



Status of substances of emerging concern in bottom sediments and suspended sediments in the St. Lawrence

This fact sheet is intended to complement the document entitled “Les contaminants organiques d’intérêt émergent : une préoccupation pour les écosystèmes d’eau douce du Québec” (Desrosiers et al., in prep.).

In 2008, the St. Lawrence River component of Environment and Climate Change Canada’s (ECCC) Water Quality Monitoring and Surveillance Section made a commitment to provide scientific support to the Chemicals Management Plan (CMP). The CMP is a federal government initiative aimed at reducing the risks posed by chemicals to Canadians and their environment. This support generated a significant amount of funding, which, in conjunction with financial support from the St. Lawrence Action Plan (SLAP), made it possible to provide an initial portrait of substances of emerging interest in sediments and suspended sediments in the St. Lawrence River from samples collected in sediment traps.

The results presented in this monitoring sheet focus mainly on the fluvial lakes, the fluvial section of the St. Lawrence and the Quebec City area. All the samples were collected between 2008 and 2018 during sediment quality monitoring campaigns as well as monitoring projects carried out in collaboration with ECCC’s Environmental Protection Operations Directorate and the Centre d’expertise en analyse environnementale du Québec (CEAEQ) of the Quebec Department of Environment and the Fight Against Climate Change (MELCC). The analytical results for suspended sediment come from the Montreal multimedia site. The multimedia site consists of eight sampling stations distributed along the Montreal effluent dispersion plume. Bottom sediment, suspended sediment and fish and macroinvertebrate samples were collected from most of these stations between 2012 and 2014.

The results are presented by substance or group of substances, and all the data can be consulted in, or obtained from, the ECCC sediment database. The data are displayed on colour maps, when sufficient in number, or as coloured dots in other cases. The different colour levels were established by taking into account the federal environmental quality guidelines for sediment. For example, the colour yellow represents the central value for polybrominated diphenyl ethers (PBDEs) and bisphenol A, whereas for the other substances, the colour yellow represents the 70th percentile of each distribution.

The colour orange represents double the central value and the colour red quadruple this central value. The colour green represents a half and blue represents one quarter. It should be noted that suspended sediments are illustrated in a graph above a map that shows the locations where they were collected. Colour coding does not apply, since there are no environmental quality guidelines for suspended sediment and the number of analyses performed is insufficient to define levels of contamination on the basis of percentiles.

Triclosan

Triclosan, an antibacterial agent that is used in hand sanitizers, falls in the category of pharmaceuticals and personal care products (PPCP), a group for which sediment quality guidelines have not yet been developed.

This substance is present at concentrations of up to 130 ng/g in sediments in Lake Saint-Pierre as well as the fluvial section, in the Contrecoeur area and near Sainte-Thérèse Island. Elevated levels are associated with urban effluents from Montreal and Contrecoeur.

An extremely high level of triclosan (2,000 ng/g) was measured in suspended sediments near Montreal's wastewater treatment plant outfall, with concentrations decreasing rapidly downstream from there (maximum concentration of 150 ng/g).

Sediment cores collected around the Boucherville Islands and in Lake Saint-Pierre show that concentrations have increased since the mid-2000s, reaching 20 ng/g in Lake Saint-Pierre and 6 ng/g in the Boucherville Islands around 2008.

While methyl-triclosan is not found at levels of concern, monitoring may be required in the future.

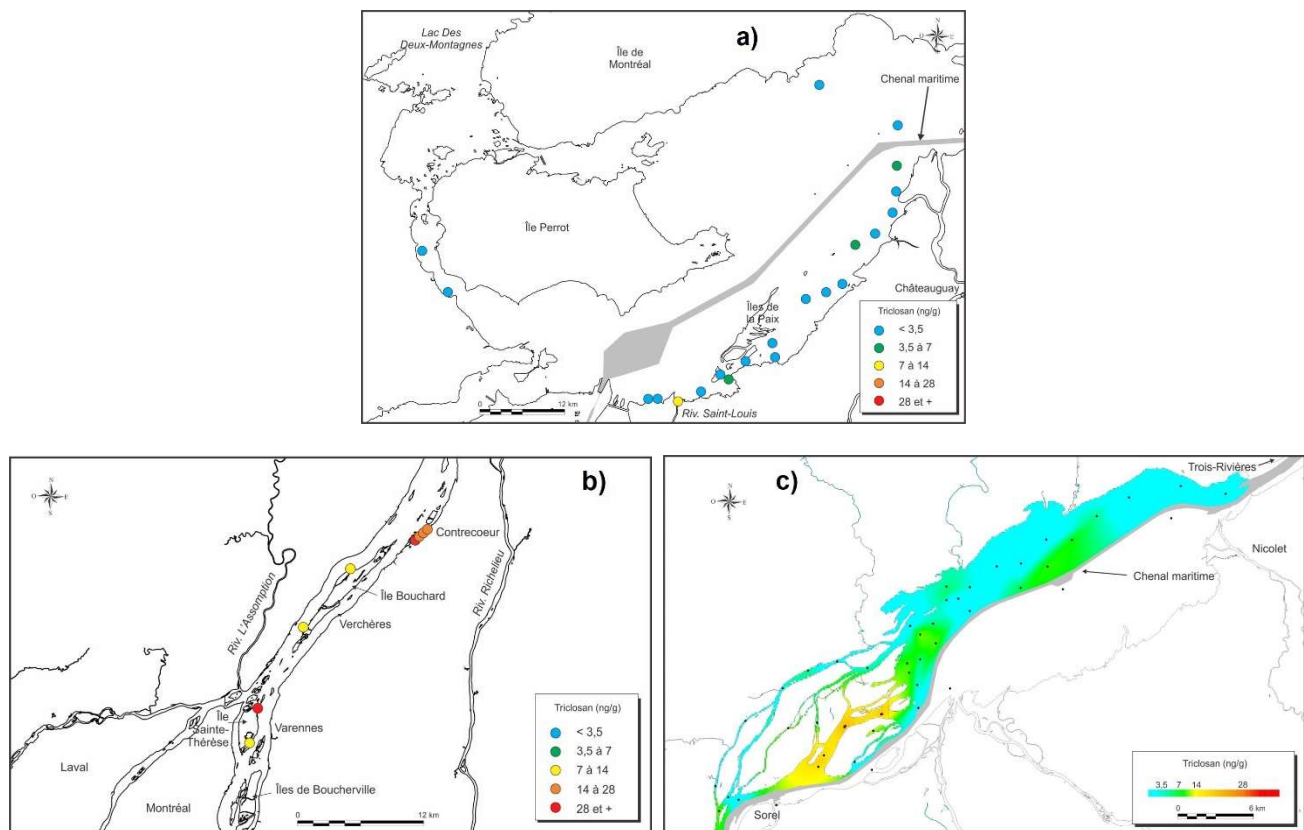


Figure 1: Distribution of triclosan concentrations in bottom sediments in Lake Saint-Louis (a), the fluvial section (b) and Lake Saint-Pierre (c).

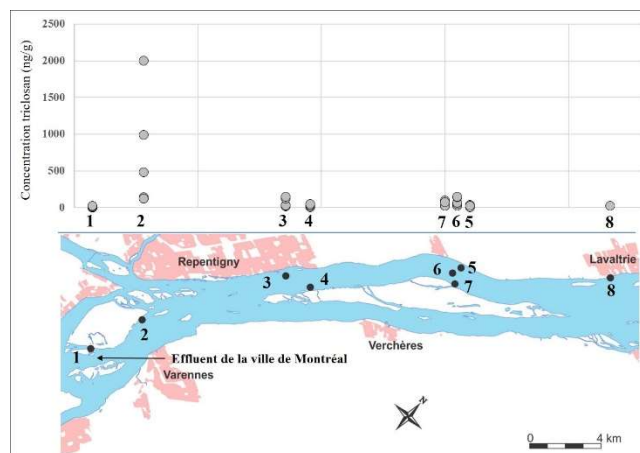


Figure 2: Distribution of triclosan concentrations in suspended sediments at the Montreal multimedia site.

Table 1. Basic statistical data for triclosan and methyl-triclosan

Substance	Material	Number of samples analyzed	% detection	Minimum (ng/g)	Mean (ng/g)	Standard deviation (ng/g)	Maximum (ng/g)
Triclosan	Bottom sediments	77	73	< 1	7.8	16.9	130
	Suspended sediments	37	97	< 1	139.2	359.6	2,000
Methyl-triclosan	Bottom sediments	77	16	< 2	< 2	2.9	22
	Suspended sediments	37	62	< 2	7.5	7.5	24

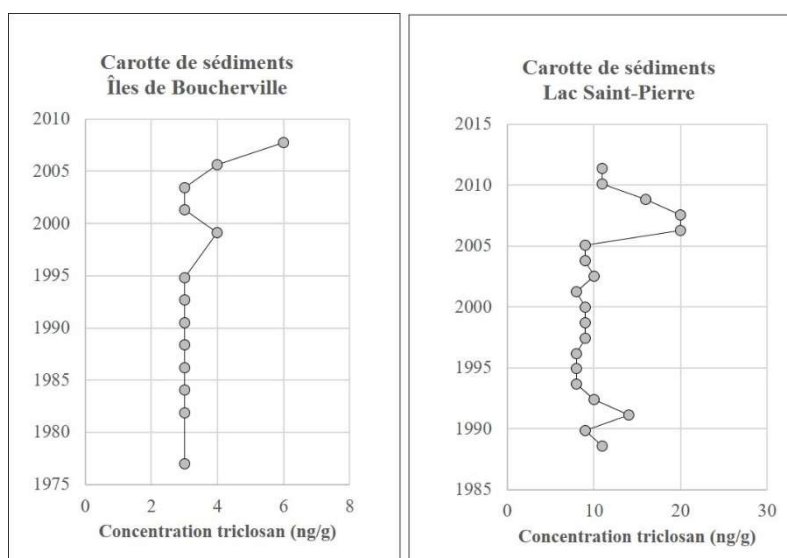


Figure 3: Triclosan profiles in sediment cores from the Boucherville Islands (-73,4898: 45,5927) and Lake Saint-Pierre (- 72,9726: 46,1339).

Triclocarban

Like triclosan, triclocarban is used in disinfectant products. There is no sediment quality guideline for this substance; it shows a stronger affinity for particles than triclosan (higher $\log K_{ow}$). Triclocarban is found in bottom sediments, mainly in Lake Saint-Pierre, with a maximum concentration of 72 ng/g measured between the Sorel and Berthier Islands, in the effluent dispersion plume from Montreal. The maximum concentration in Lake Saint-Louis (21 ng/g) was measured near the mouth of the Saint-Louis River.

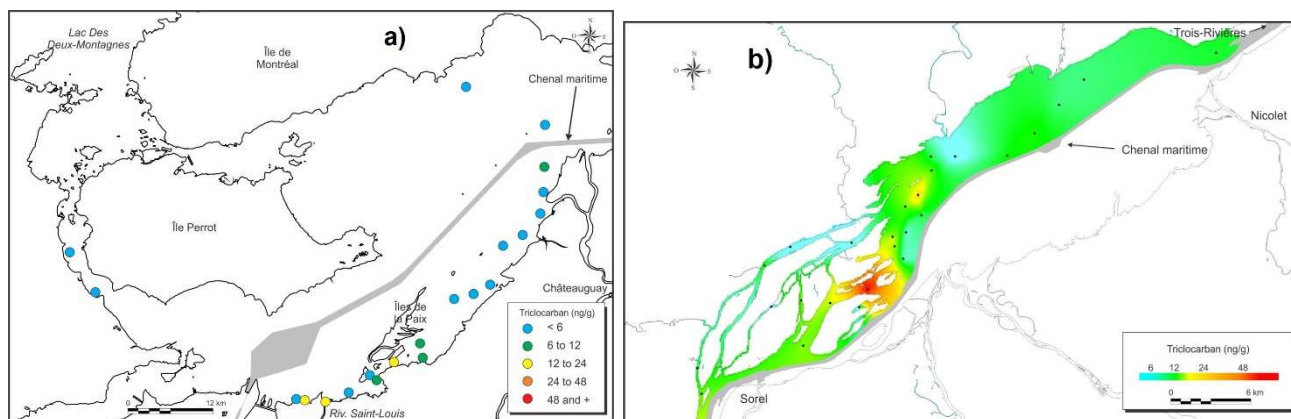


Figure 4: Distribution of triclocarban concentrations in bottom sediments in Lake Saint-Louis (a) and Lake Saint-Pierre (b).

Table 2. Basic statistical data for triclocarban

Substance	Material	Number of samples analyzed	% detection	Minimum (ng/g)	Mean (ng/g)	Standard deviation (ng/g)	Maximum (ng/g)
Triclocarban	Bottom sediments	49	92	< 1	10.7	11.5	72.0

Nonylphenol and its ethoxylates

Nonylphenol and its ethoxylates are used as detergents, emulsifiers, wetting agents and dispersing agents. The sediment quality guideline value for these substances is 1,400 ng/g (CCME, 2002). Exploratory sampling of bottom sediments was carried out at Princeville, Berthierville, Saint-Victor and Saint-Joseph-de-Beauce. Four different nonylphenols were analyzed (Table 3). All the samples had detectable concentrations of 4-nonylphenol, with the highest level (496 ng/g) measured at Berthierville. One nonylphenol, specifically 4-nonylphenol monoethoxylate, was detected on two occasions at Princeville. The other two nonylphenols (4-nonylphenol diethoxylate and 4-n-octylphenol) were not detected.

Table 3. Basic statistical data for nonylphenol and its ethoxylates

Substance	Material	Number of samples analyzed	% detection	Minimum (ng/g)	Mean (ng/g)	Standard deviation (ng/g)	Maximum (ng/g)
4-nonylphenol	Bottom sediments	8	100	0.9	118	189	496
4-nonylphenol monoethoxylate	Bottom sediments	8	25	<MDL*	7	15	43
4-nonylphenol diethoxylate	Bottom sediments	8	0	<MDL	-	-	-
4-n-octylphenol	Bottom sediments	8	0	<MDL	-	-	-

* <MDL: Below the method detection limit

Perfluorinated substances

Perfluorinated substances were used historically as water, oil and soil repellents in many consumer products. Analyses were conducted for 13 of these substances (N-Et PFOSA, N-Me PFOSA, PFOSA, FDUEA, FOUEA, FHUEA, PFuDA, PFDA, PFNA, PFOA, PFDS, PFOS and PFHxS) on 18 samples from the fluvial section and 10 samples from Lake Saint-Pierre. Only PFOS (perfluorooctane sulfonate) was detected—on two occasions in Lake Saint-Pierre and on three occasions in the fluvial section. A maximum concentration of 0.4 ng/g was observed in Lake Saint-Pierre and a maximum concentration of 0.8 ng/g in the fluvial section.

Bisphenols

Bisphenol A (BPA) has been used as an additive in plastics manufacturing since 1957. Bisphenol S and F have been used increasingly in a variety of manufacturing processes since 2008. The federal sediment quality guideline for BPA is 25 ng/g (ECCC, 2018). BPA is the bisphenol that is most frequently detected in both sediments and suspended sediments. In general, its presence has been linked to urban effluents.

The highest levels in sediments were observed at the mouth of the Saint-Louis River (18 ng/g), in the Contrecoeur area (32 ng/g), and in the middle of Lake Saint-Pierre (33 ng/g). The highest concentration (97 ng/g) in suspended sediments was measured near the Montreal wastewater outfall. Lastly, a sediment core collected from the Boucherville Islands shows an increase in concentrations since the early 2000s, reaching a level of 50 ng/g in 2008.

Bisphenol S and F are more often detected in suspended sediments than in sediments with levels of 55 ng/g measured near Montreal's wastewater outfall.

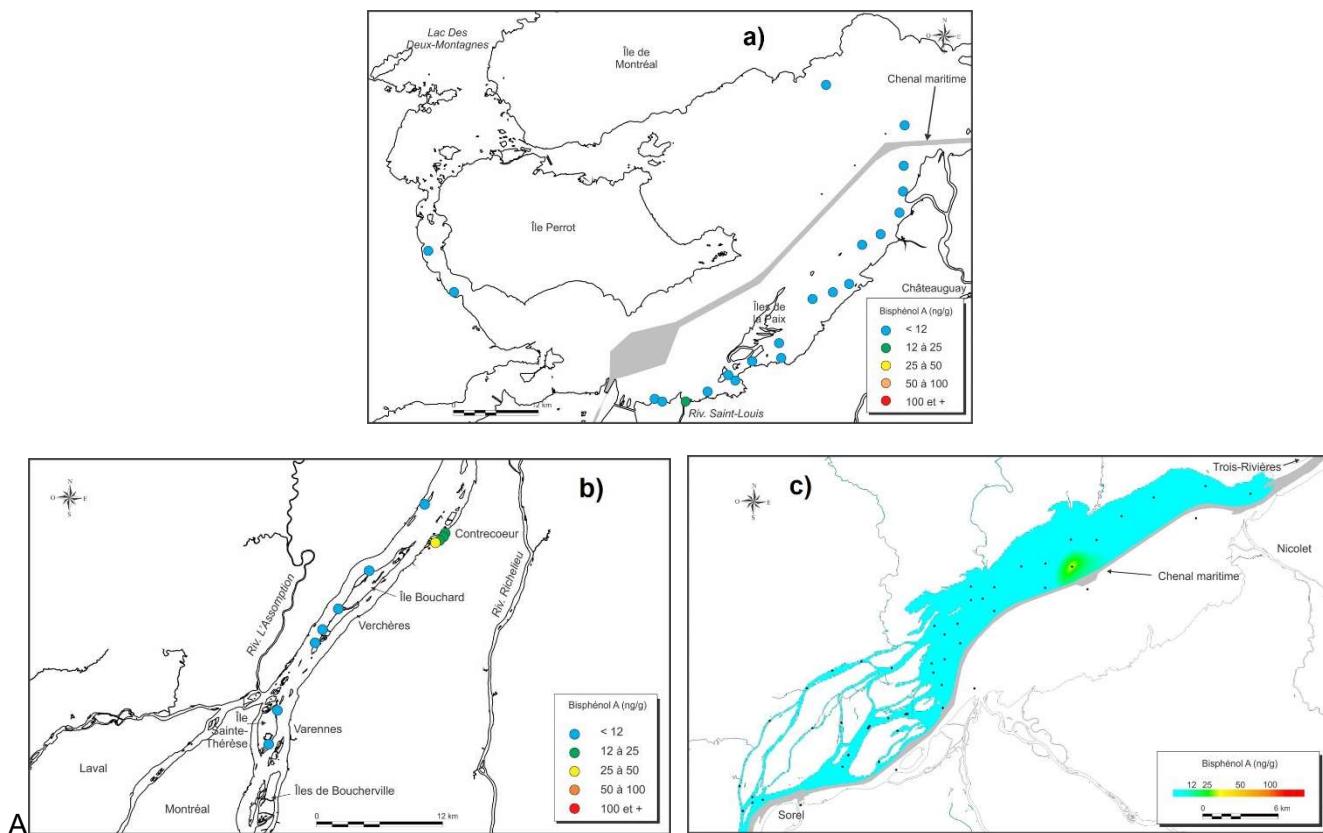


Figure 5: Distribution of bisphenol A concentrations in bottom sediments in Lake Saint-Louis (a), the fluvial section (b) and Lake Saint-Pierre (c).

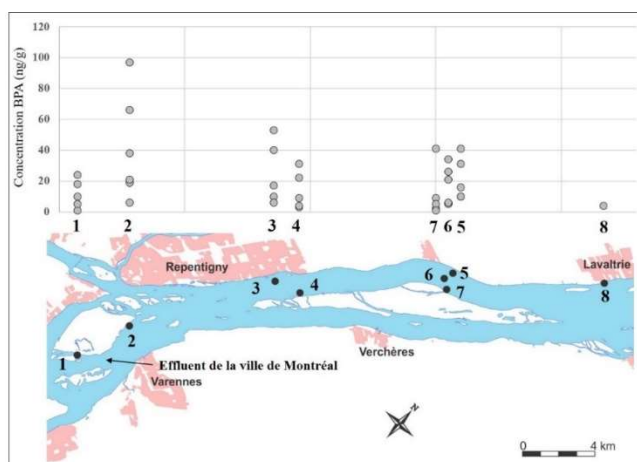


Figure 6: Distribution of bisphenol A (BPA) concentrations in suspended sediments at the Montreal multimedia site.

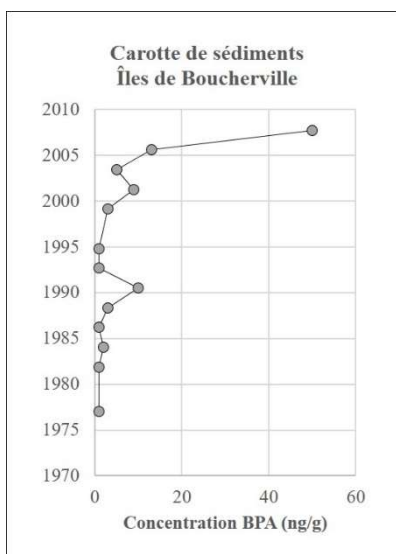


Figure 7: FiBPA profile in a sediment core from the Boucherville Islands (-73,4898: 45,5927).

Table 4. Basic statistical data for bisphenols

Substance	Material	Number of samples analyzed	% detection	Minimum (ng/g)	Mean (ng/g)	Standard deviation (ng/g)	Maximum (ng/g)
BPA	Bottom sediments	86	43	<2	4.3	6.3	33
	Bottom sediments	37	95	<2	20.6	20.4	97
BPF	Bottom sediments	78	12	<2	<2	2.8	22
	Bottom sediments	37	49	<2	6.7	11.7	55
BPS	Bottom sediments	78	0	<2	-	-	-
	Bottom sediments	37	14	<2	2.8	8.9	55

Siloxanes

Siloxanes are used in cosmetics to soften, smooth and moisten. Siloxane D5 is the most abundant siloxane in sediments and suspended sediments, followed by D4 and D6. These substances are mainly associated with urban effluents such as wastewater from Montreal.

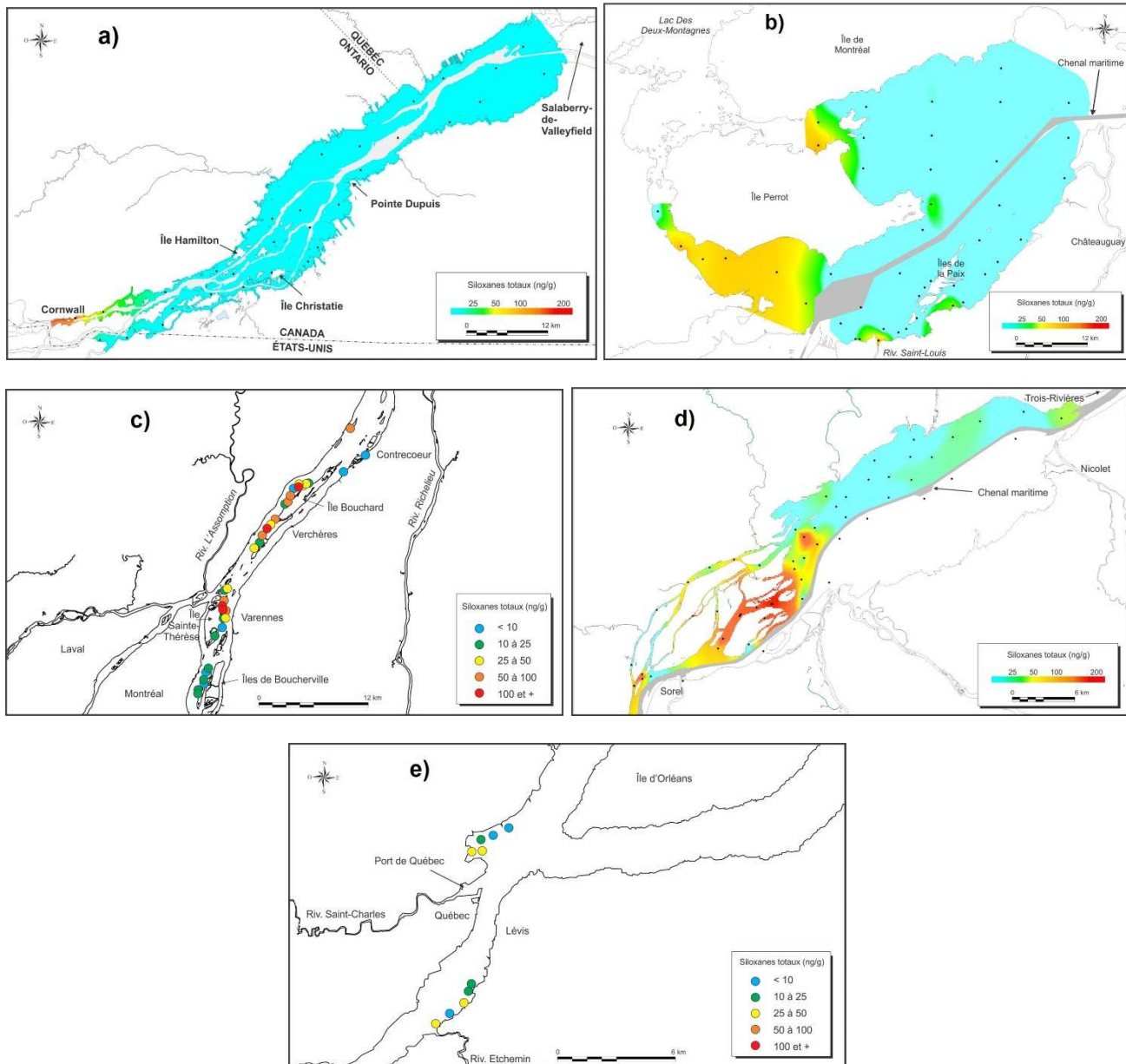


Figure 8: Distribution of concentrations of total siloxanes in bottom sediments in Lake Saint-François (a), Lake Saint-Louis (b), the fluvial section (c), Lake Saint-Pierre (d) and the Quebec City region (e).

Elevated levels of siloxane exceeding 25 ng/g and sometimes 100 ng/g were measured in all bottom sediment samples in the following areas: downstream of Cornwall, on either side of Île Perrot downstream of Vaudreuil-Dorion, in the fluvial section downstream of Montreal's wastewater outfall, downstream of Contrecoeur, between the Berthier and Sorel Islands, and in the Quebec City area.

The highest concentration (654 ng/g) was measured near Montreal's effluent plume and consisted of 83% siloxane D5. Very high levels, specifically 436 ng/g and 277 ng/g, were also observed off the northwestern part of Bouchard Island. Unlike the case for BPA, the levels of siloxanes in the Contrecoeur area appear not to be of concern. Elevated concentrations were also found in the upstream part of Lake Saint-Pierre; more specifically, levels exceeding 200 ng/g were measured in six samples collected between the Berthier and Sorel Islands. The highest concentration (516 ng/g) was detected north of Île de Grâce.

Suspended sediment collected from the Montreal multimedia site is affected by effluents, with siloxane concentrations varying between 1,230 ng/g and 4,367 ng/g a few kilometres from the wastewater discharge point, and between 600 ng/g and 1,000 ng/g more than 20 km farther downstream. At both locations, D5 accounts for 80% of the total concentrations and D6 for 17%.

The sediment cores collected in Lake Saint-Pierre and in the Boucherville Islands area have similar profiles; they show that concentrations began increasing in the late 1900s and peaked at 278 ng/g and 65 ng/g in 2006 and 2003, respectively. A sharp decrease in the concentrations is subsequently observed leading up to the 2010s.

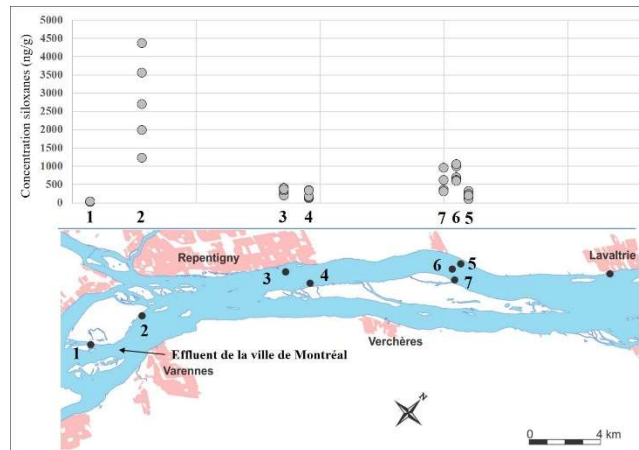


Figure 9: Distribution of siloxane concentrations in suspended sediments at the Montreal multimedia site.

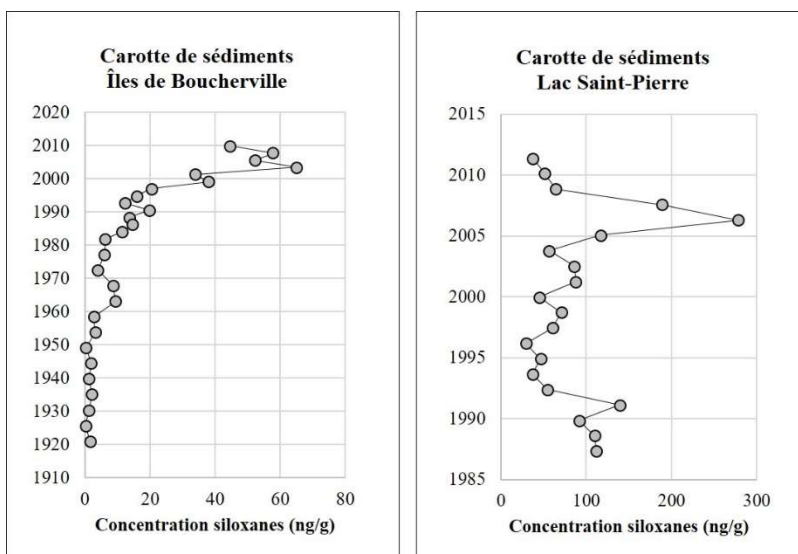


Figure 10: Profile of siloxanes in sediment cores from the Boucherville Islands (-73,4898: 45,5927) and Lake Saint-Pierre (-72,9726: 46,1339).

Tableau 5. Basic statistical data for siloxanes

Substance	Material	Number of samples analyzed	% detection	Minimum (ng/g)	Mean (ng/g)	Standard deviation (ng/g)	Maximum (ng/g)
Total siloxanes	Bottom sediments	182	74	<MDL	41	85	654
	Suspended sediments	34	100	22	714	1.004	4.367
Hexamethylcyclotrisiloxane (D3)	Bottom sediments	170	1	<MDL	-	-	1.8
	Suspended sediments	34	0	<MDL	-	-	-
Octamethylcyclotetrasiloxane (D4)	Bottom sediments	182	14	<MDL	1.7	3.5	26
	Suspended sediments	34	85	<MDL	17	24	97
Decamethylcyclopentasiloxane (D5)	Bottom sediments	182	67	<MDL	33	67	540
	Suspended sediments	34	100	18	561	771	3.300
Dodecamethylcyclohexasiloxane (D6)	Bottom sediments	182	42	<MDL	7.4	18	150
	Suspended sediments	34	100	4	126	199	950
Hexamethyldisiloxane (L2)	Bottom sediments	170	8	<MDL	1.1	0.5	4.4
	Suspended sediments	34	0	<MDL	-	-	-
Octamethyltrisiloxane (L3)	Bottom sediments	170	3	<MDL	<MDL	-	2.7
	Suspended sediments	34	0	<MDL	-	-	-
Decamethyltetrasiloxane (L4)	Bottom sediments	170	1	<MDL	<MDL	-	3.6
	Suspended sediments	34	18	<MDL	2.0	2.5	11
Dodecamethylpentasiloxane (L5)	Bottom sediments	170	4	<MDL	1.1	0.6	7.2
	Suspended sediments	34	68	<MDL	9.0	17	91
Tetrakis(trimethylsiloxy)silane (M4Q)	Bottom sediments	170	2	<MDL	<MDL	-	5.2
	Suspended sediments	34	0	<MDL	-	-	-

* <MDL: Below the method detection limit

Phthalates

The results for phthalates are similar to those for siloxanes. Phthalates are a family of chemicals used as plasticizers to increase the flexibility, transparency, durability and longevity of plastics. Effluents are the main source of these substances in the environment. High concentrations of total phthalates were observed in the Cornwall area (4,650 ng/g) and in Lake Saint-Pierre (843 ng/g) near the effluent dispersion plume from Montreal. DEHP was the most abundant phthalate, accounting for about 90% of the total concentrations. DBP and DIBP were also abundant in some samples.

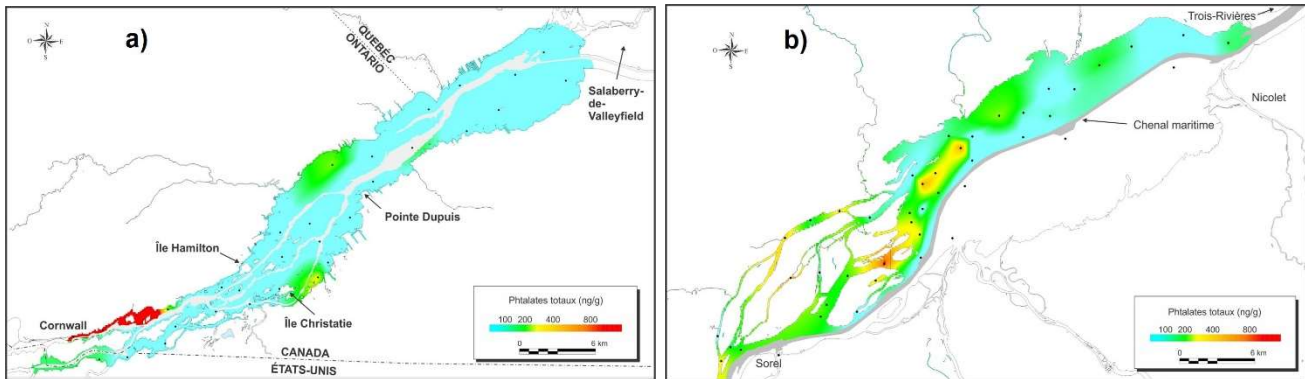


Figure 11: Distribution of concentrations of total phthalates in bottom sediments in Lake Saint-François (a) and Lake Saint-Pierre (b).

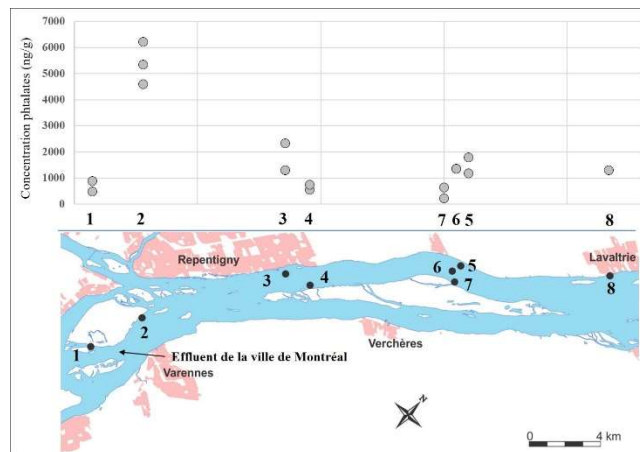


Figure 12: Distribution of phthalate concentrations in suspended sediment at the Montreal multimedia site.

All the suspended sediment samples, whether collected downstream or upstream of the Montreal effluent plume, had total phthalate concentrations higher than 200 ng/g and the same proportions of DEHP, DBP and DIBP as those measured in bottom sediments. The highest concentrations—those measured near Montreal's effluent plume—varied between 4,593 ng/g and 6,214 ng/g. It should be noted that DOP and DNP (with one exception) were detected in all samples, with mean concentrations of 40 ng/g and 60 ng/g, respectively.

Table 6. Basic statistical data for phthalates

Substance	Material	Number of samples analyzed	% detection	Minimum (ng/g)	Mean (ng/g)	Standard deviation (ng/g)	Maximum (ng/g)
Total phthalates	Bottom sediments	74	80	<MDL	242	571	4,651
	Suspended sediments	16	100	217	1,305	1,834	6,214
Benzyl-butyl phthalate (BBP)	Bottom sediments	74	32	<MDL	5.0	10.7	68
	Suspended sediments	16	63	<MDL	17.0	25.1	95
Bis (2-ethoxyethyl) phthalate (BEEP)	Bottom sediments	74	0	<MDL	-	-	-
	Suspended sediments	16	0	<MDL	-	-	-
Bis (2-ethylhexyl) phthalate (DEHP)	Bottom sediments	74	66	<MDL	210	566	4,634
	Suspended sediments	16	100	210	1,680	1,748	5,975
Bis (2-methoxyethyl) phthalate (BMEP)	Bottom sediments	74	0	<MDL	-	-	-
	Suspended sediments	16	0	<MDL	-	-	-
Bis (2-n-butoxyethyl) phthalate (DBEP)	Bottom sediments	74	0	<MDL	-	-	-
	Suspended sediments	16	0	<MDL	-	-	-
Bis (4-methyl-2-pentyl) phthalate (DMPP)	Bottom sediments	74	0	<MDL	-	-	-
	Suspended sediments	16	0	<MDL	-	-	-
Dibenzyl phthalate (DBZP)	Bottom sediments	74	3	<MDL	<MDL	0.2	2
	Suspended sediments	16	31	<MDL	8.3	16.2	67
Dicyclohexyl phthalate (DCHP)	Bottom sediments	74	0	<MDL	-	-	-
	Suspended sediments	16	0	<MDL	-	-	-
Diethyl phthalate (DEP)	Bottom sediments	74	19	<MDL	1.8	4.7	33
	Suspended sediments	16	0	<MDL	-	-	-
Di-isobutyl phthalate (DIBP)	Bottom sediments	74	12	<MDL	3.8	13.4	90
	Suspended sediments	16	69	<MDL	5.9	5.7	20
Dimethyl phthalate (DMP)	Bottom sediments	74	14	<MDL	0.6	1.7	10
	Suspended sediments	16	13	<MDL	1.2	2.2	9
Di-n-butyl phthalate (DBP)	Bottom sediments	74	27	<MDL	19.1	85.0	659
	Suspended sediments	16	38	<MDL	87.0	206.7	806
Di-n-hexyl phthalate (DHP)	Bottom sediments	74	0	<MDL	-	-	-
	Suspended sediments	16	6	<MDL	1.2	1.0	5
Di-n-octyl phthalate (DOP)	Bottom sediments	74	8	<MDL	1.3	2.9	18
	Suspended sediments	16	100	7.1	39.8	28.8	110
Dinonyl phthalate (DNP)	Bottom sediments	74	14	<MDL	2.8	8.3	52
	Suspended sediments	16	94	<MDL	56.9	53.9	178
Di-n-pentyl phthalate (DPP)	Bottom sediments	74	0	<MDL	-	-	-
	Suspended sediments	16	0	<MDL	-	-	-
Di-n-propyl phthalate (DnPP)	Bottom sediments	74	0	<MDL	-	-	-
	Suspended sediments	16	0	<MDL	-	-	-

* <MDL: Below the method detection limit

Antioxidants

The antioxidants group can be divided into three subgroups: substituted diphenylamines (SDPA), p-phenylenediamines (PPD), and other antioxidants. While SDPAs are the antioxidants most commonly detected in bottom sediments, SDPAs and PPDs were detected in more than 80% of suspended sediment samples collected from the Montreal multimedia site. Judging from the bottom sediment results, SDPAs are not associated solely with the effluent dispersion plume from Montreal which extends into the middle of Lake Saint-Pierre (concentration of 69 ng/g). Indeed, a number of high values exceeding 50 ng/g were linked to the water mass from the Ottawa River, which flows along the north shore of the lake; these levels may be related to local sources.

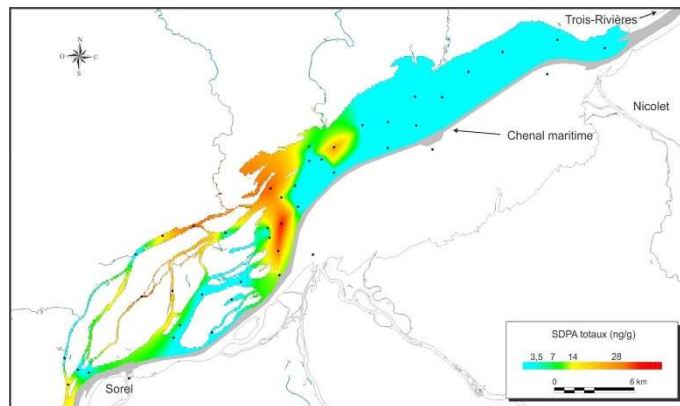


Figure 13: Distribution of concentrations of total SDPAs in Lake Saint-Pierre bottom sediments.

The suspended sediments show a direct link to Montreal's wastewater discharges, with SDPAs reaching levels of nearly 600 ng/g near the effluent. PPDs are also present at high concentrations in the Ottawa River water mass flowing out of the La Prairie and Mille-Îles Rivers, which receive inflows of urban effluents from the north shore of Montreal.

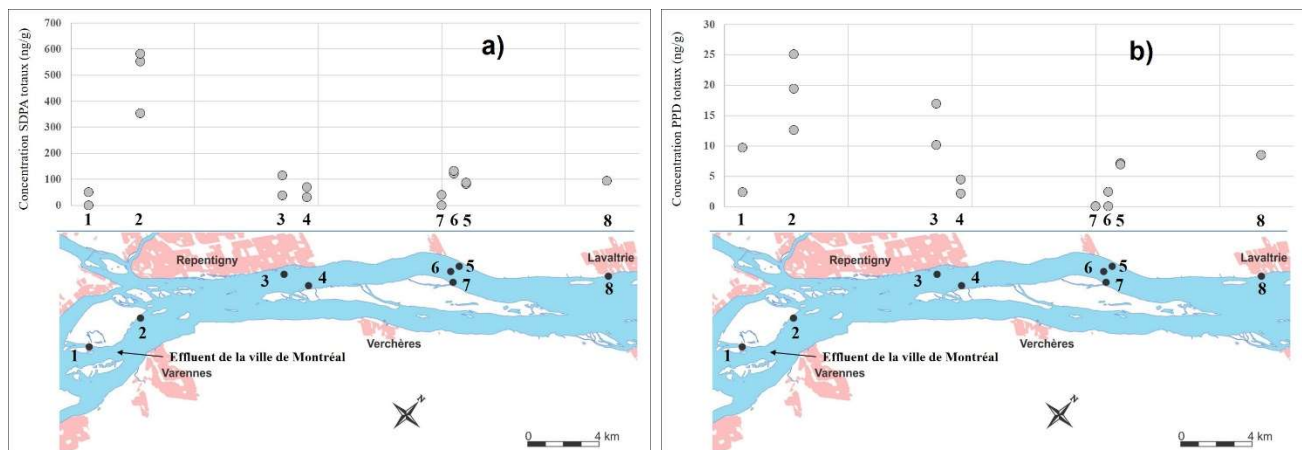


Figure 14: Distribution of concentrations of total SDPAs (a) and total PPDs (b) in suspended sediments at the Montreal multimedia site.

Table 7. Basic statistical data for antioxidants

Substance	Material	Number of samples analyzed	% detection	Minimum (ng/g)	Mean (ng/g)	Standard deviation (ng/g)	Maximum (ng/g)
Total antioxidants	Bottom sediments	44	52	<MDL	13.7	25.2	96.0
	Suspended sediments	16	94	<MDL	155.1	189.2	601.8
Total substituted diphenylamines (SDPAs)	Bottom sediments	44	52	<MDL	13.7	25.2	96.0
	Suspended sediments	16	94	<MDL	155.1	189.2	601.8
Monobutyl DPA / <i>Vanlube</i>	Bottom sediments	44	0	<MDL	-	-	-
	Suspended sediments	16	6	<MDL	0.7	2.3	9.3
Monostyrenated DPA 1 / <i>BNST</i>	Bottom sediments	44	5	<MDL	0.3	1.0	6.4
	Suspended sediments	16	81	<MDL	8.6	10.4	34.0
Monooctyl DPA / <i>BNST</i> + <i>Vanlube</i>	Bottom sediments	44	9	<MDL	0.7	2.2	11.0
	Suspended sediments	16	31	<MDL	4.1	7.8	22.3
Dibutyl DPA / <i>Vanlube</i>	Bottom sediments	44	7	<MDL	0.3	0.8	3.9
	Suspended sediments	16	25	<MDL	2.1	4.1	11.0
Monononyl-DPA / <i>Irganox</i>	Bottom sediments	44	0	<MDL	-	-	-
	Suspended sediments	16	19	<MDL	14.0	34.0	100.0
Monostyrenated-DPA 2 / <i>BNST</i>	Bottom sediments	44	2	<MDL	<MDL	1.1	7.3
	Suspended sediments	16	50	<MDL	4.9	5.5	15.0
Monobutyl-monooctyl DPA / <i>Vanlube</i>	Bottom sediments	44	25	<MDL	2.2	6.1	32.0
	Suspended sediments	16	63	<MDL	9.8	13.4	43.0
Monooctyl-monostyrenated DPA 1 / <i>BNST</i>	Bottom sediments	44	9	<MDL	0.4	1.0	5.3
	Suspended sediments	16	6	<MDL	0.2	0.6	2.3
Monooctyl-monostyrenated DPA 2 / <i>BNST</i>	Bottom sediments	44	5	<MDL	0.2	0.6	3.5
	Suspended sediments	16	0	<MDL	-	-	-
Dioctyl DPA / <i>BNST</i> + <i>Vanlube</i>	Bottom sediments	44	16	<MDL	1.3	3.7	17.6
	Suspended sediments	16	44	<MDL	10.7	19.7	65.0
Dinonyl DPA / <i>Irganox</i>	Bottom sediments	44	11	<MDL	3.8	11.3	46.0
	Suspended sediments	16	75	<MDL	82.0	105.5	360.0
Monooctyl-monostyrenated DPA 3 / <i>BNST</i>	Bottom sediments	44	16	<MDL	0.5	1.1	4.6
	Suspended sediments	16	19	<MDL	0.7	1.7	6.6
Dioctyl-monostyrenated DPA / <i>BNST</i>	Bottom sediments	44	11	<MDL	0.8	2.1	8.4
	Suspended sediments	16	13	<MDL	0.5	1.1	4.0
Dimethyl-distyrenated DPA / <i>Naugalube</i>	Bottom sediments	44	0	<MDL	-	-	-
	Suspended sediments	16	44	<MDL	9.7	17.6	69.0
Total p-phenylenediamines (PPD)	Bottom sediments	44	25	<MDL	1.4	4.5	28.0
	Suspended sediments	16	81	<MDL	8.0	7.4	25.1
Diphenyl PPD / <i>Benpat</i>	Bottom sediments	44	23	<MDL	1.0	2.3	13.0
	Suspended sediments	16	63	<MDL	2.7	2.7	7.8
Phenyl-tolyl PPD / <i>Benpat</i>	Bottom sediments	44	7	<MDL	0.6	2.3	15.0
	Suspended sediments	16	63	<MDL	4.1	3.8	12.0
Ditolyl PPD / <i>Benpat</i>	Bottom sediments	44	2	<MDL	<MDL	0.1	1.0
	Suspended sediments	16	25	<MDL	1.4	2.4	7.3
Other antioxidants	Bottom sediments	44	11	<MDL	2.5	14.5	96.0
	Suspended sediments	16	0	<MDL	-	-	-
Diphenylamine (DPA) / <i>BNST</i> + <i>Prepod</i> + <i>Vanlube</i>	Bottom sediments	44	2	<MDL	<MDL	0.3	2.3
	Suspended sediments	16	0	<MDL	-	-	-
Isopropyl DPA / <i>Prepod</i>	Bottom sediments	44	5	<MDL	0.2	0.3	1.6
	Suspended sediments	16	0	<MDL	-	-	-
9,9-dimethylacrydan / <i>Prepod</i>	Bottom sediments	44	2	<MDL	<MDL	0.6	3.9
	Suspended sediments	16	0	<MDL	-	-	-
Isopropyl dimethylacridan / <i>Prepod</i>	Bottom sediments	44	2	<MDL	<MDL	0.3	2.3
	Suspended sediments	16	0	<MDL	-	-	-
di-isopropyl-dimethylacridan / <i>Prepod</i>	Bottom sediments	44	0	<MDL	-	-	-
	Suspended sediments	16	0	<MDL	-	-	-
DPA Dimer 1 / <i>Prepod</i>	Bottom sediments	44	2	<MDL	2.3	14.5	96.0
	Suspended sediments	16	0	<MDL	-	-	-

* <MDL: Below the method detection limit

Polychlorinated naphthalenes (PCNs)

Polychlorinated naphthalenes (PCNs) were used as flame retardant substances after the commercial use of PCBs was banned. PCNs were analyzed as part of a university study (Boyer, 2003), but no follow-up was performed. Since 2012, greater emphasis has been placed on conducting analyses for these substances in order to provide a more exhaustive portrait. Although PCNs were never widely used, Lake Saint-Louis sediments show a pattern similar to that for PCBs, with levels peaking in the early 1970s. The most abundant PCNs, found at concentrations greater than 0.6 ng/g, are octo-PCNs. However, tetra-PCNs and penta-PCNs are the groups that are detected in all samples. The highest concentrations (from 0.5 ng/g to 2.5 ng/g) were measured in the Beauharnois area, between the Beauharnois Canal and the Saint-Louis River.

Table 8. Basic statistical data for polychlorinated naphthalenes

Substance	Material	Number of samples analyzed	% detection	Minimum (ng/g)	Mean (ng/g)	Standard deviation (ng/g)	Maximum (ng/g)
Polychlorinated naphthalenes (PCNs)	Bottom sediments	23	100	0.028	0.402	0.55 ^{”4}	2.586
Tri-PCN	Bottom sediments	23	4	<MDL*	-	-	0.007
Tetra-PCN	Bottom sediments	23	100	0.017	0.084	0.083	0.130
Penta-PCN	Bottom sediments	23	100	0.006	0.077	0.086	0.150
Hexa-PCN	Bottom sediments	23	96	<MDL	0.110	0.125	0.240
Hepta-PCN	Bottom sediments	23	96	<MDL	0.081	0.157	0.410
Octa-PCN	Bottom sediments	23	78	<MDL	0.049	0.141	0.680

* <MDL: Below the method detection limit

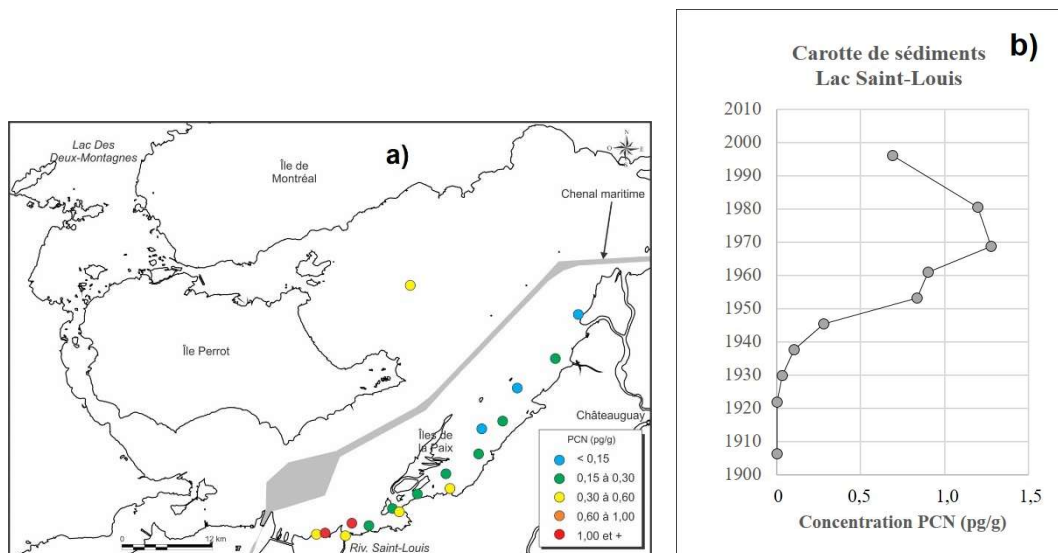


Figure 15: Distribution of concentrations of total polychlorinated naphthalenes (PCNs) in bottom sediments (a) and in a sediment core from Lake Saint-Louis (-73,8356: 45,3358) (b).

Polybrominated diphenyl ethers (PBDEs)

Polybrominated diphenyl ethers were widely used as flame retardants in a variety of commercial products in the early 2000s. These substances are now regulated and their use is banned. They are mainly entering the environment through discharges of municipal effluents, leaching from landfill sites and dusts produced from the breakdown of materials in consumer products. Among the 209 congeners of PBDE, 2 congeners with 5 bromine atoms, specifically BDE 99 and BDE 100, are very harmful to aquatic wildlife and act as endocrine disruptors. A federal sediment guideline of 0.4 ng/g was established for both of these substances (ECCC, 2011).

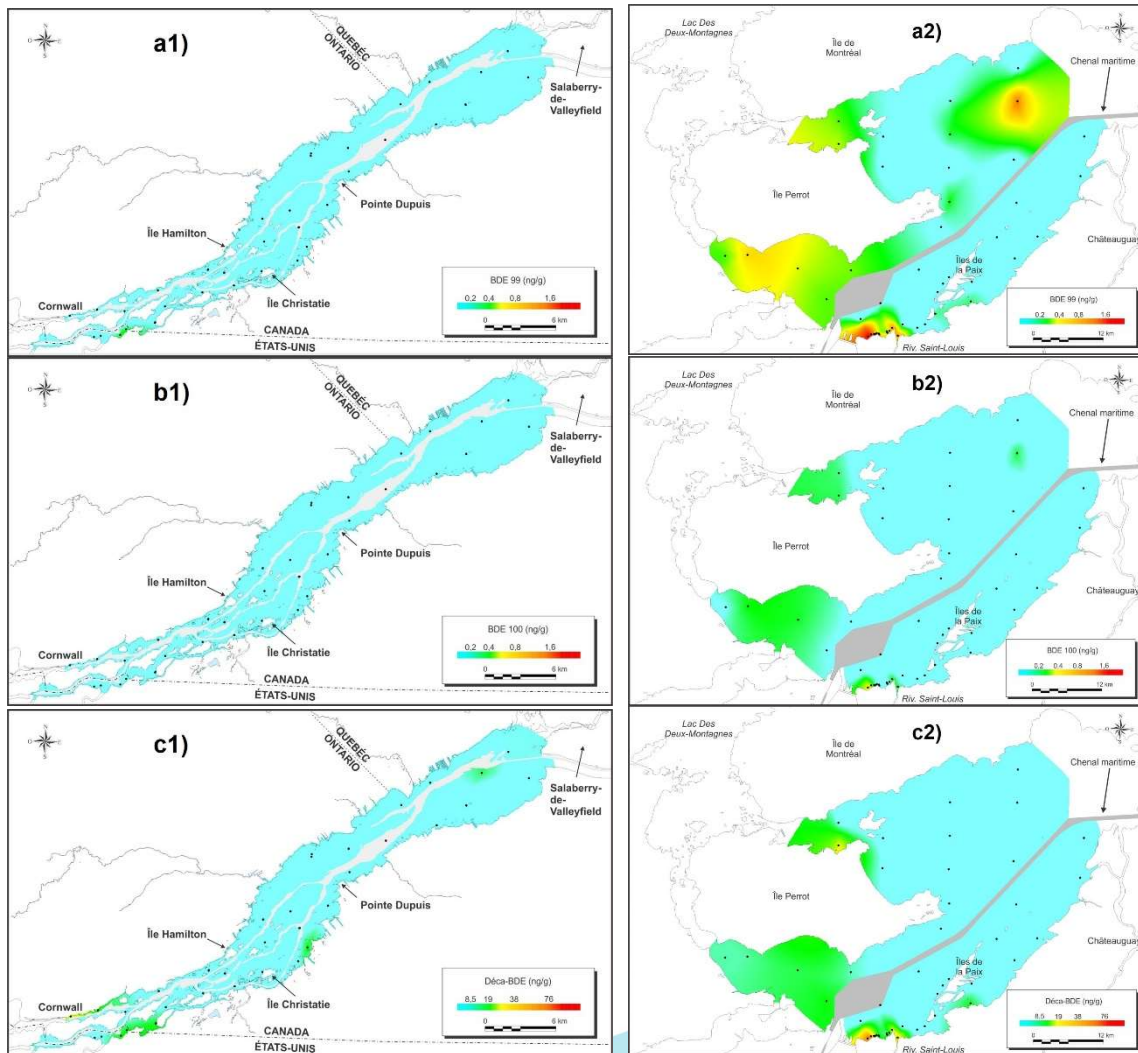


Figure 16. Distribution of concentrations of BDE 99 (a), BDE 100 (b) and deca-BDE (c) in bottom sediments in Lake Saint-François (1) and Lake Saint-Louis (2).

Table 9. Basic statistical data for polybrominated diphenyl ethers (PBDE)

Substance	Material	Number of samples analyzed	% detection	Minimum (ng/g)	Mean (ng/g)	Standard deviation (ng/g)	Maximum (ng/g)
Total polybrominated diphenyl ethers (PBDE)	Bottom sediments	249	98	<MDL	15.9	29.5	356.100
	Suspended sediments	36	100	6.65	38.1	18.2	127.220
Tri-BDE	BDE-17/25	Bottom sediments	249	14	<MDL*	0.021	0.240
		Suspended sediments	36	58	<MDL	0.074	0.370
	BDE-28/33	Bottom sediments	249	24	<MDL	0.023	0.920
		Suspended sediments	36	86	<MDL	0.129	1.000
Tetra-BDE	BDE-47	Bottom sediments	249	87	<MDL	0.606	6.500
		Suspended sediments	36	100	0.600	4.058	13.000
	BDE-49	Bottom sediments	249	42	<MDL	0.086	1.300
		Suspended sediments	36	94	<MDL	0.248	0.870
	BDE-66	Bottom sediments	249	7	<MDL	0.015	0.218
		Suspended sediments	36	81	<MDL	0.073	0.280
	BDE-71	Bottom sediments	249	3	<MDL	0.014	0.036
		Suspended sediments	36	0	<MDL	-	-
	BDE-77	Bottom sediments	249	1	<MDL	0.011	0.120
		Suspended sediments	36	0	<MDL	-	-
Penta-BDE	BDE-85	Bottom sediments	249	4	<MDL	0.014	0.620
		Suspended sediments	36	64	<MDL	0.166	2.600
	BDE-99	Bottom sediments	249	86	<MDL	0.546	5.800
		Suspended sediments	36	100	0.510	3.461	12.000
	BDE-100	Bottom sediments	249	67	<MDL	0.126	1.300
		Suspended sediments	36	97	<MDL	0.743	2.300
	BDE-119/120	Bottom sediments	249	1	<MDL	0.012	0.395
		Suspended sediments	36	3	<MDL	0.011	0.060
	BDE-126	Bottom sediments	249	3	<MDL	0.017	0.840
		Suspended sediments	36	0	<MDL	-	-
Hexa-BDE	BDE-138/166	Bottom sediments	249	7	<MDL	0.046	2.500
		Suspended sediments	36	6	<MDL	0.021	0.280
	BDE-153	Bottom sediments	249	43	<MDL	0.101	1.600
		Suspended sediments	36	92	<MDL	0.339	1.100
	BDE-154	Bottom sediments	249	43	<MDL	0.068	0.822
		Suspended sediments	36	89	<MDL	0.254	0.910
	BDE-156	Bottom sediments	249	5	<MDL	0.056	3.300
		Suspended sediments	36	3	<MDL	0.014	0.160
Hepta-BDE	BDE-183	Bottom sediments	249	44	<MDL	0.173	4.700
		Suspended sediments	36	92	<MDL	0.148	0.630
	BDE-184	Bottom sediments	249	11	<MDL	0.037	1.800
		Suspended sediments	36	0	<MDL	-	-
	BDE-191	Bottom sediments	249	8	<MDL	0.059	2.400
		Suspended sediments	36	0	<MDL	-	-
Octa-BDE	BDE-196	Bottom sediments	249	11	<MDL	0.086	3.100
		Suspended sediments	36	50	<MDL	0.091	0.350
	BDE-197	Bottom sediments	249	17	<MDL	0.112	2.700
		Suspended sediments	36	75	<MDL	0.128	0.530
Nona-BDE	BDE-206	Bottom sediments	249	32	<MDL	0.391	6.800
		Suspended sediments	36	75	<MDL	0.388	1.200
	BDE-207	Bottom sediments	249	36	<MDL	0.407	7.400
		Suspended sediments	36	75	<MDL	0.364	1.100
Deca-BDE	BDE-209	Bottom sediments	249	93	<MDL	13.238	350.000
		Suspended sediments	36	100	3.500	27.453	93.000

* <MDL: Below the method detection limit

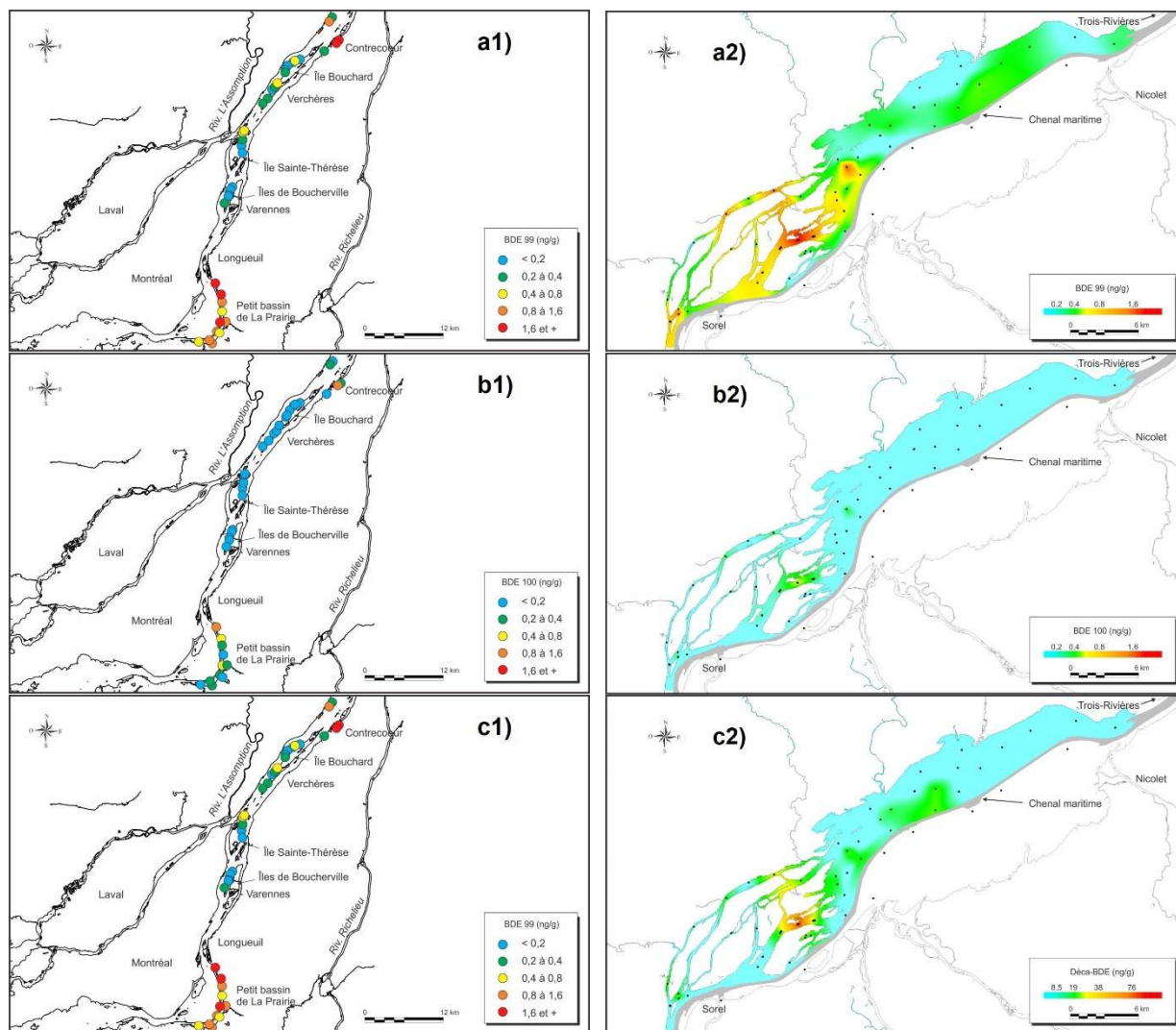


Figure 17. Distribution of concentrations of BDE 99 (a), BDE 100 (b) and deca-BDE (c) in bottom sediments in the fluvial section (1) and Lake Saint-Pierre (2).

BDE-209 is the most abundant of the PBDEs, accounting for about 80% of the total concentrations of PBDEs in sediments. BDE 209 degrades by losing a bromine to form a nona-BDE (PBDE with 9 bromines). The federal sediment quality guideline for deca-BDE is 19 ng/g (ECCC, 2011).

In Lake Saint-Pierre, BDE-99 levels exceeded the guideline value for this substance in 45% of the samples collected in 2013. The highest concentration of BDE-209 was 57 ng/g, and the highest concentration of BDE-99, 1.8 ng/g. Most of the high values were measured in the area between the Berthier and Sorel Islands, specifically in the effluent dispersion plume from Montreal.

The 11 samples taken in the Lesser La Prairie Basin in 2014 contained levels exceeding the guideline value for BDE-99, with a mean concentration of 1.6 ng/g and a maximum concentration of 5.8 ng/g. More than 50% of these samples also had deca-BDE levels above the guideline value, with a mean concentration of 55 ng/g and a maximum concentration of 350 ng/g. The source of these PBDEs in the Lesser La Prairie Basin remains unknown.

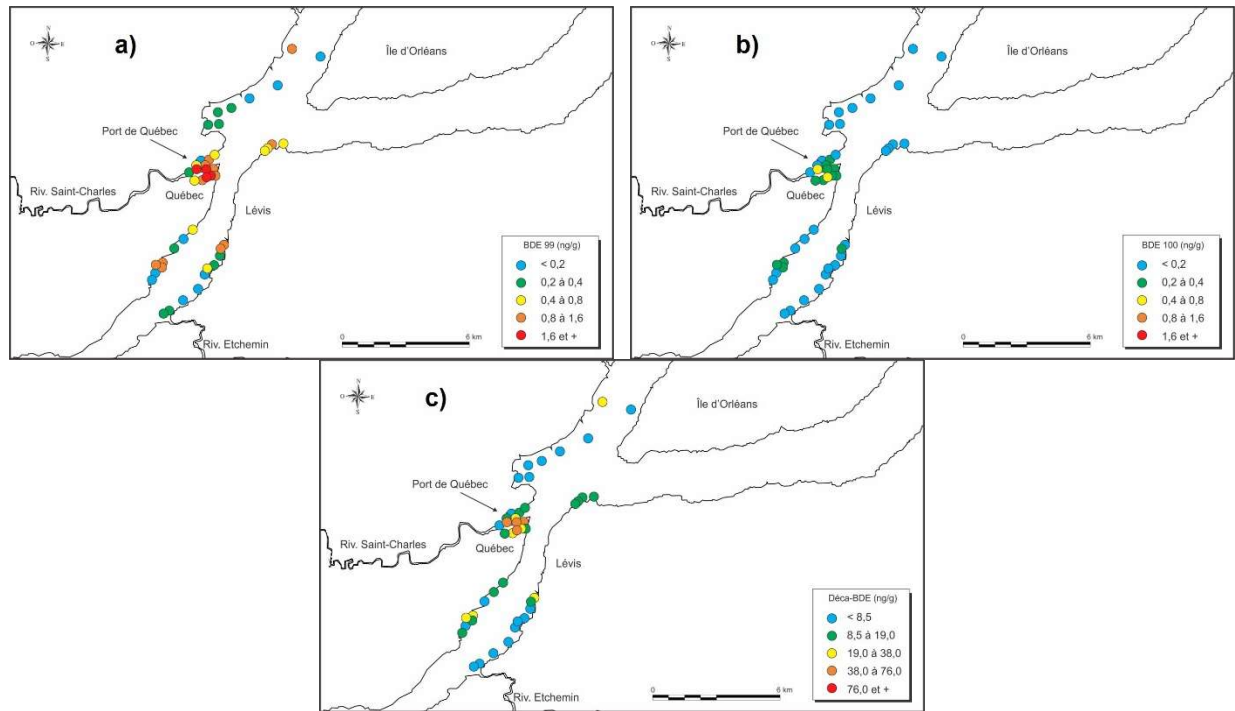


Figure 18. Distribution of concentrations of BDE 99 (a), BDE 100 (b) and deca-BDE (c) in bottom sediments in the Quebec City region.

The port area of the Quebec City sector is affected mainly by deca-BDE, but BDE-99 is also widely distributed along both shores. The maximum concentrations of BDE-99, BDE-100 and BDE-209 were 2.8 ng/g, 0.6 ng/g and 50 ng/g, respectively. The main source of these PBDE concentrations is likely effluents and overflow from Quebec City, along with wastewater discharges from nearby towns and cities.

Almost all the suspended sediment samples collected downstream of the Montreal effluent had concentrations that were above the sediment guidelines. For BDE-99, BDE 10 and deca-BDE, the highest concentrations measured near the effluent were 12 ng/g, 2.3 ng/g and 93 ng/g, respectively. For these three substances (in the same order), the mean concentrations for the study overall, upstream and downstream areas combined, were 3.5 ng/g, 0.7 ng/g and 27.5 ng/g, respectively. It should be noted that these concentrations are relatively low compared to the mean and maximum levels measured in the Lesser La Prairie Basin.

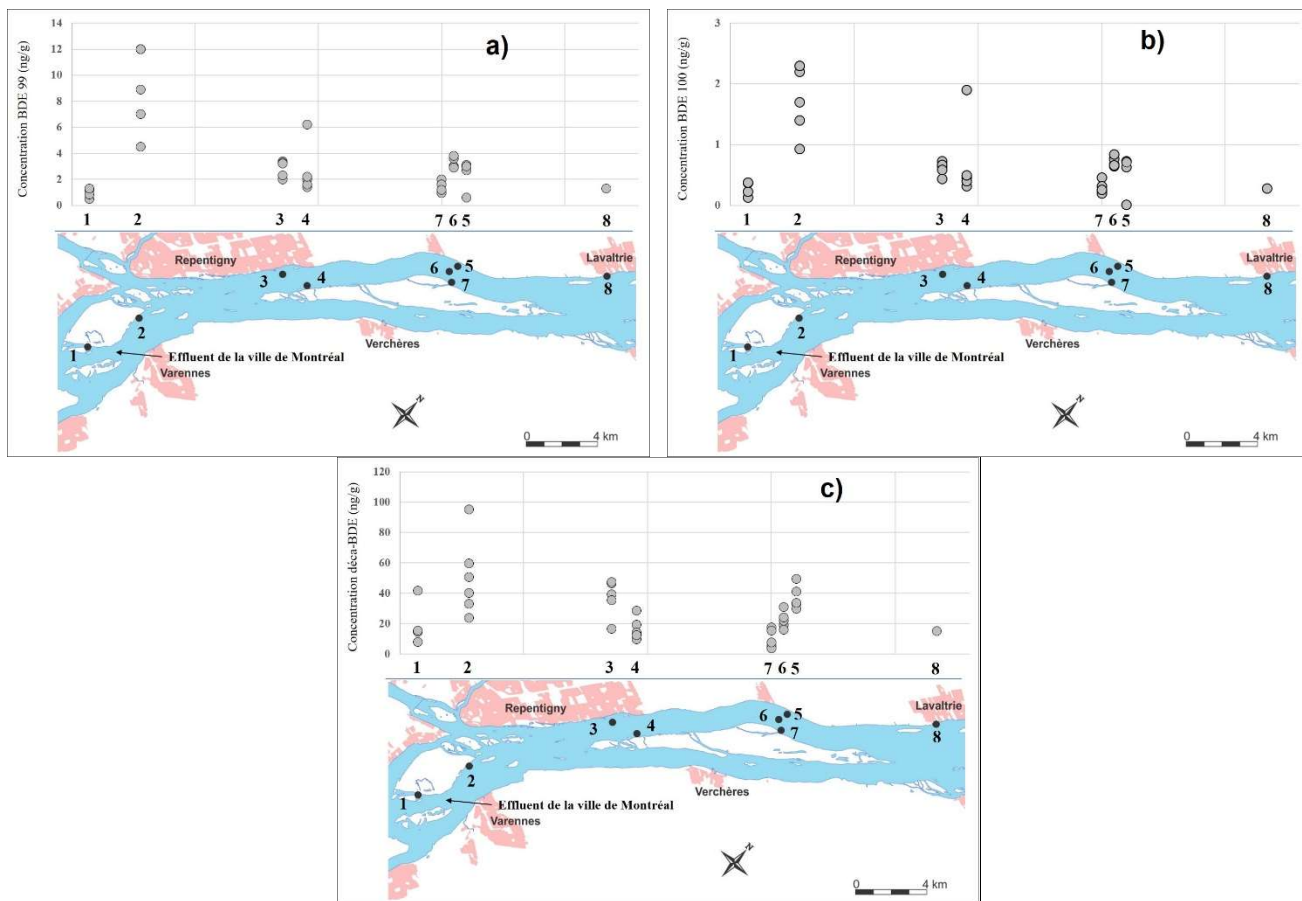


Figure 19: Distribution of concentrations of BDE-99 (a), BDE-100 (b) and deca-BDE (c) in suspended sediments at the Montreal multimedia site.

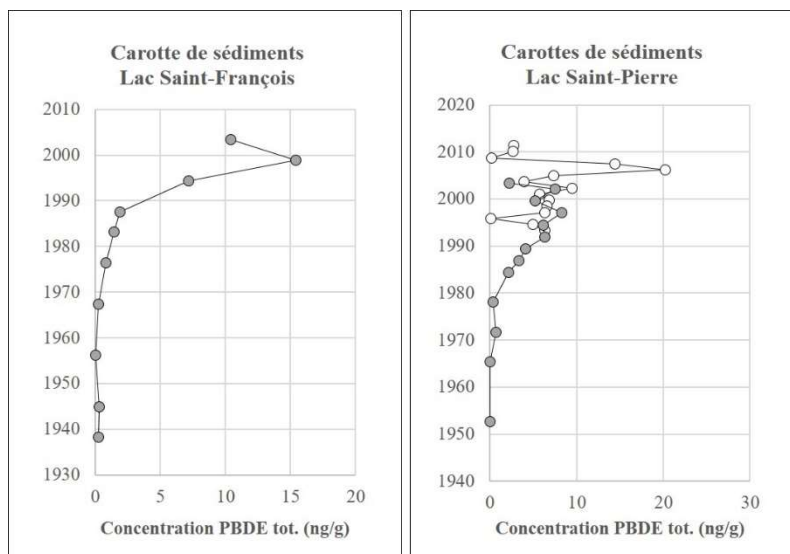


Figure 20: Profiles of total PBDEs in sediment cores from Lake Saint-François (-74,1923: 45,2433) and Lake Saint-Pierre (-72,9726: 46,1339 and -72,9784: 46,1434).

The profiles of total PBDEs in sediment cores collected from Lakes Saint-François and Saint-Pierre show that the concentrations gradually increased beginning in the 1980s. Very similar maximum concentrations, 15 ng/g and 22 ng/g, respectively, were measured in Lake Saint-François in 2000 and in Lake Saint-Pierre in 2006. It should be noted that the sediment core from Lake Saint-François was collected before the maximum concentration in Lake Saint-Pierre was measured. It would be useful to repeat this sampling and take another sediment core in order to update the portrait of sediment contamination and determine when the maximum level was reached. In Lake Saint-Pierre, a sharp decrease in total PBDEs can be seen in the early 2010s, with the concentration falling to roughly 2.5 ng/g. This corroborates the results obtained for bottom sediments in the 2003 and 2013 sampling campaigns. Specifically, a decrease of over 59% in BDE-99 concentrations was noted in bottom sediments between these two campaigns (Pelletier, 2018).

Halogenated flame retardants (HFR)

Analyses were carried out in two sectors of the St. Lawrence to detect the presence of halogenated flame retardants and determine the baseline levels of these substances for future monitoring and surveillance studies. A number of these substances are either barely detected or are detected at low levels in bottom sediments. BEHTBP (bis(2-ethylhexyl)tetrabromophthalate) was detected in 72% of samples at a mean concentration of 0.5 ng/g and a maximum concentration of 6.4 ng/g. However, the highest levels are associated with γ -1,2,5,6,9,10-hexabromocyclododecane (γ -HBCD), found mainly in the Port of Quebec area at a concentration of 18 ng/g.

Among the other halogenated flame retardants, it is worth noting the presence of 2-ethylhexyl-2,3,4,5-tetrabromobenzoate (EHTBB), decabromodiphenylethane (DBDPE), allyl 2,4,6-tribromophenyl ether (ATE) and pentabromotoluene (PBT). All these substances should be the subject of further studies given their potential effects on aquatic wildlife.

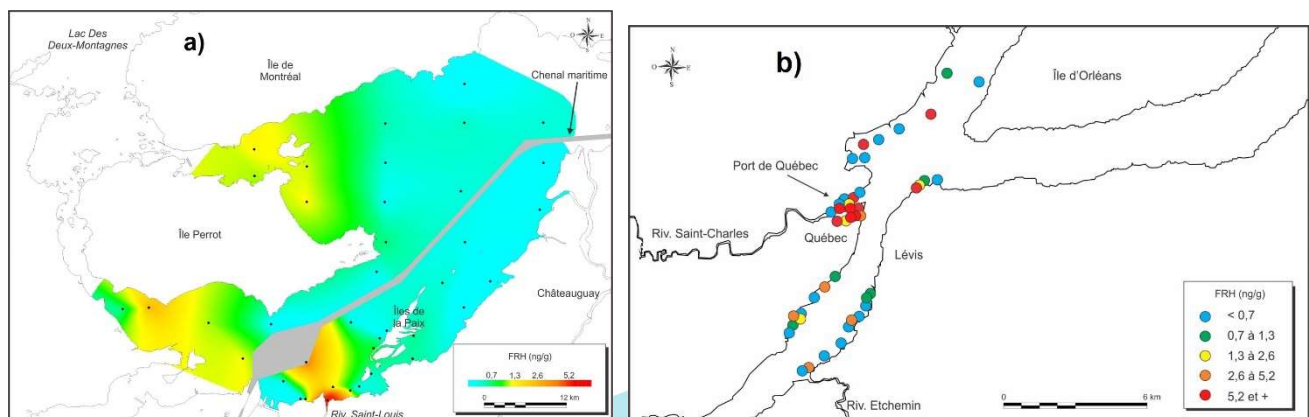


Figure 21: Distribution of concentrations of total halogenated flame retardants (HFRs) in bottom sediments in Lake Saint-Louis (a) and the Quebec City area (b).

Table 10. Basic statistical data for halogenated flame retardants (HFRs)

Substance	Material	Number of samples analyzed	% detection	Minimum (ng/g)	Mean (ng/g)	Standard deviation (ng/g)	Maximum (ng/g)
Halogenated flame retardants (HFRs)	Bottom sediments	88	92	<MDL	1.894	3.362	18.050
1,2,3,4,5-pentabromobenzene (PBB)	Bottom sediments	88	0	<MDL	-	-	-
1,2-Bis(2,4,6-tribromophenoxy)ethane (BTBPE)	Bottom sediments	88	2	<MDL	0.010	0.064	0.530
2,2',4,5,5'-pentabromobiphenyl (BB-101)	Bottom sediments	88	2	<MDL	0.002	0.007	0.066
2,3,5,6-tetrabromo-p-xylene (pTBX)	Bottom sediments	88	1	<MDL	<MDL	0.001	0.012
2,3-dibromopropyl 2,4,6-tribromophenyl ether (DPTE)	Bottom sediments	88	0	<MDL	-	-	-
2-Bromoallyle 2,4,6-tribromophenyl ether (BATE)	Bottom sediments	88	0	<MDL	-	-	-
2-ethylhexyl-2,3,4,5-tetrabromobenzoate (EHTBB)	Bottom sediments	88	38	<MDL	0.048	0.087	0.460
α -1,2,5,6-tetrabromocyclooctane (α -TBCO)	Bottom sediments	88	0	<MDL	-	-	-
Allyl 2,4,6-tribromophenyl ether (ATE)	Bottom sediments	88	18	<MDL	0.023	0.139	1.300
anti-Dechlorane Plus® (anti-DP)	Bottom sediments	88	2	<MDL	0.113	0.089	0.870
α -tetrabromoethylcyclohexane (α -TBECH)	Bottom sediments	88	0	<MDL	-	-	-
Bis(2-ethyl-1-hexyl) tetrabromophthalate (BEHTBP)	Bottom sediments	88	72	<MDL	0.512	0.944	6.400
Decabromodiphenyl ethane (DBDPE)	Bottom sediments	88	18	<MDL	0.290	0.627	5.200
Hexabromobenzene (HBB)	Bottom sediments	88	0	<MDL	-	-	-
Hexachlorocyclopentenyl-dibromocyclooctane (HCDBCO)	Bottom sediments	88	0	<MDL	-	-	-
Octabromotrimethylphenylindane (OBIND)	Bottom sediments	88	6	<MDL	0.028	0.097	0.830
Pentabromobenzyl acrylate (PBBA)	Bottom sediments	88	1	<MDL	0.002	0.006	0.057
Pentabromoethylbenzene (PBEB)	Bottom sediments	88	2	<MDL	0.005	0.041	0.390
Pentabromotoluene (PBT)	Bottom sediments	88	18	<MDL	<MDL	0.003	0.013
β -tetrabromoethylcyclohexane (β -TBECH)	Bottom sediments	88	0	<MDL	-	-	-
syn-Dechlorane Plus® (syn-DP)	Bottom sediments	88	0	<MDL	-	-	-
Tetrabromo-o-chlorotoluene (TBCT)	Bottom sediments	88	1	<MDL	<MDL	0.001	0.010
γ -1,2,5,6,9,10-hexabromocyclododecane (γ -HBCD)	Bottom sediments	88	25	<MDL	0.991	2.857	18.000

* <MDL: Below the method detection limit

Conclusion

The concentrations of substances of emerging concern in sediments may vary considerably among the various sectors of the St. Lawrence River. In general, the presence of these new substances can be directly linked to municipal effluents. They are considered to be diffuse pollution (non-point-source pollution), because multiple sources are involved which cannot be traced to specific manufacturing plants. Their occurrence stems from the use of a variety of commercial products by the public at large. Unlike polychlorinated biphenyls (PCBs) or mercury (Hg), which were abundant in the environment during the 20th century, these new contaminants are more difficult to identify and target with the aim of eliminating sources. The Chemicals Management Plan sets out to identify the substances that pose the greatest threat to aquatic wildlife as well as take stock of the situation so that the necessary measures can be taken to protect the environment. The Government of Canada implements control measures and bans in order to limit impacts on the Canadian environment. However, it will be important for future generations to remain vigilant to preserve the environment to protect the aquatic life in our lakes and rivers.

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Acknowledgements

A special thank you to Mélanie Desrosiers of the Centre d'expertise en analyse environnementale du Québec, ministère de l'Environnement et de la Lutte contre les changements climatiques (MELCC) for her invaluable advice and feedback.

Cat. no. En154-128/2021E-PDF
ISBN: 978-0-660-37524-3

Published by authority of

© Her Majesty the Queen in Right of Canada, represented by the Minister of
Environment and Climate Change, 2021

Published by authority of the Québec Minister of the Environment
and the Fight Against Climate Change

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***Également disponible en français sous le titre : État de situation des substances
d'intérêt émergent dans les sédiments de surface et les sédiments en suspension
du Saint-Laurent***