Contamination in Sediment Cores

Formerly Indicator #119

Overall Assessment

Status: **Fair**

Trend: **Improving**

Rationale: **Concentrations of legacy contaminants including PCBs and DDT are generally below guidelines in the Great Lakes and declining. Other contaminants such as the polybrominated diphenyl ethers (PBDEs) exhibit some exceedances of guidelines, particularly penta-BDE in Lake Ontario; however, temporal trends show recent declines as a result of management actions.**

Lake-by-Lake Assessment

Lake Superior

Status: Good

Trend: Unchanging

Rationale: Lake Superior is the largest, coldest and deepest of the Great Lakes; as a result, rates of decreases in concentrations of legacy contaminants are slow. However, typical offshore sediment contaminant concentrations are very low as atmospheric deposition is the primary source. Concentrations of some metals exceed the strictest sediment quality guidelines due to the nature of the watershed (pre-Cambrian shield) and historical regional sources associated with mining and smelting.

Lake Michigan

Status: Good, Fair, Poor, or Undetermined

Trend: Improving, Unchanging, Deteriorating or Undetermined

Rationale: Text is limited to 250 Characters

Lake Huron

Status: Good

Trend: Improving

Rationale: Lake Huron is similar to Lake Superior from a sediment contamination viewpoint, as the lake is large, cold and deep with atmospheric deposition as the primary source of most contaminants. Typical sediment contaminant concentrations are very low. As with Superior, concentrations of some metals exceed the strictest guidelines due to the natural geochemistry of the watershed (pre-Cambrian shield) that results in loadings of compounds such as mercury.

Lake Erie

Status: Fair

Trend: Improving

Rationale: Lake Erie exhibits a definitive spatial gradient in contamination with decreasing concentrations from the western basin to the eastern basin, and from the southern area to the northern area of the central basin. This spatial distribution in Lake Erie is influenced by industrial activities in the watersheds of major tributaries, including the Detroit River, and areas along the southern shoreline. The shallow nature of the western basin results in resuspended contaminated bottom sediment continuing to influence suspended sediment quality in the water column, while sediment quality in the eastern basin continues to be classified as excellent.

Lake Ontario

Status: Fair

Trend: Improving

Rationale: Lake Ontario continues to exhibit the poorest sediment quality of all the Great Lakes. The greatest frequency and magnitude of exceedances of sediment quality guidelines is for polychlorinated dibenzo-*p*-dioxins and dibenzofurans. This legacy contamination issue is the result of historical industrial activities in the Niagara River watershed; however, current levels of dioxin contamination represent a 70 percent decline from peak levels in the 1970s. Trends in most legacy chemicals in Lake Ontario point toward improvement in sediment quality over time.

Purpose

- To assess the occurrence, distribution and fate of chemicals in Great Lakes sediments;
- To infer potential harm, or Pressure, caused by contaminated sediments to Great Lakes aquatic ecosystems;
- To assist in identification of sources of chemicals to the Great Lakes.

Ecosystem Objective

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 health, animal or aquatic life (Great Lakes Water Quality Agreement (GLWQA) Article IIId, United States and Canada 1987). The GLWQA and the Great Lakes Binational Toxics Strategy both state the virtual elimination of toxic substances to the Great Lakes as an objective.

Ecological Condition

Measure

Bottom sediment contaminant surveys conducted in the Great Lakes from 1968 – 1974, from 1997 - 2002 and more recent surveys provide information on the spatial distribution of contaminants, the impacts of local historical sources and, in concert with sediment cores, the response to management initiatives. Contaminants across several chemical classes are measured in both surface sediment and sediment cores. The measured contaminants with the highest occurrences, causes of degradation of sediment quality and fish consumption restrictions are:

- Mercury
- PCBs
- Dioxins
- HCB
- Total DDT
- Lead
- PAHs
- Dioxins and Furans

The spatial distribution of mercury contamination in Great Lakes sediments generally represents those of other toxics, both other metals and organics such as PCBs, as accumulation of a broad range of contaminants on a lake-by-lake basis can be the result of common sources, e.g., chlor-alkali production. The highest concentrations of mercury in sediments of Lakes Michigan, St. Clair, Erie and Ontario are observed in offshore depositional areas characterized by fine-grained sediments (Figure 1). In the case of lead, the degree of contamination in Lake Michigan is similar to Lake Ontario. Contaminant concentrations are generally correlated with particle size; hence the distribution of mercury is not only a function of loadings and proximity to sources, but of substrate type and bathymetry. Mercury contamination is generally quite low in Lakes Huron, Michigan and Superior and higher in Lakes St. Clair, Ontario and the western basin of Lake Erie. There is a gradient in contamination in Lake Erie with decreasing concentrations from the western basin to the eastern basin, and from the southern area to the northern area of the central basin. The spatial distribution in Lake Erie is influenced by industrial activities in the watersheds of major tributaries, including the Detroit River, and areas along the southern shoreline. Sources and loadings of mercury to Lake Huron appear to have been reduced to the point that no apparent spatial pattern exists. Current sediment contamination is substantially lower than peak levels that occurred in the mid – 1950s through the early 1970s. Connecting channels including the Niagara, lower Detroit and upper St. Clair Rivers are associated with historical mercury cell chlor-alkali production; these areas were also intensively industrialized and were primary sources of a variety of persistent toxics to the open lakes, including PCBs. Localized areas of highly contaminated sediment, and/or hazardous waste sites may continue to act as sources of contaminants and influence spatial distributions. Conversely, local sources may no longer be predominant, and spatial patterns may now reflect resuspension, intra-lake mixing and deposition of existing sediment inventories. In this case, further declines would be expected as contaminants are deposited and buried.

Endpoint
Sediment concentrations of toxic chemicals no longer exceed sediment quality criteria.

Background

Status of Contaminants in Sediment
Sediments in the Great Lakes generally represent a primary sink for contaminants, and can act as a source through resuspension and subsequent redistribution. Conversely, burial in sediments also represents a primary mechanism by which contaminants are sequestered and prevented from re-entering the water column.
Comparisons of surficial sediment contaminant concentrations with sub-surface maximum concentrations indicate that contaminant concentrations have generally decreased by more than 35 per cent, and, in some cases, by as much as 80 per cent over the past four decades (Table 1).

Sediment concentrations can also be assessed against guideline values established for the protection of aquatic biota, e.g., Canadian Sediment Quality Guidelines Probable Effect Level (PEL, CCME, 1999). These guidelines can be applied as screening tools in the assessment of potential risk, and for the determination of relative sediment quality concerns. For metals, PEL guideline exceedances were frequent in Lake Ontario for lead, cadmium and zinc. Guideline exceedances were rare in all of the other lakes, with the exception of lead in Lake Michigan where the PEL (91.3 μg/g) was exceeded at over half of the sites. There were no PEL (277 ng/g total PCBs) guideline exceedances for PCBs in any of the Great Lakes sediments.

The presence of new persistent toxics represents a potential threat to the health of the Great Lakes ecosystem. These compounds include perfluoroalklated compounds (PFCs) and brominated flame retardants (BFRs), the latter of which are heavily used globally in the manufacturing of a wide range of consumer products and building materials. The BFRs have been found to be bioaccumulating in Great Lakes fish and in breast milk of North American women. While end of the pipe discharges may not be responsible for ongoing contamination, modern urban/industrial centres can act as diffuse sources of current inputs. Sediment core profiles of brominated diphenyl ethers (BDEs) and PFCs in Lake Ontario suggest that accumulation of these chemicals has recently peaked, or continues to increase (Figure 2). The Lake Ontario BDE profile indicates a leveling off of accumulation in the past decade, presumably as a result of voluntary cessation of production of these compounds in North America. However, the deca-substituted BDE 209 is the predominant congener in sediment, and is still currently used. Despite these trends, maximum concentrations of many BFRs and PFCs remain well below maximum concentrations of contaminants such as DDT and PCBs observed in past decades.

Assessment of the occurrence and fate of newer compounds has been incorporated into sediment assessment programs. PFCs are a broad range of substances that have attracted much scientific and regulatory interest in recent years as a result of their detection globally in humans and wildlife. PFCs are routinely detected in precipitation and air in urban and rural environments. These compounds have a myriad of applications, but have been primarily used as soil and liquid repellents for papers, textiles and carpeting. Production of PFCs as stain repellents in carpets historically exceeded $1 billion annually. Two classes of PFCs, the perfluoroalkyl sulfonate acids, particularly perfluorooctane sulfonate (PFOS), and the perfluorocarboxylates, particulary perfluorooctanoic acid (PFOA), are the most commonly measured PFCs; these compounds are highly stable and persistent in the environment, and are potentially toxic. PFCs have been detected in environmental samples far from urban areas, including remote areas such as the Canadian Arctic. The physical and chemical properties of PFCs are different from many other semi-volatile pollutants that can significantly influence their pathways through the environment.

Concentrations of PFCs in sediments of Great Lakes tributaries are highest in urbanized and/or industrialized watersheds. In general levels of perfluoroalkylsulfonate acids and PFOS in tributaries (Figure 3) and open waters of the Great Lakes are slightly higher than the perfluorocarboxylates with the highest levels of PFCs generally found in areas of Lake Ontario and the western end of Lake Erie and the Detroit River corridor. There is a gradient toward increasing PFC contamination from the upper Great Lakes (Superior and Huron) to the lower Great Lakes (Erie and Ontario) for both tributary and open-lake sediments (Figure 4). Concentrations of PFCs in open-lake sediments are driven not only by proximity to sources, but physical processes and bathymetry as well. The highest PFC concentrations in open-lake sediments were found in Lake Ontario. The spatial distributions of PFCs in Lake Ontario are fairly consistent across the lake, which is primarily due to lake currents that evenly distribute suspended particles and across the three major depositional basins.

The spatial distributions of PFCs in Great Lakes sediments are heavily influenced by shoreline-based urban and industrial activities, which in some cases stand in contrast to distributions of legacy contaminants such as PCBs. These results suggest that large urban areas can act as diffuse sources of PFCs associated with modern industrial and consumer products, and therefore management action should focus on prevention of pollutant emissions from consumer and industrial products.

Linkages

Sediment contamination affects both water quality and aquatic dependent life. Sediment is a source of mercury and other toxic chemicals to enter the water column. These chemicals are components of the indicators in the top level categories of Water Quality, Aquatic Dependent Life, Fish & Wildlife, and Restoration & Protection. Relevant indicators include “Toxic chemicals in offshore waters”, water quality as measured by contaminants in whole fish, water birds, and bald eagles, “Fish disease occurrences,” and “Sediment remediation.”

Management Challenges/Opportunities

Management efforts to control inputs of historical contaminants have resulted in decreasing contaminant concentrations in the Great Lakes open-water sediments for the standard list of chemicals. However, chemicals such as BFRs and current-use pesticides may represent emerging issues and potential future stressors to the ecosystem. These results corroborate observations made globally, which indicate that large urban centers act as diffuse sources of chemicals that are heavily used to support our modern societal lifestyle.

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:						

Acknowledgments
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Information Sources

Environment Canada Great Lakes Fact Sheet. Polybrominated diphenyl ethers in sediments of tributaries and open-water areas of the Great Lakes. Catalogue No. En84-70/2009E.

Environment Canada Great Lakes Fact Sheet. Perfluoroalkyl compounds in sediments of tributaries and open-water areas of the Great Lakes. ISBN No. 978-1-100-145025-4.

Environment Canada Great Lakes Fact Sheet. Contaminants in sediments of Canadian tributaries and open-water areas of the lower Great Lakes. ISBN No. 978-0-662-46896-7.

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Last Updated

State of the Lakes Ecosystem Conference (SOLEC) 2011

Parameter	Ontario	Erie	St. Clair	Huron	Superior
	%Reduction	%Reduction	%Reduction	%Reduction	%Reduction
Mercury	73	37	89	82	0
PCBs	37	40	49	45	15
Dioxins	70	NA	NA	NA	NA
HCB	38	72	49	NA	NA
Total DDT	60	42	78	93	NA
Lead	45	50	74	43	10

Table 1. Estimated percentage declines in sediment contamination in the Great Lakes (1970 – 2010) based on comparison of surface sediment concentrations with maximum concentrations at depth in sediment cores. Source: Environment Canada

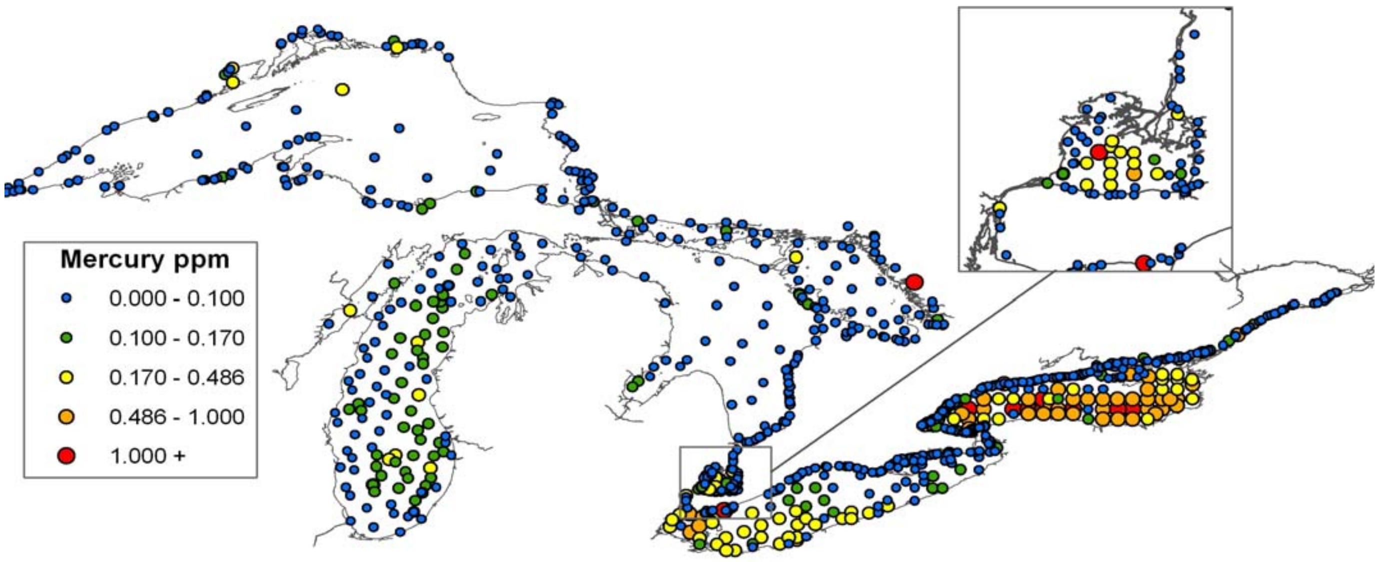

Figure 1. Spatial distribution of mercury contamination in surface sediments in open-lake areas and tributaries of the Great Lakes.
Sources: Environment Canada and USEPA.

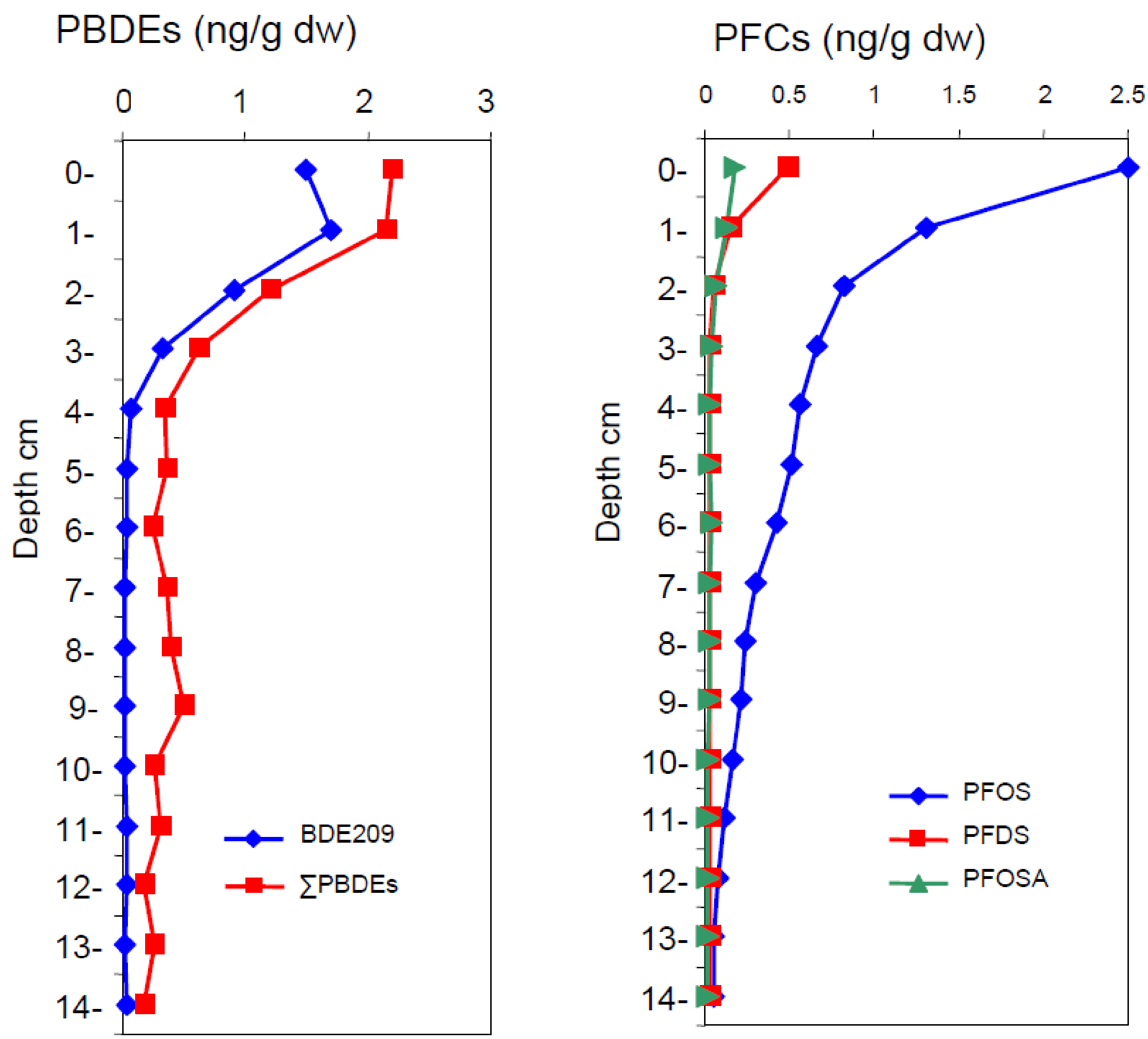

Figure 2. Core profiles of perfluoroalkyl compounds (PFCs) and polybrominated diphenyl ethers (PBDEs) in sediment cores from the central (Mississauga Basin) basin of Lake Ontario. Sources: Environment Canada and Ontario Ministry of the Environment.

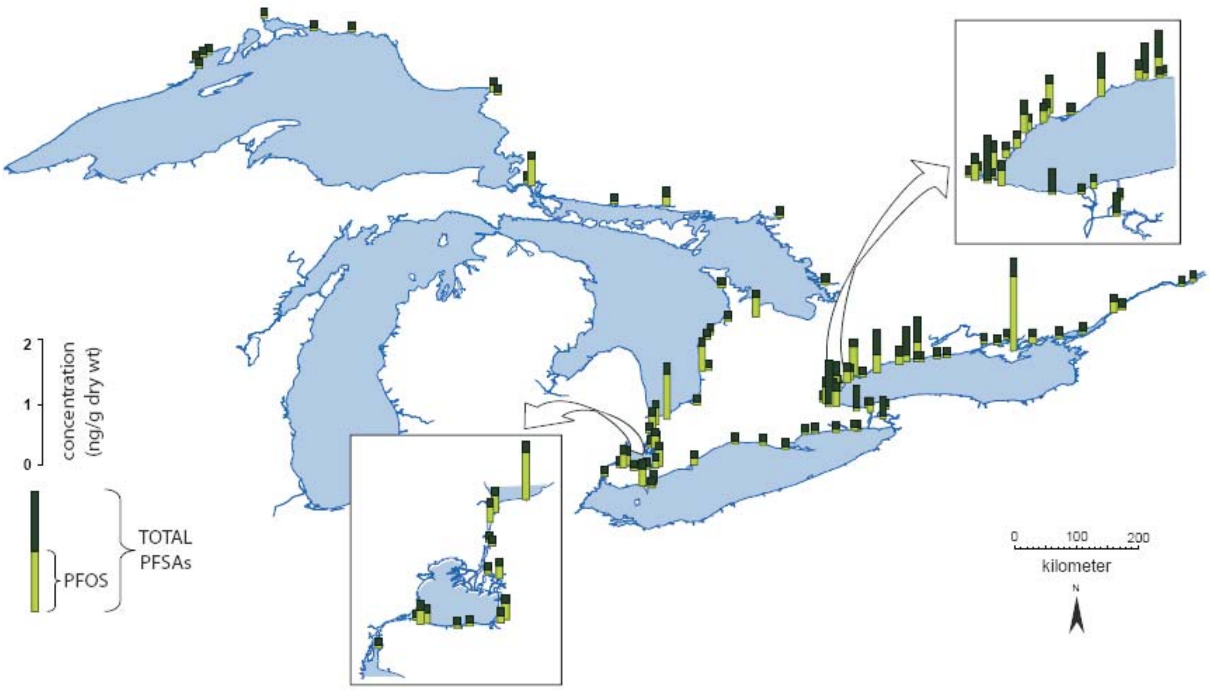

Figure 3. Total PFSAs perfluoroalkyl sulfonate acids (PFSAs) and perfluorooctane sulfonate (PFOS) concentrations in surficial sediments in tributaries of the Great Lakes.
Source: Environment Canada and the Ontario Ministry of the Environment.

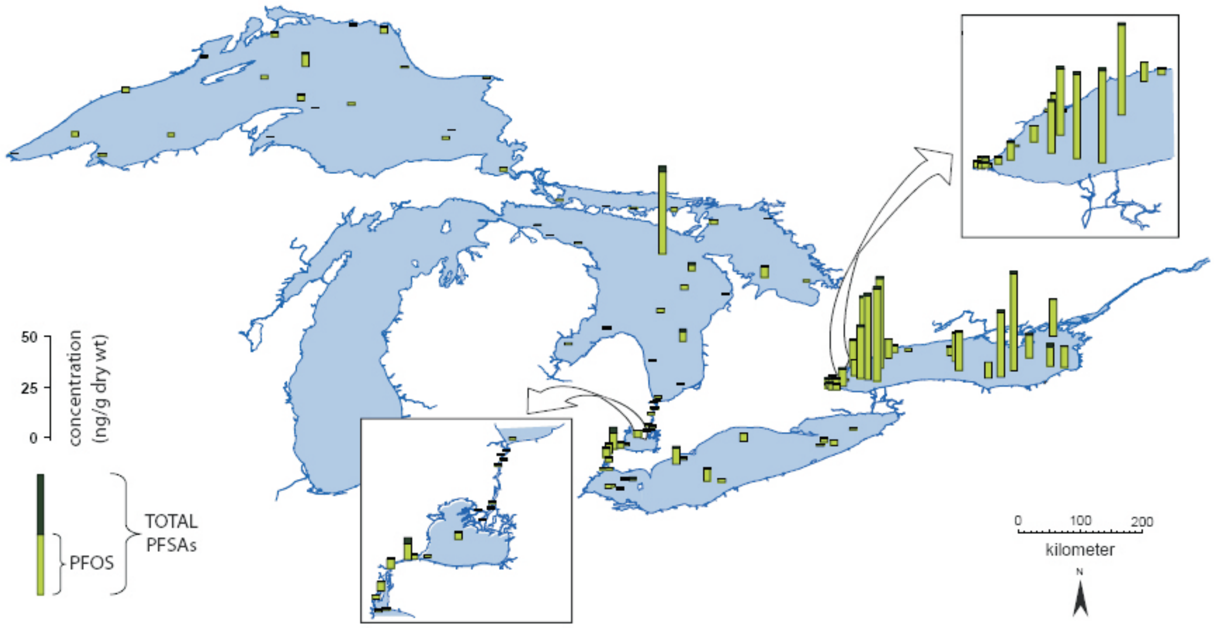

Figure 4. Total PFSAs perfluoroalkyl sulfonate acids (PFSAs) and perfluorooctane sulfonate (PFOS) concentrations in surficial sediments of open-water areas of the Great Lakes.
Source: Environment Canada and the Ontario Ministry of the Environment.