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CONCENTRATIONS OF SELECTED ELEMENTS IN THE GREAT LAKES SEDIMENTS

by

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EXECUTIVE SUMMARY

A literature survey was carried out to obtain information on recent and background concentrations of selected elements (As, Cd, Cu, Cr, Ni, Fe, Pb, Zn and Hg) in the sediments at different areas in the Great Lakes. The information was needed for the revision of the Ontario Ministry of the Environment guidelines for open water disposal of dredged sediment in the Great Lakes. Large differences in reported concentrations of trace elements in the Great Lakes sediments reflected different sediment sampling localities and techniques, and analytical methods used for the quantitative determination of the trace elements. It was recommended to develop and test a standard sediment sampling protocol as well as standard analytical techniques for the assessment of the contamination of the Great Lakes sediments. The work was carried out under study ECD-236 in cooperation with the Environmental Protection, Ontario Region, and the Ontario Ministry of the Environment, Water Resources Branch, Toronto.

MANAGEMENT PERSPECTIVE

Reported results suggested a need for the development and testing of a standard sediment sampling protocol and standard analytical procedures for the assessment of contamination of the sediments from different areas in the Great Lakes.

SOMMAIRE

On a fait une étude de la documentation afin d'obtenir des informations sur les concentrations récentes et les concentrations de base d'éléments choisis (As, Cd, Cu, Cr, Ni, Fe, Pb, Zn et Hg) dans les sédiments à divers endroits dans les Grands Lacs. Cette information était nécessaire pour la révision des directives du ministère de l'Environnement de l'Ontario pour l'élimination en eau libre des matériaux de dragage dans les Grands Lacs. Les fortes différences qui existent entre les concentrations signalées d'éléments à l'état de trace dans les sédiments des Grands Lacs sont attribuables aux différents sites d'échantillonnage et aux différentes techniques d'échantillonnage, ainsi qu'aux méthodes analytiques utilisées pour doser les éléments à l'état de trace. On a recommandé d'élaborer et de tester un protocole normalisé d'échantillonnage des sédiments ainsi que des techniques analytiques normalisées pour l'évaluation de la contamination des sédiments des Grands Lacs. Ces travaux ont été effectués dans le cadre de l'étude ECD-236, en coopération avec la Protection de l'environnement, région de l'Ontario, et la Direction des ressources en eau du ministère de l'Environnement de l'Ontario, à Toronto.

PERSPECTIVE - GESTION

Les résultats suggèrent qu'il faudrait élaborer et tester un protocole normalisé d'échantillonnage des sédiments et des méthodes analytiques normalisées pour l'évaluation de la contamination des sédiments provenant de divers endroits dans les Grands Lacs.

ABSTRACT

A literature survey was carried out to obtain recent and background concentrations of selected elements (As, Cd, Cu, Cr, Fe, Ni, Pb, Zn and Hg) in the sediments from different areas of the Great Lakes. This information was required for the revision of the guidelines for the disposal of dredged material at the Canadian side of the Great Lakes. Surveyed literature included articles published during the past 15 years in different scientific journals and governmental and U.S. and Canadian universities reports. Large differences in concentrations of selected elements reported in the Great Lakes sediments reflected different sampling localities and techniques, and methods used for sediment analyses. Concentration ranges reported for surveyed elements were wider for the surface sediments of the depositional basins than those for the pre-colonial sediments. The results of the literature search indicated the need for a development of a standard sediment sampling protocol and standard analytical procedures for the assessment of contamination of the sediments at different areas of the Great Lakes.

Key words: surface sediments, pre-colonial sediments, dredging guidelines.

RÉSUMÉ

On a fait une étude de la documentation afin d'obtenir des informations sur les concentrations récentes et les concentrations de base d'éléments choisis (As, Cd, Cu, Cr, Ni, Fe, Pb, Zn et Hg) dans les sédiments, à divers endroits dans les Grands Lacs. Cette information était nécessaire pour la révision des directives en matière d'élimination des matériaux de dragage du côté canadien des Grands Lacs. La documentation examinée incluait des articles publiés au cours des quinze dernières années dans diverses revues scientifiques et divers rapports gouvernementaux et universitaires des États-Unis et du Canada. Les grandes différences qui existent entre les concentrations signalées d'éléments à l'état de trace dans les sédiments des Grands Lacs sont attribuables aux différents sites d'échantillonnage et aux différentes techniques d'échantillonnage, ainsi qu'aux méthodes utilisées pour analyser les sédiments. Les plages de concentrations signalées pour les éléments à l'étude étaient plus étendues dans le cas des sédiments de surface des bassins de dépôt que dans celui des sédiments pré-coloniaux. Les résultats de ce dépouillement ont indiqué la nécessité de mettre au point un protocole normalisé d'échantillonnage des sédiments et des méthodes analytiques normalisées pour l'évaluation de la contamination des sédiments à différents endroits dans les Grands Lacs.

Mots clés : sédiments de surface, sédiments pré-coloniaux,
directives en matière de dragage.

INTRODUCTION

In the absence of federal guidelines, Environment Canada utilizes the Ontario Ministry of the Environment guidelines to evaluate the acceptability of sediment for open water disposal in the Great Lakes. Provincial guidelines and regulations are used to prevent water quality and degradation of the nearshore areas of the lakes. Present guidelines, established in 1970, are based on the bulk chemical composition of the sediments. In 1984, a joint committee was formed by the Department of the Environment (DOE) and the Ontario Ministry of the Environment (OME) to review the guidelines. One of the objectives of this committee was to obtain all available information on concentrations of parameters in the Great Lakes sediments listed in the current OME guidelines. A literature survey was carried out to compile concentrations of As, Cd, Cr, Cu, Fe, Ni, Pb, Zn and Hg found in the past 15 years in the Great Lakes sediments. Scientific journals, DOE and OME unpublished reports, and various reports by the U.S. and Canadian universities used as a source for the compilation are listed in Table 1. Table 1.

REPORTED CONCENTRATIONS OF TRACE ELEMENTS IN THE SEDIMENTS

Concentrations of above listed parameters were compiled for depositional basins, areas with no deposition of fine grained sediments, such as nearshore zones, embayments, harbours, tributary mouths, and, where available, for shorelines bluffs and drainage basin soils of the Great Lakes. The concentrations in the surface sediments related in the majority to the topmost 3 cm layers, but also to a 1, 2 or 5 cm surface sediment layer. The background concentrations represented usually those in the pre-colonial sediments as determined by the Ambrosia pollen horizon or radionuclide dating

of the sediments. In some cases, the background was the concentration of a parameter reached at certain sediment depth without further concentration changes below this depth. The concentrations of As, Cd, Cr, Cu, Ni, Pb, Zn, Fe and Hg in the Great Lake sediments obtained by the literature survey are summarized in Table 2. Table 2.

Results of the Survey

Reported concentrations of surveyed parameters at specific areas in each lake varied widely. The variations resulted most likely from different sampling localities, sampling methods and analytical techniques used for the determination of the concentrations of the elements.

The concentration ranges of selected trace elements (Cr, Cu, Pb, Hg, Ni and Zn) in the surface and pre-colonial sediments of the Great Lakes depositional basins reported in the literature are summarized in Figures 1 and 2. These elements had wider concentration ranges in the surface than in the pre-colonial sediments. Figs.1&2

Sampling Localities

One of the reasons of this greater variability of concentrations of the elements reported for the surface than the pre-colonial sediments could be the extent of the contamination of surficial sediments within and between the depositional basins of the Great Lakes.

We tested the homogeneity of the sediments in the Western Basin of Lake Ontario in 1984. Box cores were collected at five stations on a 30 km long west-east transect and at four stations on a 20 km long north-south transect in the area of fine grained sediment deposition (Figure 3). At eight of these sampling stations, surface 3 cm sediment was collected from each box core. To test the homogeneity of the surface sediment over a small area, the surface area (0.25 m^2) of one box core collected at station 7 (Figure 3) was divided into nine fields of equal size. Surface 3 cm of sediment was collected from each field and treated as a separate sample. Particle size distribution was determined on each sample by the sedigraph (Duncan and LaHaie, 1979). For chemical analyses, the samples were freeze dried and ground. Concentrations of major elements (Si, Al, Fe, Ca, Mg, K, Na, Ti, Mn and P) and trace elements (Ni, Co, Cr, V, Pb and Zn) in the sediments were determined by x-ray fluorescence spectrometry using methods described by Mudroch (1985).

Figure 3.

All sediments were silty clay (55-65% of silt and 35-45% of clay size particles). Concentration ranges of determined elements are shown in Table 3. Concentrations of major elements indicated similar geochemistry of surface sediments collected along the transects. Concentration ranges of trace elements in the sediments were smaller than those obtained from the literature survey (Figures 1 and 2). These results suggested that other factors were involved which affected the variability of reported concentrations of trace elements.

Table 3.

Sediment sampling

According to the surveyed literature, different coring equipment and grab

samplers were used for sediment collection. Benthos gravity corer, box corer, Jenkin corer, and some custom made gravity and piston corers were used for sediment coring by many investigators. Some coring was diver-assisted. Retrieved sediment cores were subsampled into sections which varied in size from 1 to 10 cm. Shipek, mini-Shipek, Ekman dredge and Ponar grab samplers were used for surface sediment sampling. In some studies, surface 2 or 3 cm of sediment from a grab sampler was collected and used for the analyses.

The thickness of a sediment subsample from a core can affect the results of the determination of contaminants. It is obvious from the example of concentration profiles of Pb and Zn in the sediment from the Western Basin of Lake Ontario shown in Figure 4 that values reported for 0-1 cm, 0-2 cm, 0-5 cm and 0-10 cm sediment layers will be different. In addition to the differences in the concentrations of trace elements in various sediment layers, there is also a decreasing water content with increasing sediment depth. Consequently, a thicker sediment subsample will contain a greater weight of less contaminated deeper sediment layer. Figure 4.

The depth of the sediment obtained by a Shipek grab sampler can be about 8 cm, by a mini-Shipek about 5 cm, and by an Ekman dredge and a Ponar grab samplers about 10 cm. However, this sampling depth depends often on the texture of sampled sediments. Most of the grab samplers penetrate fine grained sediment (silty clay) to a greater depth than coarse grained (sandy) sediments. In addition, the very fine surface sediment (about 3 cm) may be washed off the Shipek grab sampler during the upward transport of the sampler through the water column.

We tested the effects of sediment sampling by a Shipek grab sampler and a box corer by the chemical analyses of a 3 cm surface sediment layer. These surface sediment layers were obtained by mixing the sediment obtained by nine drops of a Shipek grab sampler, and by collecting the sediment from one box corer. All samples were collected within a small area (about 100 m^2) at a 100 m water depth in the Western Basin of Lake Ontario. Sampled sediment was silty clay. Identical analytical methods were used for the determination of selected parameters in both sediment samples. The concentrations of all determined parameters were lower in the sediment obtained by the Shipek grab sampler than in that collected by the box corer (Table 4). This is in a good agreement with the observation by Bourbonniere et al. (1986) who compared the concentration of organic and inorganic C in surface sediments sampled by a box corer and a Shipek grab. Concentration profiles shown in Figure 4 indicated greater concentrations of Pb and Zn in the 3 cm surface sediment than in the deeper sediment layers in the Western Basin of Lake Ontario. In addition, a greater concentration of Mn and Fe is found in the Great Lakes surface sediments due to the upward migration and precipitation of these elements at the sediment - water interface with increased redox potential (Gorham and Swine, 1965). The results in Table 4 suggest the loss of much of the surface (about 3 cm) sediment from the Shipek grab sampler.

Table 4.

Analytical Techniques

The use of different analytical methods could be another reason of the variability of reported concentrations of selected elements in the surface and pre-colonial sediments. Since the depth of the pre-colonial sediments in a sediment core can be defined, the differences in the reported background concentrations of elements resulted most likely from different methods used for sediment analyses.

Atomic absorption spectrometry (AAS) was the most often used technique for the analyses. Flameless AAS was used mainly for the determination of Hg. However, at least four different methods were reported for the sediment extraction used prior to the AAS analyses. Different combination and strength of acids, temperature and extraction time were used in the described extraction procedures. Reported extraction procedures included HCl conc. at 90°C for 90 minutes, HNO_3 conc.: HCl conc. (1:1) at 90°C for 60 minutes, boiling aqua regia for 60 minutes, open digestion by $HClO_4$: HNO_3: HF mixture, and HF: $HClO_4$: HNO_3 mixture in a Teflon bomb. In some cases, the authors reported only "acid extraction" of the sediments.

Other methods used for the determination of the eight parameters (As, Cd, Cu, Cr, Fe, Pb, Ni and Zn) were x-ray fluorescence spectrometry (mainly for Fe) and D.C. argon plasma atomic emission spectrometry. HNO_3 conc: HCl conc. (1:1) and a mixture of H_2SO_4 conc: HNO_3 conc. (Inland Waters Directorate, Water Quality Branch, 1979) were used for the extraction of Hg from the sediments.

DISCUSSION

Sampling and analyses of the sediments are an important task in the definition of the pollution problem in the Great Lakes. Sediment contamination represents a significant problem as in-situ source of pollutants, in particular in the localities designated by the U.S.-Canada International Joint Commission as Areas of Concern. Even after elimination of external inputs, contaminants will remain in the sediments and can be released into the water column or transported with the sediment particles

from an Area of Concern into the open lake. The knowledge of the concentrations of contaminants in the sediments can be used for establishing the degree and spatial extention of sediment contamination, determination of sediment accumulation and investigation of historical inputs of contaminants into the lakes, estimation of present input loads, and assessing of toxicity of sediment-associated contaminants to the lake biota. The variability of concentrations of As, Cd, Cu, Cr, Ni, Pb, Fe, Hg, and Zn in the sediment, sampling techniques and analytical methods found during the literature survey suggested a need for a development of a standard sediment sampling protocol and standard analytical procedures for the determination of the concentration of contaminants.

As far as the guidelines for the dredged material disposal are considered, greater concentrations of some of the surveyed parameters, than those given in the guidelines, were found in the pre-colonial sediments, drainage basins soils and bluff material. However, sediment sampling and analytical techniques were too varied to allow quantitative comparison of many data. It was recommended that a bioassessment procedure and standardized techniques for sediment sampling and chemical analyses be included in the revision of the guidelines for the disposal of dredged material on the Canadian side of the Great Lakes.

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TABLE 1 **Sources of compiled concentrations of As, Cd, Cn, Cr, Fe, Pb, Hg, Ni and Zn in the Great Lakes Sediments**

JOURNALS	PROCEEDINGS CONF./ SYMPOS.	GOVERNMENT AGENCIES REPORTS	UNIVERSITIES REPORT
Adv. Environ. Sci. Technol.	Am. Chem. Soc., Div. Environ. Chem.	Dep. Environ. Canada	Bowling Green State Univ., Bowling Green, Ohio
Can. J. Fish. Aquat. Sci.	Am. Chem. Nucl. Soc. Top. Meeting	Dep. Fish. Oceans, Canada	Ohio State Univ., Columbus, Ohio
Can. J. Earth Sci.	Conf. Great Lakes Res.	Geol. Survey, Canada	State Univ. Coll., Buffalo
Can. Mineralogist	Environ. Energy Res.	Ill. State Geol. Surv. Division	Univ. Illinois, Ubana-Champaign, Water Res. Centre
Chemical Geology	Environ. Mercury Contam.	NOAA	Univ. Michigan, Ann Arbor
Environ. Geology	Inter. Sediment Fresh Water	Ohio Div. Geol. Survey	Univ. of Toronto Toronto, Ontario
Environ. Pollution	Inter. Conf. Heavy Metals in Environ.	Ontario Min. Environ.	Univ. of Minnesota, Minneapolis
Environ. Research	Inter. Conf. Nucl. Methods	US Environ. Protec. Agency	Univ. of Minnesota, Duluth
Environ. Sci. Technology	Inter. Conf. Transp. Persist. Chem. in Aquat. Ecosystem	US NTIS	Univ. of Wisconsin, Milwaukee
Geochem. Cosmochem. Acta	Inter. Geol. Congress		
Geol. Soc. Am. Bull.	Manag. Contr. Heavy Met. Environ.		
J. Fish. Res. B. Can.	Sandusky River Basin Sympos.		
J. Great Lakes Res.	Trace Met-Org. Inter. Nat. Waters		
J. Sed. Petrology			
Limnol. Oceanogr.			
Ohio J. Sci.			
Sci. Total Environ.			
Trans. Am. Fish. Soc.			
Water, Air, Soil, Poll.			
Water Res.			

TABLE 2 **Reported Ranges of Concentrations of As in the Great Lakes sediments (ug/g)**

Lake:	Ontario	Erie	St. Clair	Huron	Michigan	Superior
Depositional Basins:						
- surface	0.2-17.0	0.45-12.3	2.5-3.4[1]	14.7-54.0	5-15	-
- background	-	0.16- 1.0	-	-	5- 8	-
Nondepositional Zones:						
- surface	0.2-24.0	-	-	-	-	-
- background	-	-	-	-	-	-
Embayments:						
- surface	-	-	-	-	0.2-42	-
- background	-	-	-	-	8-15	-
Harbours:						
- surface	-	6.0-8.0	-	-	-	-
- background	-	0.5-1.2	-	-	-	-
River Mouth:						
- surface	-	-	-	-	-	-

1 Whole lake including the nearshore zone

TABLE 2 **Reported Ranges of Concentrations of Cd in the Great Lakes Sediments (ug/g)**

Lake:	Ontario	Erie	St. Clair	Huron	Michigan	Superior
Depositional Basins:						
- surface	0.1- 6.2	0.8-13.7	1.4; 1.7[1]	< .3-4.3	.05-1.8	1.4-2.5
- background	0.9- 3.7	0.1- 1.7	-	.2-1.8	0.5 -0.7	0.4-0.7
Nondepositional Zones:						
- surface	< 0.20-20.6	0.1- 8.3	-	-	-	-
- background	-	0.1- 1.3	-	-	-	-
Embayments:						
- surface	< .30-22.0	-	-	< .3-4.6	0.07-1.93	-
- background	-	-	-	.6-1.5	0.5 -1.3	-
Harbours:						
- surface	< 0.5-10.0	0.1	< .5-1.0	-	-	-
- background	1.1[2]	-	-	-	-	-
River Mouth:						
- surface	1.2-18.3	.6-7.8	.9-5.5	.1-2.0	0.1 -16.6	.1-1.3

1 Mean values for the whole lake including the nearshore zone (standard deviation = 0.5 for both values)

2 Mean (standard deviation = 1.9)

TABLE 2 **Reported Ranges of Concentrations of Cr in the Great Lakes Sediments (ug/g)**

Lake:	Ontario	Erie	St. Clair	Huron	Michigan	Superior
Depositional Basins:						
- surface	8.0-133	12-362	1.0-275[1]	5.5-86.4	140	29.5-60.2
- background	63-86	9-25	-	30.0-47.1	50	26.1-73.1
Nondepositional Zones:						
- surface	3.7-500	6-211	-	-	-	37.6-45.6
- background	45-100	-	-	-	-	49.8-51.8
Embayments:						
- surface	4-665	-	-	5-81	2-72	13.7-87.3
- background	-	-	-	28.5-43.7	-	-
Harbours:						
- surface	0.3-390	13-150	12.0-155	-	-	-
- background	34[2]	30-250	-	-	-	-
River Mouth:						
- surface	5-143	4.5-124.5	6.0-77.9	0.1-30.0	0.5-1,295	.9-22.8

1 Whole lake including the nearshore zone

2 Mean (Standard deviation = 45)

TABLE 2 **Reported Ranges of Concentrations of Cu in the Great Lakes Sediments (ug/g)**

Lake:	Ontario	Erie	St. Clair	Huron	Michigan	Superior
Depositional Basins:						
- surface	26-109	5-207	2.0-48.0[1]	3.3-78	54	113-173
- background	35-56	20- 48	-	31-48	15	30- 84
Nondepositional Zones:						
- surface	2.1-200	3-138	-	-	-	162-213
- background	60-100	-	-	-	-	57-69
Embayments:						
- surface	3-265	-	-	2-95	0.8-54	12-300
- background	-	-	-	25-51	-	-
Harbours:						
- surface	1.0-860	2-100	1.0-54.0	-	-	-
- background	-	10-110	-	-	-	-
River Mouth:						
- surface	6.8-83	1.5-69.8	4.5-80.6	1.9-61.2	0.5-84	.6-262.8

1 Whole lake including the nearshore zone

TABLE 2 **Reported Ranges of Concentrations of Fe in the Great Lakes Sediments (%)**

Lake:	Ontario	Erie	St. Clair	Huron	Michigan	Superior
Depositional Basins:						
- surface	2.41-9.62	1.1-7.79	-	.47-5.11	-	4.91-5.76
- background	1.92-5.25	.89-4.82	-	1.15-5.02	-	3.18-5.88
Nondepositional Zones:						
- surface	.29-8.31	1.34-13.72	-	-	-	5.52-6.23
- background	-	-	-	-	-	5.37-5.94
Embayments:						
- surface	-	-	-	.53-6.7	0.4-2.55	5.10[2]
- background	-	-	-	4.07-5.20	-	-
Harbours:						
- surface	.39-13.7	1.01-6.10	-	-	-	-
- background	2.0[1]	.1-1.5	-	-	-	-
River Mouth:						
- surface	.35-4.06	-	-	-	-	-
Bluffs:	1.29-3.52	1.71-3.09	-	-	-	-
Soils:	-	2.71-3.36	-	-	-	-

1 Mean (standard deviation = 0.8)

2 Mean (standard deviation = 0.58)

TABLE 2 Reported Ranges of Concentrations of Pb in the Great Lakes Sediments (ug/g)

Lake:	Ontario	Erie	St. Clair	Huron	Michigan	Superior
Depositional Basins:						
- surface	7.0-285	6-299	7.-67.0[1]	3.0-151.4	10-130	74.9-138.2
- background	18 - 32	21- 49	-	14.4- 36	8-10	20.5- 68.0
Nondepositional Zones:						
- surface	1.8-287	9-227	-	-	-	68.7-143.9
- background	25	-	-	-	-	18.4- 24.6
Embayments:						
- surface	6-520	-	-	.3-2.30	1.3-56.2	10.5- 39.7
- background	-	-	-	83.9-93.0	8-29	-
Harbours:						
- surface	1.0-1,600	1-192	1.0-52.0	-	-	-
- background	28[2]	-	-	-	-	-
River Mouth:						
- surface	7.3-168.6	-	12.1-151.1	3.5-258.7	1.3-149.0	1.2- 61.8
Bluffs:	12-35	33-47	-	-	-	-
Soils:	-	33-40	-	-	-	-

1 Whole lake including the nearshore zone

2 Mean (standard deviation = 34)

TABLE 2 Reported Ranges of Concentrations of Hg in the Great Lakes Sediments (ug/g)

Lake:	Ontario	Erie	St. Clair	Huron	Michigan	Superior
Depositional Basins:						
- surface	.140-3.95	.045-4.8	.30-10.28[1]	.01-.805	0.030-0.380	0.094-0.160
- background	.03-.09	.01-.19	-	.035-.080	-	0.044-0.68
Nondepositional Zones:						
- surface	.01-7.76	.080-1.881	-	-	-	.172-.856
- background	0.40-0.70	-	-	-	-	.080-.084
Embayments:						
- surface	0.01-1.20	.33-1.44	2.1-2.3	.01-9.50	-	.030-.420
- background	-	-	-	.030-.323	-	-
Harbours:						
- surface	0.01-7.00	.015-2.2	.020-.320	-	-	-
- background	-	.05-7.00	-	-	-	-
River Mouth:						
- surface	.01-3.90	.06-.86	.07-2.77	.01-.36	0.01-1.20	.010-1.050
Bluffs:	-	.04-.05	-	-	-	-
Soils:	-	.08-.09	-	-	-	-

[1] Whole lake including the nearshore zone

TABLE 2 Reported Ranges of Concentrations of Ni in the Great Lakes

Lake:	Ontario	Erie	St. Clair	Huron	Michigan	Superior
Depositional Basins:						
- surface	29.0-99.0	16-150	5.0-43.0[1]	5.3-96.7	25	28.9-66.4
- background	42-48	10- 76	-	29.9-50.9	20	24.4-69.8
Nondepositional Zones:						
- surface	4.0-160	9-69	-	-	-	55.6-59.2
- background	.30-100	-	-	-	-	57.7-63.5
Embayments:						
- surface	-	-	-	15-132.2	1.7-54.2	5.7-70
- background	-	-	-	49.6- 61.1	-	-
Harbours:						
- surface	1.0-75.0	2-90	2.0-35.0	-	-	-
- background	14[2]	55-65	-	-	-	-
River Mouth:						
- surface	8.9-140	4.5-37.2	8.7-49.2	1.8-184.8	1.6-74.8	1.1-33.4

1 Whole lake including the nearshore zone

2 Mean (standard deviation = 7)

TABLE 2 **Reported Ranges of Concentrations of Zn in the Great Lakes Sediments (ug/g)**

Lake:	Ontario	Erie	St. Clair	Huron	Michigan	Superior
Depositional Basins:						
- surface	87-3,507	18-536	8.0-107.0[1]	8.2-233	40-350	143-195
- background	83- 163	8-128	-	60- 88	40- 50	53-137
Nondepositional Zones:						
- surface	6-1,120	16-351	-	-	-	165-202
- background	100	-	-	-	-	105-117
Embayments:						
- surface	14-1,225	-	-	6-230	2.4-160	36-150
- background	-	-	-	78-116	50- 80	-
Harbours:						
- surface	5-2,010	12-650	9.0-132.0	-	-	-
- background	210[2]	40- 50	-	-	-	-
River Mouth:						
- surface	24.5-500	15.7-220.8	31.2-330.3	5.7-257.2	3.5-398.0	.3.0-85.5
Bluffs:	16-65	39-76	-	-	-	-
Soils:	-	59-89	-	-	-	-

1 Whole lake including the nearshore zone

2 Mean (standard deviation = 260)

TABLE 3 Concentration ranges of major and trace elements in surface 3 cm sediments of the Western Basin, Lake Ontario

Major Elements (%)

	SiO_2	Al_2O_3	Fe_2O_3	MgO	CaO	Na_2O	K_2O	TiO_2	MnO	P_2O_5
8 stations[1]	56.7-58.0	13.9-14.4	6.8-7.7	2.7-3.2	10.9-13.1	0.60-0.69	3.46-3.56	0.61-0.73	0.80-1.24	0.35-0.40
One box core[2]	57.0-57.2	13.9-14.1	6.8-6.9	2.6-2.7	12.9-13.4	0.58-0.65	3.39-3.44	0.60-0.62	1.14-1.37	0.35-0.37
Precision test[3]	58.7-59.2	11.8-11.9	4.7-5.4	2.6-3.8	15.1-15.3	1.18-1.31	2.78-2.91	0.57-0.59	0.08-4.03	0.33-0.36

Trace Elements (ug/g)

	Ni	Co	Cr	V	Pb	Zn
8 stations[1]	77-93	19-22	108-120	89-108	120-144	359-458
One box core[2]	83-85	15-20	102-110	87- 95	125-133	394-419
Precision test[3]	33-35	13-15	74- 81	62- 66	348-369	267-275

1 surface 3 cm at sampling stations 1,2,3,4,5,6,8 and 9 (Figure 3)
2 surface 3 cm from one box core (station 7, Figure 3) divided into 9 fields
3 four samples of homogenized sediment collected by a grab sampler in Lake Ontario

TABLE 4 Comparison of Sampling Techniques

Station *	Parameter								
	%			ug/g					
	Fe_2O_3	MnO	P_2O_5	Ni	Cr	Pb	V	Zn	Cu
Shipek (0 - 3 cm)	4.5	0.79	0.28	79	74	205	47	183	26
Box Corer (0 - 3 cm)	5.0	1.25	0.37	129	71	226	52	264	41

*Sediment from the Western Basin of Lake Ontario

FIGURE CAPTIONS

Figure 1 Concentration ranges of Cr, Cu and Pb in surficial and pre-colonial Great Lakes sediments.

Figure 2 Concentration ranges of Hg, Ni and Zn in surficial and pre-colonial Great Lakes sediments.

Figure 3 Sampling stations for testing sediment heterogeneity in Lake Ontario.

Figure 4 Concentration profiles of Pb and Zn in Lake Ontario sediments.

Figure 1

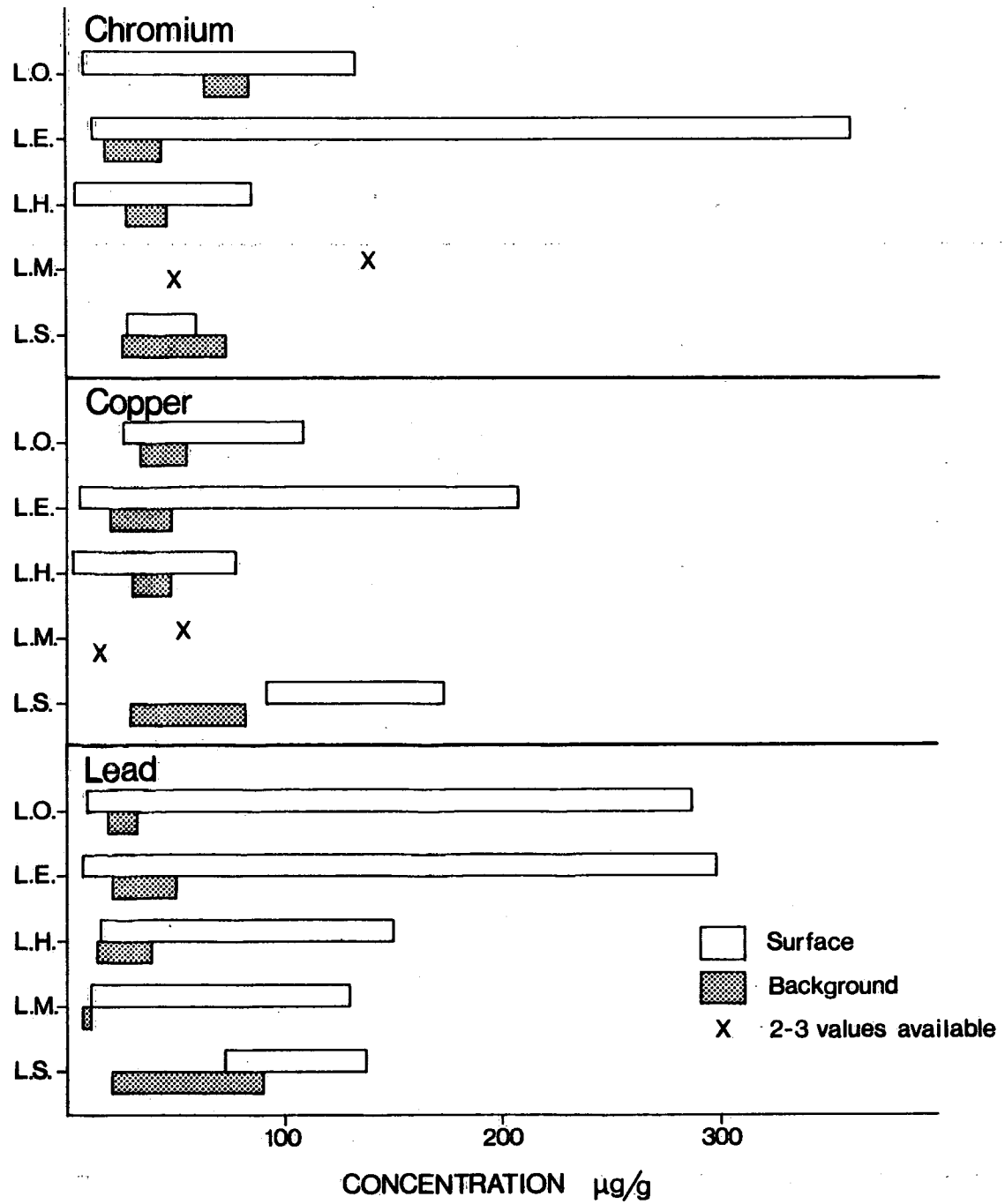

Chromium
L.O.
L.E.
L.H.
L.M.
L.S.
Copper
L.O.
L.E.
L.H.
L.M.
L.S.
Lead
L.O.
L.E.
L.H.
L.M.
L.S.
Surface
Background
X 2-3 values available
100
200
300
CONCENTRATION µg/g

Figure 2.

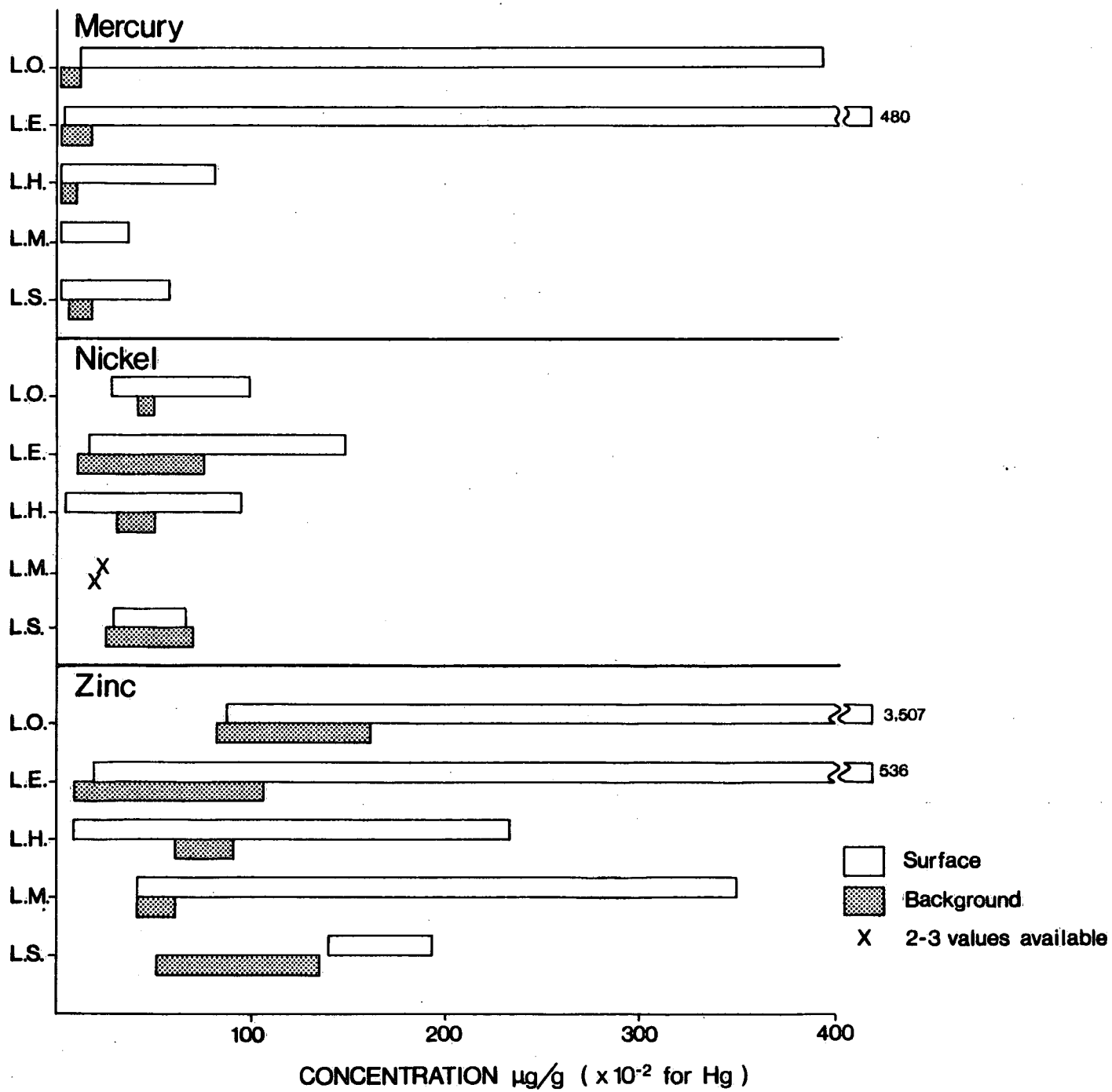

Mercury
L.O.
L.E.
L.H.
L.M.
L.S.
480
Nickel
L.O.
L.E.
L.H.
L.M.
L.S.
X
X
Zinc
L.O.
L.E.
L.H.
L.M.
L.S.
3,507
536
Surface
Background
X 2-3 values available
100
200
300
400
CONCENTRATION µg/g (x 10-2 for Hg)

Figure 3.

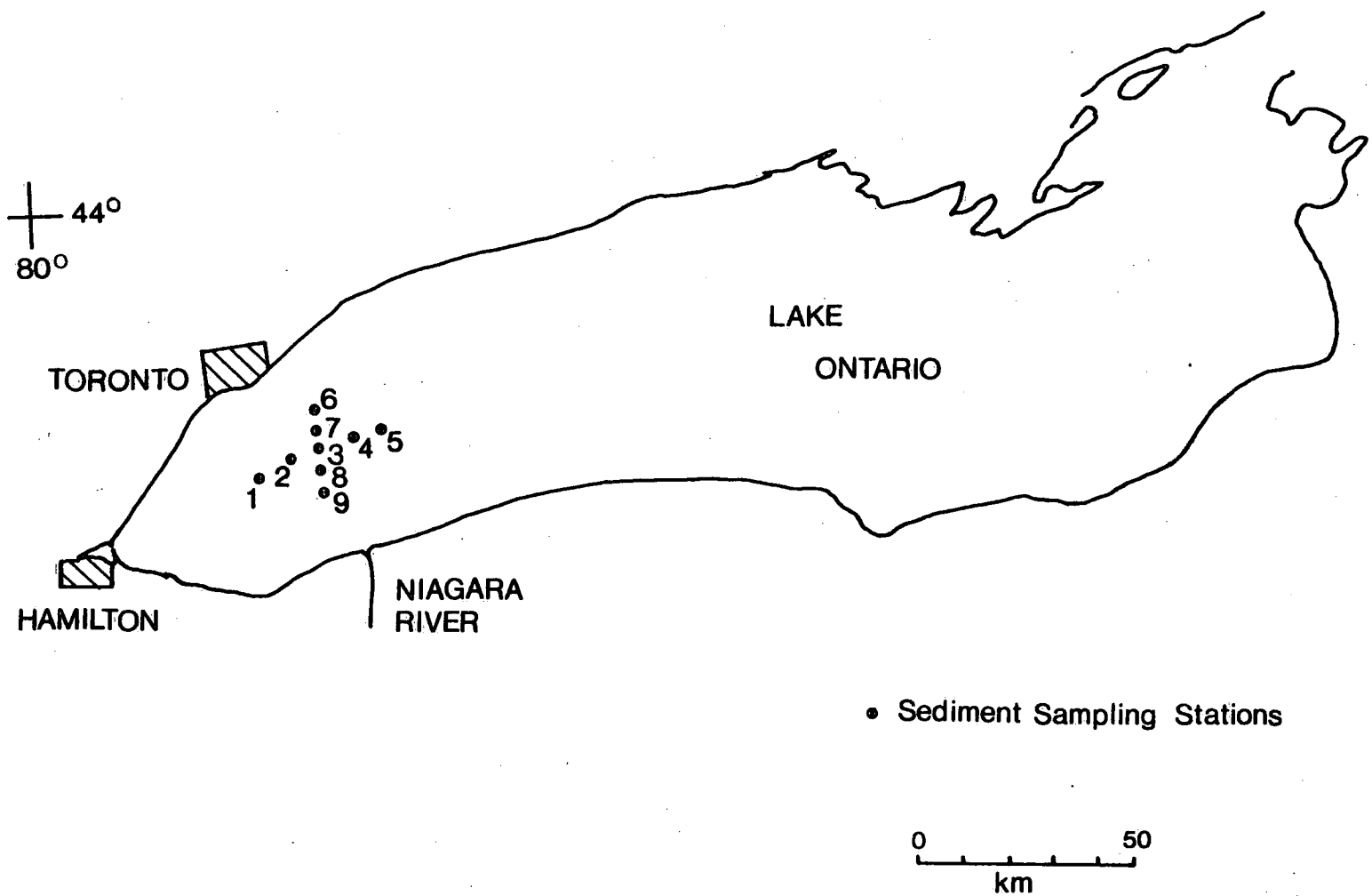
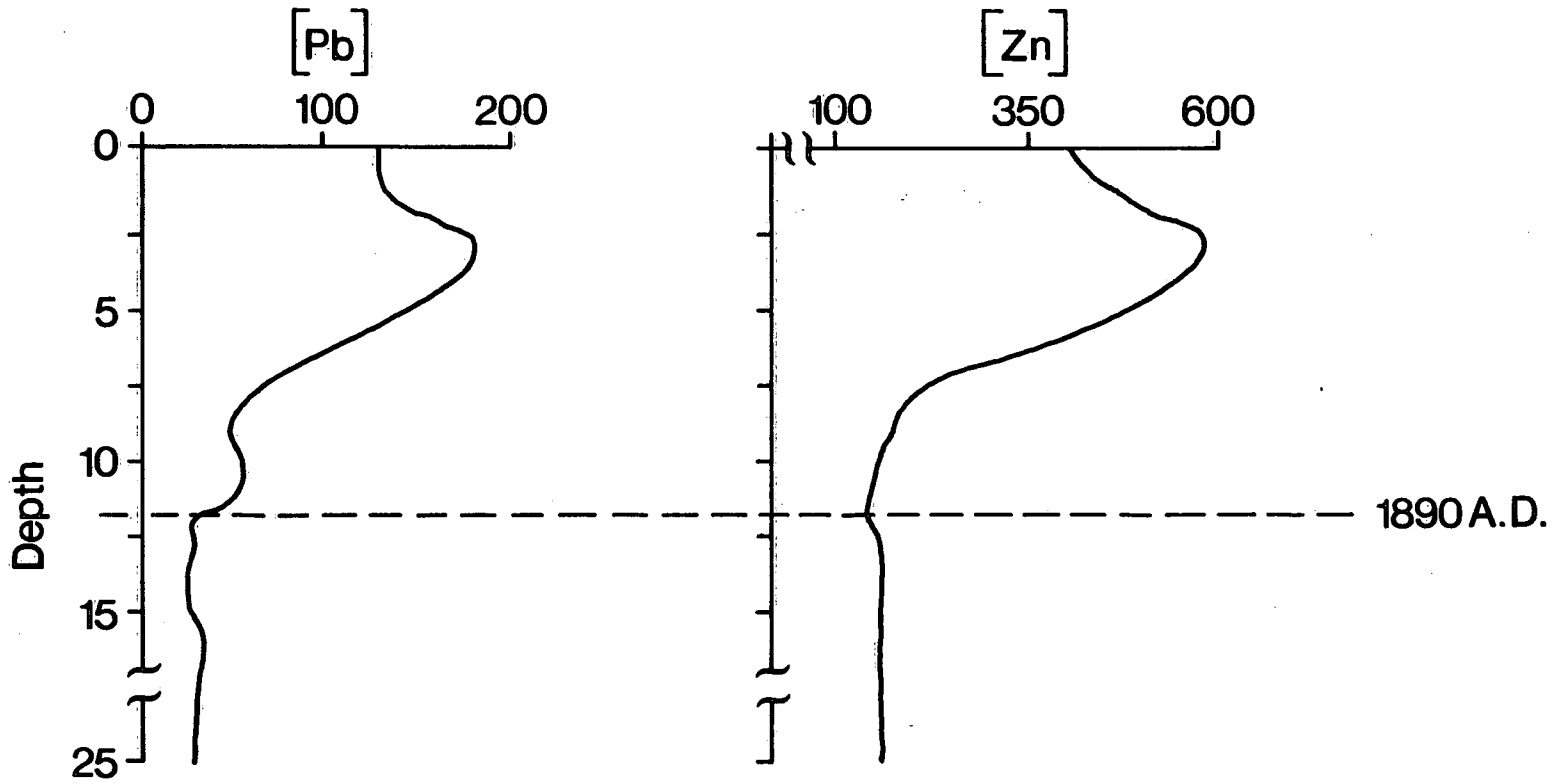

44°
80°
TORONTO
HAMILTON
NIAGARA
RIVER
LAKE
ONTARIO
1
2
3
4
5
6
7
8
9
• Sediment Sampling Stations
0
50
km

Figure 4.



LAKE ONTARIO WESTERN BASIN 1983