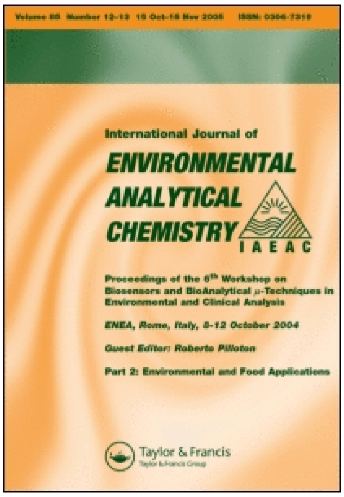

International Journal of Environmental Analytical Chemistry
Publication details, including instructions for authors and subscription information:
http://www.informaworld.com/smpp/title~content=t713640455

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To cite this Article Tsui, Philip T. P. and McCart, Peter J.(1981) 'Chlorinated Hydrocarbon Residues and Heavy Metals in Several Fish Species from the Cold Lake Area in Alberta, Canada', International Journal of Environmental Analytical Chemistry, 10: 3, 277 — 285
To link to this Article: DOI: 10.1080/03067318108071551
URL: http://dx.doi.org/10.1080/03067318108071551

Intern. J. Environ. Anal. Chem., 1981, Vol. 10, pp. 277–285
0306-7319/81/1004-0277 $06.50/0

Chlorinated Hydrocarbon Residues and Heavy Metals in Several Fish Species from the Cold Lake Area in Alberta, Canada

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(*Received January 8, 1981: in final form March 23, 1981*)

Existing levels of chlorinated hydrocarbon residues and heavy metal concentrations in the tissue reservoir of several fish species in the Cold Lake area of Western Canada were investigated. An attempt was made to correlate bioccumulations with feeding habits of the fish.

KEY WORDS: Bioaccumulation, chlorinated hydrocarbons, heavy metals, fish, monitoring.

INTRODUCTION

Residues of chlorinated hydrocarbons, mainly DDT and its metabolites (DDD, DDE), and PCB (polycholorinated biphenyls) have been found in a variety of fish species in the Cold River Drainage of Alberta. It is thought that the pesticides may have contributed to the decline of lake trout populations in Cold Lake. Other adjacent drainages may also have been affected. The present reservoir of chlorinated hydrocarbons in the Cold River Drainage probably owes its origin to the large-scale spraying of DDT by the Department of National Defence, prior to 1969, in Primrose Lake and the Martineau River.[1] The sources of the PCBs in the Cold Lake area are unknown.

Wobeser *et al.*[2] first reported the discovery of mercury contamination in

Canadian fish from the Saskatchewan River. The concentrations found were higher than those reported for fish from uncontaminated environments, and correspond to values reported for Scandinavian fish collected in areas of industrial pollution, Since then much interest and concern have been generated in the presence of heavy metals in the Canadian environment.

In relation to the proposed Cold Lake heavy oil development, this study was undertaken in order to investigate the existing levels of chlorinated hydrocarbon residues and heavy metal concentrations in the tissue reservoir of several important fish species in lakes within or adjacent to the proposed development area.

METHODS

Chlorinated hydrocarbon analyses were performed according to procedures specified in:

"Analytical Methods for Pesticide Residues in Foods. Health and Welfare Canada, Health Protection Branch, 7–32 ff (1973)."

All gas chromatographic analyses were conducted with a Hewlett–Packard Model 1510A gas chromatograph equipped with a Ni-63 electron capture detector operated in the modulated-pulse mode.

Heavy metal analyses were determined by Perkin-Elmer Atomic Absorption methodology.

Samples of tissue were taken from five species of fish collected during the spring and summer of 1978: lake cisco (*Coregonus artedii*), lake whitefish (*Coregonus clupeaformis*), lake trout (*Salvelinus namaycush*), white sucker (*Catostomus commersoni*), and northern pike (*Esox lucius*). The tissue samples included back muscle and body cavity (abdominal) fat for fish from eight lakes all of which lie within or adjacent to the proposed heavy oil development area (Figure 1). Both the muscle and fat samples were analysed for chlorinated hydrocarbons but only the muscle tissue was analysed for heavy metals. Except for lake trout, for which the only analysis performed was for heavy metals in muscle, a full range of analyses was performed for each species.

The five fish species were delected primarily because they represent different feeding habits and modes of life. Pike and lake trout, at least as adults, are primarily predators on other fish, whereas ciscos are plankton feeders, and whitefish and white suckers are primarily bottom feeders. Habitat and mode of life are the most important ecological characteristics in determining uptake and final concentration of chlorinated hydrocarbons in aquatic organisms.[3] Hence, the wide spectrum of feeding habits represented by the chosen species gives a good indication of the present range of hydrocarbon residues in fish populations.

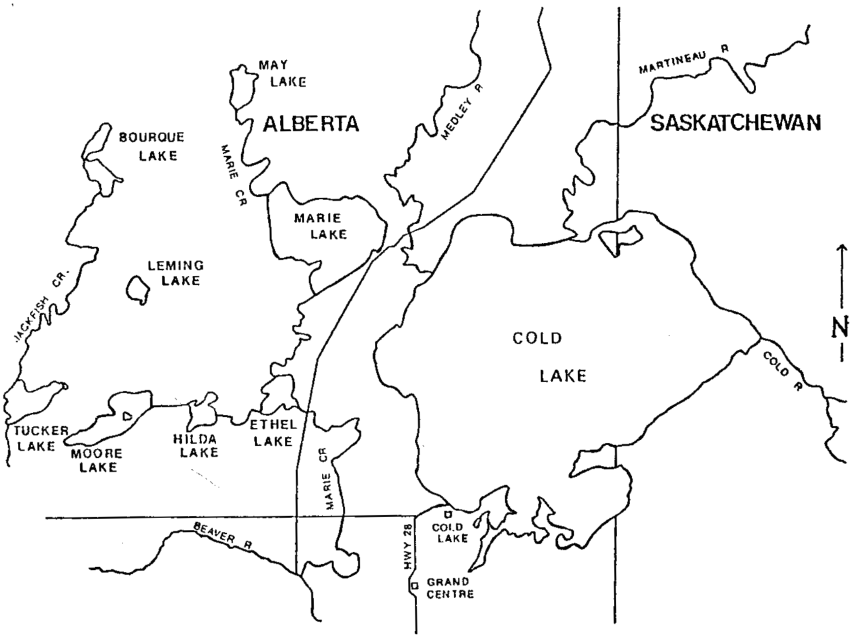

FIGURE 1 Lakes from which the fish population were samples.

Tissue samples were frozen on dry ice and wrapped with aluminum foil, then returned to the laboratory for analysis.[4]

Concentrations (ppm) were determined for the following:

Chlorinated Hydrocarbons

pp′ DDT –ortho and para isomers of 1,1′ (2,2,2,trichloroethylidene)
op′ DDT bis (4-chlorobenzene)

DDE—1,1′ (dichloroethylidene) bis (4-chlorobenzene)

DDD—1,1′ (2,2-dichloroethylidene) bis (4-chlorobenzene)

PCB—polychlorinated biphenyls

HCB—hexachlorobenzene

αBHC—1,2,3,4,5,6-hexachorocyclohexane (or α benzenehexachloride)

Heavy Metals

As—Arsenic

B—Boron

Cu—Copper

Hg—Mercury

Pb—Lead

V—Vanadium

Zn—Zinc

RESULTS AND DISCUSSION

Chlorinated Hydrocarbons

Results of the analyses indicate that ΣDDT was the most abundant of the chlorinated hydrocarbons for which analyses were performed (Table I). This was true for both muscle and fat tissues and for each of the fish species sampled. In fat tissue, where concentrations were by far the highest and comparisons therefore most meaningful, DDE was the most abundant of the four related compounds (74.8% of ΣDDT) followed by DDD (14.7%), pp′ DDT (7.8%), and op′ DDT (2.5%). Among the other chlorinated hydrocarbons in fat tissues, concentrations of PCB were second to those of ΣDDT, averaging about one third (36.0%) of the concentration of ΣDDT. Less important were HCB (5.8% of ΣDDT) and αBHC (11.0% of ΣDDT).

For all of the chlorinated hydrocarbons analysed, concentrations in fat tissue were consistently higher than those in muscle (Table I). For ΣDDT, the mean concentration in fat was nearly 99 times that in muscle tissue. For PCBs the difference in concentration between the two tissues was 125 times; for HCB, at least 40 times; and for αBCH, 38 times. Data for fats also indicate that there were considerable differences in mean concentrations between species.

The rank order for both ΣDDT and PCBs, the two most common chlorinated hydrocarbons, was the same: pike > whitefish > cisco > white sucker (Table II). This is in general accord with the trophic level occupied by the various species, respectively, predator, bottom feeder, zooplankton feeder, and omnivore (suckers include a large proportion of vegetable material in their diets). Cisco however, had the greatest mean concentrations of the two less common compounds, HCB, and αBHC. The diet of ciscos is composed, in large part, of copepods, a group characterized by high levels of fat.

Heavy Metals

Bioaccumulation of heavy metals appears to be widespread in aquatic organisms.[5] Fish, in particular, are known to accumulate heavy metals differentially.[6] The Canadian Food and Drug Directorate has set fish tissue tolerance limits for various metals including arsenic (5 ppm), copper (100 ppm), mercury (0.5 ppm), lead (10 ppm), and zinc (100 ppm). Based on the data obtained from this study (Table III), it does not appear that the fish tissues from the study area will present any health hazard for human consumption. There were only two instances where the recorded levels appeared to be high: (1) a mercury concentration of 0.407 ppm in a pike caught in Tucker Lake, and (2) a zinc concentration of 74.90 ppm in a

TABLE I

Summary of data describing chlorinated hydrocarbon concentrations in tissues of fish from lakes in the vicinity of Cold Lake, Alberta, 1978. ND = not detectable, T = trace (less than 0.001 ppm)

Species	N	PCB mean (range)	HCB mean (range)	αBHC mean (range)	pp'DDT mean (range)	op'DDT mean (range)	DDE mean (range)	DDD mean (range)	ΣDDT mean (range)
MUSCLE									
Cisco	13	0.002 (ND-0.006)	0.001 (T-0.002)	0.002 (T-0.005)	T (ND—T)	T (ND-0.002)	0.007 (T-0.035)	T (ND-0.002)	0.007+ (T-0.035)
Whitefish	12	0.002 (ND-0.157)	0.001 (T-0.021)	0.004 (T-0.042)	0.001 (ND-0.004)	T (ND-0.002)	0.011 (T-0.038)	0.002 (ND-0.016)	0.014+ (T-0.050)
White Sucker	8	0.001 (ND-0.004)	T (T-1.001)	0.001 (T-0.002)	T (ND-0.001)	ND	0.002 (ND-0.009)	T (ND-0.003)	0.002+ (T-0.009)+
Pike	11	0.002 (ND-0.008)	T (ND-T)	T (T-0.003)	T (ND-0.005)	T (ND-T)	0.002 (ND-0.013)	0.001 (ND-0.006)	0.004+ (T-0.016)
Mean of Means–Muscle		0.002	<0.001	0.002	<0.001	<0.001	0.006	0.001	0.007+
FAT									
Cisco	6	0.113 (ND-0.939)	0.055 (0.030.195)	0.098 (0.037–0.274)	0.018 (ND-0.037)	0.022 (ND-0.127)	0.458 (0.05–1.589)	0.111 (ND-0.402)	0.609 (0.054–2.154)
Whitefish	12	0.274 (ND-2.600)	0.047 (0.009–0.213)	0.071 (0.027–0.278)	0.047 (ND-0.458)	0.026 (ND-0.216)	0.591 (0.026–5.252)	0.082 (ND-0.350)	0.746 (0.03–6.230)
White Sucker	4	0.057 (0.001–0.162)	0.023 (T-0.048)	0.051 (T-0.104)	0.016 (0.001–0.035)	0.004 (ND-0.015)	0.117 (0.005–0.211)	0.069 (0.002–0.152)	0.206 (0.008–0.382)
Pike	9	0.55 (0.101–1.703)	0.034 (0.006–0.086)	0.084 (0.044–0.162)	0.135 (0.004–0.861)	0.017 (ND-0.110)	0.907 (0.044–4.520)	0.148 (0.011–0.711)	1.207 (0.07–4.607)
Mean of Means—Fat		0.249	0.04	0.076	0.054	0.017	0.518	0.102	0.692
as % of ΣDDT		36.0	5.8	11.0	7.8	2.5	74.8	14.7	100.0
Mean Concentration in fat/mean concentration in muscle		124.5	40.0	38.0	54.0	17.0	86.3	102.0	98.8

TABLE II

Rank of fish species with respect to concentrations of various chlorinated hydrocarbons. Samples from lakes in the vicinity of Cold Lake, Alberta, 1978

	Rank	PCB	HCB	αBHC	ΣDDT
	1	Pike	Cisco	Cisco	Pike
Decreasing	2	Whitefish	Whitefish	Pike	Whitefish
Concentration	3	Cisco	Pike	Whitefish	Cisco
↓	4	White Sucker	White Sucker	White Sucker	White Sucker

cisco caught in Cold Lake. All other measurements were well below the tolerance standards.

Table IV compares the tissue levels of certain heavy metals found in this study with those found in other industrialized and non-industrialized areas in Canada. The data indicate that arsenic levels found in this study are comparable to or higher than those found in industrialized areas of Canada. Copper levels in pike and white sucker from the Cold Lake area are higher than those of fish from Lake Erie. Mercury levels were low in fish from the Cold Lake area, but zinc concentrations were high in cisco.

In order to determine which fish species were most prone to accumulate heavy metals, an enrichment ratio was determined for every heavy metal in each fish species (Table III). The enrichment ratio is the ratio of the concentration of a particular heavy metal in fish tissue to the concentration of that element in the water.[5] From the data it can be seen that the enrichment ratios varied between species of fish for the same element and for different elements. Lake trout, lake whitefish, and cisco appeared to have greater tendencies to accumulate arsenic, whereas pike and white sucker had a greater tendency to accumulate copper. The mercury enrichment ratio was higher in lake trout and lake whitefish, while white suckers appeared to be more prone to accumulating lead, and ciscos to accumulating zinc.

Enrichment ratios are of considerable importance in selection of suitable organisms for monitoring heavy metals (especially those that are toxic to humans) over long periods. For example, data from this study indicate that tissues of lake trout and lake whitefish will be more suitable in monitoring the levels of arsenic and mercury.

Acknowledgement

This study was funded by Esso Resources Canada Limited, Cold Lake Project, Heavy Oil Department.

TABLE III

Mean concentration of heavy metals in fish from seven lakes in the vicinity of Cold Lake, Alberta, 1978. Concentrations are expressed in ppm and enrichment is indicated by the ratio of tissue value to that in the water

	Water chemistry	Lake Trout (N=1)		Pike (N=8)		Lake Whitefish (N=12)		White Sucker (N=6)		Cisco (N=5)	
Element	(max. average concentration)	Tissue conc.	Minimum enrichment ratio	Tissue conc.	Minimum enrichment ratio	Tissue conc.	Minimum enrichment ratio	Tissue conc.	Minimum enrichment ratio	Tissue conc.	Minimum enrichment ratio
V	0.0102	4.74	464.71	3.88	380.39	3.72	364.71	6.43	630.39	5.59	548.04
As	0.0079	0.32	40.51	0.096	12.15	0.28	35.44	0.058	7.34	0.322	40.76
B	0.0627	4.7	74.96	3.96	63.16	3.23	51.52	12.44	198.41	4.0	63.80
Cu	0.0212	0.64	30.19	1.58	74.53	0.51	24.06	1.36	64.15	0.662	31.23
Hg	0.0383	0.27	7.05	0.075	1.96	0.16	4.18	<0.005	<0.13	0.009	0.24
Pb	0.0402	<0.02	<0.49	0.055	1.37	0.017	0.42	1.493	37.14	<0.02	<0.49
Zn	0.0905	6.03	66.63	2.069	22.86	6.223	68.76	6.596	72.88	27.246	301.06

TABLE IV

A comparison of concentations (ppm) of several heavy metals in fish tissues (muscle) from selected Canadian waters

	Species	Locality	Arsenic	Copper	Mercury	Lead	Zinc	Source
NON-INDUSTRIAL AREAS	Lake trout	Alberta, Cold Lake area	0.32	0.64	0.27	<0.02	6.03	This study
	Pike	Alberta, Cold Lake area	0.096	1.58	0.075	0.055	2.069	This study
	Lake whitefish	Alberta, Cold Lake area	0.28	0.51	0.16	0.017	6.223	This study
	White sucker	Alberta, Cold Lake area	0.058	1.36	<0.005	1.493	6.596	This study
	Cisco	Alberta, Cold Lake area	0.322	0.662	0.009	<0.02	27.246	This study
	Lake whitefish	Moose Lake, Manitoba	0.09	0.50	0.07	<0.5	14.0	Uthe & Bligh[4]
	Pike	Moose Lake, Manitoba	<0.5	0.70	0.11	<0.5	19.0	Uthe & Bligh[4]
INDUSTRIAL AREAS	Lake whitefish	Lake Ontario	0.70	0.94	0.17	<0.5	12.0	Uthe & Bligh[4]
	Pike	Lake St. Pierre	0.09	0.89	0.70	<0.5	19.0	Uthe & Bligh[4]
	Pike	Lake Erie	<0.05	0.70	0.49	<0.5	11.0	Uthe & Bligh[4]
	Rainbow smelt	Lake Erie	0.15	0.78	0.05	0.5	20.0	Uthe & Bligh[4]
	Yellow perch	Lake Erie	<0.55	1.28	0.22	<0.5	12.0	Uthe & Bligh[4]
	Pike	North Saskatchewam R.	—	—	1.2	—	—	Wobeser *et al.*[2]
	White sucker	North Saskatchewan R.	—	—	0.9	—	—	Wobeser *et al.*[2]
	White sucker	South Saskatchewan R.	—	—	8.3	—	—	Wobeser *et al.*[2]

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