spatial distribution of dissolved alpha-hexachlorocyclohexane in Great Lakes surface waters. Most recent available spring cruise values shown, 2004-2007.

Source: Environment Canada's Great Lakes Surveillance Program

Figure 2. Spatial distribution of dissolved hexachlorobenzene in Great Lakes surface waters. Most recent available spring cruise values shown, 2004-2007.

Source: Environment Canada's Great Lakes Surveillance Program

Figure 3. Temporal trend of dissolved lindane in Great Lakes surface waters. Data are spring, surface, open lake mean values \pm standard deviation.

Source: Environment Canada's Great Lakes Surveillance Program

Figure 4. Temporal trend of dissolved atrazine in Great Lakes surface waters. Data are spring, surface, open lake mean values \pm standard deviation.

Source: Environment Canada's Great Lakes Surveillance Program

Figure 5. Spatial distribution of total mercury in Great Lakes surface waters. Great Lakes samples from most recent survey (2006 – 2009); Detroit and St. Clair Rivers average values 2004; Niagara and St. Lawrence Rivers average values 2002 – 2006.

Source: Environment Canada's Great Lakes Surveillance Program

Figure 6. Average mercury concentrations in the Niagara River upstream at Fort Erie (open squares) and downstream at Niagara-on-the-Lake (solid squares), 1986 – 2005. Data are from mercury on suspended sediments, recombined with suspended sediment concentration to give whole-water equivalents. Dotted lines are linear regressions fitted to the average values and error bars indicate 90% confidence intervals.

STATE OF THE GREAT LAKES 2012 - DRAFT

Source: Environment Canada's Great Lakes Surveillance Program

Last Updated

State of the Lakes Ecosystem Conference (SOLEC) 2011

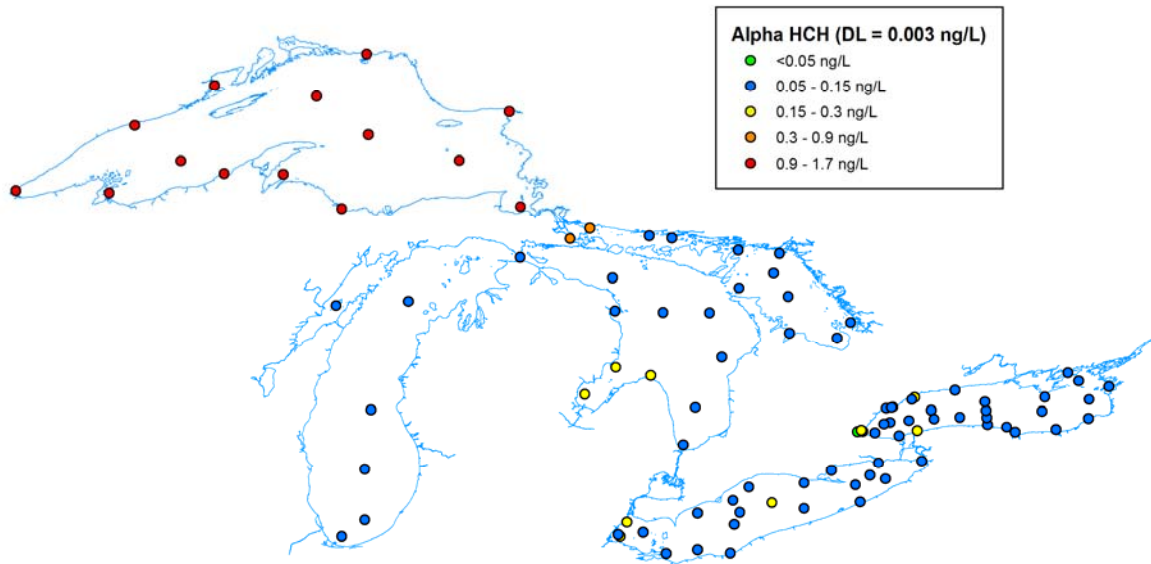


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STATE OF THE GREAT LAKES 2012 - DRAFT

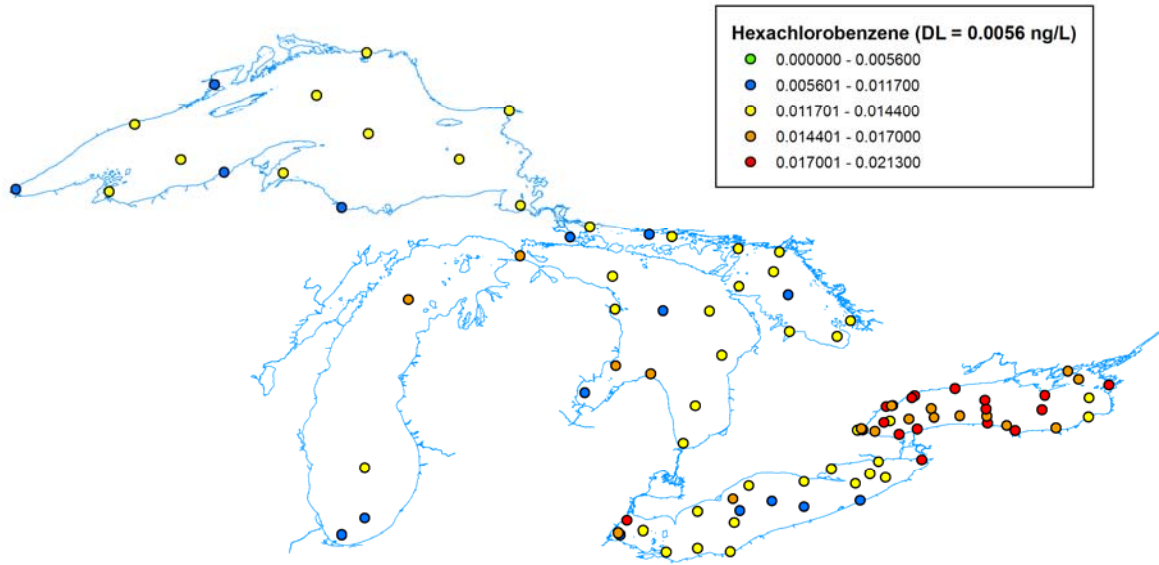


Figure 2. Spatial distribution of dissolved hexachlorobenzene in Great Lakes surface waters. Most recent available spring cruise values shown, 2004-2007. Source: Environment Canada's Great Lakes Surveillance Program

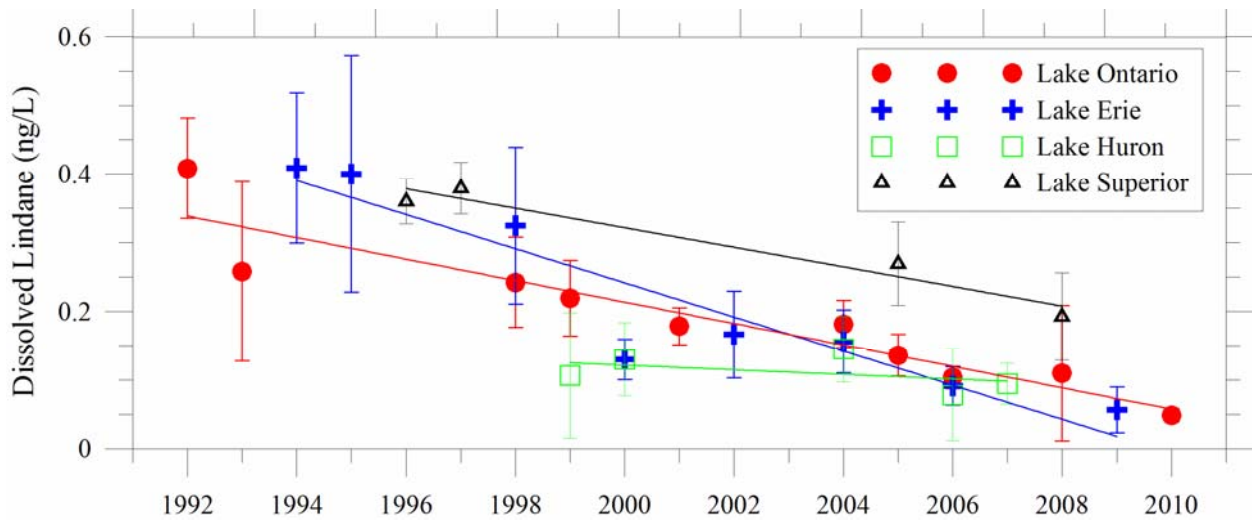


Figure 3. Temporal trend of dissolved lindane in Great Lakes surface waters. Data are spring, surface, open lake mean values \pm standard deviation. Source: Environment Canada's Great Lakes Surveillance Program

STATE OF THE GREAT LAKES 2012 - DRAFT

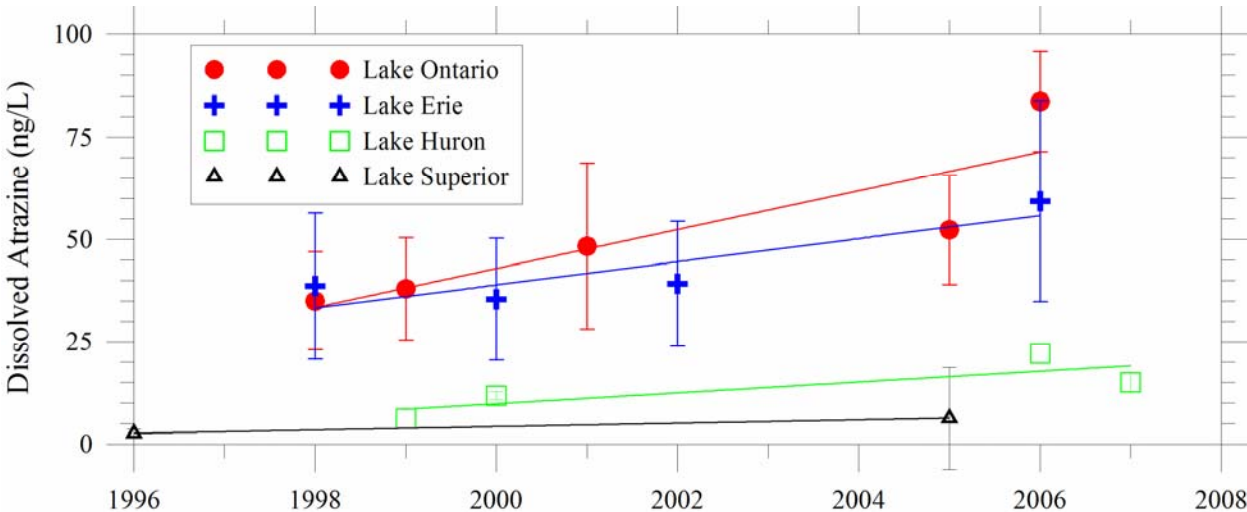


Figure 4. Temporal trend of dissolved atrazine in Great Lakes surface waters. Data are spring, surface, open lake mean values \pm standard deviation.
 Source: Environment Canada’s Great Lakes Surveillance Program

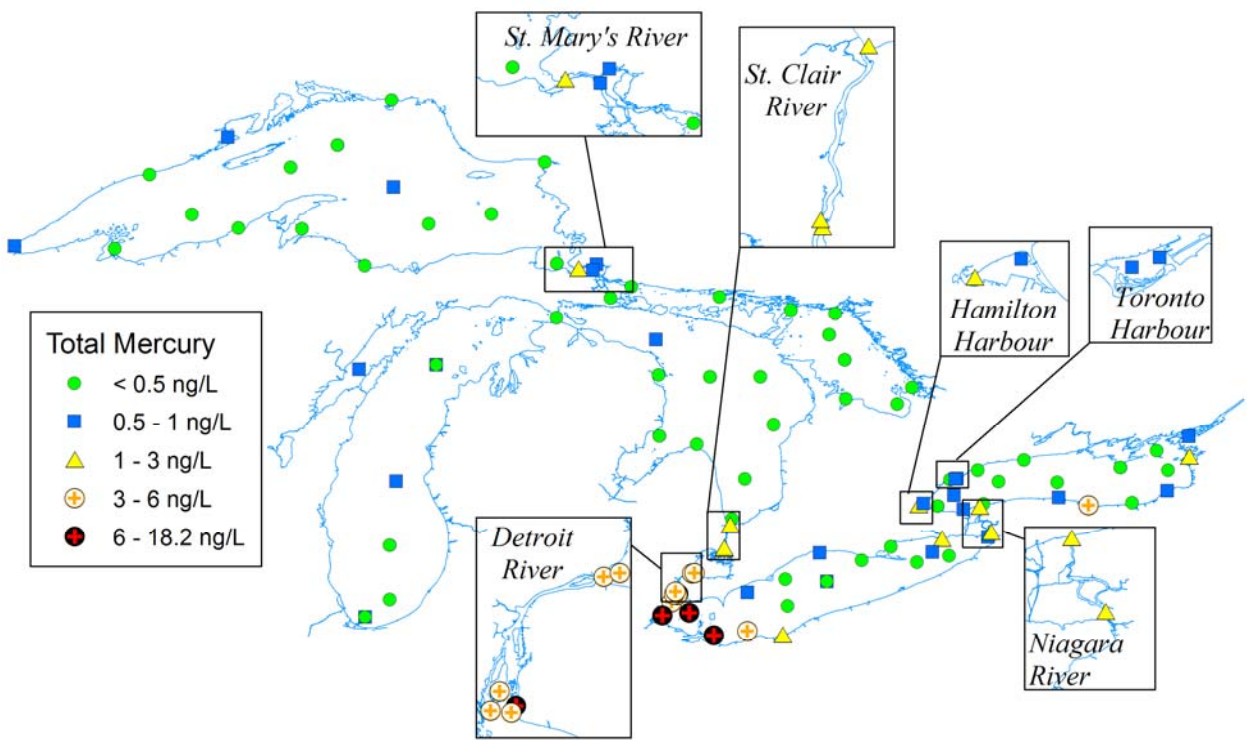


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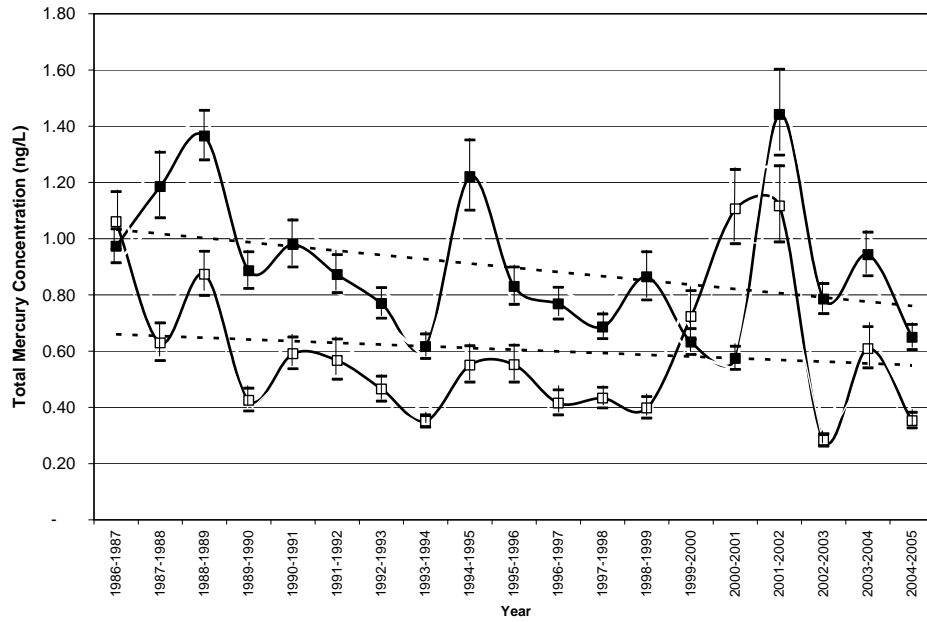


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