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PCB Levels and Trends within the Detroit River – Western Lake Erie Basin: A Historical perspective of ecosystem monitoring

By:
T. Heidtke, J. Hartig, M. Zarull, B. Yu

NWRI Contribution # 04-207

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Abstract

An international workshop held in the spring of 2002 convened a group of technical experts to address monitoring, modeling, and management of PCBs within the Detroit River-western Lake Erie basin. Participants shared and discussed a diverse set of research data bases pertaining to PCB levels within the region, discussed observed changes within different components of the local ecosystem, and identified several primary issues impacting future PCB management strategies. Results presented at the workshop indicate dramatic reductions in PCB contamination levels have been observed in much of study area between the late 1970s and mid-1990s. Estimates of loadings attributable to water and atmospheric sources have generally declined, as have PCB concentrations in herring gull eggs, smelt and walleye. Nevertheless, additional improvements have not been observed during recent years and elevated contamination levels remain a concern within local hot spots, particularly in the lower Detroit River and Trenton Channel. A primary recommendation broadly supported by workshop participants is the need to maintain, support, and coordinate a comprehensive ecosystem monitoring program for the Detroit River-western Lake Erie basin, one that incorporates both near-field and far-field monitoring elements. Such a program is crucial to provide necessary data in support of understanding ecosystem trends, calculating annual mass loadings to the system, assessing impacts of remediation actions, developing improved modeling frameworks, and formulating cost-effective management strategies for the future.

Concentrations et tendances concernant les PCB à l'intérieur du bassin de la rivière Détroit et de l'ouest du lac Érié : perspective historique de la surveillance de l'écosystème

Thomas Heidtke, John H. Hartig, Michael A. Zarull, Bonnie Yu

Résumé

Un atelier international tenu au printemps de 2002 a réuni un groupe d'experts techniques pour examiner la surveillance, la modélisation et la gestion des PCB à l'intérieur du bassin de la rivière Détroit et de l'ouest du lac Érié. Les participants ont partagé et étudié un ensemble diversifié de bases de données de recherche sur les concentrations de PCB à l'intérieur de la région, examiné les changements constatés à l'intérieur de différentes composantes de l'écosystème local, et caractérisé plusieurs enjeux primaires touchant les futurs stratégies de gestion des PCB. Les résultats présentés à l'atelier montrent qu'entre la fin des années 1970 et le milieu des années 1990, il y a eu des réductions spectaculaires des concentrations de PCB dans la majeure partie de la zone étudiée. Les estimations des charges attribuables à des sources aqueuses ou atmosphériques ont généralement décliné, tout comme les concentrations de PCB dans les oeufs de goéland argenté ainsi que chez les éperlans et le doré jaune. Cependant, ces dernières années il n'y a pas eu d'autres améliorations et les concentrations élevées de contaminants demeurent préoccupantes dans des points chauds, particulièrement dans le bassin inférieur de la rivière Détroit et dans le canal Trenton. Une première recommandation, bénéficiant d'un large consensus parmi les participants de l'atelier, concernait le maintien, le soutien et la coordination d'un programme complet de surveillance de l'écosystème pour le bassin rivière Détroit - ouest du lac Érié, programme qui incorpore des éléments de surveillance aussi bien en champ éloigné qu'en champ proche. Un programme de ce type est d'une importance cruciale pour l'obtention des données nécessaires à la compréhension des tendances de l'écosystème, au calcul des charges massiques annuelles entrant dans le système, à l'évaluation des impacts des mesures correctives, à l'élaboration de cadres de modélisation, et enfin à la formulation de stratégies de gestion rentables pour le futur.

NWRI RESEARCH SUMMARY

Plain language title

PCB Levels and Trends Within the Detroit River-Western Lake Erie Basin

What is the problem and what do scientists already know about it?

Considerable volumes of sediment containing PCBs have been removed from the watershed, resulting in measurable improvements proximal to the remediation projects. However, far-field effects were not initially examined. Ambient monitoring data, from a variety of sources, were inspected for measurable improvements in the aquatic ecosystem.

Why did NWRI do this study?

NWRI participated in this study as part of our ongoing involvement and commitment to RAPs, LaMPs, the GLWQA and the binational toxics strategy.

What were the results?

Dramatic reductions in PCB contamination levels were observed throughout much of the study area, in all media, from the late 1970s through the mid-1990s. However, additional improvements have not been observed during recent years and elevated contamination remains a concern within local hot spots, particularly in the lower Detroit River and the Trenton Channel.

How will these results be used?

Results should assist in focusing additional effort in hot spots identified. Research and monitoring recommendations should assist in the formulation of programmes to measure the effectiveness of remedial actions.

Who were our main partners in the study?

US Coast Guard and Wayne State University

Sommaire des recherches de l'INRE

Titre en langage clair

Concentrations et tendances concernant les PCB à l'intérieur du bassin de la rivière Détroit et de l'ouest du lac Érié.

Quel est le problème et que savent les chercheurs à ce sujet?

Des volumes considérables de sédiments contenant des PCB ont été retirés du bassin hydrographique, ce qui a permis d'obtenir des améliorations mesurables avoisinant les projets de mesures correctives. Cependant, au départ, les effets en champ éloigné n'ont pas été examinés. Les données de surveillance du milieu ambiant, provenant de diverses sources, ont été examinées pour déterminer les améliorations mesurables dans les écosystèmes aquatiques.

Pourquoi l'INRE a-t-il effectué cette étude?

L'INRE a participé à cette étude dans le cadre de notre engagement et de notre mobilisation à l'égard des PA, PAP, de l'AQEGL, et enfin de la stratégie binationale sur les produits toxiques.

Quels sont les résultats?

Des réductions spectaculaires des concentrations de PCB contaminants ont été constatées entre la fin des années 1970 et le milieu des années 1990 dans la majeure partie de la zone étudiée et dans tous les milieux. Cependant, ces dernières années il n'y a pas eu d'autres d'améliorations et les concentrations élevées de contaminants demeurent préoccupantes dans des points chauds, particulièrement dans le bassin inférieur de la rivière Détroit et dans le canal Trenton.

Comment ces résultats seront-ils utilisés?

Les résultats devraient aider à déployer des efforts additionnels dans les points chauds repérés. Les recommandations en matière de recherche et de surveillance devraient aider à la formulation de programmes pour mesurer l'efficacité des mesures correctives.

Quels étaient nos principaux partenaires dans cette étude?

Garde côtière américaine et Wayne State University

PCB LEVELS AND TRENDS WITHIN THE DETROIT RIVER – WESTERN LAKE ERIE BASIN: A HISTORICAL PERSPECTIVE OF ECOSYSTEM MONITORING

THOMAS HEIDTKE[1,*], JOHN H. HARTIG[2], MICHAEL A. ZARULL[3], BONNIE YU[4]
[1]Department of Civil and Environmental Engineering, Wayne State University, Detroit, MI, U.S.A.; [2]Large Lakes Research Station, Grosse Ile, MI, U.S.A.; [3] National Water Research Institute, Canada Centre for Inland Waters, Burlington, Ontario Canada, [4]Department of Civil and Environmental Engineering, Wayne State University, Detroit, MI, U.S.A.
(*author for correspondence, email: theidtke@eng.wayne.edu)

Abstract: An international workshop held in the spring of 2002 convened a group of technical experts to address monitoring, modeling, and management of PCBs within the Detroit River-western Lake Erie basin. Participants shared and discussed a diverse set of research data bases pertaining to PCB levels within the region, discussed observed changes within different components of the local ecosystem, and identified several primary issues impacting future PCB management strategies. Results presented at the workshop indicate dramatic reductions in PCB contamination levels have been observed in much of study area between the late 1970s and mid-1990s. Estimates of loadings attributable to water and atmospheric sources have generally declined, as have PCB concentrations in herring gull eggs, smelt and walleye. Nevertheless, additional improvements have not been observed during recent years and elevated contamination levels remain a concern within local hot spots, particularly in the lower Detroit River and Trenton Channel. A primary recommendation broadly supported by workshop participants is the need to maintain, support, and coordinate a comprehensive ecosystem monitoring program for the Detroit River-western Lake Erie basin, one that incorporates both near-field and far-field monitoring elements. Such a program is crucial to provide necessary data in support of understanding ecosystem trends, calculating annual mass loadings to the system, assessing impacts of remediation actions, developing improved modeling frameworks, and formulating cost-effective management strategies for the future.

Keywords: PCBs, Detroit River, Lake Erie, ecosystem health, sediments, remediation, monitoring

1. Introduction

Since the production of PCBs was banned in 1977, the Detroit River- western Lake Erie basin has been extensively studied in terms of a range of ecosystem health indicators affected by PCB loadings, including contaminated sediment, fish and wildlife, and impairment of other beneficial uses within the area. During this time, millions of dollars

have been spent on monitoring, modeling and managing PCBs. Although these initiatives have fostered an improved understanding of contamination levels within different parts of the ecosystem, until recently there has been little if any effort to integrate available data and to share ideas and insights regarding ecosystem trends and impacts directly attributable to PCBs.

In response to the need for a framework under which information and ideas could be shared and conclusions drawn regarding historical changes and trends directly or indirectly linked to PCB contamination and remediation within the Detroit River – western Lake Erie basin, a two-day workshop was convened in Windsor, Ontario during the summer of 2002. Over fifty technical experts from universities, government agencies, research laboratories and other relevant organizations participated in the workshop. The primary objectives were to share and discuss past and current research focused on PCBs levels within the basin, to assess what is currently known and what remains uncertain regarding the magnitude and distribution of PCBs within the local ecosystem, and ultimately develop advice to help guide future monitoring, modeling and management initiatives designed to protect the health of the system.

The purpose of this paper is to provide an overview of research and related data bases which illuminate current conditions and historical trends in PCB levels within different segments of the Detroit River-western Lake Erie basin. The discussion focuses on several important contamination sources and ecosystem health indicators, including atmospheric and tributary loadings, sediments, zoobenthos and adult aquatic insects, fish, snapping turtles, and herring gull eggs. Following is a summary of major findings presented at the 2002 PCB workshop.

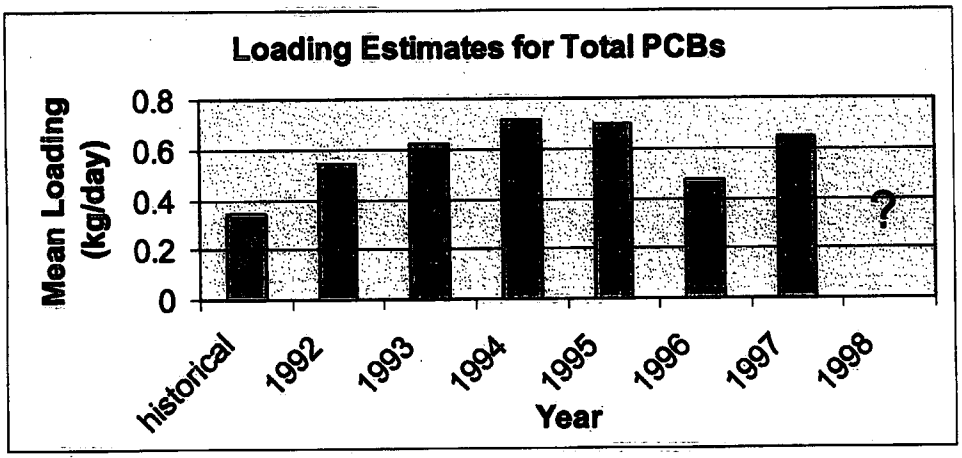
2. SOURCES AND LOADINGS

Painter et al. (2003) presented an overview of PCB sources and loadings as developed for the Lake Erie Lakewide Management Plan. Results indicate that available PCB concentration data from point sources and tributaries are currently insufficient for calculating annual loadings. More specifically, only 5 percent of approximately 1,000 PCB concentrations measured between 1986 and 1997 at 15 discharge facilities within the U.S. portion of the basin were above the reporting limit (a value that is unique for each source). In addition, PCB concentrations obtained from tributary monitoring programs in the U.S. and Ontario do not meet minimum criteria for characterizing loadings to Lake Erie. Painter et al. (2000) provide a detailed discussion of these minimum criteria.

Dolan (2003) reported on trends in annual PCB loads to the Detroit River from point sources between 1992 and 1997. Inspection of Figure 1 reveals loadings did not decline during this period, but rather exhibited a modest increase over the historical mean of the previous ten to fifteen years. Suitable data for computing reliable loading estimates after 1997 is now lacking, largely due to censoring of data and high detection limits for

reporting PCB concentrations in point source effluents. This problem severely constrains efforts to develop reliable loading estimates essential for trend analyses, remediation assessments, and modeling enhancements.

Figure 1. Detroit River Total PCB Loads (kg/day), 1992-1997. (From Dolan, 2003).



Dolan and others noted the importance of implementing lower detection limits for PCB monitoring of point sources, along with congener-specific methods for measuring effluent concentrations. Current effluent monitoring using sampling methods and frequencies designed to confirm compliance with discharge permits does not provide suitable data for calculating reliable estimates of annual PCB loadings to the Detroit River system.

On a macroscopic basis, the Detroit River and Trenton Channel remain a major source of PCBs to Lake Erie. Marvin et al. (2003) noted that Trenton Channel is the most contaminated area within the overall region. A study by Drouillard et al. (2003) indicated that the stretch of the Detroit River downstream of Trenton Channel, while representing only 17 percent of the total sediment surface, holds approximately 62 percent of the total PCB mass contained within the River. Reitsma et al. (2003) observed that the PCB-enriched sediments downstream of Trenton Channel are susceptible to periodic re-suspension during extreme storm events. More specifically, storm events equivalent to or exceeding a 20-year frequency pose a significant risk of producing pulse loadings of PCBs to Lake Erie due to sediment re-suspension in the lower Detroit River. In spite of relatively high PCB loadings from the Detroit River, Painter reported that overall PCB loadings to Lake Erie have decreased significantly over the past 15 years.

Whittle et al. (2003) also reported that contaminants contained in the sediments of the shallow western Lake Erie basin often re-suspend during storm events, thereby becoming available in the water column in a freely dissolved form. According to Whittle, models developed by Morrison et al. (1997, 2002) indicate that continued reduction in

PCB inputs and further decontamination of bottom sediments will reduce the availability of PCBs to aquatic biota of the region.

Nettesheim (2003) analyzed data collected at a number of atmospheric background stations and urban satellite stations within the U.S. portion of the Great Lakes basin. These stations are part of USEPA's Integrated Atmospheric Deposition Network (IADN). According to the available information to date, there has been a general decline in atmospheric concentrations of PCBs near Lake Erie and other Great Lakes. It appears that concentrations of PCBs in the air may now be approaching an equilibrium condition.

3. WATER AND CONTAMINATED SEDIMENT

Researchers attending the workshop agreed that water concentrations of PCBs in the Detroit River have decreased since the late 1970s. However, Drouillard et al. (2003) noted that little improvement has occurred over the past five years. This finding was based on estimated PCB water concentrations as extrapolated from levels in biomonitors, specifically freshwater mussels, deployed at five strategic locations within the Detroit River Area of Concern from 1996 to 2000. Extrapolated water concentrations ranged from 0.01 to 1.0 ηg/L with an overall geometric mean of 0.16 ηg/L for the Detroit River.

It appears the magnitude and distribution of PCB-contaminated sediment within the Detroit River have not exhibited similar improvement. Although there has been a general decline in the overall average concentration of PCBs in surficial sediment, localized hotspots remain a threat to beneficial uses. Laboratory sediment dilution bioassays conducted in 1991 showed that PCB concentrations in sediment samples from Trenton Channel were four times greater than that needed for Hexagenia mayfly survival to emergence (Corkum, 2003).

Painter and Marvin (2003) reported that concentrations of PCBs in Lake Erie sediments have declined significantly since the late 1970s, especially in the western basin. PCB concentrations in sediment cores have dropped by as much as 80 percent at some locations. PCB concentrations in sediment remained highest near the mouth of the Detroit River in 1997, exceeding 195 ηg/g. Sediment concentrations at several locations in the western basin of Lake Erie ranged from 130 – 195 ηg/g.

4. FISH

Research findings and monitoring data presented at the workshop revealed that PCB concentrations in fish inhabiting the Detroit River-western Lake Erie basin do not exhibit an obvious trend over the past fifteen years. Elevated concentrations are still measured in

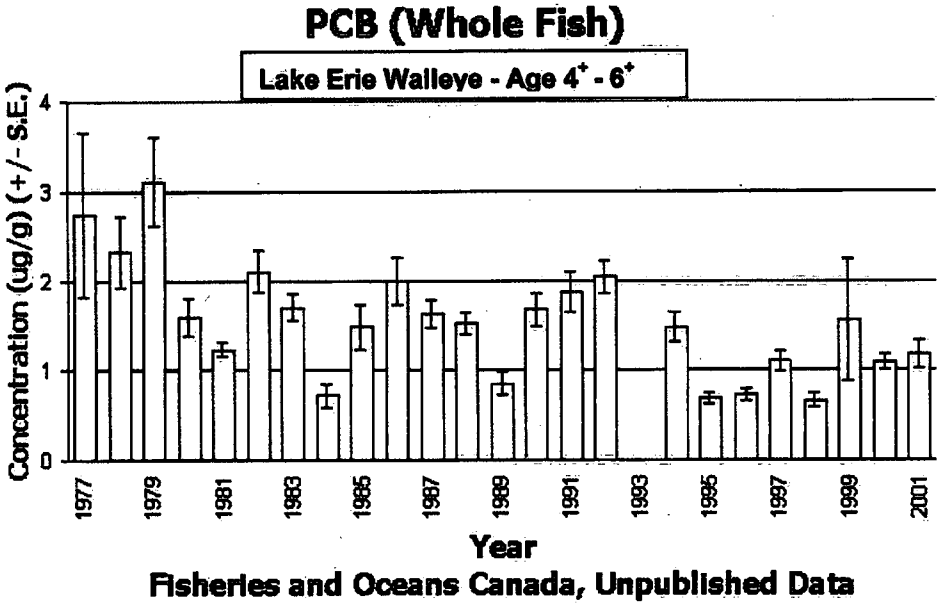
fish within certain locations of the region (Ostaszewski, 2003). Letcher et al. (2003) reported that benthic fish species from the Detroit River currently exhibit high levels of PCB congeners in their tissue. Drouillard et al. (2003) reported that forty six percent of biota samples (including forage fish and benthic invertebrates) collected from the Detroit River and western Lake Erie near Middle Sister Island exceeded the International Joint Commission (IJC) PCB tissue residue objective for the protection of fish-consuming birds and wildlife (0.100mg/kg wet wt.).

The Canadian Department of Fisheries and Oceans has maintained annual monitoring of contaminant levels in Lake Erie fish since 1977. Whittle et al. (2003) presented results of this effort which indicate that PCB concentrations in walleye predominantly inhabiting the western basin of Lake Erie were much lower in 2001 as compared to the late 1970s (Figure 2). Nevertheless, concentrations varied widely during the past 25 years. Periodic increases in PCB body burdens were observed from 1984-86 and again from 1989-1992, followed by a consistent decrease up to the mid-1990s. Since that time, body burdens of PCBs in walleye from the western basin of Lake Erie walleye in the age range of 4 – 6 years have remained relatively constant at roughly 1.0 mg/kg, well below the concentrations of 2.0 – 3.0 mg/kg typically measured in the late 1970s.

Additional data on PCB concentrations in Lake Erie rainbow smelt were presented by Whittle. Smelt collected from western Lake Erie since 1977 have exhibited a significant increase in body burdens of PCBs from 1985/86 through 1990. Although concentrations in smelt have since declined from their peak level of approximately 0.76 µg/g in 1990, Whittle reported that body burdens of PCBs in smelt have remained at levels averaging approximately 0.10 µg/g over the past several years.

Hickey et al. (2003) presented information pertaining to PCB concentrations in fish following implementation of remediation projects completed in 1997 and 1998 . Available data indicates that the decline in body burdens of PCBs in carp and largemouth bass from several locations along the Detroit River was less than expected. Hickey et al. also noted that the full effect of these efforts has probably not yet been seen.

Figure 2. Total PCB trends in Lake Erie Western Basin Walleye, 1977-2001 (Whittle et al., Canada Department of Fisheries and Oceans).



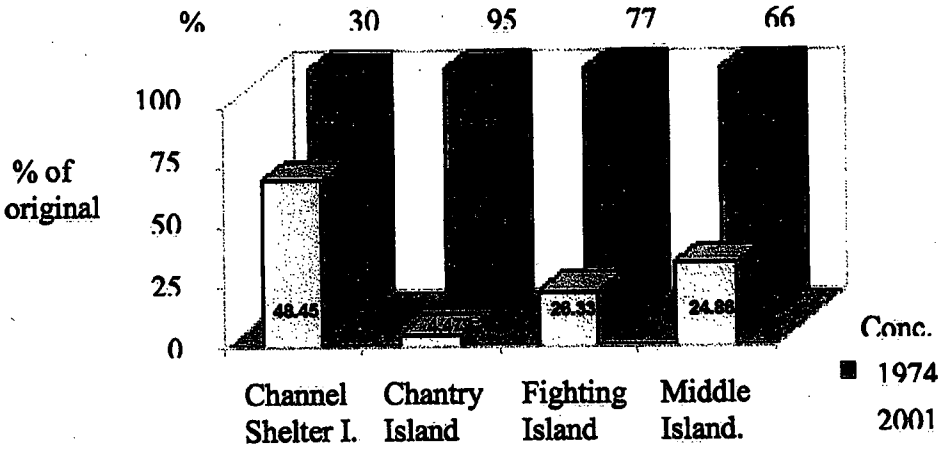
5. ADDITIONAL ECOSYSTEM INDICATORS

5.1. Birds: Technical experts participating in the workshop agreed that long-term monitoring of herring gull eggs conducted by the Canadian Wildlife Service provides one of the most complete and reliable databases for assessing PCB levels and ecosystem trends within the Detroit River-western Lake Erie basin. Based on research findings presented by Weseloh (2002), herring gull eggs collected from fifteen sites throughout the Great Lakes basin from 1974 to 2001 were analyzed to evaluate temporal trends in PCB levels (Figure 3). Two of these sites are located in the Detroit River – western Lake Erie basin: one at Fighting Island in the Detroit River and one at Middle Island in the western basin of Lake Erie. PCB concentrations in herring gull eggs gathered from Fighting Island exhibited a declining trend from 1978 to 1996, dropping by approximately 77 percent. No further reduction was observed after 1996. A similar trend was observed from 1974 – 2001 in eggs from Middle Island. At the latter location, PCB concentrations in eggs declined by roughly 66 percent up to 1996, with little additional reduction thereafter.

Weseloh also reported that PCB levels in herring gull eggs from the Detroit River and western Lake Erie were higher in 2001 than levels at all other locations from which eggs were collected with the exception of Channel-Shelter Island in Saginaw Bay. His findings indicate that ecosystem improvement within the study area has been evident from increased breeding populations of colonial waterbirds, notably cormorants and herring gulls. It is unclear whether this improvement is due to declining PCB levels

within the ecosystem, declines in levels of other chemical compounds, or some combination of the two.

Figure 3. PCB 1:1 (ug/g, wet weight) and percent declines in herring gull eggs from 1974 (Fighting = 1978; Channel-Shelter = 1980) to 2001. (from Weseloh, 2002).



5.2. Snapping Turtles: Fernie (2003) presented preliminary research on potential PCB impacts on snapping turtles within the lower Great Lakes. Turtles live-trapped at locations within three Areas of Concern (St. Clair, the Detroit River, and Wheatley Harbour) exhibited poorer hatching success than those captured at two reference sites (Tiny Marsh and Algonquin Park, ON). Turtles captured within the Detroit River were the exception, exhibiting higher hatching success than those at all other sites. There were no differences among the AOCs in terms of hatchling survival, while the frequency of hatchling deformities observed at AOC sites was comparable to that at reference sites (approximately 26 percent). Fernie also reported that reproductive success, development of young, as well as some physiological endpoints and morphology of adult male snapping turtles differed between those captured at AOC sites and those taken from reference sites. To what extent these impacts and disparities among sites are attributable to PCB contamination at those sites is unclear. Further research is needed to address this potential link.

5.3. Caddisflies: Corkum (2003) presented data, collected between 1987 and 1990 within the Detroit River, showing that PCB concentrations were notably higher in caddisflies inhabiting Detroit River sites as compared to those observed in 1988 at reference sites along the AuSable and Gull rivers in Ontario. Furthermore, a comparison of PCB body burdens in caddisflies collected in 1988 from the Detroit River revealed levels to be significantly higher in organisms from the U.S. side of the River as compared to the Canadian side.

Corkum also discussed results of laboratory sediment dilution bioassays conducted in 1991 which revealed that the concentration of PCBs and other contaminants in Trenton Channel sediments was four times greater than that needed for Hexagenia mayfly survival to emergence. Body burdens of Hexagenia adults collected in 1994 exhibited a decreasing concentration gradient from east (closest to the Detroit River) to west (farthest from the Detroit River).

5.4. Additional Findings: Technical experts participating in the workshop agreed that PCB contamination within the upstream portion of the Detroit River has exhibited a consistent pattern of decline over the past two decades. However, significantly less improvement has occurred in the lower Detroit River, i.e., within and below Trenton Channel.

6. KEY ADVICE FOR FUTURE MONITORING

Extensive and reliable data for PCBs and other contaminants are crucially important for advancing our understanding of ecosystem trends, remediation successes, and ultimately our ability to protect and manage the health of the Detroit River-western Lake Erie basin. Based on feedback from workshop participants, monitoring programs are currently inadequate for providing the essential data to meet these needs. Funding in support of monitoring is generally limited and coordination is weak. As a result, it is becoming increasingly more difficult to provide the data needed to:

- derive reliable annual PCB loading estimates and historical trends;
- improve our understanding of fundamental relationships which govern short and long-term changes within the ecosystem attributable to PCBs and other contaminants;
- enhance ecosystem models used to project the expected outcome of management alternatives;
- evaluate ecosystem impacts attributable to remediation activities implemented within the basin.

Workshop participants were in strong agreement that inadequate PCB detection limits severely constrain the ability to develop accurate PCB loading estimates. Detection limits and monitoring protocols applied at many point sources are now designed simply to establish compliance with discharge permits. This approach ignores the importance of lesser PCB loadings which satisfy operating requirements while still impacting local ecosystem conditions. To address this critically important issue, it was recommended that PCB detection limits be lowered and point source

monitoring protocols standardized. This step would provide a more reliable, consistent basis for calculating loads and developing accurate assessments of historical loading trends.

Technical experts attending the workshop identified inadequate coordination of monitoring initiatives and lack of funding as major obstacles constraining our ability to develop and share information, eliminate unnecessary overlap or redundancy, and achieve the greatest scientific and practical benefit from resources committed to monitoring. Monitoring programs vary in their objectives and scope. Some focus on data necessary to establish compliance with permit requirements, some are designed to determine post-remediation ecosystem changes (near-field monitoring), some emphasize data to calibrate and validate mathematical models, while others seek to develop data suitable for evaluating short and long-term ecosystem changes on a macroscopic level (far-field monitoring). Workshop participants recommended that a single agency or organization receive authority and resources needed to assist in planning and execution of future monitoring programs. This coordination entity would assume a leadership role for planning, reviewing, and developing funding strategies in support of monitoring. It would also assume responsibility for coordination of data base management activities, including data organization and dissemination to facilitate its most cost-effective use.

Finally and perhaps most importantly, workshop participants strongly recommended that there be a concerted effort to establish and sustain a mechanism to formally integrate and interpret historical monitoring data, thereby enhancing our understanding of important trends and ecosystem relationships pertaining to PCBs and other chemical contaminants within the Detroit River-western Lake Erie basin. The health and diversity of resident biological communities strongly reflects the condition of the local ecosystem. Robust information on distributions of benthos, plankton, fish, birds, and turtles is crucial to an improved understanding of ecosystem impacts, trends and emerging problems. The research findings discussed above suggest the need to maintain existing monitoring of these and other key ecosystem health indicators while expanding our efforts to integrate, interpret, communicate and ultimately apply these data in the design of adaptive, cost-effective management strategies for the basin.

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351 boul. St-Joseph
Gatineau (Québec)
K1A 0H3 Canada