Concentrations of Contaminants in Sediment Cores

Indicator #119

Overall Assessment

Status: **Mixed**

Trend: **Improving/Undetermined**

Rationale: **There have been significant declines over the past several decades in concentrations of many contaminants including PCBs, DDT, lead, and mercury due to successful management actions. Current focus is on the determination of the occurrence, distribution and fate of modern societal contaminants including brominated flame retardants and fluorinated surfactants.**

Lake-by-Lake Assessment

Each lake was categorized with a not assessed status and an undetermined trend, indicating that assessments were not made on an individual lake basis.

Purpose

- To infer potential harm to aquatic ecosystems from contaminated sediments by comparing contaminant concentrations to available sediment quality guidelines
- To infer progress towards virtual elimination of toxic substances in the Great Lakes by assessing surficial sediment contamination and contaminant concentration profiles in sediment cores from open lake and, where appropriate, Areas of Concern index stations
- To determine the occurrence, distribution, and fate of new chemicals in Great Lakes sediments

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 III(d), 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.

State of the Ecosystem

Sediments in the Great Lakes generally represent a primary sink for contaminants, and can act as a source through resuspension and subsequent redistribution within the individual lakes. However, burial in sediments also represents a primary mechanism by which contaminants are sequestered and prevented from re-entering the water column.

Bottom sediment contaminant surveys conducted in the Great Lakes from 1968 - 1974 and from 1997 - 2002 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. 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. Table 1 shows percentage reductions in contaminant concentrations (surface vs. sub-surface) in Lakes Ontario, Erie, Huron, Superior and St. Clair from available sediment core data.

Spatial distributions in mercury contamination generally represent 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). The spatial distribution of mercury across the Great Lakes is generally representative of the distributions of the other metals, with the exception of lead, where 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 the influence of substrate type and bathymetry as well. Mercury contamination is found 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 an apparent spatial distribution 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 pattern 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. Elevated concentrations of mercury are found in the central and east-central areas of Lake St. Clair, the western basin of Lake Erie, and the three major depositional basins of Lake Ontario. The current degree of contamination in these areas is substantially lower than peak levels that occurred in the mid – 1950s through the early 1970s. However, the similarity in spatial patterns between recent and historical surveys indicates significant sources within the individual lake basins continue to influence contaminant distributions over large areas. Areas of the major connecting channels including the Niagara, lower Detroit and upper St. Clair Rivers are all 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 associated with these industrial historical sources, may continue to act as sources of these contaminants and influence their spatial distributions. Conversely, these local sources may no longer be predominant, and the spatial patterns observed in our most recent surveys may reflect resuspension, intra-lake mixing and deposition of existing sediment inventories. In this case, further declines would be expected as these contaminants are ultimately deposited and buried in the sedimentary record.

Surficial sediment concentrations can also be assessed against guideline values established for the protection of aquatic biota, e.g., the 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 and PCBs, 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 an emerging threat to the health of the Great Lakes ecosystem. These compounds include perfluoroalklated substances (PFAs) and the 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. Assessment of the occurrence and fate of these new compounds has recently been incorporated into bottom sediment monitoring programs. While government initiatives in reducing indiscriminant urban and industrial discharges of legacy compounds like PCBs have resulted in decreasing trends, the new and emerging compounds have not shown corresponding trends. 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 PFAs in Lake Ontario suggest that accumulation of these chemicals has only 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 PFAs remain well below maximum concentrations of contaminants such as DDT and PCBs observed in past decades.

Pressures

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, additional chemicals such as brominated flame retardants (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.

Management Implications

The Great Lakes Binational Toxics Strategy needs to be maintained to identify and track the remaining sources of legacy contamination and to explore opportunities to accelerate their elimination. In addition, targeted monitoring to identify and track down local sources of pollution should be considered for those chemicals whose distribution in the ambient environment suggests local or sub-regional sources. Ongoing monitoring programs in the Great Lakes connecting channels (e.g., Detroit River, Niagara River) provide valuable information on the success of binational management actions to reduce or eliminate discharges of toxic substances to the Great Lakes. The Great Lakes Binational Toxics Strategy also needs to be proactive in addressing issues related to the distribution and fate of chemicals heavily used by our modern urban/industrial society.

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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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 based on comparison of surface sediment concentrations with maximum concentrations at depth in sediment cores. Source: Environment Canada

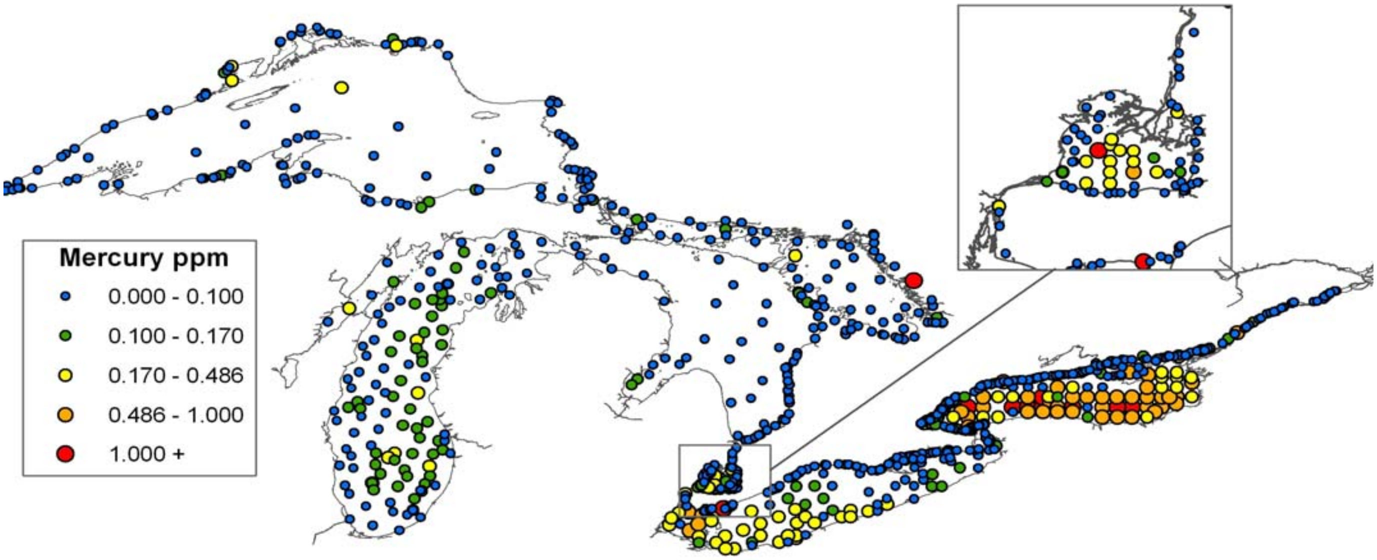

Figure 1. Spatial distribution of mercury contamination in surface sediments in open lake areas and tributaries of the Great Lakes. Sources: Environment Canada and USEPA.

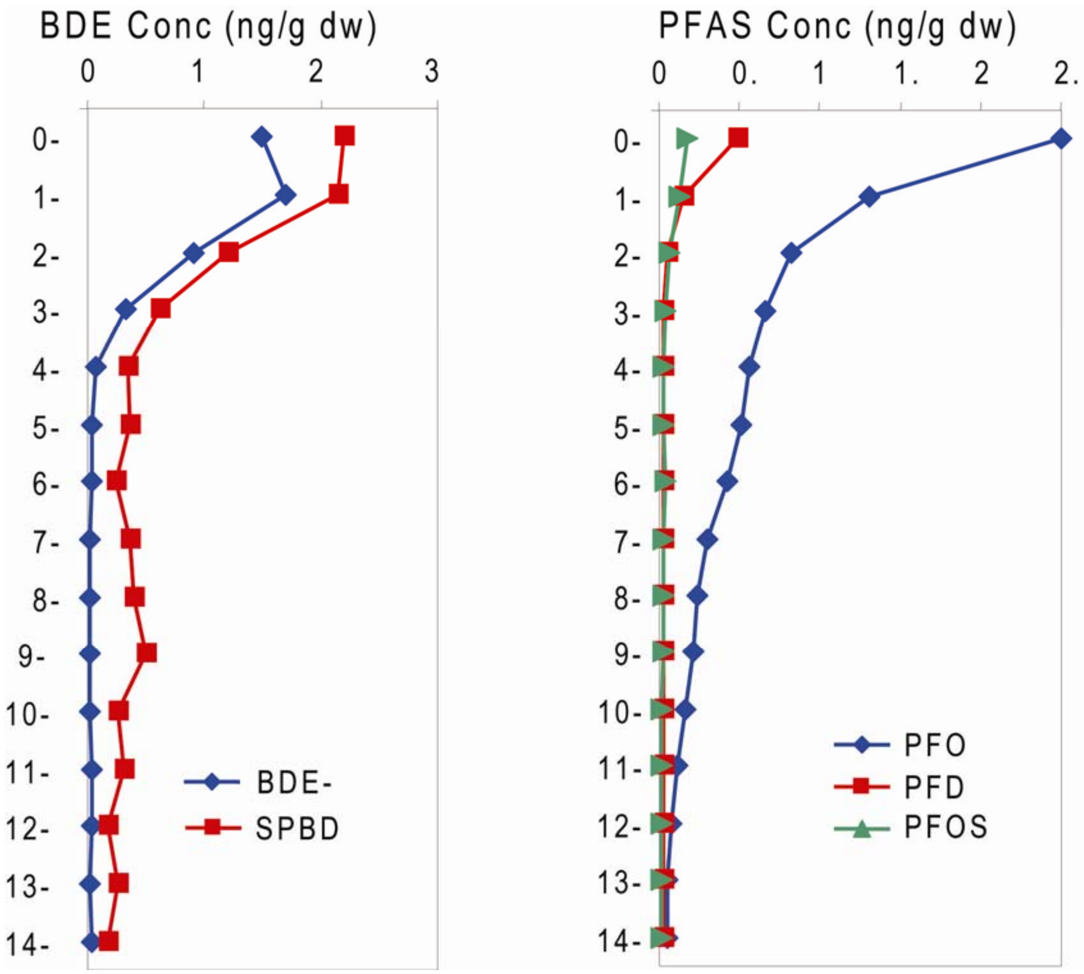

Figure 2. Core profiles of perfluoroalkyl subtances (PFAS) and brominated diphenyl ethers (BDEs) is sediment cores from the central (Mississauga Basin) basin of Lake Ontario. Sources: Environment Canada and Ontario Ministry of the Environment.