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Organic Contaminants in Isolated Lakes of Southern Labrador, Canada

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The atmospheric transport of organic contaminants is known to be occurring in eastern North America. Strachan (1985, and unpublished data) has measured DDT isomers, alpha- and gamma-BHC, PCB's, and HCB in precipitation from Lake Superior and in New Brunswick, while Brun (1985) has shown measurable levels of alpha- and gamma-BHC, chlordane and PCB's in rain and snow from Nova Scotia and Prince Edward Island. Rappaport et al. (1985) show that there has been a constant input of DDT from the atmosphere to bog ecosystems, though recently at levels lower than before the early 1970's when it was banned in North America. Schmitt et al. (1985) have shown that body burdens of organochlorine chemicals (OC's) in fish from the United States, including Alaska, have been decreasing since the 1970's, but that OC's were nevertheless found everywhere fish were sampled. Apart from these few studies, there is very little data showing the extent of organic contamination of various parts of ecosystems in areas far from generating sources, nor is there much information from remote areas which would allow us to put data from sites closer to pollution sources into perspective.

From 1980 to 1984, the Water Quality Branch of Environment Canada studied the chemical quality of the aquatic ecosystems straddling the Labrador and Quebec border in northeastern Canada. The object of the work was to get baseline information on the aquatic resources of potential hydroelectric development sites. One result from this work was the discovery of measurable levels of organic contaminants in areas isolated from any major human activity. The purpose of this report is to describe results from the survey of the five transboundary basins and, to place the results in the perspective of other work.

MATERIALS AND METHODS

Five lakes (Brulé, Fonteneau, Donquan, St. Augustin and St. Paul) were selected because of easy access by

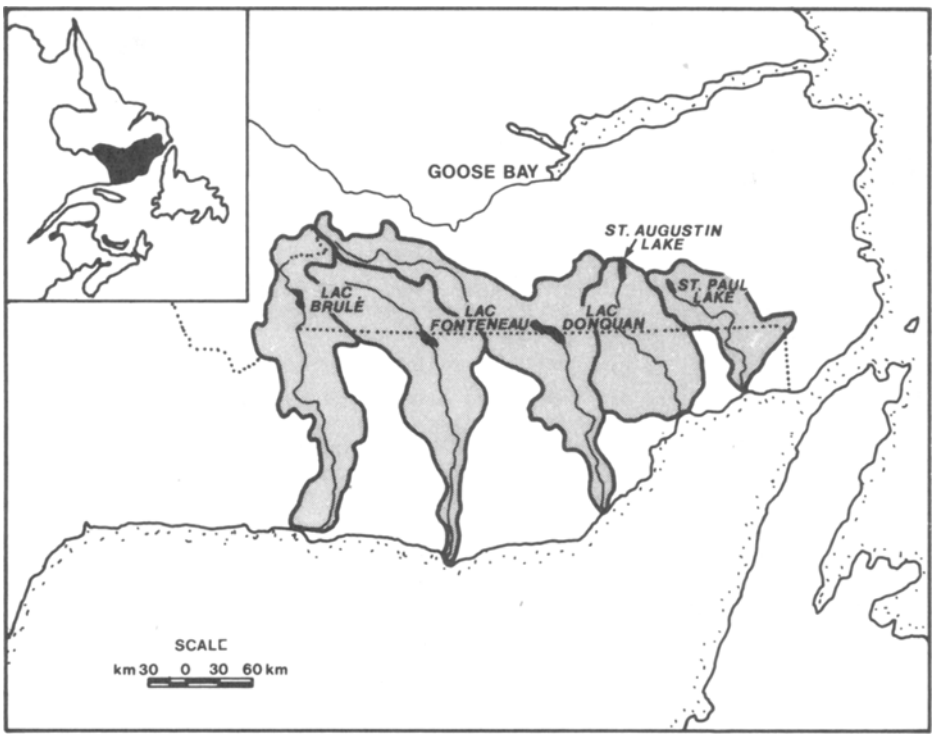

FIGURE 1. Map of the five transboundary basins on the Quebec-Labrador border

float plane and because they were most likely to accumulate sediments and provide habitats for large fish. (Fig. 1, Table 1). Each lake basin contained plant communities dominated by black spruce (Picea mariana) forest, with major parts of each basin composed of Sphagnum bogs. In each sampled lake, surface waters and sediments were collected at 4 sites, corresponding to the lake inflow, outflow, and two sites in between. Water samples for organic contaminants were collected in 4L pre-cleaned glass jugs and preserved immediately with the appropriate solvent (Lockerbie 1987). At each lake, water for major ion and metal analyses was also collected to allow an assessment of overall lake water quality. Sediment samples were collected in triplicate at each site using a brass $(15.2\ cm)^3$ Ekman sampler, or a stainless steel Petite Ponar dredge. The top 1 cm of each grab was taken, and transported to the laboratory in pre-cleaned aluminum pie-plates. At each lake, fish were captured using two 46 m long gill nets one with 7.6 cm mesh and the other 9.0 cm. All fish and sediment samples were kept cool and frozen upon arrival in Goose Bay, Labrador, which meant a delay of

TABLE 1. Physical characteristics of five southern Labrador lakes. going from west to east

	Lac Brulé	Lac Fonteneau	Lac Donquan	St Augustin Lake	St Paul Lake
Year Sampled	1980	1981	1982	1983	1984
Surface Area (sq km)	95.0	51.0	14.5	5.6	7.0
Drainage Area (sq km)	2820.	635.	8210.	30.	80.7
Rel Drainage Area	0.0337	0.0803	0.0018	0.1867	0.0867
Max Length (km)	25.0	43.3	6.4	3.8	5.3
Max Width (km)	6.4	1.9	5.6	2.3	1.9
Max Depth sampled (m)	7.8	26.0	11.0	3.1	1.5
Sampling station mean depth	5.2	18.4	5.6	2.9	0.75
Surface Elevation (m)	480	399	280	452	357
Lake Type	River Expansion	Headwater Lake	River Expansion	Headwater Lake	Head-water Lake

up to five days between sampling and freezing. Analytical methodology for major ions are described in Anonymous (1984), while those for organic contaminants are in Lockerbie (1987). For purposes of this report, values reported as "Trace" resulted from chromatogram peak heights which were below the detection limit of the analytical method, but which were felt by the analyst to be a positive indication of the presence of the compound.

RESULTS AND DISCUSSION

Median values for major ions from the four surface water sites are shown in Table 2. Very little variability in chemistry was found within each lake, though there were some differences between them. However, all lake waters were soft, with low conductances, moderate to high colour and dissolved organic carbon (DOC). pH values ranged from 5.7 to 6.5. These values are well within those reported by Clair et al. (1982) for Labrador and Newfoundland lakes.

Of the organic contaminants analysed for in water, only alpha-BHC was found in measurable quantities in 4 of the 5 lakes. Gamma-BHC (Lindane) was found in one Lac Brulé sample. Lac Donquan, the site where no alpha-BHC was found was not a true lake but a widening in the river, and so had a very low water residence time.

TABLE 2. Median values of major ion physical and nutrient parameters from five study lakes

Parameter	Study Lake				
	Brulé	Fonteneau	Donquan	St Augustin	St Paul
Turbidity (J.T.U.)	0.6	0.3	0.4	0.6	-
Water temp. (°C)	10.7	14.5	10.0	8.0	9.2
specific cond. ($uSie/cm^{-1}$)	8	12	12	9	7
colour (rel. units)	20	20	40	15	70
Ca ($mg.L^{-1}$)	1.3	1.0	1.4	1.1	0.83
Mg ($mg.L^{-1}$)	0.35	0.25	0.38	0.43	0.21
Na ($mg.L^{-1}$)	0.5	0.6	0.7	0.5	0.2
K ($mg.L^{-1}$)	0.4	0.2	-	0.2	0.1
SO_4 ($mg.L^{-1}$)	1.9	1.9	2.3	1.5	1.5
Cl ($mg.L^{-1}$)	0.5	0.4	0.4	0.5	0.5
NO_2 NO_3 ($mg.L^{-1}$)	L0.01	-	L0.01	L0.01	L0.01
Total P ($mg.L^{-1}$)	0.003	-	0.012	-	-
Total N ($mg.L^{-1}$)	0.36	-	0.21	0.08	0.15
pH	6.6	6.1	6.7	5.9	6.1
Alkalinity ($mg.L^{-1}$)	2.9	1.6	3.8	2.8	1.2

Organic contaminants were more prevalent in sediments than in water, with p,p'-DDD, p,p'-DDE and PCB's being measured in Lac Brule, Lac Fonteneau and St. Paul Lake. p,p'-DDD was measured in trace amounts in some samples from Brule and at up to 3 ppb in St. Paul, while p,p'-DDE was measured in trace amounts in Fonteneau and Brule. Fonteneau samples all contained PCB's ranging in concentration from trace amounts to 15 ppb. No correlation could be drawn between a sediment contaminant concentration and potential sources of chemicals, as Brule and Fonteneau were well separated from St. Paul.

The data for all fish species were lumped together, due to the small numbers of fish caught in some lakes (Table 3), while concentrations of the only parameters measured are shown in Table 4. It was noted that very little of the DDT compounds are in the parent form (o,p-DDT) nor as p,p'-DDD. The major form detected in all lakes was p,p'-DDE. Considering the mechanism of uptake and metabolism of DDT by biota (Brooks 1974), this is not surprising, as its incorporation into fish tissue usually involves altering the form of the residue.

Significant correlations between total DDT compounds, and tissue lipid content (R^2 = 0.78, n = 75), BHC and

Table 3. Fish species and numbers collected at the five sampled lakes.

Species	Study Lake Brulé	Fonteneau	Donquan	St. Augustin	St. Paul
Lake trout (Salvelinus namaycush)	15	--	1	--	--
Ouaniche (Salvelinus alpinus)	10	--	--	--	--
Eastern Brook Trout (Salvelinus fontinalis)	--	--	--	6	22
White Sucker (Catostomus commersoni)	12	--	--	15	48
Longnose Sucker (Catostomus catostomus)	--	--	--	--	33
Northern pike (Esox lucius)	7	19	6	13	--
Whitefish (Coregonus clupeaformis)	15	--	6	--	--
Muskellunge (Esox masquinongy)	--	4	--	--	--

% lipid (R^2 = 0.83, n = 75) and total PCB and % lipid (R^2 = 0.71, n = 75) were calculated, regardless of the fish species or of tissue type, though no relationship existed between fish size, (and thus age), sex or weight versus contaminant level. As can also be noted from Table 4, liver tissue contains higher levels of both lipid and contaminants, as is expected, considering liver's metabolic function as a site of fat storage and detoxification of poisonous substances.

The nearest recorded use of DDT in the area (P.M. Marcotte, Quebec Energy & Resources) was in a forest spray program on the Gaspé peninsula during the period 1957 to 1961. These sites were approximately 420 km southwest of the nearest study lake.

Our results differ from those of Musial et al. (1979) who found higher PCB values in Labrador fish, though at a site probably contaminated by a power dam operation. Because of this, we feel that the two studies are not comparable.

Our data were compared to values reported by Schmitt et al. (1985) from species taken in the United States, including Alaska. They used whole fish tissue for

TABLE 4: Median value and range of organic contaminant concentrations in various tissues from all fish analyzed in each lake. Values in ug.g^{-1}, wet weight. L denotes lower than detection limit.

	o,p-DDT	p,p-DDD	p,p-DDE	alpha-BHC	gamma-BHC	PCB
Lac Donquan						
muscle	L	L	.002 L-0.12	L	L	L L-.068
liver	L	L	.017 .001-.14	L	L	0.01 L-2.2
gonads	L	L	.006 L-.13	L	L	L L-0.11
Lac Fonteneau						
muscle	L	L	0.001 0.001-0.001	L	L	L
liver	0.001 0.001-0.005	L	0.007 0.001-0.03	L	0.001 0.001-0.002	0.019 0.005-0.091
gonads	L	L	0.009 0.002-0.065	L	L	0.005 L-0.09
Lac Brulé						
muscle	L L-0.006	L L-0.014	0.002 0.001-0.44	L L-0.001	0.001 0.001-0.002	0.005 L-0.1
liver	L L-0.05	0.001 0.002-0.82	0.014 L-0.003	0.001 0.001-0.033	0.003 0.005-0.18	0.016
gonads	L L-.005	L L-0.013	0.009 0.002-0.22	0.001 L-0.001	0.002 0.001-0.012	0.016 L-0.15
Lac St. Augustin						
muscle	L L-0.003	L L-0.002	0.001 0.001-0.055	L	0.001 0.001-0.002	L L-0.037
liver	0.003 L-0.031	0.006 L-0.017	0.84 0.003-0.2	L	0.006 0.002-0.01	0.065 L-0.19
gonads	L L-0.002	0.001 L-0.001	0.012 0.001-0.027	L	0.001	0.019 L-0.023
Lac St. Paul						
muscle	L	L L-0.002	L L-0.007	L	L L-0.002	L

their analyses, unlike our work where we isolated individual tissue types. However we compared their total fish values with the least contaminated of our tissues, muscle. We then find that Labrador levels of DDT, DDD and DDE are lower than most continental U.S. fish, though fairly similar to the levels they report from their Alaskan and other isolated sites.

This work demonstrates that long range atmospheric transport of long-lived organic contaminants is occurring into northeastern Canada and we provide present day background levels of contamination. The most water soluble compounds, such as BHC isomers are found most commonly in lake water, while the least water soluble, DDT and PCB's, are found in lake sediments and fish. Though no data are available to determine what sediment characteristics control contaminant levels, % tissue lipid content of 4 fish species from 2 of the lakes correlated quite well with tissue burden. Study of tissue contaminant loads from the other three lakes shows that the highest concentrations are located in livers, corresponding with the data from the two lakes where lipid content was measured.

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