Sub-Indicator: Toxic Chemicals in Water

Note: There have been factors that have resulted in limited updates to this sub-indicator since the 2019 State of the Great Lakes Report. Between 2018 and 2022, water quality data collection was greatly impacted by issues with the Canadian Coast Guard Ship (CCGS) LIMNOS, laboratory sample losses, and suspended operations throughout the COVID-19 pandemic. Since 2022, a more routine collection scheduled has resumed on a lake-by-lake rotating basis. These data gaps have impacted our ability to assess and report on the trends of toxic chemicals in water in this report. Long-term trends using all available data since 2004 are reported in this sub-indicator rather than 10-year trends as there is insufficient data to assess trends in the most recent 10 years for the majority of the lakes and reported contaminants. This will likely be the case for subsequent reports as Environment and Climate Change Canada (ECCC) is currently the sole generator of open water contaminant data used in this report and available resources do not permit annual sampling in all the Great Lakes.

Overall Assessment

Status: Fair

Trends:

10-Year Trend/Long-term Trend (2004-2023): No Trend

Rationale: Compounds considered in this report include Chemicals of Mutual Concern (CMCs), chemicals that could become CMCs due to their properties that make them persistent, bioaccumulative, and/or toxic (PBT), and relevant legacy contaminants. The majority of legacy contaminants that are PBT have decreased over the long term. The number of compounds being monitored is increasing, thereby improving our base of knowledge. Analysis from more recent data for polycyclic aromatic hydrocarbons (PAHs), indicates exceedances of water quality objectives in all lakes. The 10-year trend of polychlorinated biphenyl (PCB) contamination could not be assessed in this report due to on-going analytical method re-evaluation. Over the long term, PCB concentration in the lakes have decreased overall, requiring analytical methods to be refined to increase the accuracy in measuring lower concentrations. Status and trends for monitored CMCs, by lake, and overall are visualized in Table 1.

*The long-term trend for the chemicals assessed in this report will be used in the place of a 10-year trend determination due to disruptions in the water quality sampling schedule beginning in 2018, as detailed in the preface note.

Status and Trend assessment definitions are included following the Lake-by-Lake Assessment section.

Lake-by-Lake Assessment

Lake Superior

Status: Good

10-Year Trend/Long-term Trend (2004-2016*): Undetermined

Rationale: The majority of contaminant data for Lake Superior has not been updated since the last report due to interruptions to field and laboratory operations, as well as the global COVID-19 pandemic, which have had significant impacts on the collection of data in the Great Lakes. Lake Superior was sampled in 2024 for the first

time since 2016, however chemical analysis results, apart from mercury, were not available for inclusion in this report and will therefore be considered in future reports. Mercury concentrations continue to improve in Lake Superior, with 2024 detections all <1.0 ng/L. An in-depth evaluation of existing contaminant data has been conducted, including an exhaustive analysis on PAH concentrations and trends. Instances where PAHs exceeded guidelines decreased from 22% in 2005 to 5% in 2016. There is insufficient data to trend polybrominated diphenyl ethers (PBDEs), PCBs, and per- and polyfluoroalkyl compounds (PFAS); however, detections are all below guidelines as of 2016. Lindane contamination is improving up to 2016, despite having the highest concentrations found in the Great Lakes. With this in-depth contaminant analysis, status has changed from Fair to Good; however, the trend has changed from Improving to Undetermined due to the lack of recent data upon which to base a trend assessment.

*The long-term trend for the chemicals assessed in this report will be used in the place of a 10-year trend determination due to disruptions in the water quality sampling schedule beginning in 2018, as detailed in the preface note.

Lake Michigan

Status: Undetermined

10-Year Trend/Long-term Trend (2006-2015): Undetermined

Rationale: Few data are available for inclusion in this sub-indicator for Lake Michigan. In the 2022 report, the available information indicated Unchanging conditions for many compounds (except improving for dieldrin) and no exceedances of available water quality guidelines were observed. No new offshore contaminant information has been collected supporting basin-wide assessment since the previous report. These data gaps will significantly impact our ability to assess and report on the trends of toxic chemicals in Lake Michigan in subsequent reports as well. Trends cannot be determined because of the lack of data/information upon which to base the assessment.

Lake Huron

Status: Fair

10-Year Trend/Long-term Trend (2003-2022*): Improving

Rationale: Concentrations of mercury and lindane in Lake Huron and Georgian Bay remain low and continue to improve. Trends for perfluorooctane sulfonate (PFOS) and perfluorooctanoic acid (PFOA) contamination are improving following regulation. Total PFAS concentrations remain elevated; there is evidence of increasing concentrations of perfluorobutanoate (PFBA), which is an unregulated short-chain PFAS that has been used as a substitute post-regulation of the longer chain PFAS compounds, although, at this time, data are insufficient to assess a trend. The long-term trend of PAH guideline exceedance is improving, although approximately 8% of PAHs exceeded their associated water quality guidelines in 2022.
*The long-term trend for the chemicals assessed in this report will be used in the place of a 10-year trend determination due to disruptions in the water quality sampling schedule beginning in 2018, as detailed in the preface note.

Lake Erie

Status: Fair

10-Year Trend/Long-term Trend (2004-2023*): No Trend

Rationale: Lake Erie displays relatively high concentrations of certain legacy organochlorines and industrial byproducts due to its location downstream of historic sources. Some PAHs are also highest in Lake Erie. Observed variability is highest in Lake Erie for most monitored parameters and few trends are discernible. The highest concentrations of mercury and PCBs were detected in the western basin of Lake Erie; however, they remain below established water quality guidelines, and the long-term mercury trend continues to improve. Trends for PFOS and PFOA contamination are improving, while PFBA is unchanging. The trend for PAH guideline exceedance appears to be deteriorating with >20% of regulated PAHs exceeding their guidelines in 2022. Due to different chemicals trending in different directions, the trend was assessed as No Trend.
*The long-term trend for the chemicals assessed in this report will be used in the place of a 10-year trend determination due to disruptions in the water quality sampling schedule beginning in 2018, as detailed in the preface note.

Lake Ontario

Status: Fair

10-Year Trend/Long-term Trend (2004-2023*): No Trend

Rationale: Due to its position downstream of the other Great Lakes and in a highly populated region, relatively high concentrations of some contaminants are observed in Lake Ontario. Mercury, Lindane, PFOS, and PFOA trends continue to improve in Lake Ontario, while the PFBA trend is unchanging. Elevated PCB concentrations and the highest concentration of PBDEs were detected in Hamilton Harbour, although data are insufficient to assess trends for both contaminants. PAH guideline exceedances were assessed separately in Hamilton Harbour, Toronto Harbour, and the offshore region due to known elevated contamination in the harbours. The frequency of exceedance is unchanging in offshore waters and improving in both Hamilton Harbour and Toronto Harbour; however, the frequency of exceedance in Hamilton Harbour remains the highest with 26% of PAHs exceeding guidelines in 2022. Due to the fact that different chemical concentrations are trending in different directions, the trend was assessed as No Trend.

*The long-term trend for the chemicals assessed in this report will also be used for the 10-year trend determination.

Status Assessment Definitions

Good: The metrics show that the toxic chemical concentrations are meeting the ecosystem objectives, or they are otherwise in an acceptable condition.

Fair: The metrics show that the toxic chemical concentrations are not meeting the ecosystem objectives, but they are exhibiting minimally acceptable conditions.

Poor: The metrics show that the toxic chemical concentrations are not displaying minimally acceptable conditions and are severely impacted.

Undetermined: Data are not available or are insufficient to assess the condition of the ecosystem components.

Trend Assessment Definitions

Improving: The conditions of the sub-indicator have improved. Decrease in concentration or frequency of detection of toxic chemicals.

Unchanging: There is low variability, and the conditions of the sub-indicator have remained stable. No change in the concentration or frequency of detection of toxic chemicals.

No Trend: There is high variability and no clear trend in the data ***OR*** multiple parameters being measured are showing mixed trends.

Deteriorating: The conditions of the sub-indicator have deteriorated. Increased concentration or frequency of detection of toxic chemicals.

Undetermined: A sufficient amount of data is not available to determine a trend. Data are not available or are insufficient to assess the trends or frequency of detection of toxic chemicals concentrations.

Endpoints and/or Targets

The target or endpoint for this sub-indicator will have been met when the waters of the Great Lakes are free from pollutants in quantities or concentrations that could be harmful to human health, wildlife or aquatic organisms, through direct exposure or indirect exposure through the food chain. Because of the complexity (mixtures of compounds, sources and potential effects), and the presence of potentially conflicting trends (increases in some compounds amidst declines in others), status and trend determination takes a weight-of-evidence approach in making an expert assessment, including the number of compounds that are detectable and/or are below water quality guidelines and the relative effect of the compound, if known. Table 2 identifies the compounds monitored in this sub-indicator with associated water quality guidelines and the source agencies, where available. Progress will be determined based on whether trends of the toxic chemicals are positive or negative, the rate of change in the concentrations, and by the number of chemicals which are doing so, with an emphasis on those compounds identified by the Parties as Chemicals of Mutual Concern, and compounds with known PBT characteristics.

Sub-Indicator Purpose

The purpose of this sub-indicator is to assess the concentration of toxic chemicals in Great Lakes waters; to infer the potential for impairment to the quality of the waters of the Great Lakes by harmful pollutants; to infer progress toward virtual elimination of chemicals of mutual concern and compounds with known PBT characteristics; to inform the risk assessment of toxic chemicals and the development of risk management strategies; to inform the development of environmental quality guidelines; and to report on environmental response (i.e., progress) toward the achievement of targets identified in action plans and risk management strategies for toxic chemicals in the Great Lakes basin.

Ecosystem Objective

This sub-indicator best supports work towards General Objective #4 of the 2012 Great Lakes Water Quality Agreement (GLWQA) which states that the Waters of the Great Lakes should “be free from pollutants in quantities or concentrations that could be harmful to human health, wildlife, or aquatic organisms, through direct exposure or indirect exposure through the food chain”.

Methods

This sub-indicator assesses the current status of toxic chemicals and will track whether contamination is

decreasing, staying the same, or increasing in Great Lakes waters over time by tracking concentrations and guideline exceedances, where available. The chemicals included are the chemicals of mutual concern (CMCs) identified in Annex 3 of the Great Lakes Water Quality Agreement. Additional chemicals that are persistent, bioaccumulative and/or toxic (PBT) are also assessed in this report. These include, but are not limited to, other organochlorine pesticides, polycyclic aromatic hydrocarbons, chlorobenzenes, metals, pesticides in current use, and other toxic chemicals. Monitoring data are used to inform the continued assessment and potential selection of additional CMCs as well as monitor to assess the progress and effectiveness of pollution prevention and control measures for these and other compounds. The sub-indicator will primarily report offshore data to assess status and trends for open waters of the Great Lakes; nearshore data is included where the information is available (see data limitations section).

A suite of compounds is monitored on the Cooperative Science Monitoring Initiative (CSMI) rotation schedule (i.e., once every five years, per lake), with additional monitoring conducted in the intervening years, depending on appropriateness, feasibility and the availability of resources. The number of stations sampled varies by lake. This rotating schedule will require several decades to be able to detect potential trends for CMCs such as Hexachlorobutadiene (HCBD) and PBDEs that were not monitored in water in a consistent way prior to 2011.

Discussion

Programs and Methods

Toxic chemicals in Great Lakes waters are monitored by the Canadian and United States federal governments. Environment and Climate Change Canada (ECCC) conducts ship-based cruises to collect water quality samples as part of its Great Lakes Surveillance Program. Since 2004, this has included monitoring for the “legacy organic contaminants”, including organochlorines, PCBs, chlorinated benzenes and polycyclic aromatic hydrocarbons, using a specialized and improved technique that permits the accurate detection of concentrations in Great Lakes waters. Monitoring is generally conducted during spring cruises as this timing has been determined to be optimal to establish annual maxima for many of these compounds (Williams et al. 2001). From 2004 to 2013, monitoring for contaminants was conducted on each lake every two or three years. Since 2013, monitoring is coordinated with the CSMI so that work is focused on one of the Great Lakes each year and the frequency has been somewhat reduced. For some CMCs including PCBs and mercury, high quality and consistent data are available since 2004 for all of the Great Lakes that ECCC monitors. Contamination of PCBs has continued to improve long term, which has necessitated a review and refinement of sampling and analytical methods to increase detection accuracy at low concentrations.

Data from a subset of 18 stations distributed throughout all five of the Great Lakes were collected as part of a binational sampling effort in 2011 – 2012, using a technique to concentrate very large sample volumes (100-200 L) onto resin columns (Venier et al. 2014). These data have permitted assessment of the status of legacy contaminants as well as the CMCs HBCD, PCBs, PBDEs, and certain PBDE replacement compounds that may not otherwise be detected in smaller volumes. Resin data collected since that time will be incorporated into future reporting; however, due to the low resampling frequency (once every five years), it may take up to several years to observe trends in Great Lakes waters.

For the CMCs PFOA and PFOS, the first surveillance occurred in 2008 in Lakes Ontario and Superior, and more consistent monitoring has been initiated since 2012. Sampling has been more frequent than the CSMI schedule. A mass-balance approach to assessing perfluorinated compounds in the Great Lakes can be found in Xia et al (2024).

The nearshore, offshore, and major embayments in each of the Great Lakes bordering Canada are monitored in ECCC's program. Tributary sampling, closer to sources and more informative with respect to maximum concentrations, is largely lacking; some information may exist but has not been incorporated in this report. Due to inherently high sample collection and laboratory costs, sample sizes are in general quite small, limiting our ability to assess all areas and parameters. Additional field techniques to reduce sample costs are being considered. The status of contaminants in the Great Lakes is performed using all available quality-assured data and the trends are based on data collected since 2004 because laboratory and field techniques improved greatly at that time, as described above.

Status of Chemicals of Mutual Concern (CMCs)

The Parties to the GLWQA designated the first set of CMCs in May 2016. For State of the Great Lakes reporting in 2025 and moving forward, the toxic chemical sub-indicators where possible will support reporting on CMCs in a more fulsome, consistent and transparent way. Information on additional chemicals of interest for the Great Lakes (non-CMCs) is valuable for inclusion in the report and will be included in a separate section below, as appropriate. For the 2025 Toxic Chemicals in Water sub-indicator report, the assessment is not based solely on CMCs.

The CMCs are:

- Hexabromocyclododecane (HBCD)
- Long-chain perfluorinated carboxylic acids (LC-PFCAs)
- Mercury (Hg)
- Perfluorooctanoic acid (PFOA)
- Perfluorooctane sulfonate (PFOS)
- Polybrominated diphenyl ethers (PBDEs)
- Polychlorinated biphenyls (PCBs)
- Short-chain chlorinated paraffins (SCCPs)

Table 3 provides the monitoring record since 2011 for CMCs in each of the Great Lakes.

Polychlorinated biphenyls

PCBs are both a CMC and a legacy contaminant. Despite being banned in 1977 in the United States and Canada, PCBs continued to be used and stored. While inventories have been reduced over the past several decades, PCBs continue to be detected throughout the Great Lakes. Concentrations of total PCBs are observed according to the following spatial trend: Ontario ≈ Erie > Huron ≈ Michigan > Superior ($p < 0.001$; Venier et al. 2014). Within each lake, spatial distributions indicate higher concentrations in harbours and nearshore regions compared to offshore waters (Figure 1). The highest individual concentrations are observed in the western basin of Lake Erie and concentrations decrease as waters flow to the central and eastern basins of the lake. In Lake Huron, PCB concentrations are highest in Saginaw Bay and offshore concentrations are lower and appear to decline from south to north within the main body of the lake. The Ontario Provincial Water Quality Objective of 1 ng/L is used as a benchmark, and it has been exceeded in some years in Lake Erie and Hamilton Harbour (Lake Ontario). The most recent data demonstrate the above-noted spatial distribution, but no exceedances of the benchmark are observed.

There is no temporal trend in total PCBs since 2004, although we know from sediment core data (see Toxic Chemicals in Sediment sub-indicator) and fish tissue data (see Toxic Chemicals in Whole Fish sub-indicator) that PCB concentrations have declined over the longer term. Over the past 10 years, PCB analysis has been refined to

increase accuracy measuring lower concentrations; however, due to interruptions from the global COVID-19 pandemic, and interruptions to field and laboratory operations, there is insufficient data to trend the refined method. Data quality assurance is underway to address the comparability between the historical and refined methods for future reports.

Mercury

Concentrations of total mercury (i.e., unfiltered water) are highest in Lake Erie and significantly lower in offshore waters of the other Great Lakes (Figure 2). The Canadian Council of Ministers of the Environment (CCME 1999) guideline for mercury in water (26 ng/L for the protection of aquatic life) has not been exceeded although maximum concentrations in the western basin of Lake Erie in 2009 at the stations sampled (mean 13.2 and maximum 18.2 ng/L) approached the guideline. Higher concentrations of mercury have been noted in Lake Erie previously (Dove et al. 2011), due to the historic presence of chlor-alkali and other industries in the St. Clair River – Detroit River inter-connecting channel.

The overall decline in mercury from historic high levels is supported by long-term measurements in fish and sediment (for example, see the Toxic Chemicals in Whole Fish and Toxic Chemicals in Sediment sub-indicator reports). Mercury in water declined significantly between 2003 and 2009 (Dove et al. 2011). Since that time, it continues to decline, however the rate of which appears to have slowed (Figure 3). This observed trend is reflected in fish tissue, where mercury levels have remained stable or slightly improved (please refer to the Toxic Chemicals in Whole Fish sub-indicator report for further information on trends of mercury in fish tissue).

Flame Retardants

Recent work conducted on each of the Great Lakes sampled for polybrominated diphenyl ethers (PBDEs) and other flame retardants (Venier et al. 2014). The results showed higher concentrations in the lower Great Lakes and the spatial patterns were consistent with consumer products as a primary source (Figure 4); however, there was insufficient data to trend PBDEs due to interruptions in sample collections. In aquatic environments, PBDEs generally bind to sediment, therefore sediment sampling will provide additional information on PBDE contamination that may not be captured in surface water samples (Palm et al. 2002). The ubiquity of flame retardants reflects their widespread usage in commercial products, and it will remain important to continue risk assessment activities, monitor ambient levels, and to track trends.

Perfluoroalkyl and Polyfluoroalkyl Substances (PFAS)

Results for PFAS are consistent with patterns of consumer product sources, with higher concentrations noted near urban regions (Gewurtz et al. 2013, 2019). In general, total PFAS are observed according to the following spatial trend: Ontario > Erie ≈ Huron > Superior (Figure 5). Concentrations of PFOS and PFOA are improving in all lakes following regulation. This trend is not reflected in all alternative PFAS, such as PFBA, where trends are mostly unchanging with some evidence of deterioration (Figure 6). A mass-balance approach was used to conduct an in-depth assessment of PFAS contamination in the Great Lakes in Xia et al (2024), finding that, in general, the upper lakes are accumulating PFAS, while Lake Erie and Lake Ontario are eliminating them. Information about recent concentrations of these compounds is shared promptly with risk assessment and risk management agencies in order that decision making is based on the most recently available, best science.

Other Chemicals of Interest

Organochlorine Pesticides

Organochlorine pesticides have been banned, restricted or discontinued but many remain ubiquitous in the Great Lakes. Overall, the most abundant organochlorines present in Great Lakes waters are alpha-

hexachlorocyclohexane (a-HCH), dieldrin and lindane. Concentrations of a-HCH and lindane (Figure 7) are highest in Lake Superior. Due to its large surface area, cold water temperature and long retention time, Lake Superior is most susceptible to accumulation of these compounds. All three of these compounds are declining over time. The voluntary removal of lindane was announced by the Canola Council of Canada in 1998 (National Round Table on the Environment and the Economy, 2001). In 2006, the U.S. EPA banned the agricultural use of lindane and in 2009 the production and agricultural use of lindane was banned under the Stockholm Convention. Figure 8 demonstrates that the in-lake concentrations responded to these reductions with declines observed in each of the Great Lakes since our measurements began in 2004.

Polycyclic Aromatic Hydrocarbons (PAHs)

A comprehensive performance measurement evaluation of PAH trends and concentrations in the Great Lakes was completed using long-term surveillance data up to 2022. Concentrations of total PAHs (the sum of 17 individual PAH compounds) are highest in lakes Erie and Ontario, intermediate in lakes Huron and Michigan, and lowest in Lake Superior. This spatial distribution follows the pattern of usage, with more intense industry and urbanization observed in the lower Great Lakes. Naphthalene was the most abundant PAH observed, frequently in concentrations disproportionate to other compounds. For each water body analyzed, guideline exceedances were frequently recorded for benzo[g,h,i]perylene, chrysene and perylene. The highest frequency of guideline exceedances exists in Hamilton Harbour due to legacy pollution and dense industrialization (Figure 9). A containment structure and subsequent sediment dredging took place in Randle Reef, an area of heavily contaminated sediment in Hamilton Harbour between 2017 and 2021. Shutdowns due to the COVID-19 pandemic reduced sampling frequency, therefore this remedial measure will be reflected in future reports. Trends of guideline exceedance are improving in Lake Superior, Lake Huron, and Hamilton Harbour, while offshore Lake Ontario exceedances remain stable, and there is evidence of increased exceedance (deteriorating quality) in Lake Erie.

Linkages

Linkages to other sub-indicators in the Toxic Chemicals indicator suite include:

- Toxic Chemicals in Whole Fish – interpretation of status and trends is conducted jointly to determine the degree of concordance between the information sources – for example to determine if temporal trends observed in fish are due to water quality changes or due to biological mediation.
- Toxic Chemicals in Sediment – longer-term trends of Great Lakes toxics may be discerned from retrospective analyses in sediment cores. Trends of high molecular weight PAHs may be more accurately monitored in sediments; a disadvantage is that it may take a very long time to be able to track progress.
- Toxic Chemicals in the Atmosphere – water quality data are required for the calculation of fluxes, and temporal data are required to interpret trends in atmospheric concentrations and changes in deposition rates.

Assessing Data Quality

Data Characteristics	Agree	Neutral or Unknown	Disagree	Not Applicable

Data are documented, validated, or quality-assured by a recognized agency or organization	X			
Data are from a known, reliable and respected generator of data and are traceable to original sources	X			
Geographic coverage and scale of data are appropriate to the Great Lakes Basin			X	
Data obtained from sources within the U.S. are comparable to those from Canada		X		
Uncertainty and variability in the data are documented and within acceptable limits for this sub-indicator report	X			
Data used in assessment are openly available and accessible	Yes*	https://open.canada.ca/data/en/dataset/cfdafa0c-a644-47cc-ad54-460304facf2e		
Clarifying notes: The scale of data is basin-wide using consistent methods and analysis. The geographic coverage is insufficient to be able to assess all areas and especially those closer to sources. Additional U.S. data are currently being gathered or generated and will be incorporated into future sub-indicator reports.				

* The content used in this report is currently incomplete on the open data site provided, but will be made available in the future.

Notes on Accessing Data

The URL leads directly to the Great Lakes Water Quality Monitoring and Surveillance datasets. Press *Explore* or *Go to resource* to find the desired dataset, which can be downloaded in comma-separated values (CSV) format. Metadata, code definitions, and table descriptions are available within the data folder.

Data Limitations

- Currently, ECCC is conducting routine monitoring for contaminants in the offshore in each of the Great Lakes. There are very limited data available from the open waters of Lake Michigan or from U.S. sources for the basin.
- Although some nearshore information is available, inclusion of additional data from the States and the Province of Ontario and other potential contributors, where available, may be useful to assess nearshore status and trends, and to identify potential sources of pollutants.
- Monitoring data from the Great Lakes Connecting Channels (e.g., Niagara River and St. Clair River) may be incorporated in the future for reporting long-term trends.
- Analytical method refinement is underway therefore historical and recently generated PCB data cannot be compared until quality assurance and quality control has been completed

Additional Information

Monitoring by the Parties will continue to track the status of toxic chemicals in Great Lakes waters. The assessment of organic contaminants in water can be challenging given the relatively complex field and laboratory requirements. The associated high costs limit the monitoring of toxic chemicals in Great Lakes waters. Water provides a stable medium for the assessment of contaminants which may be more challenging in other media (e.g. for compounds having short residence times in air, those not bioaccumulating in fish tissue or binding to sediment, or those undergoing dramatic or complex transformations or biogeochemical cycling in the environment). Information from other media should be considered for certain compounds, especially those that are bioaccumulative and/or persistent. The assessment of contaminants in Great Lakes offshore waters is a valuable means to determine the status and trends for soluble and/or toxic compounds including many of the CMCs and to collect information for compounds that may be identified as CMCs in the future.

Several of the environmental quality guidelines that were previously available for legacy organic contaminants have been withdrawn. The Canadian Council of Ministers of the Environment has withdrawn guidelines for a-HCH and PCBs in water in favour of the use of fish and sediment guidelines as these compounds are hydrophobic and/or bioaccumulative. There is therefore a lack of benchmarks against which to gauge the status of these contaminants in Great Lakes waters. Despite the lack of guidelines, the assessment of toxic contaminants is important as the current status represents an important means of assessing exposure for biota and the offshore temporal data series provides a means of assessing trends.

The concentrations of many legacy organic contaminants are low in the offshore waters of the Great Lakes, are reduced from historical maxima, and are currently changing slowly. The realignment of the monitoring schedule with the CSMI will result in less frequent data collection for these compounds, and this is warranted. For potential CMCs requiring surveillance, and for those requiring more frequent assessment due to changing levels in the environment, the schedule may not follow the CSMI in order to effect adequate monitoring.

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References

Canadian Council of Ministers of the Environment, 1999, Canadian Environmental Quality Guidelines, updated 2001, 2002, 2003, 2004, 2005, 2006 and 2007, http://ceqg-rcqe.ccme.ca/en/index.html, Accessed January 15,

2016.

Dove, A., B. Hill, P. Klawunn, J. Waltho, S. Backus and R.C. McCrea, 2011, Spatial distribution and trends of total mercury in waters of the Great Lakes and connecting channels using an improved sampling technique, Environmental Pollution 161: 328 - 334, http://dx.doi.org/10.1016/j.envpol.2011.06.004.

Gewurtz, S.B., S.M. Backus, A.O. De Silva, L. Ahrens, A. Armellin, M. Evans, S. Fraser, M. Gledhill, P. Guerra, T. Harner, P.A. Helm, H. Hung, N. Khera, M. G. Kim, M. King, S. C. Lee, R.J. Letcher, P. Martin, C. Marvin, D.J. McGoldrick, A.L. Myers, M. Pelletier, P. Pomeroy, E.J. Reiner, M. Rondeau, M-C. Sauve, M. Sekela, M. Shoeib, D.W. Smith, S.A. Smyth, J. Struger, D. Spry, J. Syrgiannis, J. Waltho, 2013, Perfluoroalkyl acids in the Canadian environment: Multi-media assessment of current status and trends, Environment International 59: 183-200

Gewurtz, S.B., L.E. Bradley, S. Backus, A. Dove, D. McGoldrick, H. Hung and H, Dryfhout-Clark, 2019, Perfluoroalkyl Acids in Great Lakes Precipitation and Surface Water (2006 – 2018) Indicate Response to Phase-outs, Regulatory Action, and Variability in Fate and Transport Processes, Environmental Science and Technology, https://doi.org/10.1021/acs.est.9b01337

National Round Table on the Environment and Economy, 2001, Managing Potentially Toxic Substances in Canada, http://publications.gc.ca/collections/Collection/En134-32-2001E.pdf. Accessed January 8, 2016.

Ontario Ministry of the Environment and Climate Change, 2015, Guide to Eating Ontario Fish, https://www.ontario.ca/document/guide-eating-ontario-fish#!/ Accessed January 15, 2016

Palm, A., I.T. Cousins, D. Mackay, M. Tysklind, C. Metcalfe and M. Alaee, 2002. Assessing the environmental fate of chemicals of emerging concern: a case study of the polybrominated diphenyl ethers. Environmental Pollution 117(2): 195-213. https://doi.org/10.1016/S0269-7491(01)00276-7

Venier, M., A. Dove, K. Romanak, S. Backus and R. Hites. 2014. Flame Retardants and Legacy Chemicals in Great Lakes Waters. Environmental Science and Technology 48(16): 9563–9572. http://dx.doi.org/10.1021/es501509r

Williams, D.J., K.W. Kuntz, S. L'Italien and V. Richardson, 2001, Great Lakes Surveillance Program – Organic Contaminants in the Great Lakes 1992 to 1998, Intra- and Inter-lake spatial distributions and temporal trends, Environmental Conservation Branch/Ontario Region, Ecosystem Health Division, Environment and Climate Change Canada, Report No. EHD/ECB-OR/01-01/I.

Xia, C., S.L. Capozzi, K.A. Romanak, D.C. Lehman, A. Dove, V. Richarson, T. Greenberg, D. McGoldrick, M. Venier, 2024. The Ins and Outs of Per- and Polyfluoroalkyl Substances in the Great Lakes: The Role of Atmospheric Deposition. Environmental Science and Technology 58(21): 9303-9313. https://doi.org/10.1021/acs.est.3c10098

List of Tables

Table 1. Status and trends of toxic chemicals in the Great Lakes. *Contaminants with an asterisk indicate chemicals of mutual concern.

Source: Environment and Climate Change Canada

Table 2. List of compounds and guidelines monitored in the sub-indicator. Compounds without guidelines are indicated by a dash (-). Agencies listed are Environment and Climate Change Canada - Federal Environmental Quality Guidelines (ECCC-FEQG), Canadian Council of Ministers of the Environment (CCME), Province of Ontario's Ministry of Environment, Conservation, and Parks (MOECP), and the New York State Department of Environmental Conservation (NYSDEC). *Contaminants with an asterisk indicate chemicals of mutual concern.

Table 3. Monitoring schedule of the Eight Chemicals of Mutual Concern in Great Lakes waters, 2014-2024.

Source: Environment and Climate Change Canada, except [a] from Clarkson University.

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Figure 1. Spatial distribution of the concentrations of total PCBs, pg/L. Information on Lake Michigan was not sufficient for inclusion.

Source: Data are from Environment and Climate Change Canada's Great Lakes Surveillance Program.

Figure 2. Spatial distribution of the concentration of total mercury (ng/L) in the Great Lakes. Information on Lake Michigan was not sufficient for inclusion.

Source: Data are from Environment and Climate Change Canada's Great Lakes Surveillance Program

Figure 3. Temporal changes of total mercury in the Great Lakes. Boxes show central median and interquartile range, whiskers show 1.5x interquartile range. Temporal trends indicate improving conditions in all of the lakes. Information on Lake Michigan was not sufficient for inclusion. Data are compared to Canadian Water Quality Guideline (CWQG) value of 26 ng/L.

Source**:** Data are from Environment and Climate Change Canada's Great Lakes Surveillance Program.

Figure 4. Spatial distribution of the concentrations of total PBDEs, pg/L. Information on Lake Michigan was not sufficient for inclusion.

Source: Venier et al. 2014

Figure 5. Spatial distribution of the concentrations of total PFAS, ng/L. Information on Lake Michigan was not sufficient for inclusion.

Source: Data are from Environment and Climate Change Canada's Great Lakes Surveillance Program.

Figure 6. Annual median PFOS, PFOA, and PFBA concentrations in the Great Lakes. In Lake Superior, PFOS was below detection limit in 2008 and 2016; PFBA was below detection limit in 2008. Dashed lines indicate temporal trends, points represent annual median values for each compound, and error bars indicate interquartile range. Information on Lake Michigan was not sufficient for inclusion.

Source: Data are from Environment and Climate Change Canada's Great Lakes Surveillance Program.

Figure 7. Spatial distribution of dissolved lindane (gamma hexachlorocyclohexane) in the Great Lakes. Data are the most recent available spring, surface data for all stations. Information on Lake Michigan was not sufficient for inclusion.

Source: Data are from Environment and Climate Change Canada's Great Lakes Surveillance Program.

Figure 8. Temporal changes of dissolved lindane in the Great Lakes. Boxes show central median and 25% and 75% values, whiskers show 1.5x interquartile range. Information on Lake Michigan was not sufficient for inclusion.
Source: Data are from Environment and Climate Change Canada's Great Lakes Surveillance Program.

Figure 9. Temporal trends for PAH guideline exceedance, where bars indicate the percentage of measured PAHs with water quality guidelines that are exceeded each year. Hamilton and Toronto Harbours were considered separately from offshore stations in Lake Ontario due to industrialization in the harbour areas. Information on Lake Michigan was not sufficient for inclusion.

Source: Data are from Environment and Climate Change Canada's Great Lakes Surveillance Program.

Last Updated

State of the Great Lakes 2025 Report

Tables and Figures

Table 1. Status and trends of toxic chemicals in the Great Lakes. *Contaminants with an asterisk indicate chemicals of mutual concern.

Source: Environment and Climate Change Canada

Contaminant	Superior	Michigan	Huron	Erie	Ontario	Overall
Overall	●	●	↗	~	~	~
Hexabromocyclododecane (HBCD)*	→	●	→	→	→	→
Lindane	↗	●	↗	↗	↗	↗
Mercury*	↗	●	↗	↗	↗	↗
Perfluorobutanoic acid (PFBA)	●	●	●	→	→	→
Perfluorooctane sulfonate (PFOS)*	●	●	↗	↗	↗	↗
Perfluorooctanoic acid (PFOA)*	●	●	↗	↗	↗	↗
Polybrominated diphenyl ethers (PBDEs)*	●	●	●	●	●	●
Polychlorinated biphenyls (PCBs)*	●	●	●	●	●	●
Polycyclic aromatic hydrocarbons (PAHs)	↗	●	↗	→	→	→

Status	
	Good or below guidelines
	Fair
	Poor or exceeds guidelines
	Undetermined

Trends	
↗	Improving, contaminant concentrations are decreasing
→	Unchanging, contaminant concentrations remaining stable
↘	Deteriorating, contaminant concentrations are increasing
●	Undetermined, insufficient data available to assess trend
~	No trend, multiple parameters being measured are showing mixed trends

Table 2. List of compounds and guidelines monitored in the sub-indicator. Compounds without guidelines are indicated by a dash (-). Agencies listed are Environment and Climate Change Canada - Federal Environmental Quality Guidelines (ECCC-FEQG), Canadian Council of Ministers of the Environment (CCME), Province of Ontario's

Ministry of Environment, Conservation, and Parks (MOECP), and the New York State Department of Environmental Conservation (NYSDEC). *Contaminants with an asterisk indicate chemicals of mutual concern.

Compound		Guideline concentration (ng/L)	Agency
Hexabromocyclododecane (HBCD)*		560	ECCC-FEQG
Lindane		10	MOECP
Mercury*		26	CCME
Perfluorobutanoic acid (PFBA)		-	-
Perfluorooctane sulfonate (PFOS)*		6800	ECCC-FEQG
Perfluorooctanoic acid (PFOA)*		-	-
Polybrominated diphenyl ethers (PBDEs)*		-	-
Total polychlorinated biphenyls (PCBs)*		1	MOECP
Polycyclic aromatic hydrocarbons (PAHs)	1-Methylnaphthalene	2000	MOECP
	2- Methylnaphthalene	2000	MOECP
	2-Chloronaphthalene	200	MOECP
	Acenaphthene	5800	CCME
	Anthracene	0.8	MOECP
	Benzo(a)anthracene	0.4	MOECP
	Benzo(a)pyrene	15	CCME
	Benzo(b,k)fluoranthene	2.2	MOECP/NYSDEC
	Benzo(b)fluoranthene	2	NYSDEC
	Benzo(k)fluoranthene	0.2	MOECP
	Benzo(ghi)perylene	0.02	MOECP
	Chrysene	0.1	MOECP
	Dibenzo(a,h)anthracene	2	MOECP
	Fluoranthene	0.8	MOECP
	Fluorene	200	MOECP
	Indeno(1,2,3,-CD)pyrene	2	NYSDEC
	Naphthalene	1100	CCME
	Perylene	0.07	MOECP
	Phenanthrene	30	MOECP
	Pyrene	25	CCME

Table 3. Monitoring schedule of the Eight Chemicals of Mutual Concern in Great Lakes waters, 2014-2024.

Source: Environment and Climate Change Canada except [a] from Clarkson University. Programs without on-going monitoring are indicated by -.

Parameter	Lake Superior	Lake Michigan	Lake Huron	Georgian Bay	Lake Erie	Lake Ontario
Mercury	2016, 2019, 2024	2014[a]	2014, 2015, 2017, 2022	2014, 2017, 2022	2014, 2017, 2019, 2022, 2023, 2024	2015, 2018, 2022, 2023

PFOA	2016	-	2014, 2017, 2022	2014, 2017, 2022	2014, 2015, 2019, 2021, 2022, 2023, 2024	2015, 2018, 2021, 2022, 2023
LC-PFCAs	-	-	-	-	-	-
HBCD	2016, 2024	-	2017, 2022	2017, 2022	2014, 2022, 2023, 2024	2018, 2023
PCBs	2016, 2024	2015[a]	2017, 2022	2017, 2022	2014, 2022, 2023, 2024	2018, 2023
PFOS	2016	-	2014, 2017, 2022	2014, 2017, 2022	2014, 2015, 2019, 2021, 2022, 2023, 2024	2015, 2018, 2021, 2022, 2023
PBDEs	2016, 2024	-	2017, 2022	2017, 2022	2014, 2022, 2023, 2024	2018, 2023
SCCPs	-	-	-	-	-	-

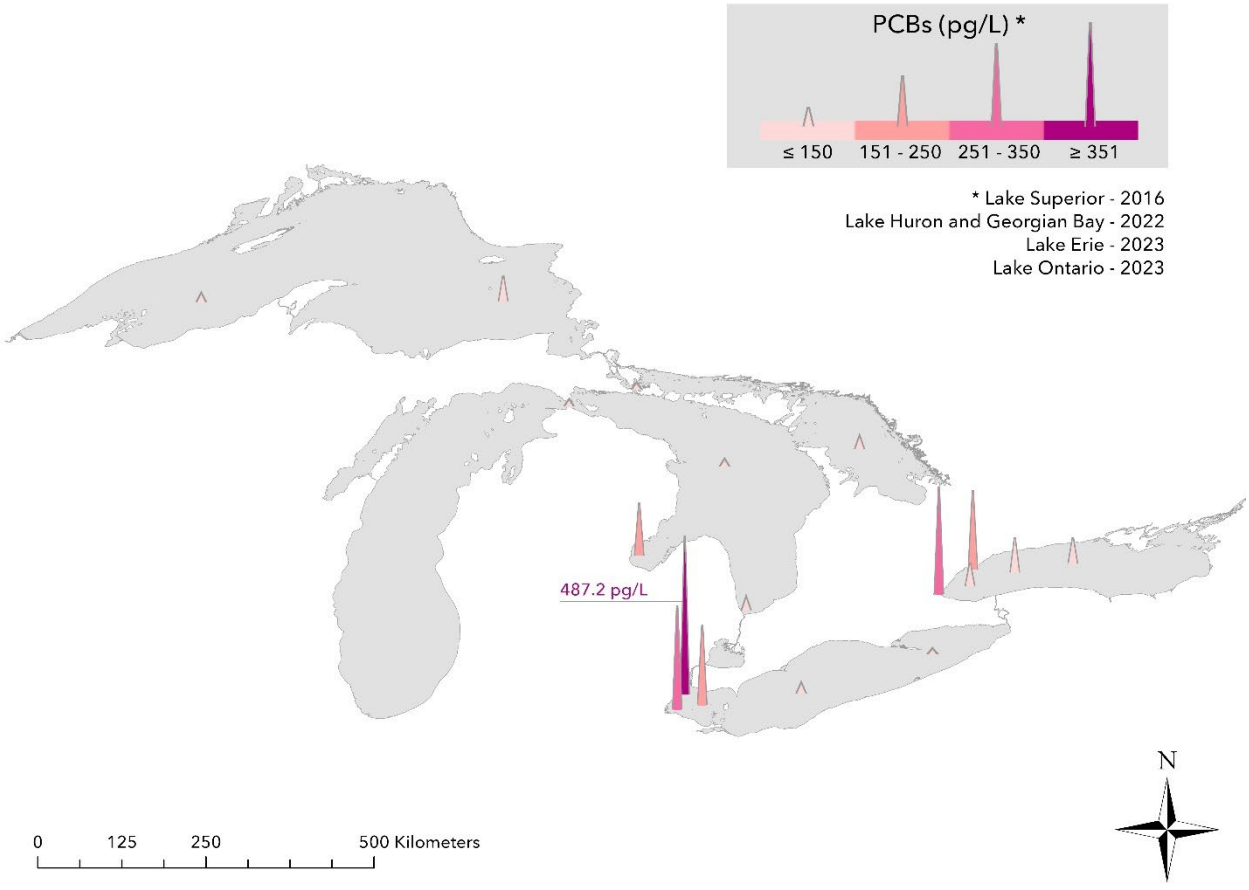


Figure 1. Spatial distribution of the concentrations of total PCBs, pg/L. Information on Lake Michigan was not sufficient for inclusion.

Source: Data are from Environment and Climate Change Canada's Great Lakes Surveillance Program.

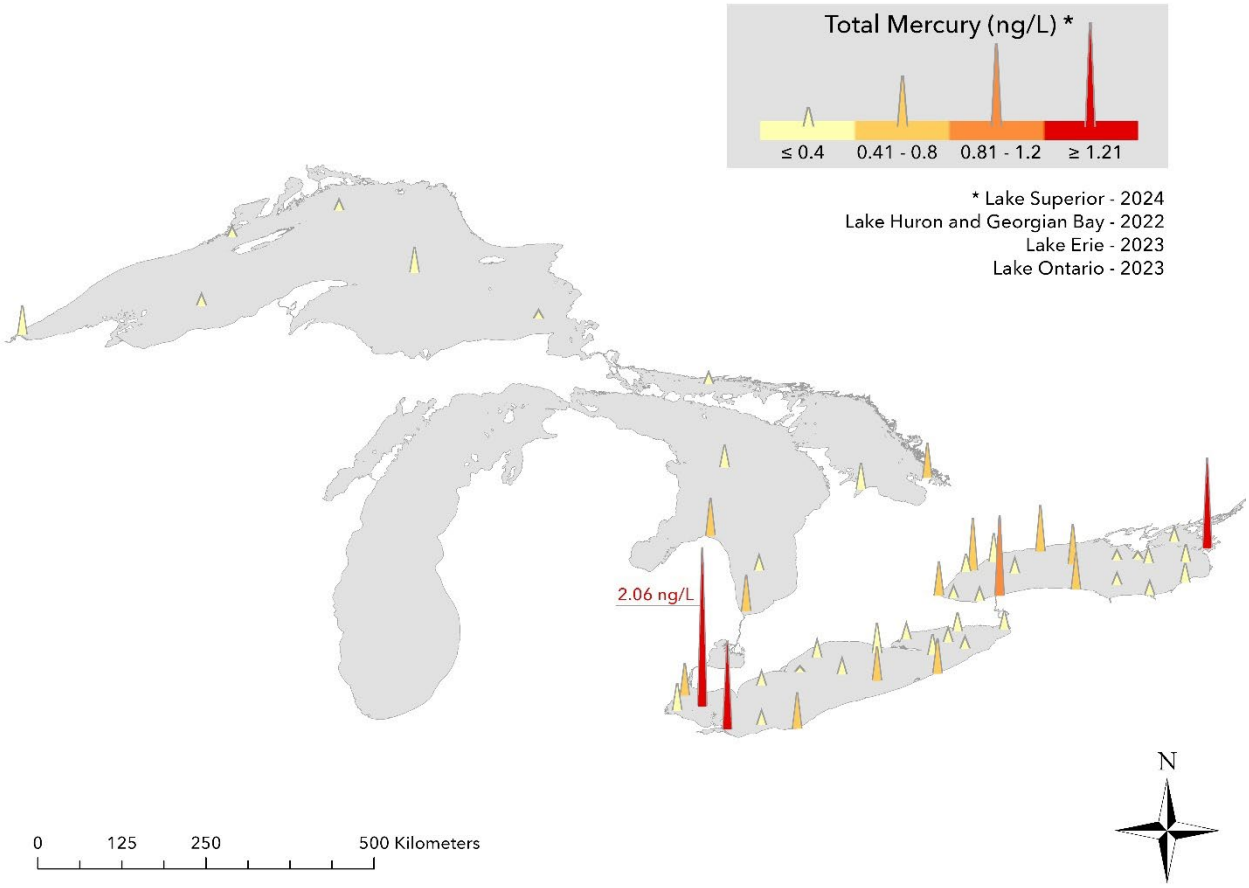


Figure 2. Spatial distribution of the concentrations of total mercury, ng/L. Information on Lake Michigan was not sufficient for inclusion.

Source: Data are from Environment and Climate Change Canada's Great Lakes Surveillance Program.

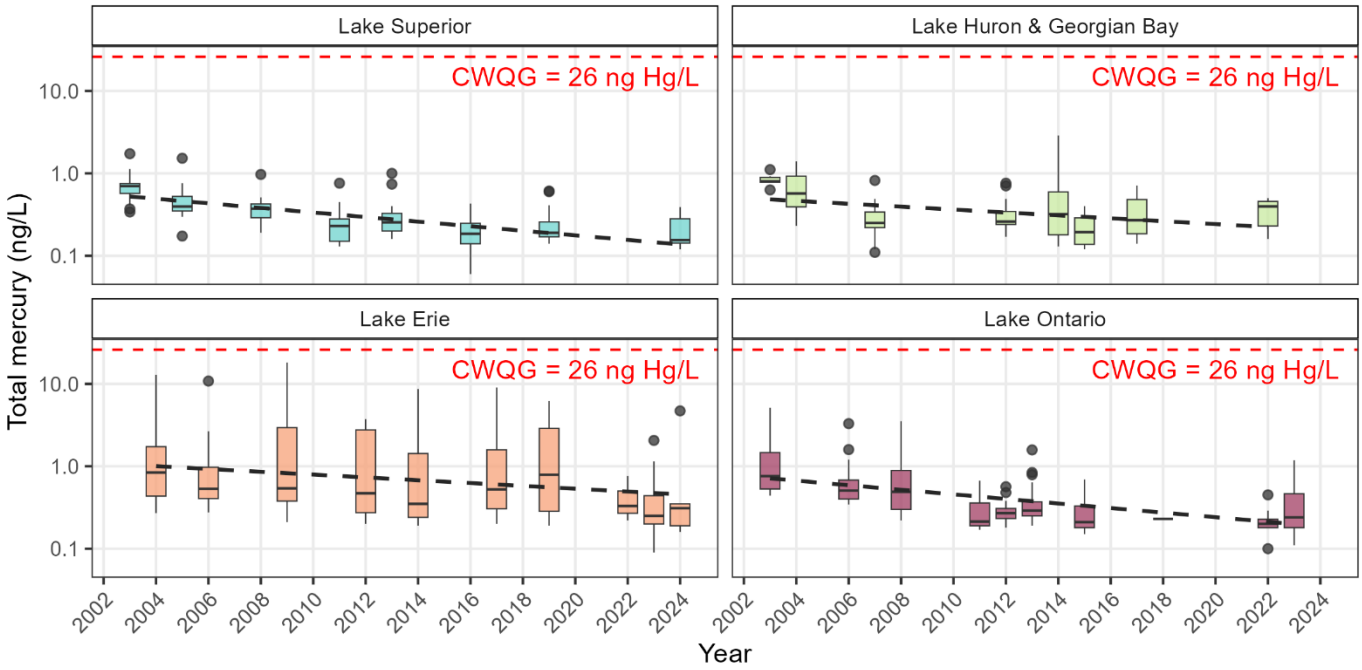
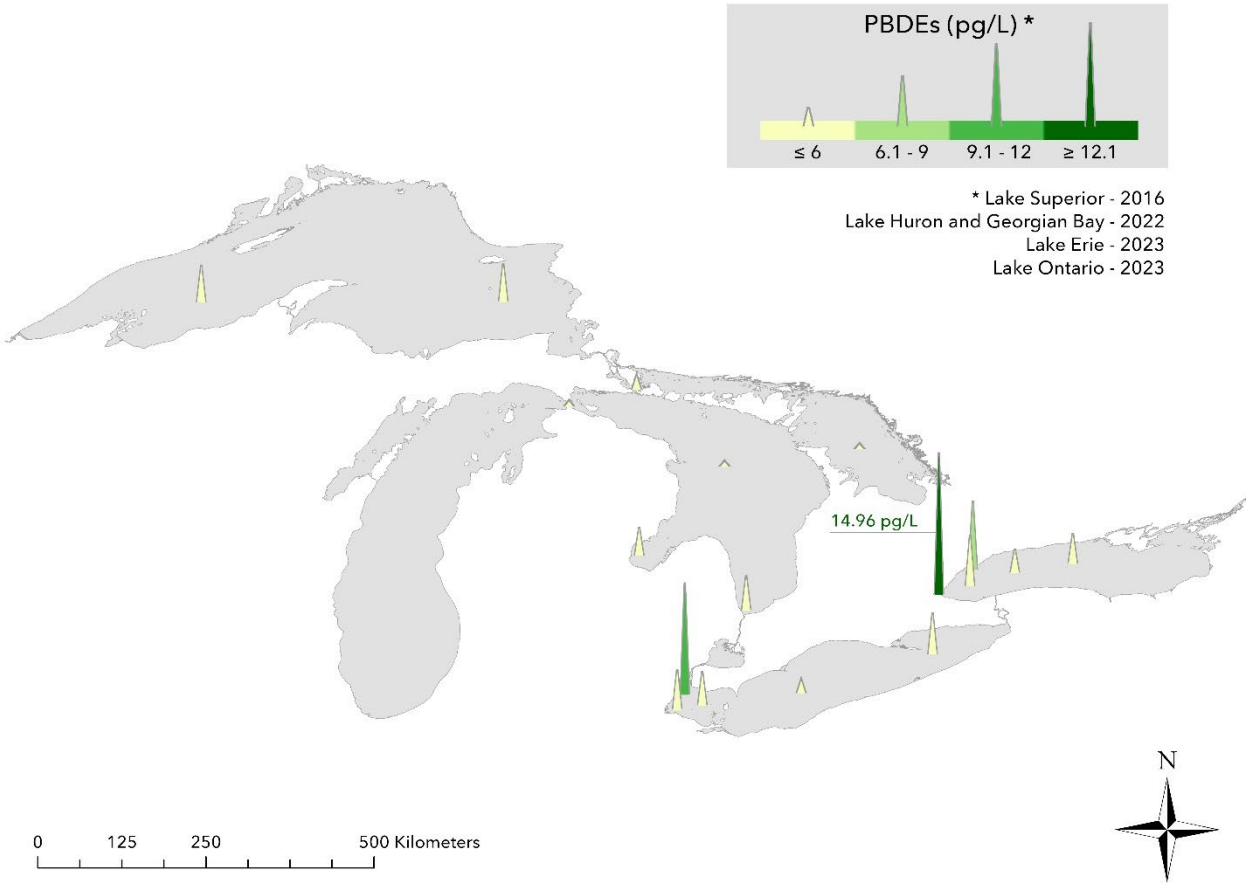


Figure 3. Temporal changes of total mercury in the Great Lakes. Boxes show central median and interquartile range, whiskers show 1.5x interquartile range. Temporal trends indicate improving conditions in all of the lakes. Information on Lake Michigan was not sufficient for inclusion. Data are compared to Canadian Water Quality Guideline (CWQG) value of 26 ng/L.

Source: Data are from Environment and Climate Change Canada's Great Lakes Surveillance Program.



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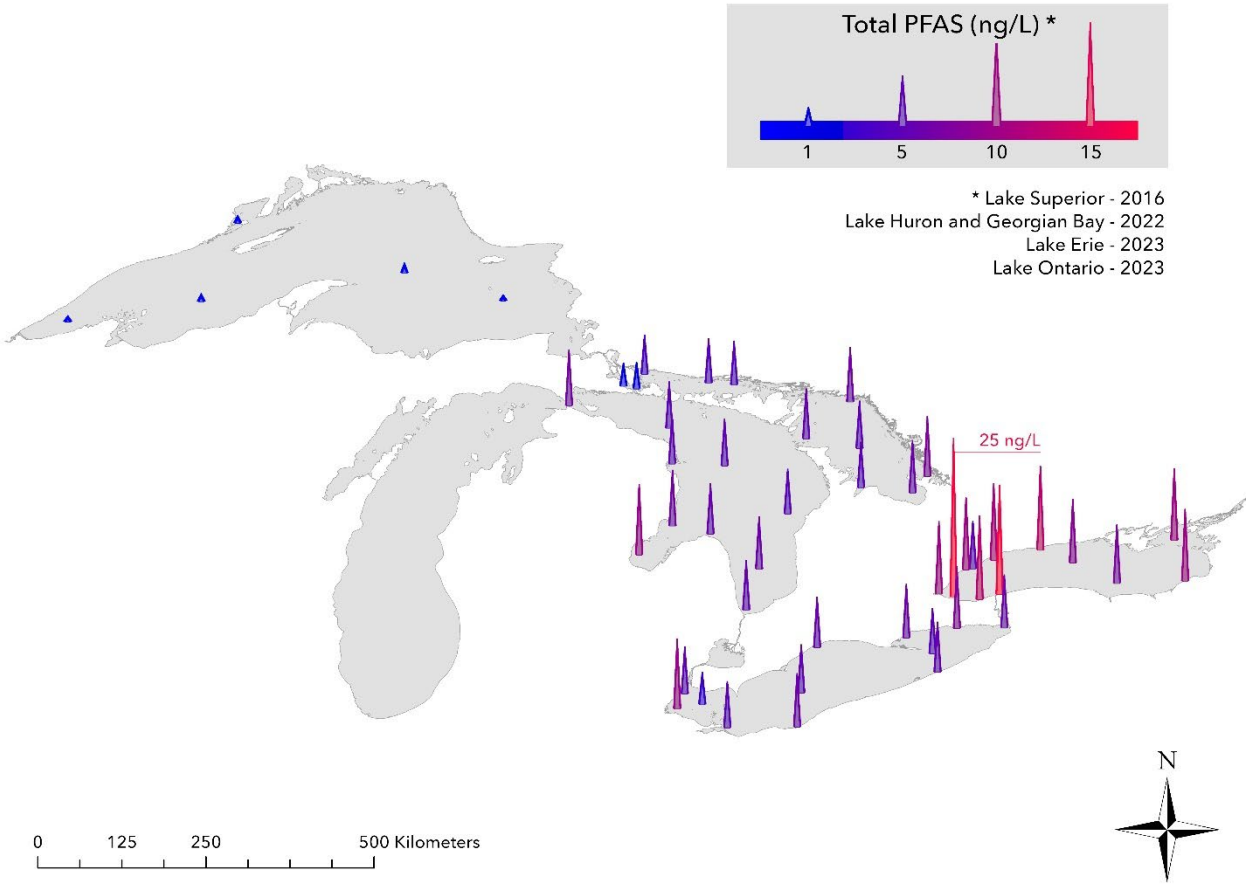

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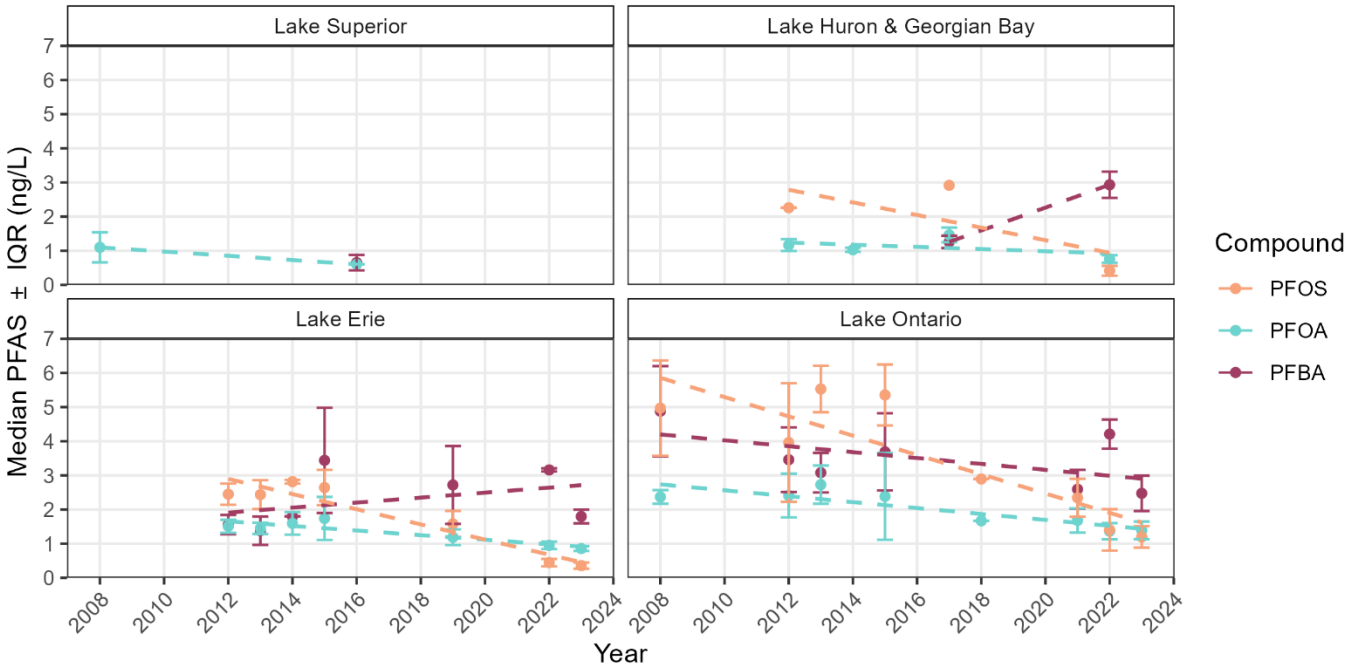

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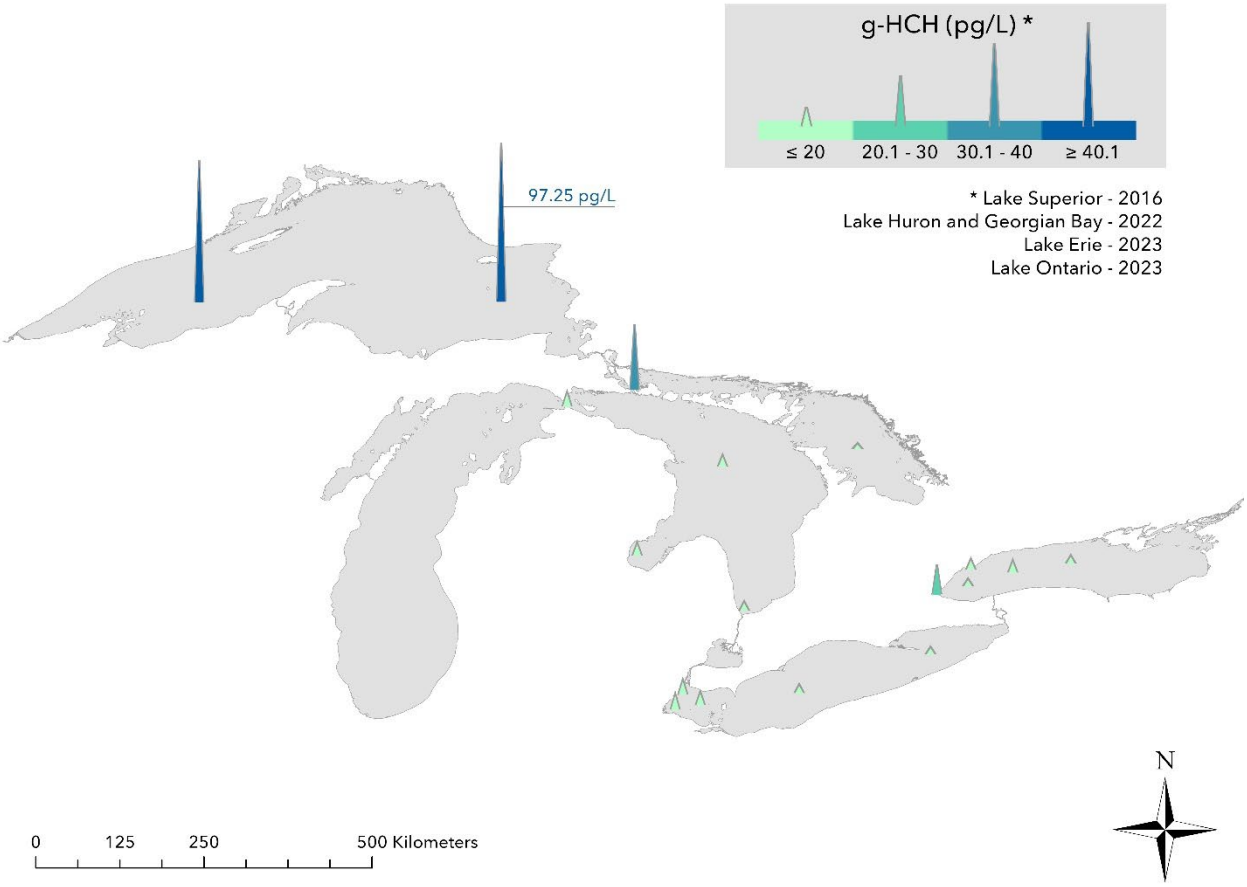

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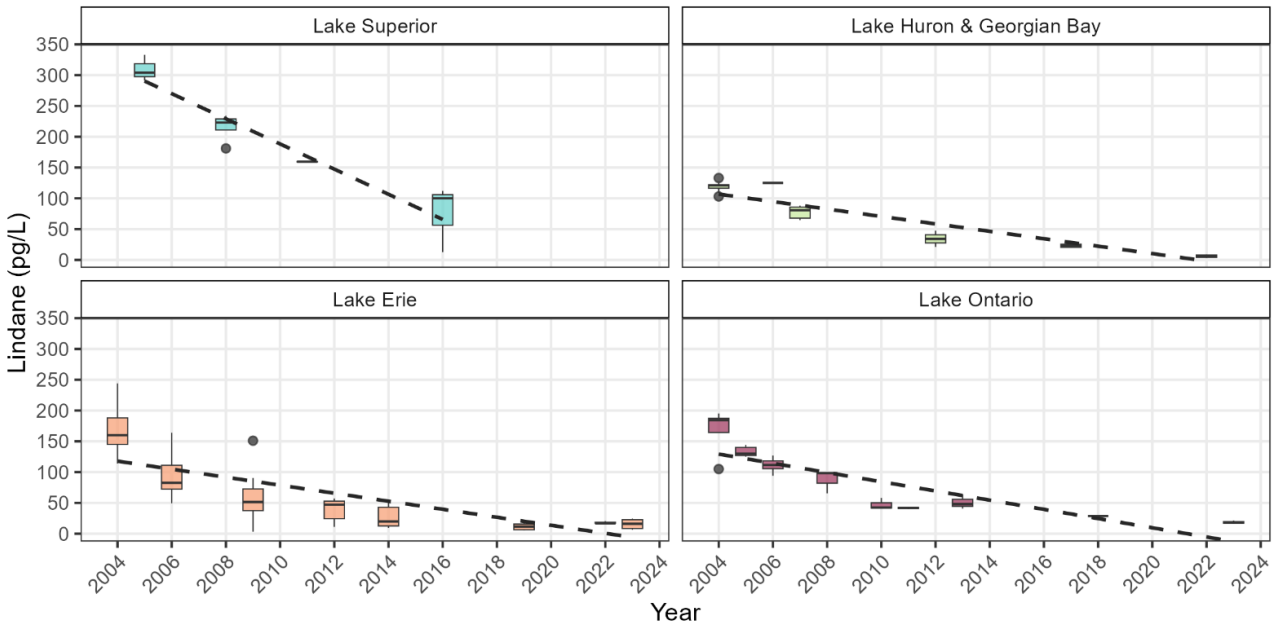

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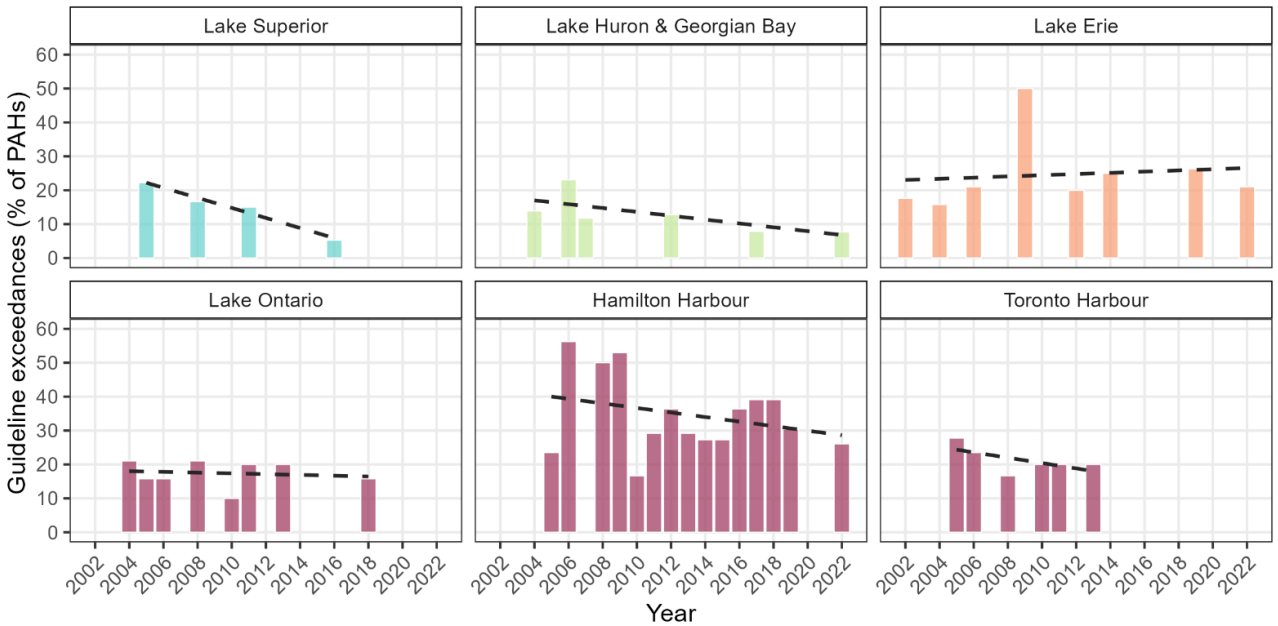

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