

**DISTRIBUTION OF
POLYCHLORINATED BIPHENYLS IN WATER,
SEDIMENT AND BIOTA OF TWO HARBOURS**

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EXECUTIVE SUMMARY

The distribution of PCBs was investigated in sediments, water and selected biota in Hamilton Harbour, Lake Ontario, and Wheatley Harbour, Lake Erie. The Open Tabular Column Gas Chromatography (OTC) was used for the determination of the PCB homologues (tri-, tetra-, penta-, hexa-, hepta-, octa- and nonachlorobiphenyls) in all samples. The concentration patterns of individual homologues were similar in biota and sediments. In the water, a greater concentration of the lower chlorinated biphenyls existed than in the sediments and biota from both harbours. The investigation was carried out under studies 84-AED-545 and 84-ECD-236.

MANAGEMENT PERSPECTIVE

Quantitative determination of individual PCB congeners allows the assessment of concentration patterns of these congeners in different compartments of the aquatic system, such as water, biota and sediments. This is important for the evaluation of the sources and pathways of PCBs at different localities, in particular at the Areas of Concern in the Great Lakes.

RÉSUMÉ

On a mesuré la concentration d'homologues individuels de PCB par chromatographie gazeuse à colonne capillaire dans des échantillons d'eau, de sédiments et de biote provenant du port de Hamilton (lac Ontario) et du port de Wheatley (lac Érié) au Canada. Les concentrations de PCB totaux variaient de 166 à 14 185 ug/kg (poids sec) dans les sédiments portuaires, et de 58,7 à 262,7 ug/kg (poids humide) dans le biote. Dans les deux ports, les concentrations de PCB faiblement chlorés étaient plus élevées dans l'eau que dans les sédiments. La distribution des concentrations d'homologues dans le biote (oligochètes, gastéropodes, isopodes et poissons) se rapprochait plus de celle observée dans les sédiments que dans l'eau pour les deux ports. Les sédiments des deux ports, considérés comme l'habitat biotique, présentaient plus de similitudes physiques (c.-à-d. granulométrie) que chimiques. La concentration des métaux (Zn, Pb, Cu et Cr) était plus élevée dans le port de Hamilton que dans les sédiments du port de Wheatley.

PERSPECTIVES DE GESTION

La mesure quantitative des congénères individuels de PCB permet une évaluation de la distribution des concentrations de ces congénères dans différentes composantes du système aquatique comme l'eau, le biote et les sédiments. Cette analyse est importante pour l'évaluation des sources et des voies d'acheminement des PCB en diverses localités, en particulier, les Secteurs préoccupants des Grands Lacs.

RÉSUMÉ

On a étudié la distribution des PCB dans les sédiments, l'eau et des échantillons choisis de biote dans le port de Hamilton (lac Ontario) et dans le port de Wheatley (lac Érié). La chromatographie gazeuse à colonne capillaire a été utilisée pour mesurer les homologues de PCB (tri-, tétra-, penta-, hexa-, hepta-, octa- et nonachlorobiphényles) dans tous les échantillons. La distribution des concentrations des homologues individuels était semblable dans le biote et les sédiments. Cependant, les concentrations de biphényles faiblement chlorés étaient plus élevées dans l'eau que dans les échantillons de sédiments et de biote prélevés dans les deux ports. Ces travaux ont été effectués dans le cadre des études 84-AED-545 et 84-ECD-236.

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ABSTRACT

The concentrations of individual PCB homologues were determined by Open Tubular Column Gas Chromatography (OTC) in the water, sediments and biota collected from Hamilton Harbour, Lake Ontario, and Wheatley Harbour, Lake Erie, Canada. Concentrations of total PCBs ranged from 166 to 14,185 µg/kg (dry weight) in harbour sediments, and from 58.7 to 262.7 µg/kg (wet weight) in biota. Concentrations of lower chlorinated PCBs were greater in the water than in the sediments in both harbours. The concentration patterns of the homologues in the biota (oligochaetes, snails, isopods and fish) were more similar to those in the sediment than in the water in both harbours. The sediment, considered the biotic habitat, was more similar physically (i.e., particle size distribution) than chemically in the two harbours. Concentrations of metals (Zn, Pb, Cu, and Cr) were greater in Hamilton Harbour than those in Wheatley Harbour sediments.

INTRODUCTION

Polychlorinated biphenyls (PCBs) are ubiquitous as a class of anthropogenic organic contaminants in the freshwater and marine environment (1-3). An estimated amount of 2.10^6 metric tons of PCBs have been commercially available in the past 50 years (4). PCBs have been identified and measured in water, sediment and fish in the Great Lakes (5,6). Widely distributed residues in Lake Huron, Georgian Bay and North Channel sediments are considerably lower than those found in Lakes Erie and Ontario (7,8). Concentrations of total PCBs in many Lake Ontario and Lake Erie harbours exceed the Ontario Ministry of the Environment (MOE) guidelines (50 ng/g) for open-water disposal of dredged material (9).

Since 1979, the PCBs have been under scrutiny. The concern was intensified by the fact that these commercial products may contain trace amounts of polychlorinated dibenzofurans. Although such suspicions are currently proven, many questions still persist, such as the fate of individual PCB congeners and their presence and toxicity in the aquatic environment. A major problem associated with the analysis and toxicology of PCBs is the multiplicity of possible isomers. Moreover, the composition of PCB mixtures which has been identified in environmental samples is different from that of the commercial mixtures (10,11). This can be attributed to numerous factors which are associated with biological processes and degradation. Many quantitative data for the PCBs have been reported as total loading values or "total PCBs". Some were determined by packed column gas chromatography. The packed columns were not able to separate the majority of peaks and the produced data have been questionable in many instances (12). It has been a common practice to determine PCBs by comparing their packed column chromatograms with the patterns of known concentration of individual PCB isomers or commercial PCB mixtures (13).

High resolution open tubular column (OTC) gas chromatography allows the quantitative determination of almost all congeners of PCBs (14,15). However, accurate data were reported for the 43 isomers only (15,16).

Recently, splitless and cold on-column injection techniques for the determination of priority micropollutants were evaluated and reported for the identification and determination of PCBs by high resolution gas chromatography (17-19). Reporting PCB data as total PCBs or specific Aroclors appears to be insignificant. Degradation or "weathering" of PCBs in sediment, fish and other biota is a frequent problem. In addition, PCBs from various sources contain different concentrations of homologues. Consequently, determination of specific homologues or isomers provides detailed information about analyzed samples and clearly indicates eventual sources of pollution and degradation from the pattern recognition data (20).

Our objectives were to investigate the distribution of specific homologues or isomers in biota, to compare the concentrations with those in sediment and water, and to relate the bioconcentration to the structurally different chlorinated biphenyl congeners in various biota. The investigation was carried out at two Great Lakes harbours: Hamilton Harbour located on Lake Ontario and Wheatley Harbour on Lake Erie. Recently, sediment from both harbours was found contaminated by PCBs (9). Major industries at Hamilton Harbour include steel mills, an incinerating plant and a variety of other industries. On the other hand, Wheatley Harbour is located in an agricultural area and is used mainly by a fishing fleet. A fish-processing plant is on the adjacent shore.

MATERIALS AND METHODS

Sediment, water and biota were collected from Wheatley and Hamilton Harbours in the summer of 1984 at sampling stations outlined in Figures 1 and 2. Sediment samples were collected by an Ekman dredge. For the determination of PCBs, 0 to 3 cm surface sediment was subsampled into prewashed glass jars covered with Al-foil and frozen within 48 hours. In addition, from each sampling site about 200 g of 0 to 3 cm surface sediment was subsampled into a large glass jar for geochemical analyses and the determination of particle size distribution.

Water samples were collected from the middle of the water column by a Van Dorn bottle at sampling stations in each harbour (Figures 1 and 2). Each water sample was stored in a solvent rinsed bottle.

Physa integra, Zonitoides arborens and Lymnaea stagnalis, and fish (Eupomotis gibbosus) and Isopods were collected from the nearshore and offshore area between station A and B in Wheatley Harbour (Figure 1). Isopods and Physa integra were collected from the area between stations 2 and 4 in Hamilton Harbour (Figure 2). Approximately 5 g of oligochaete worms (wet weight) was collected from offshore zone at each location in both harbours. After washing with distilled water, the oligochaetes were allowed to ingest clean sediments for 48 hours to displace the original sediment from the harbour and to void these sediments in clean water prior to analysis. All biota samples were collected into an n-hexane prewashed Al-foil and stored frozen for further analysis. No attempt was made to separate soft parts from shells of collected snails.

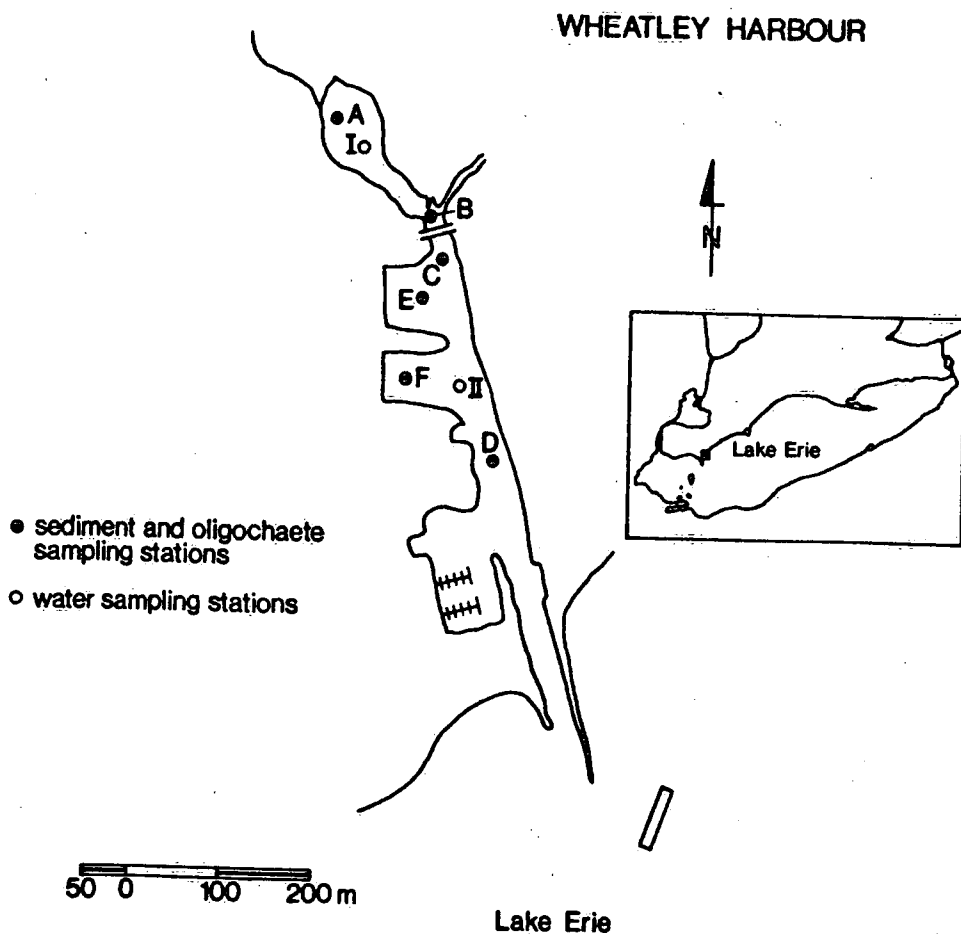


FIGURE 1. Sampling stations in Wheatley Harbour.

Particle Size Distribution and Geochemistry of the Sediment

The particle size distribution was determined by short pipet analyses (21). Samples for geochemical analyses were freeze dried, sieved through 20 mesh (841 μm) sieve and ground to 150 μm size. Concentrations of organic and inorganic C were determined with a Leco carbon analyzer. Concentrations of major elements (Si, Al, Ca, Mg, Fe, Mn, Ti, P, Na, K) and metals (Pb, Ni, Cu, Cr, and Zn) were determined by X-ray fluorescence spectrometry. The precision of the analysis was determined by analyzing five pellets made from a homogenized sediment sample. Relative deviations for elements in sediment samples can be expected at the following levels: SiO_2 2%, K_2O and Al_2O_3 4%, Fe_2O_3 and CaO 2%, MgO and Na_2O 10%. Absolute deviations of 0.01% to 0.02% were found for MnO , TiO_2 and P_2O_5 . For metals absolute deviations are to be expected in the range of 3 to 15 $\mu\text{g/g}$ at the determined levels. The accuracy of the analyses was verified by running Canadian reference standards Syenite SY-2 and soils SO-2 and SO-4 and comparing the analytical results with the stated reference values for the determined elements. The mineralogical composition of the sediment was investigated by powder X-ray diffraction using a Cu-target with a Ni-filter.

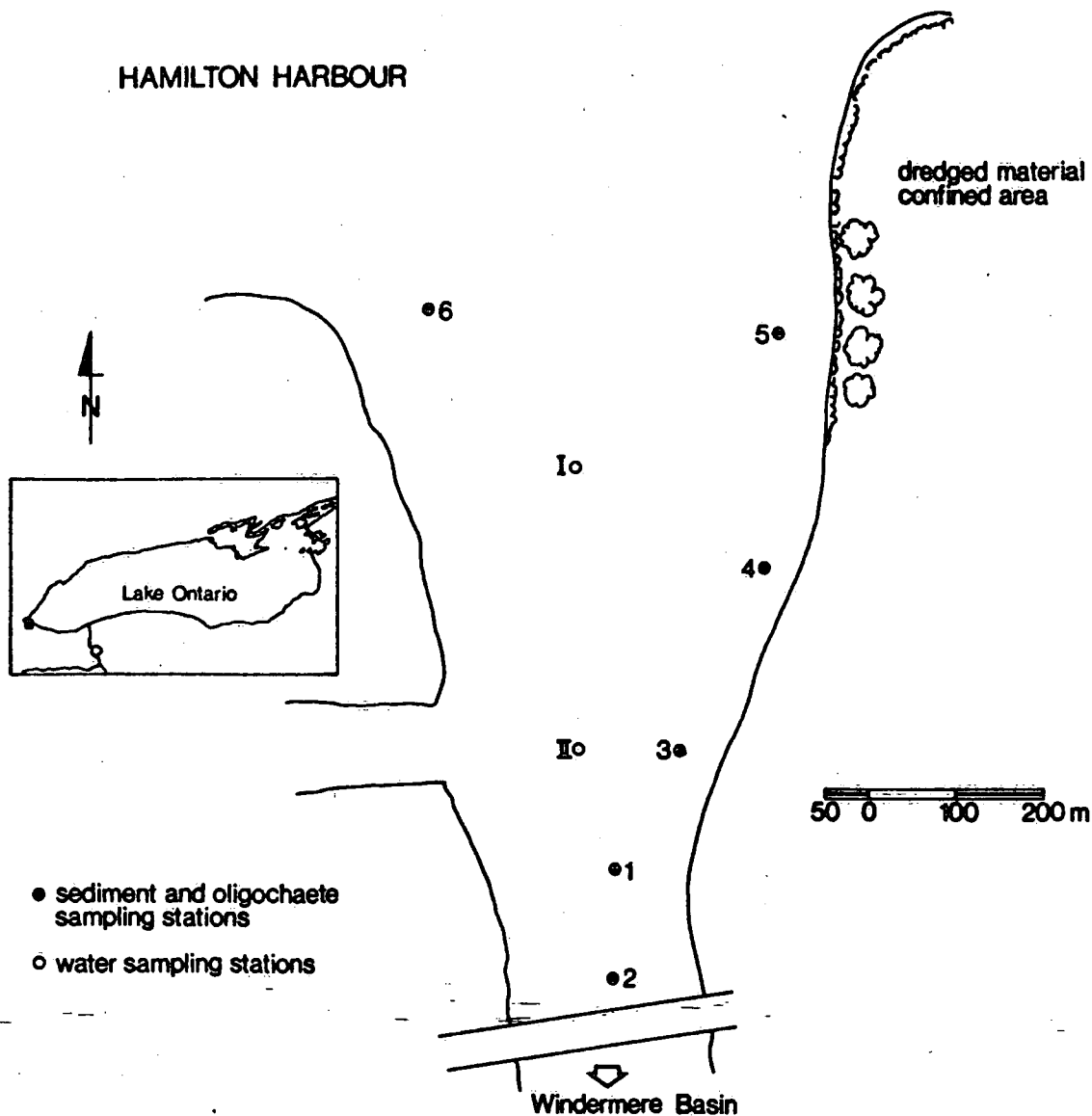


FIGURE 2. Sampling stations in Hamilton Harbour.

Determination of PCBs in Water, Sediment and Biota

Water samples were filtered (Whatman GF/C) and 2 L aliquot in duplicate were extracted using 250, 100 and 100 mL volumes of methylene chloride for the serial extraction of PCBs and all base/neutral contaminants at pH 11. All water samples were spiked with 86.2 μg of decachlorobiphenyl giving concentrations of 43.1 $\mu\text{g}/\mu\text{L}$ to check recoveries.

The methylene chloride extract was collected in a 500 mL Erlenmeyer flask. The combined extract was poured through a drying column containing about 10 cm layer of anhydrous sodium sulfate and the effluent was collected in a 500 mL round bottom flask. Ten mL of iso-octane

was added and the sample was evaporated on the Buchi-evaporator to 10 mL. The liquid-liquid extraction procedure was 90 to 100% efficient.

Sediment samples (equivalent of 5 g dry sediment) were extracted using ultrasonic extraction with 1:1 hexane-acetone mixture (22). This extract was partitioned with water and then back extracted with benzene. The combined organic extracts were dried, reduced in volume, cleaned on a gel permeation chromatograph (ABC-Autoprep-1002A) and silica gel partitioning. The general scheme is outlined in Figure 3. All glassware was soaked in a heavy duty soap solution, washed with hot water, rinsed with distilled water, analytical grade acetone and pesticide grade petroleum ether, heated at 400°C overnight and rinsed again with pesticide grade petroleum ether immediately before use. All solvents used for the extraction were pesticide grade. The water used in the process was filtered via a Millipore filter which had been benzene extracted. The Celite used was non-acid washed.

Sulfur was removed by vortex-stirring of the final extract with mercury several times until mercuric sulfide formation was not evident.

To check on the purity of used solvents the entire extraction and cleanup procedure was repeated using appropriate amounts of solvents to obtain solvent blanks. The known amount of worms and biota was analyzed by decomposing them in concentrated HCl (80 mL) at ambient temperature overnight. Eighty mL of organics free distilled water (hexane washed) was added to the sample. The mixture was transferred to a separatory funnel and extracted with three volumes of 20 mL each of n-hexane for PCB analysis. The hexane extract was concentrated to approximately 5 mL volume. Methods for the cleanup have been described above.

Open Tubular Column Gas Chromatography (OTC)

The OTC gas chromatographic analyses were performed on a Varian Model 6000 gas chromatograph equipped with a cold on-column injector, electron capture detector (ECD), and a Spectra Physics 4100 computing integrator. A phase bonded SE-54 fused silica OTC was employed (30 m x 0.25 mm i.d., $d_f = 0.15 \mu\text{m}$ film thickness). The carrier gas was hydrogen. An initial temperature of 75°C was held for 2 min after the temperature was programmed as 40°C/min to 120°C and afterwards to 240°C at 2°C/min. The detector temperature was 350°C. Nitrogen was employed as a make-up gas at 30 mL/min.

Quantitative Analysis

The response of the electron capture detector is not equal for all PCB congeners, being much affected by the degree and position of chlorination. This phenomenon leads to difficulties which are not easy to overcome. Especially, difficulties are encountered when the PCBs in the sample have undergone selective environmental biodegradation. Several investigators have noted that the pattern of peaks from such samples follows closely that of one or other of the higher chlorinated PCB mixtures such as Aroclor 1242, 1254 and 1260.

The chlorine content of the PCB peaks in the WCOT chromatograms have been previously identified and confirmed by GC/MS (18). Afterwards, the peaks were identified by a method of relative retention time (RRT) matching. Decachlorobiphenyl with an absolute retention time of 48.37 ± 0.03 min was used as a reference peak and assigned a RRT of 1.000. RRT-values for the PCB congeners were calculated as the ratio of the individual peak retention time to that of decachlorobiphenyl. Retention times for decachlorobiphenyl were very reproducible

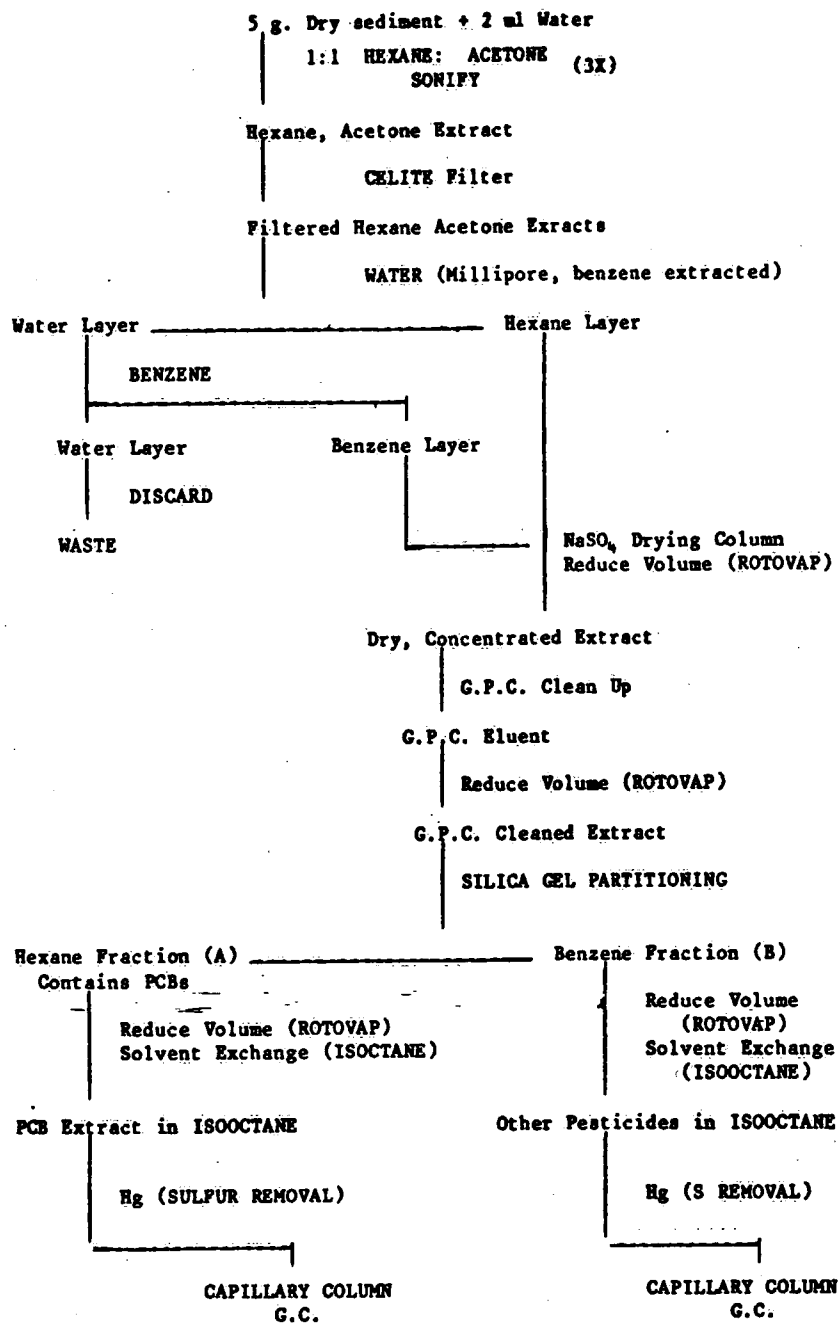


FIGURE 3. Extraction and clean up of sediment samples.

permitting a GC-peak matching identity range of ± 0.002 RRT units for peaks in reference standards as in samples. Details for quantitation were given previously (18).

The unknown extracts can be quantified using the calibrated 600 pg/ μ L Aroclor 1242:1254:1260 (1:1:1) standard mixture. By matching RRT and using the averaged RRF data

along with precise RRFs for the 19 isomers, the amount of each PCB homolog group and the total amount of all PCBs in the sample was calculated. The injection sequence was one PCB standard mixture followed by three samples. To compensate for any variation from 1 µL injections the data were normalized to the decachlorobiphenyl peak. The injections were performed manually, using cold on-column injector and using a 10 µL syringe with a fused silica needle.

RESULTS AND DISCUSSION

Sediment Characteristics

Concentration of major elements and particle size distribution in Wheatley Harbour and Hamilton Harbour sediment is shown in Table 1. Silt and clay (63 µm particle size) were major components of sediment collected in both harbours. Hamilton Harbour sediment contained greater concentrations of Ca, Fe, Mn and Mg than Wheatley Harbour sediment. These higher concentrations originated most likely from the industrial input, particularly from the steel production in Hamilton. The greatest concentration of organic carbon was found in the sediment collected at the northern part of Wheatley Harbour (Figure 1). The concentration of metals in Hamilton Harbour sediment exceeded many times that in Wheatley Harbour sediment (Table 2). Generally, concentrations of metals in sediment collected from both harbours exceeded the MOE dredging guidelines for open-water disposal. Major minerals in sediment from both harbours were quartz, calcite, feldspars and illite.

The results indicated that the bottom sediment as a biotic habitat in both harbours was more similar physically than chemically: the sediment grain size is similar but the concentration of some elements, in particular metals, chemically places the sediment into different categories.

TABLE 1. Concentration of Major Elements and Particle Size Distribution in Harbour Sediment.

Station	% dry weight											% Silt and Clay	
	SiO ₂	Al ₂ O ₃	Fe ₂ O ₃	MgO	CaO	Na ₂ O	K ₂ O	TiO ₂	MnO	P ₂ O ₅	Org. C		
Wheatley Harbour	A	56.9	15.8	6.8	2.5	5.3	0.4	3.4	0.89	0.07	0.83	7.95	90.6
	B	57.5	15.2	6.9	2.6	5.1	0.5	3.3	0.88	0.07	0.75	8.05	84.5
	C	58.2	15.2	7.1	2.4	5.1	0.6	3.5	0.88	0.07	0.85	6.95	92.3
	E	56.8	15.1	6.9	2.3	5.0	0.5	3.4	0.89	0.06	0.87	7.13	92.9
	F	57.9	15.2	7.1	3.1	6.7	0.5	3.6	0.89	0.07	0.41	4.81	98.0
	D	57.2	15.9	7.5	3.6	5.0	0.4	3.6	0.93	0.06	0.67	4.22	94.7
Hamilton Harbour	1	45.2	11.3	9.3	3.9	12.1	0.7	3.7	0.76	0.16	0.78	4.83	97.7
	2	54.0	10.9	7.1	3.5	11.6	0.9	3.2	0.60	0.17	0.44	3.47	87.9
	3	47.8	10.4	8.0	3.6	14.9	0.8	3.2	0.62	0.19	0.48	4.33	82.1
	4	46.3	11.1	9.8	3.8	10.8	0.7	3.4	0.76	0.17	0.98	5.45	83.4
	5	47.2	10.0	7.0	3.5	17.0	0.7	2.8	0.59	0.20	0.43	3.61	89.5
	6	48.0	10.9	9.6	4.0	11.5	0.7	3.2	0.75	0.17	0.98	5.14	85.6

TABLE 2. Concentration of Metals in Harbour Sediment ($\mu\text{g/g}$).

	Station	Pb	Ni	Cu	Cr	Zn
Wheatley Harbour	A	48	42	47	90	245
	B	57	50	45	93	252
	C	35	39	39	99	237
	E	38	54	44	85	205
	F	36	48	46	87	165
	D	41	37	50	92	189
Hamilton Harbour	1	340	90	82	365	2,970
	2	201	65	90	180	1,710
	3	205	58	105	175	1,950
	4	430	95	198	425	3,250
	5	155	60	79	135	1,510
	6	320	89	85	350	2,735

Distribution of PCBs

Water

Water was sampled at two stations in each harbour. Table 3 shows that significant concentrations of PCBs were found at all sampling stations. In both harbours, PCB concentration was almost four-fold greater at station 1 than at station 2. All samples contained PCB concentration above the detection limit (100 pg PCBs/ μL injected) and exceeded the 1978 OME objectives for the protection of aquatic habitat (1 $\mu\text{g/L}$).

A homolog distribution pattern showed significant differences between studied harbours. This appears clearly from the lower concentration of tetrachlorobiphenyl and a greater content of octachlorobiphenyl homologues in Hamilton Harbour water samples. The total PCB values, however, were similar in each harbour at stations 1 and 2 (Table 3, Figure 4).

TABLE 3. Concentration of PCBs in water (ng/L).

	Tri-	Tetra-	Penta-	Hexa-	Hepta-	Octa-	Total PCB
<u>Wheatley Harbour</u>							
Station 1	36.2	148.5	91.0	13.0	2.3	0.1	291.0
Station 2	13.9	35.9	27.3	7.4	1.8	0.1	86.3
<u>Hamilton Harbour</u>							
Station 1	39.1	68.8	69.7	24.4	10.3	2.4	213.7
Station 2	26.3	33.3	18.8	5.0	1.6	1.0	86.0

Sediments

Levels of PCBs in sediments from the Hamilton Harbour area were approximately up to over ten times greater than those in the Wheatley Harbour (Table 4). Distribution patterns of

homologues in sediments from all locations at the Wheatley Harbour were generally similar. The same observation applied to the Hamilton Harbour with an exception of station 3 containing a high level of nonachlorobiphenyl homolog. However, there were significant differences in patterns of individual homolog series between the harbours (Figure 5).

The levels of total PCBs in both harbour sediments are alarmingly high, especially at station 3 in Hamilton Harbour, showing 14.2 mg/kg total PCBs (dry weight basis).

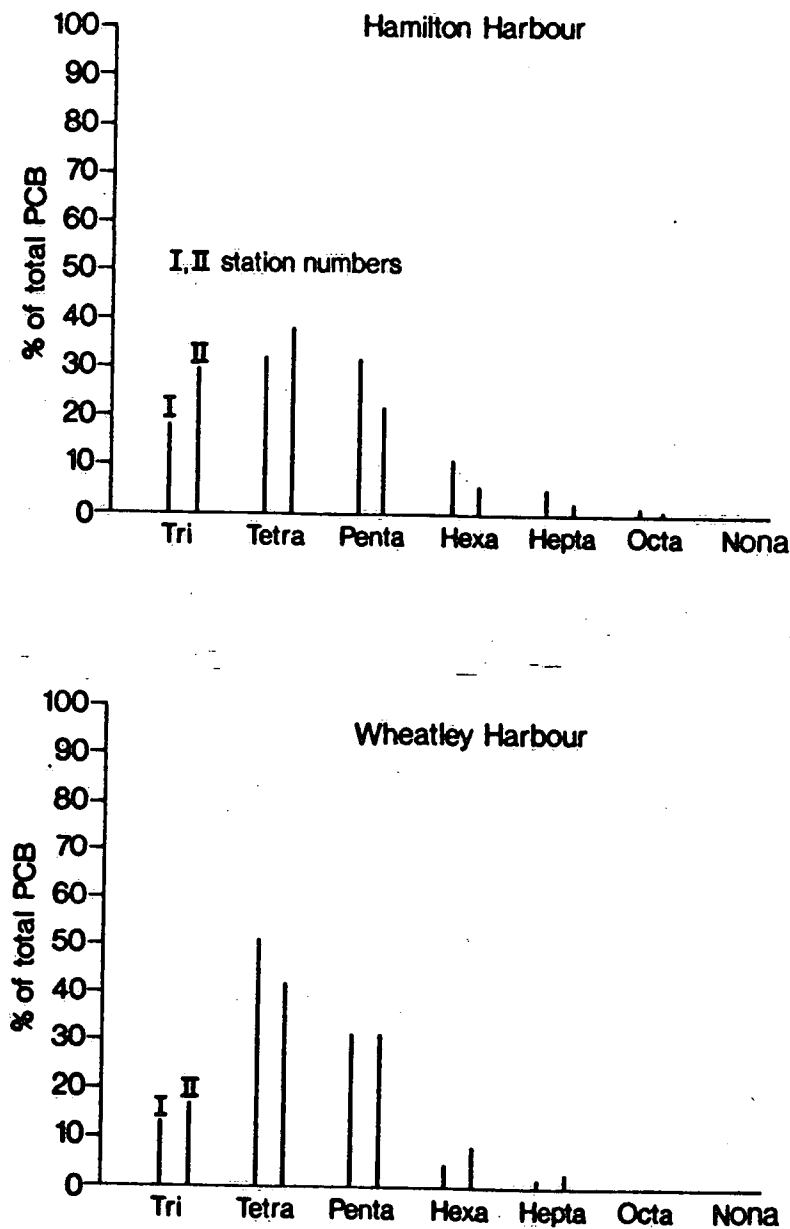


FIGURE 4. Distribution of PCBs in water.

TABLE 4. Distribution of PCBs in Sediments ($\mu\text{g}/\text{kg}$ dry weight).

	Tri-	Tetra-	Penta-	Hexa-	Hept-	Octa-	Non-	Total
<u>Wheatley Harbour</u>								
Station A	28.8	111.2	474.0	358.0	175.8	26.6	2.4	1176.8
Station B	5.6	20.0	67.8	51.0	16.8	2.0	2.8	166.0
Station C	14.8	64.6	252.2	140.8	91.6	14.6	1.4	580.0
Station D	5.8	30.8	103.2	53.0	31.2	5.6	0.4	230.0
Station E	5.6	34.0	155.4	110.0	40.2	5.8	0.1	351.1
Station F	21.4	54.2	189.8	132.2	59.6	7.7	0.5	465.0
<u>Hamilton Harbour</u>								
Station 1	97.4	134.9	324.6	284.5	30.9	70.9	5.3	948.5
Station 2	41.0	72.4	174.3	140.3	146.2	31.4	2.3	608.0
Station 3	733.0	1065.0	3321.0	3289.0	4044.0	985.0	748.0	14185.0
Station 4	235.7	451.0	777.5	451.3	462.7	112.0	8.8	2499.0
Station 5	205.9	441.6	724.8	443.6	350.5	75.8	6.1	2248.0
Station 6	148.4	267.4	825.6	744.2	865.1	206.3	15.8	3073.0
Blank	3.1	20.1	10.5	11.3	0.6	-	-	45.6

Biota

Distribution of individual homologues and concentration of total PCBs in biota collected in both harbours are shown in Table 5. In Wheatley Harbour, oligochaetes accumulated the greatest quantities of PCBs of all sampled biota. Physa integra and Limnaea stagnalis accumulated similar quantities and less than Zonitoides arborens. In Hamilton Harbour, oligochaetes accumulated greater concentrations of PCB than Physa integra and Isopoda. The concentration of total PCB in Physa integra collected from Hamilton Harbour was about two times higher than in those from Wheatley Harbour. However, the concentration of total PCB in oligochaetes from Wheatley Harbour was higher than in those from Hamilton Harbour.

Generally, the concentration patterns of PCB homologues in sampled biota were more similar to those in the sediments than in the water in both harbours. Concentrations of penta- and hexachlorobiphenyls were significantly greater than the other homologues in both oligochaetes and sediments from Wheatley Harbour. This was also found in Hamilton Harbour, but the differences were less pronounced. Duinker *et al.* (23) found a greater concentration of penta- and higher degree of chlorinated PCBs in marine benthic invertebrates from the Dutch Wadden Sea, and suggested that this may be due to a more rapid uptake of these components, or to their higher persistence, or both.

Concentration patterns of homologues were similar in all types of biota from Wheatley Harbour. However, in Hamilton Harbour, the pattern in oligochaetes differed more from that in the other biota than in Wheatley Harbour (Figure 6). These results may reflect the differences in the size of each harbour affecting most likely the homogeneity of sediments and water. Wheatley Harbour represents a much smaller ecosystem with water depth about 3 m, and frequent mixing by an inflowing stream and occasional back-flow from Lake Erie.

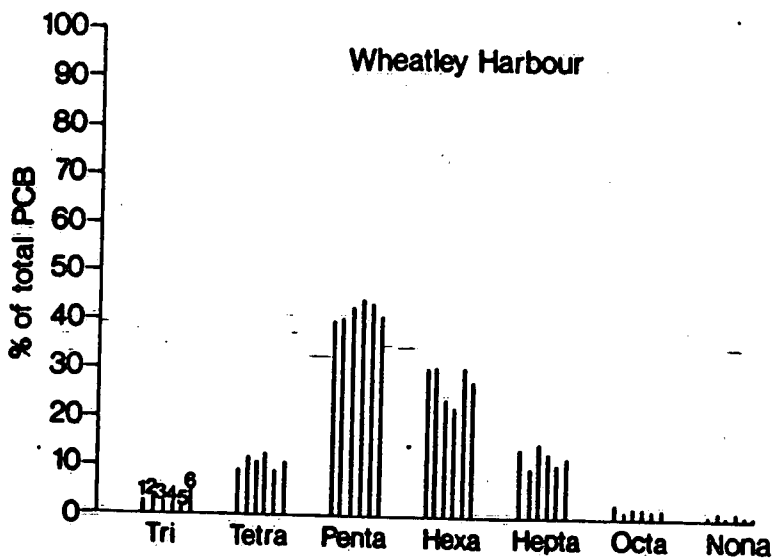
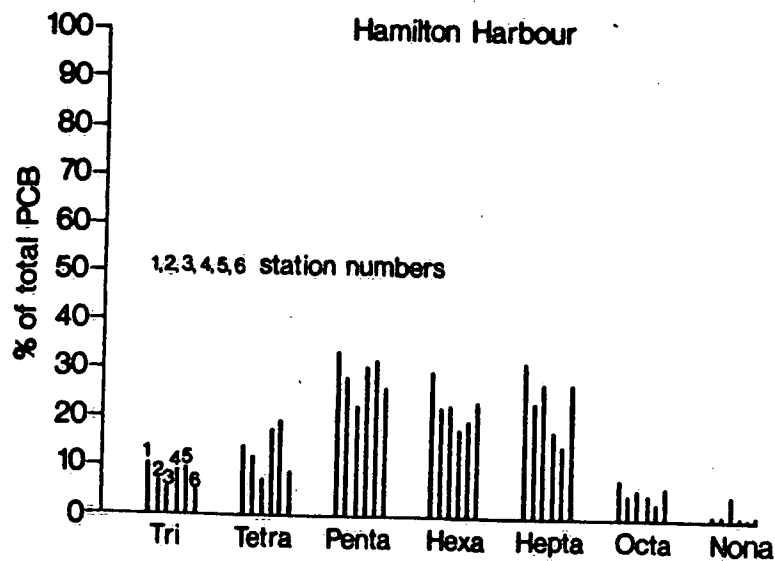


FIGURE 5. Distribution of PCBs in sediments.

Consequently, this system may be more homogeneous than Hamilton Harbour with a much larger surface area (Figures 1 and 2) and water depth about 9 m. In Hamilton Harbour, the nearshore area represents most likely a different environment (with more heterogeneous distribution of PCBs) than the offshore area from which the sediment and oligochaetes were sampled. The components of higher degree of chlorination (penta- and higher) were found in greater concentrations in most of the sampled biota. However, some of the species represented a different trophic level, and were exposed to the ambient water or to the sediments, or both.

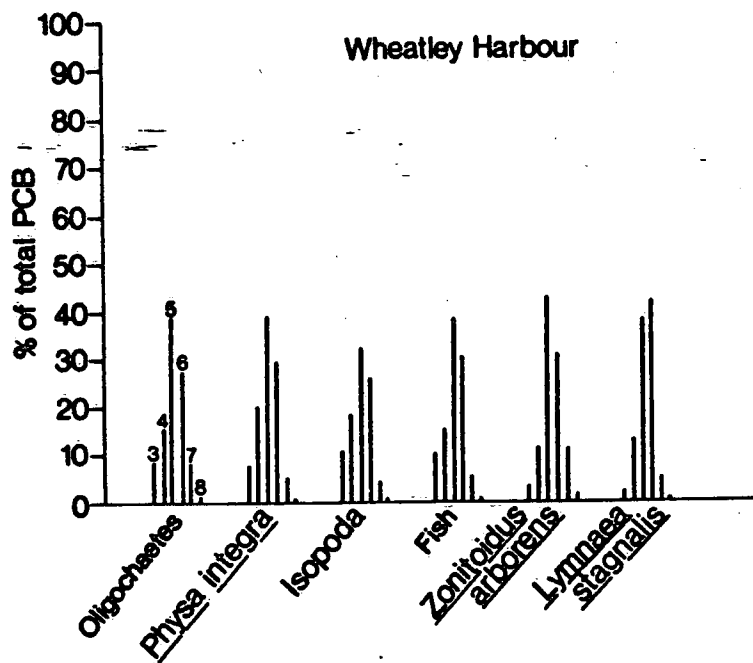
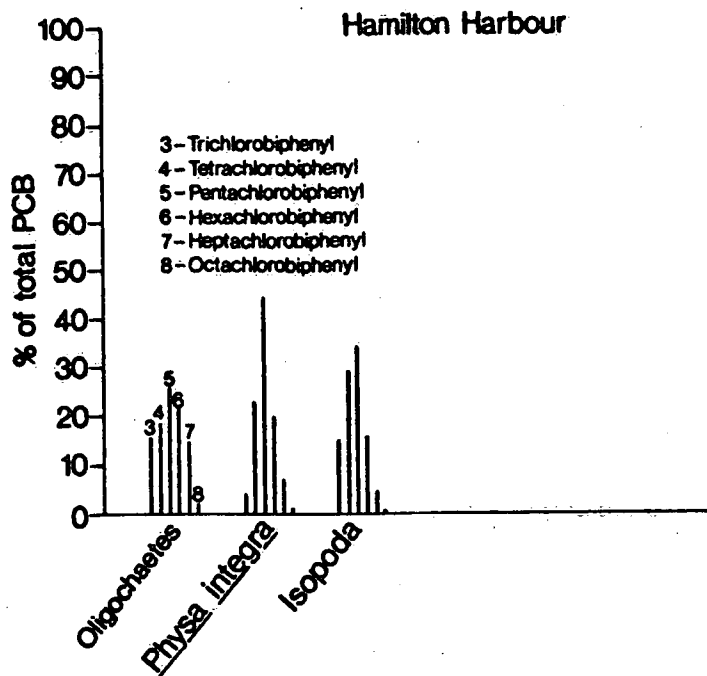


FIGURE 6. Distribution of PCBs in bota.

TABLE 5. Distribution of PCBs in Biota ($\mu\text{g}/\text{kg}$ wet weight).

	Tri-	Tetra-	Penta-	Hexa-	Hepta-	Octa-	Total
<u>Wheatley Harbour</u>							
<u>Fish (<i>Eupomotis gibbosus</i>)</u>	7.0	10.3	26.5	21.6	3.9	-	69.3
<u>Zonitoidus arborens</u>	5.1	17.3	64.8	46.3	16.3	1.6	151.4
<u>Physa integra</u>	5.6	14.3	27.9	21.2	3.1	-	72.1
<u>Oligochaetes</u>	22.4	40.2	102.8	72.2	22.6	2.5	262.7
<u>Lymnaea stagnalis</u>	1.2	7.4	22.7	24.5	2.9	-	58.7
<u>Hamilton Harbour</u>							
<u>Isopoda</u>	16.7	32.2	37.9	17.5	5.3	-	109.6
<u>Physa integra</u>	5.5	36.5	71.2	32.0	12.0	1.1	158.3
<u>Oligochaetes</u>	32.6	39.5	54.5	45.3	30.5	4.8	207.2

Several of the organisms that have been shown to accumulate PCBs from the environment can be suggested as indicators of the extent of local pollution with PCBs. We presume that analyzing as many environmental compartments as possible provides better understanding of the movement and distribution of the compounds in the ecosystem. These data can be of significant value for modelling purposes because the transfer of PCBs could be expressed as a first-order rate process (24).

The concentration of PCB can vary considerably due to differences in sampling techniques and analytical methodology. Residue levels given in different reports should be compared very carefully. However, there was a similarity between the levels of PCBs reported in this study and those reported from Lake Erie sediments considered seriously contaminated by PCBs (Table 6).

TABLE 6. Concentrations of PCBs in Lake Erie and Harbour Sediments ($\mu\text{g}/\text{kg}$ dry weight).

	Lake Erie* (depositional basin)	Wheatley Harbour	Hamilton Harbour
Minimum	4.0	166.0	608.0
Maximum	660.0	1,176.0	14,185.0

* After Frank et al. (1977).

Difficulties in determination of the origin or PCB content in biota play also an important role in the interpretation of the results. Surface adsorption on biota tissue may partially account for their relatively high PCB content. In addition, the similarity of PCB concentrations in biota sampled from different areas may be partially due to a simple partitioning of PCBs between water/sediment and organism lipids. More studies are necessary to determine the relative importance of biomagnification versus partitioning of PCBs in an aquatic ecosystem. We would like also to emphasize that in this study the sediments were physically similar. However, Hamilton Harbour sediment contained significantly greater metal

concentrations than that from Wheatley Harbour. Further studies are necessary to assess the effects of different metal concentrations in sediments on the uptake of PCBs, in particular a selective uptake of various homologues.

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