Environment Canada
Environnement Canada

Further Studies on the Heavy Metal Levels in Ottawa and Rideau River Sediments

Barry G. Oliver and Haig Agemian

SCIENTIFIC SERIES NO. 37
(Résumé en français)

*INLAND WATERS DIRECTORATE,
WATER QUALITY BRANCH,
OTTAWA, CANADA, 1974*

Environment Canada / Environnement Canada

Further Studies on the Heavy Metal Levels in Ottawa and Rideau River Sediments

Barry G. Oliver and Haig Agemian

SCIENTIFIC SERIES NO. 37
(Résumé en français)

INLAND WATERS DIRECTORATE,
WATER QUALITY BRANCH,
OTTAWA, CANADA, 1974

Cat. No.: En 36-502/37

Contract No. 02KX.KL327-3-8060
Thorn Press Limited

Contents

Page

ABSTRACT v

RÉSUMÉ v

INTRODUCTION 1

EXPERIMENTAL 1
Sampling 1
Analysis 1

RESULTS AND DISCUSSION 4

REFERENCES 9

Illustrations

Figure 1. Sampling locations on the Ottawa River. 2

Figure 2. Sampling locations on the Rideau River. 3

Figure 3. Bed material sampler, U.S. BMH-60. 4

Figure 4. Average lead concentration (ppm) in Rideau River sediments *vs.* sampling location. 5

Tables

1. Atomic absorption spectrophotometer, instrument parameters and detection limits. 5

2. Chemical analyses of Ottawa and Rideau Rivers sediments
(a) Ottawa River sediments. 6
(b) Rideau River sediments. 7

3. Mean background concentration of absorbed and precipitated heavy metals in the −80 mesh fraction of Ottawa and Rideau River sediments. 9

Abstract

Sediment samples, collected at two-mile intervals on the Ottawa and Rideau Rivers in the summer of 1972, were analyzed for lead, mercury, zinc, copper, nickel, cobalt, iron, manganese, chromium, and cadmium by atomic absorption spectrophotometry. Unusually high levels of mercury were recorded near pulp and paper industrial discharges as a result of former use by the industry of mercurial slimicides. Elevated metal levels were found at sewage plant and storm sewer outfalls. This is to be expected as sewage contains a significant quantity of metals, especially in the particulate form. The removal of snow disposal sites away from the Rideau River lowered the lead sediment levels in this river in the city of Ottawa.

Résumé

Durant l'été 1972, des échantillons de sédiments avaient été rassemblés à des intervalles de deux milles le long des rivières Ottawa et Rideau. Le taux de concentration de ces sédiments en plomb, mercure, zinc, cuivre, nickel, cobalt, fer, manganèse, chrome et cadmium fut alors determiné en utilisant la technique de la spectrophotométrie à absorption atomique. Des taux exceptionnellement élevés de concentration en mercure ont été enregistrés au voisinage des endroits de décharge des déchets des usines de bois et de papier qui utilisaient des "slimicides de mercure". Aux débouchés des systèmes d'égouts et d'évacuation des eaux de pluie, des taux de concentration en éléments métalliques plus élevés ont été observés. Ceci résulte du fait que les égouts contiennent une importante quantité de métaux existant notamment sous forme de particules. Le déplacement des sites de décharge de neige loin de la rivière Rideau a abaissé le taux de concentration du plomb dans les sédiments de la rivière à Ottawa.

Further Studies on the Heavy Metal Levels in Ottawa and Rideau River Sediments

Barry G. Oliver and Haig Agemian

INTRODUCTION

In the summer of 1971, an extensive study of the heavy metal concentrations in Ottawa and Rideau River sediments was completed (Oliver and Kinrade, 1972). Elevated levels of mercury were found to be present in the sediments downstream from pulp and paper mill outfalls because of the industry's use of methoxyethylmercuric acetate as a slimicide. Also, excessive accumulation of lead occurred in sediments at a river snow-dumping site and high sediment levels for several metals occurred at a sewage plant outfall. These results showed that heavy metals could prove to be a long-term hazard to the ecology of the rivers.

To confirm these findings, a further survey of sediment heavy-metal levels in the rivers was undertaken in the summer of 1972. Samples were collected from the same locations as in the previous year; additional samples were collected above Ottawa and downstream from Thurso on the Ottawa River. As the use of mercury by the pulp and paper industry had ceased in the spring of 1971 and snow dumping into the river was curtailed in the fall of 1971, the short-term impact of these changes on sediment metal levels could also be assessed.

EXPERIMENTAL

Sampling

Sediment samples were collected at two-mile intervals along the Ottawa River from Constance Bay to Carillon, and along the Rideau River from Smiths Falls to Ottawa, during the period May 29 – June 16, 1972. The sampling stations, labelled from −4 to 34 for the Ottawa River and A to Z for the Rideau River, are shown in Figures 1 and 2, respectively. Sampling sites 1 to 20 on the Ottawa River and A to Z on the Rideau River are identical with the 1971 sites. The other numbers represent the extension of the study area. At each sampling location three samples were taken – one sample about 10 yards from each bank and one in the centre of the river. For the Ottawa River, the first sample at each station was obtained on the Quebec side, the second in the centre, and the third on the Ontario side. For example, at Station 8, sample number 8-1 was taken on the Quebec side, sample number 8-2 in the centre, and sample number 8-3 on the Ontario side. For Rideau River stations, the first sample was collected close to the east bank, the second in the centre, and the third close to the west bank.

Sediment samples were collected by a US BMH-60 bed material sampler (Fig. 3). This sampler was found to work well for all types of sediments but, of course, it did not collect samples where the river bottom was rocky. As it closes, the bucket penetrates the stream bed to a depth of approximately 4.45 cm (1.75 in) and completely encloses a 175-ml sample of bed material. This sampler is more reliable than the Lane Sampler employed in 1971.

Analysis

The sediment samples were air dried, then sieved to −80 mesh with a stainless steel sieve. One gram of the −80 mesh fraction was accurately weighed and digested in 100 ml of acid solution – 4*M* HNO_3, 0.7*M* HCl – for 2 h at 70° – 90°C. The efficiency of this partial extraction technique is fairly variable depending on the nature of the sample. But the difference between the amount of metal obtained using a HF – HNO_3 – $HClO_4$ total extraction method and the procedure above was roughly constant for twenty representative samples collected throughout the study area. This indicates that the dilute HNO_3 – HCl technique has little effect on the metals bound in the sediment minerals, but removes only surface-absorbed or precipitated metals from the sample. For the cadmium analysis it was necessary to increase the amount of sediment to 5 g and decrease the amount of acid to 25 ml because the cadmium levels were very low. In this case a stronger acid mixture was used – 10*M* HNO_3, 2*M* HCl.

The acid extracts were analyzed for lead, mercury, zinc, copper, nickel, cobalt, iron, manganese, chromium, and cadmium by a Perkin-Elmer Model 403 atomic absorption spectrophotometer. Conventional atomic absorption techniques are not sensitive enough to measure the concentration of mercury, so a flameless method was used for this metal (Oliver and Kinrade, 1972, Hatch and Ott, 1968). Atomic absorption was too sensitive for use with iron because the iron levels were extremely high, and atomic emission was substituted. The instrument parameters and precision of the analysis for the elements are given

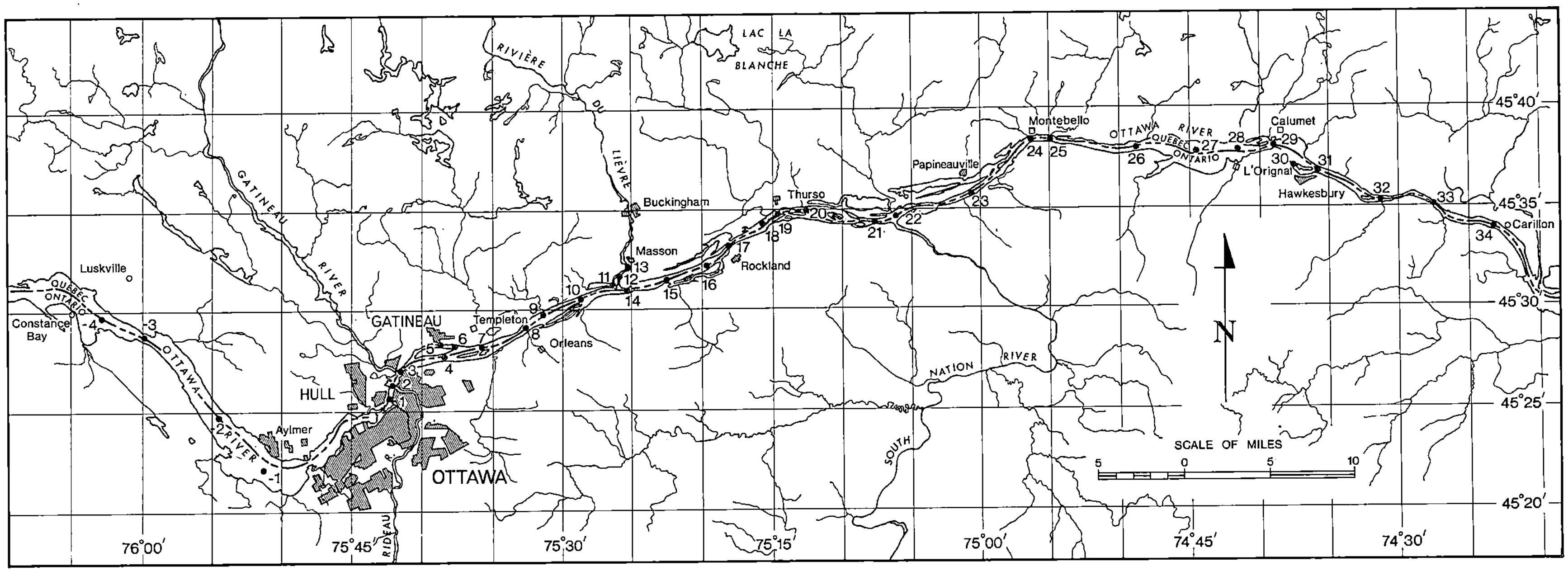

Figure 1. Sampling locations on the Ottawa River.

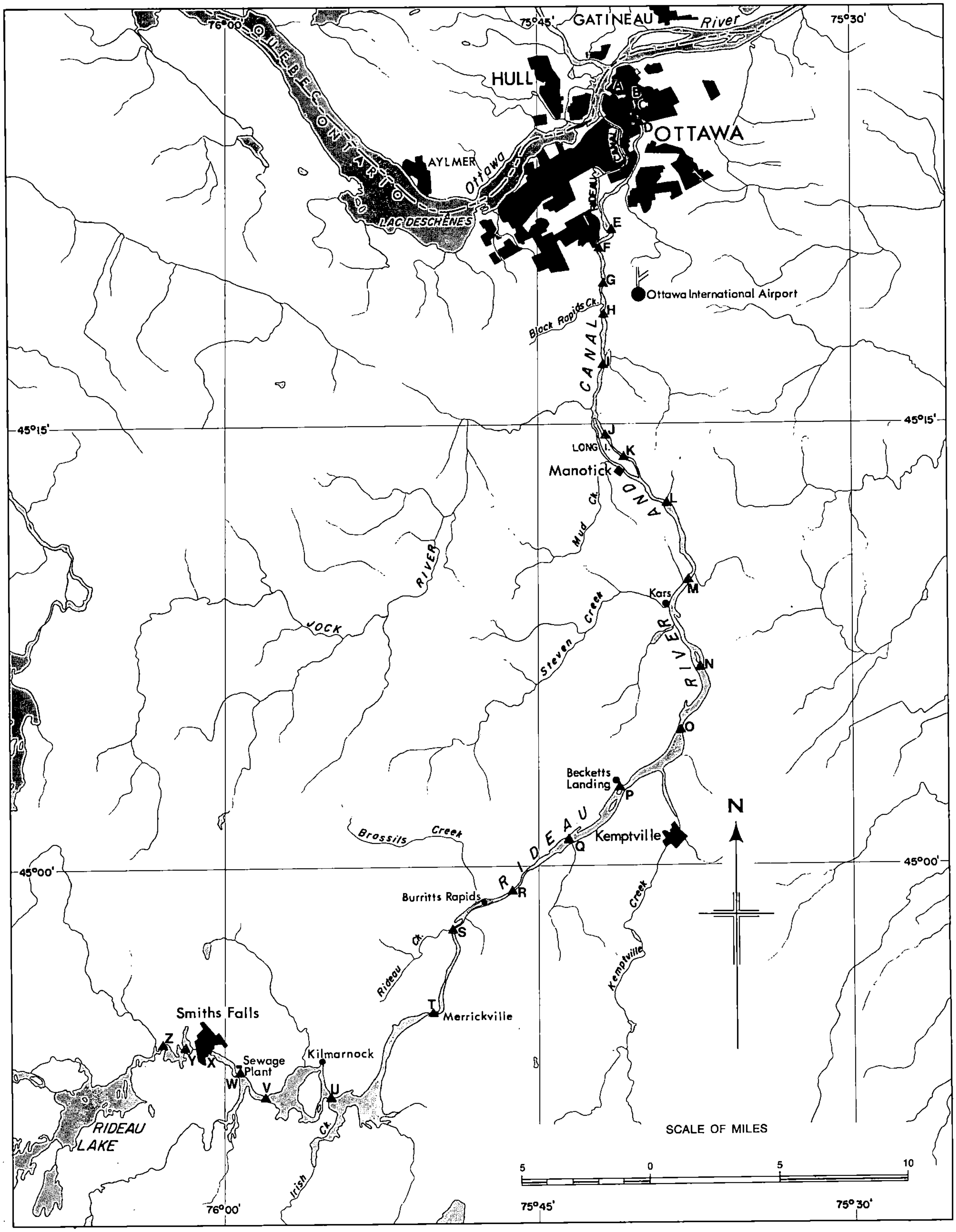

Figure 2. Sampling locations on the Rideau River.

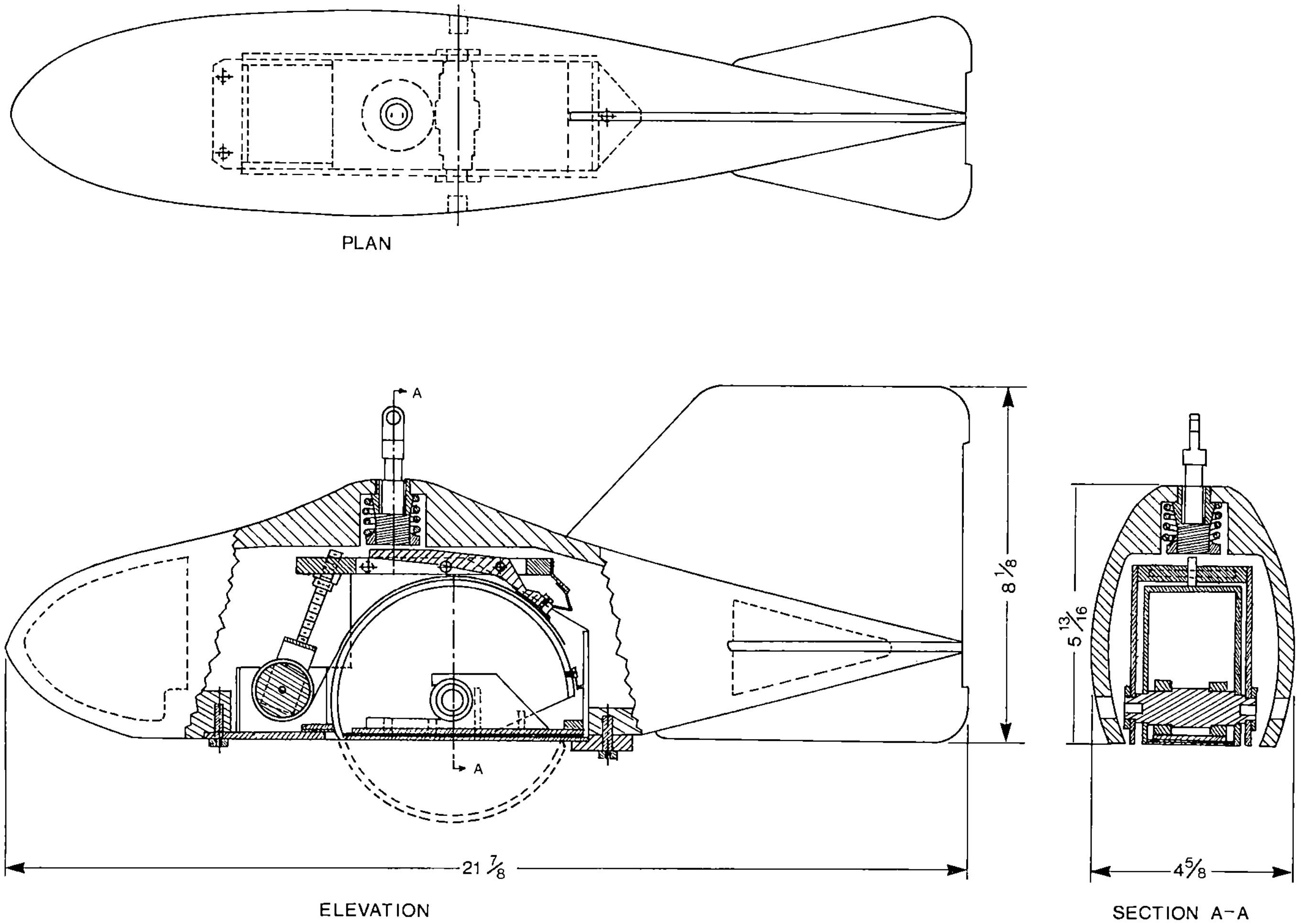

Figure 3. Bed Material Sampler, U.S. BMH-60, hand line suspension.

in Table 1. No spectral interferences are reported in the procedure manual (Analytical Methods for Atomic Absorption Spectroscopy, 1968) for these elements, and laboratory studies confirmed that this was the case. Proper standards were prepared with acid and metal concentrations approximately the same as those of the samples.

The organic content of a few selected samples was determined by the dichromate oxidation method (Atkinson et al., 1958; Peech et al., 1917). A known amount of $K_2Cr_2O_7$ was added to 0.5 g of sediment. The excess dichromate was then titrated with ferrous sulphate using barium diphenylaminesulphonate as the indicator. This method is approximate only (± 20%), but it does give an order of magnitude estimate when more sophisticated carbon analysis instrumentation is not available.

RESULTS AND DISCUSSION

In this study the analysis was performed only on the −80 mesh portion of the sediment sample rather than on a representative part of the whole sample. This procedure was recommended by Hawkes and Webb (1972), as it provides the greatest contrast between anomalously high and background levels. Also the previous study (Oliver, 1972) had shown that particle size of the sediment strongly influenced the metal content. The surface area of the sediments was measured and a definite correlation was established between this parameter and metal content. When metal concentration was plotted against surface area, the metal content increased rapidly for surface areas up to about $10 m^2/g$, then levelled off for larger surface areas. Thus, to compare the metal levels of samples with vastly different particle sizes or surface areas, it is necessary to analyze the

Table 1. Atomic Absorption Spectrophotometer Instrument Parameters and Detection Limits

Element	Wavelength Setting (mμ)	Slit Width (A)	Type of Flame	Detection Limit (ppm)	
				In Acid Extract	In Sediment
Pb	283	4	oxidizing	0.05	5
Hg	254	5	none	0.0001	0.01
Zn	214	5	oxidizing	0.01	1
Cu	325	4	oxidizing	0.01	1
Ni	232	3	oxidizing	0.05	5
Co	241	3	oxidizing	0.05	5
Fe	372	3	emission	1	100
Mn	279	4	oxidizing	0.02	2
Cr	358	3	reducing	0.01	1
Cd	229	4	oxidizing	0.01	0.05

fine portion of the sample (−80 mesh) where the surface area is greater than about 10 m^2/g.

The results of the analysis are shown in Tables 2(a) and 2(b). These tables also report the sample description, weight percent −80 mesh, and weight percent organic matter. A strong correlation exists between particle size of the sample and organic content. The finer samples contain considerably more organic matter than do the coarser samples. The correlation between the various heavy metal levels and the organic content, however, is weaker than was expected. The linear correlation coefficients between organic content and metal level are as follows: Pb, 0.36; Hg, 0.06; Zn, 0.40; Cu, 0.02; Ni, 0.20; Co, 0.24; Fe, 0.35; Mn, 0.22; Cr, 0.21. Higher correlations have been reported in the literature (Thomas, 1972).

Mean background levels for the metals were calculated as in 1971 and are presented in Table 3. Any sample containing more than three times this mean value or more

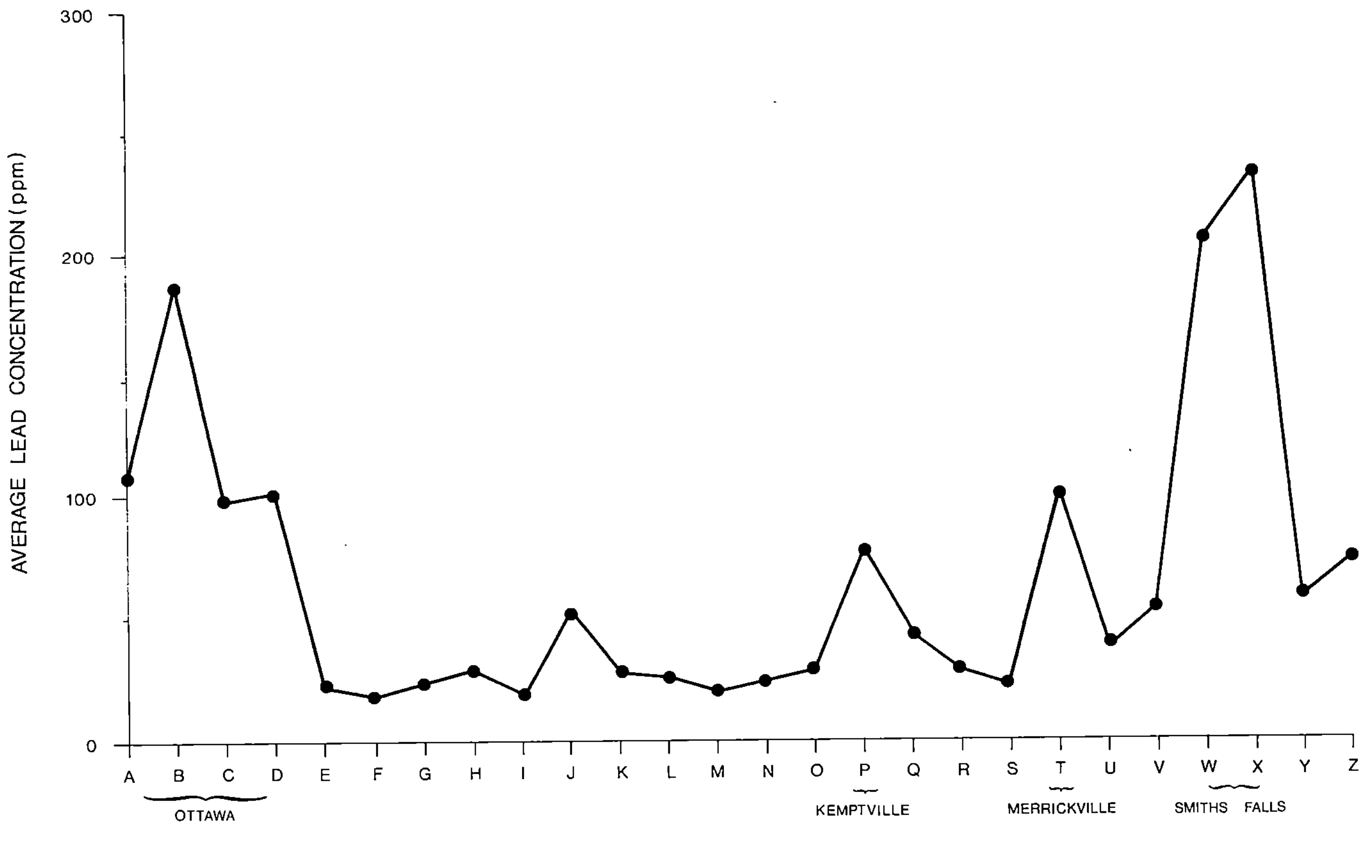

Figure 4. Average lead concentration (ppm) in Rideau River sediments *vs.* sampling location.

Table 2(a). Chemical Analyses of Ottawa and Rideau River Sediments
Ottawa River Sediments

Sample Number	Sample Description	Weight % −80 Mesh	Weight % Organic	Concentration in ppm									
				Pb	Hg	Zn	Cu	Ni	Co	Fe	Mn	Cr	Cd
−4-1	S.	96	3.2	36	0.24	172	34	5	32	41000	775	80	
−4-2	S.C.	28	1.9	44	0.18	203	39	6	33	58000	1940	111	
−4-3	S.O.	19	3.7	99	0.30	222	21	45	29	33400	972	50	
−3-1	F.S.	40		16	0.21	35	7	1	10	11900	166	10	
−3-2	S.	84		74	0.24	288	34	5	34	40000	1240	74	
−2-2	S.	86		117	0.54	287	32	45	30	40400	1181	74	
−2-3	S.	95		100	0.36	280	32	45	30	38800	1084	65	
−1-1	S.O.	96	3.0	36	0.27	93	15	2	12	18700	334	28	
−1-2	C.	100	4.7	118	0.66	333	34	5	24	41800	1307	72	
−1-3	F.S.	76	0.8	10	0.36	24	5	5	11	5600	135	2	0.15
1-1	S.O.	18		314	2.09	360	144	25	19	17700	168	27	1.15
1-2	F.S.	35		295	0.90	272	62	35	19	23800	152	45	0.60
2-1	S.O.	25		275	1.47	485	179	9	15	31500	275	114	2.40
2-3	S.O.	20		140	0.42	205	59	25	18	24700	232	38	
3-1	M.S.	14		25	0.18	53	13	15	11	14100	130	20	0.35
4-1	S.O.	87	1.6	50	0.21	117	27	30	20	26200	320	51	0.20
4-2	M.S.	1	2.3	6	0.30	30	5	10	10	10200	76	11	
4-3	S.O.	82	4.3	16	0.18	42	8	10	6	10000	93	12	
5-1	Mx.S.	10		30	0.71	81	11	10	21	23700	465	28	
5-2	F.S.O.	10		10	0.15	31	10	10	4	12500	200	10	0.20
6-1	F.M.S.O.	19	2.5	39	2.70	54	57	20	13	23800	407	14	
6-3	M.S.O.	54	2.1	12	0.12	40	3	10	17	11200	134	14	0.10
7-1	F.S.O.	12		20	0.25	47	10	10	13	13600	244	10	0.20
7-2	C.S.	1		11	0.33	16	1	10	6	10800	121	10	
8-1	M.S.O.	87		7	0.33	16	1	10	5	3600	27	2	
8-2	C.S.	1		37	0.42	109	4	18	14	18500	206	14	0.15
8-3	S.O.	60		50	0.26	183	31	50	33	38000	493	73	0.55
9-1	F.S.O.	61	5.2	20	0.33	69	15	20	22	19800	204	34	0.20
9-2	M.S.	3	0.7	18	0.27	22	0	5	2	6500	58	2	
9-3	C.S.	2	0.6	15	0.09	24	0	5	11	8700	99	8	
10-1	F.S.O.	69		6	0.09	28	5	10	13	9800	100	12	
10-2	C.S.	1		12	0.74	116	0	37	17	22900	242	22	0.15
11-1	M.S.O.	36		32	0.87	399	54	20	18	20500	172	32	
11-2	M.S.O.	34		40	0.58	383	50	35	19	32500	317	58	
11-3	S.O.	55		34	0.98	350	48	20	5	17200	153	33	0.55
12-1	F.S.O.	73	2.6	29	0.48	100	33	20	19	14400	120	18	0.20
12-2	M.C.S.	1		35	0.78	28	0	24	12	16000	154	12	
12-3	S.F.S.O.	85	2.6	11	0.29	47	8	10	20	18600	222	20	
13-1	F.S.O.	45		31	0.44	77	23	20	11	27800	133	35	0.20
13-2	C.S.	9		39	0.24	23	8	10	15	10900	89	10	
13-3	C.	27		19	0.34	139	38	70	38	58800	908	109	
14-1	F.S.O.	63		13	0.45	25	3	10	14	10500	75	12	
14-2	C.S.	1		14	0.37	50	1	10	10	12100	129	13	0.85
14-3	S.	70		66	0.87	267	45	50	34	41800	636	94	
15-3	C.	66		13	1.18	115	38	85	39	55900	918	118	0.20
16-1	F.S.O.	26	0.7	9	0.32	19	0	5	10	7200	73	6	
16-2	F.S.O.	39	1.9	15	2.16	76	8	10	15	15000	142	22	0.30
16-3	S.F.S.O.	88	1.4	28	0.49	104	17	10	11	18600	205	32	
17-3	S.F.S.O.	63		44	0.48	107	19	20	12	21200	272	38	0.15
18-1	S.O.	70		29	0.43	125	25	25	10	23900	222	37	0.50
18-3	S.	77		90	1.01	320	56	55	39	45100	663	97	
19-1	S.	66		30	1.13	135	26	40	25	39400	70	72	
19-2	F.M.S.	2		15	0.26	27	3	20	5	8300	69	9	

Key to Symbols: C - Clay
S - Silt
F.S., M.S., C.S., Mx.S. - fine, medium, coarse, and mixed particle size sand
O - Organic Matter

The designations are in the order C., S., F.S., M.S., C.S., Mx.S., O.
The only exception is when clay and silt occur together and then S.C.
is used instead of C.S,

Table 2(a). Chemical Analyses of Ottawa and Rideau River Sediments
Ottawa River Sediments (Cont'd)

Sample Number	Sample Description	Weight % −80 Mesh	Weight % Organic	Concentration in ppm									
				Pb	Hg	Zn	Cu	Ni	Co	Fe	Mn	Cr	Cd
19-3	S.F.S.O.	93		27	0.63	104	15	15	16	17900	190	33	
20-1	S.O.	89	5.0	21	0.47	107	22	25	18	28500	263	50	
20-2	F.S.	6	0.4	18	0.40	24	1	10	5	8200	94	8	
20-3	F.S.O.	89	2.8	22	1.22	75	9	20	5	16400	198	24	0.30
21-1	S.O.	80		38	0.49	135	23	30	21	25400	338	50	0.20
21-2	C.	100		14	0.35	95	25	50	24	39800	692	80	
21-3	S.O.	64		29	0.46	70	10	15	5	13800	138	22	
22-2	S.O.	78		24	0.65	63	9	20	14	16700	202	26	0.15
23-1	S.O.	98		36	0.34	166	32	45	23	37800	400	68	
23-3	S.O.	95		34	0.54	128	21	30	23	26600	304	47	
24-1	S.O.	82	2.2	18	0.35	66	12	25	7	22300	294	27	
24-2	S.C.O.	74	8.3	44	0.70	185	33	40	23	37700	402	63	
24-3	Mx.S.O.	65	2.1	18	0.52	57	8	15	17	14500	162	21	0.20
25-1	S.	82		44	0.80	230	41	40	20	43000	443	72	0.85
25-3	S.O.	61		43	0.40	164	26	35	26	34000	320	61	
26-1	S.	73		59	0.73	270	49	55	27	45000	530	84	0.90
26-2	S.	77		67	0.75	258	42	45	27	46000	589	88	
26-3	S.C.	73		56	0.64	223	37	60	37	52500	772	104	
27-1	S.C.O.	17		7	0.26	42	3	0	9	10600	113	7	
27-2	S.F.M.S.	18		48	0.77	210	35	50	22	45000	456	76	0.60
27-3	S.C.	71		29	0.30	132	31	50	35	43700	533	88	
28-1	F.S.O.	94		13	0.20	112	17	40	36	33000	547	64	
28-2	S.	79		29	0.44	248	38	65	32	49800	786	100	
28-3	S.O.	98		70	0.17	97	15	15	7	24800	400	28	
29-1	S.	91		32	0.26	145	22	20	18	30000	378	42	
29-2	C.	49		55	0.29	123	31	40	26	40400	463	76	
29-3	F.M.S.O.	23		58	0.39	101	27	20	14	23800	306	37	0.20
30-1	S.O.	89	6.1	36	0.29	173	25	30	18	33300	566	49	
30-2	Mx.S.O.	33	5.4	23	0.23	65	12	20	10	15200	123	27	
30-3	Mx.S.O.	25	4.0	142	1.56	158	92	20	12	17300	132	24	0.60
31-1	S.F.S.O.	78		40	0.40	192	27	20	15	31800	427	52	
31-2	S.	92		33	0.26	173	23	35	24	31100	388	52	
31-3	S.O.	76		39	0.25	153	27	40	21	32400	341	62	0.55
32-1	S.O.	70		47	0.49	205	36	40	26	39500	395	72	
32-3	S.O.	82		55	0.29	123	20	30	18	29000	288	54	0.50
33-1	S.	29		55	0.40	225	35	45	26	44500	631	82	0.60
33-3	S.C.	55		44	0.28	98	21	45	22	87000	637	44	

Table 2(b). Chemical Analyses of Ottawa and Rideau River Sediments
Rideau River Sediments

Sample Number	Sample Description	Weight % −80 Mesh	Weight % Organic	Concentration in ppm									
				Pb	Hg	Zn	Cu	Ni	Co	Fe	Mn	Cr	Cd
A-1	F.S.O.	65		33	0.26	42	14	15	5	18700	285	20	
A-2	F.S.O.	69		72	0.34	61	19	15	17	25500	266	22	
A-3	M.C.S.	19		215	0.43	81	24	20	14	39900	258	22	
B-1	S.F.S.	59		78	0.36	122	96	15	11	19700	227	19	
B-3	S.O.	80		295	0.53	670	121	35	21	34400	415	56	1.00
C-2	C.S.	3		98	0.18	34	5	20	5	20200	410	18	
D-1	S.O.	43		98	0.27	128	16	20	18	24500	207	29	
D-2	F.S.	39		26	0.23	35	14	10	13	18200	225	18	
D-3	S.F.S.O.	56		183	0.39	113	17	20	13	29300	297	33	0.55

Table 2(b). Chemical Analyses of Ottawa and Rideau River Sediments
Rideau River Sediments (Cont'd)

Sample Number	Sample Description	Weight % -80 Mesh	Weight % Organic	Concentration in ppm									
				Pb	Hg	Zn	Cu	Ni	Co	Fe	Mn	Cr	Cd
E-1	Mx.S.	14		33	0.35	21	4	10	6	18400	195	20	
E-2	M.C.S.	26		8	0.33	28	1	10	10	16500	252	20	0.15
E-3	F.S.O.	81		25	0.26	44	9	10	9	22200	352	27	
F-1	C.	84	1.0	15	0.26	75	23	45	32	35500	562	79	0.15
F-2	M.S.	2	1.8	23	0.20	25	6	10	8	33800	328	26	
F-3	F.S.	71	1.7	17	0.12	18	0	10	10	10400	121	10	
G-1	S.	71		22	0.20	34	9	20	10	28600	313	28	0.15
G-2	C.S.	13		31	0.33	24	7	10	20	23300	172	27	
G-3	M.S.O.	48		15	0.28	16	0	10	4	9600	113	14	
H-1	C.	43		35	0.42	108	28	35	24	50000	776	70	
H-2	S.	60		26	0.27	84	14	20	19	29800	572	43	
H-3	S.O.	51		26	0.20	80	10	15	15	26500	576	40	0.40
I-1	S.	52		24	0.27	75	9	20	18	26000	459	43	0.30
I-2	S.	98		12	0.25	62	11	30	21	39800	458	42	
I-3	S.	88		20	0.28	80	12	30	14	28700	722	46	
J-1	C.	100	12.4	70	0.33	175	24	40	30	41200	1270	70	
J-2	S.O.	70	23.5	61	0.30	150	20	30	26	36900	1795	57	0.55
J-3	S.	66	4.7	28	0.23	80	15	30	19	34200	575	53	0.22
K-1	C.S.	7		21	0.35	16	23	10	7	16600	198	12	0.20
K-3	C.	27		34	0.18	81	20	30	32	58600	601	62	
L-1	S.O.	73		42	0.48	94	12	20	15	25000	609	41	
L-2	F.S.O.	59		12	0.20	30	0	10	18	12300	293	14	0.10
L-3	S.O.	60		25	0.37	83	10	25	21	31800	847	45	
M-1	S.O.	80	6.2	29	0.47	102	15	30	21	36800	741	52	0.40
M-2	S.F.S.	16	2.9	6	0.21	31	0	15	9	14000	340	13	
M-3	S.O.	79	10.4	24	0.22	74	14	20	24	33600	567	41	
N-1	F.S.O.	73		12	0.18	28	1	20	7	9600	167	13	
N-2	S.O.	36		34	0.23	105	19	25	15	29900	1037	42	
N-3	S.O.	59		27	0.36	80	13	20	24	25600	481	35	0.50
O-1	S.O.	52		25	0.28	73	9	25	14	20200	505	25	
O-2	S.O.	57		40	0.37	127	19	20	18	31200	947	47	0.70
O-3	S.F.S.O.	76		23	0.15	57	2	10	16	14100	274	20	
P-1	S.O.	86	15.3	35	0.32	105	12	25	18	26700	555	40	0.40
P-2	S.	74	21.8	42	0.24	104	17	35	25	34200	648	56	
P-3	F.S.O.	50	14.6	158	0.22	65	2	10	11	21600	270	19	
Q-1	S.O.	78		40	0.34	106	12	20	21	32400	595	42	0.55
Q-2	S.F.S.	75		52	0.37	118	16	30	21	37200	502	45	
Q-3	S.O.	45		34	0.32	139	21	25	17	39600	512	56	
R-1	S.O.	71		25	0.19	82	6	25	21	29600	365	35	
R-2	F.S.O.	10		16	0.25	43	2	10	7	26800	248	16	
R-3	S.O.	82		42	0.35	104	12	20	20	32800	462	41	
S-1	S.O.	70	7.4	26	0.27	85	15	20	12	29800	475	40	
S-3	S.F.S.O.	48	7.0	17	0.29	81	14	30	27	39500	477	48	
T-1	S.O.	80	8.7	80	0.36	197	29	40	19	35900	769	56	
T-2	S.O.	78		156	0.66	570	57	135	18	39900	717	138	
T-3	Mx.S.	7		70	0.34	140	2500	10	7	29000	418	32	
U-1	S.O.	57		25	0.43	45	7	0	18	13900	224	16	
U-2	S.O.	45		64	0.85	220	37	30	20	27800	1339	47	0.40
U-3	S.O.	30		22	0.33	84	16	10	12	22200	585	31	
V-1	S.O.	63	23.5	65	0.59	211	25	15	20	24200	500	41	
V-2	S.F.S.	36	21.0	42	0.53	105	8	0	15	17100	255	19	
V-3	S.F.S.O.	28	15.2	54	0.60	327	14	10	15	38400	473	33	
W-1	S.O.	48		190	1.69	327	102	15	16	22500	180	63	0.90
W-2	S.O.	67		157	1.31	345	54	40	18	30800	379	57	
W-3	S.O.	30		270	1.05	370	54	45	19	40500	302	58	
X-1	Mx.S.	23		150	0.46	138	37	10	15	58700	4000	74	
X-3	S.F.S.O.	74		317	0.89	325	37	10	19	37900	413	32	0.90
Y-3	S.O.	58		77	0.38	98	13	15	10	20000	449	27	0.75
Z-3	S.F.S.	73		63	0.30	59	7	15	12	27000	363	20	0.35

than the mean plus twice the standard deviation is said to be "anomalous". As in 1971, samples collected downstream from the pulp and paper mills in the Ottawa River contained high amounts of mercury (2.09 ppm, 1.47, and 2.70). As the use of mercury slimicides by the industry was discontinued in the spring of 1971, these values indicate that mercury will be a long-term hazard to the river environment.

Table 3. Mean Background Concentration of Absorbed and Precipitated Heavy Metals in the −80 Mesh Fraction of Ottawa and Rideau River Sediments

Heavy Metal	Mean Concentration (ppm)	
	Ottawa River	Rideau River
Pb	46	62
Hg	0.53	0.38
Zn	138	118
Cu	26	20
Ni	26	22
Co	19	16
Fe	26800	28500
Mn	373	534
Cr	44	38
Cd	0.45	0.46

An interesting plot of average lead concentration versus sample location on the Rideau River is shown in Figure 4. The Rideau River is fairly small and the graph indicates how sensitive the river is to lead discharge. It shows a jump in lead levels in the city of Smiths Fall, the village of Merrickville, the town of Kemptville, and finally in the city of Ottawa. Lead levels are particularly high in Smiths Falls and Ottawa because of discharge from storm and sanitary sewers, and from snow-dumping operations near the river.

In the 1971 study (Oliver and Kinrade, 1972; Oliver, 1972), exceedingly high lead sediment levels (336 and 1344 ppm) were measured at a river snow dump. An extensive study on the content of lead in snow and snowmelt, carried out in the winter of 1971-72 (LaBarre et al., 1971; Oliver et al., in press), revealed that this accumulation of lead in the sediments was due to particulate form of lead in snow. When the snow is dumped directly into the river, the particulate simply sinks to the bottom, becoming part of the sediment. The snow study showed also that runoff from snow disposal sites contained only about 1% of the lead burden in the snow site. The rest of the lead remained in the soil at the site. In the fall of 1971, the Ontario Ministry of the Environment recommended that snow-disposal sites be located at least 100 ft away from watercourses. As a result of this recommendation, the city of Ottawa did not dump any snow into the Rideau River during the winter of 1971-1972. This had the immediate effect of reducing the amount of lead in the sediments from the 336 – 1315 ppm range in 1971 to the 100 – 200 ppm range in 1972. Clearly the amount of lead finding its way into the river was significantly reduced by improved snow-disposal practices.

Again in 1972, high levels of heavy metals were found in sediments downstream from sewage outfalls. Near the Smiths Falls primary sewage treatment plant outfall (sample site W-1, 2, 3), elevated levels were found for several metals: Pb, 206 ppm; Hg, 1.35; Zn, 347; Cu, 70. A sample collected at the mouth of Brewery Creek (2-1), which receives the drainage from six sanitary sewers in Hull contained high levels of Pb (275 ppm), Hg (1.47 ppm), Zn (485 ppm), Cu (179 ppm), Cr (114 ppm), and Cd (2.4 ppm). At a storm and combined sewer outfall in Hawkesbury (30-3), elevated levels were found for Pb (142 ppm), Hg (1.56 ppm), and Cu (92 ppm). Currently a research project on heavy metals in sewage treatment systems is underway in the Water and Wastewater Treatment Research Subdivision at the Canada Centre for Inland Waters in Burlington (B. G. Oliver). Preliminary indications are that a significant portion of metals entering the sewage system is removed by the conventional activated sludge secondary treatment and to a lesser extent by primary treatment. However, some of the heavy metals do find their way into the watercourse. Improved sewage treatment methods are required, especially when metallic industrial wastes are being discharged in large quantities to the sewer system.

One problem area that did not show up in the 1971 study, but that was quite apparent in the 1972 study, was Merrickville on the Rideau River. The samples (T-1, 2, 3 in Table 2(b)) collected in this location showed high levels of Pb, Zn, Cu, Ni, and Cr. In the past, untreated waste from two metal plating industries in the village were discharged directly into the river. Now apparently these industries are required to treat their wastewater to conform to the guidelines specified by the province of Ontario, which should improve the situation.

Cadmium analysis was performed on fifty-four samples to determine the cadmium levels of the sediments. The mean cadmium level in the river was 0.45 ppm. Only one sample (2-1 in Table 2(a)), collected at the mouth of Brewery Creek, contained an anomalously high amount of Cd (2.4 ppm). Cadmium is an extremely toxic element. It is important, therefore, to keep cadmium discharges into watercourses to a minimum.

REFERENCES

Analytical Methods for Atomic Absorption Spectroscopy, 1968. Perkin-Elmer Corporation, Norwalk, Connecticut.

Atkinson, H. J., G. R. Giles, A. J. MacLean, and J. R. Wright. 1958. Contribution No. 169, Chemistry Division — Science Service, Canada Department of Agriculture, Ottawa, Ontario.

Hatch, W. R., and W. L. Ott. 1968. Anal. Chem., 40, 2085.

Hawkes, H. E., and J. S. Webb. 1972. *Geochemistry in Mineral Exploration.* Harper and Row, New York, N.Y.

LaBarre, N., J. B. Milne, and B. G. Oliver. 1973. Water Research, 7, 1215.

Oliver, Barry G. 1972. Environ. Sci. Technol., 6, 274.

Oliver, B. G., and J. Kinrade. 1972. Inland Waters Branch, Department of the Environment, Ottawa, Ontario, Scientific Series No. 14.

Oliver, Barry G., John B. Milne, and Norman LaBarre. In press. J. Water Poll. Control Fed.

Peech, M., L. T. Alexander, L. A. Dean, and J. F. Reed. 1917. U. S. Department of Agriculture, Circ. 757.

Thomas, R. L. 1972. Can. J. Earth Sci., 9, 636.