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OLDMAN RIVER DAM: MERCURY IN FISH - INTERIM REPORT 1993

Alberta
ENVIRONMENTAL CENTRE

OLDMAN RIVER DAM: MERCURY IN FISH - INTERIM REPORT 1993

by

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1 SUMMARY

During the third year of this five-year project, the total mercury (THg) concentration in muscle tissue was assayed in samples of 135 fish representing 5 different species. The fish collection sites were the same as in 1992 and 1991: two sites on the Oldman River Dam Reservoir, two sites downstream of the reservoir on the Oldman River, one upstream site on the Oldman River, and one upstream site on the Crowsnest River. The five species of fish collected for analysis included mountain whitefish, rainbow trout, bull trout, white sucker and longnose sucker. Based on the analysis of the fish tissue, it was observed that:

i) Mean THg concentrations in the 1993 collections were generally within the bounds of mean THg estimated for the same species in the 1992 and 1991 collections,

ii) Mean THg concentrations were always <0.5 mg kg^{-1}, regardless of species or site,

iii) Bull trout, white sucker and longnose sucker carried slightly higher THg concentrations than the other species,

We conclude that mercury residues in fish from the reservoir and surrounding rivers posed no health threat to human consumers of fish in 1993.

2 INTRODUCTION

2.1 Background

In 1991, the Alberta Environmental Centre (AEC) initiated a five year research project on mercury in fish inhabiting the newly constructed Oldman River Dam Reservoir and rivers within the Oldman River basin. The project, planned in association with two government departments (Alberta Public Works, Supply and Services and Alberta Environmental Protection), formed part of a much larger fisheries mitigation strategy for the basin (Alberta Public Works, Supply and Services, 1990). This strategy requires that there be no net loss of fish habitat or recreational fishing opportunities.

The impetus for this project, resulted from the general hypothesis that mercury concentrations in fish might increase during and after the impoundment of reservoirs. Mercury in fish primarily occurs in an organic form (methyl mercury) that may affect the central nervous system of consumers. These effects, when fully manifested, induce a condition known as Minamata disease (Friel, 1974). The term Minamata refers to Minamata Bay (Japan), the site where the disease was first diagnosed in fish consumers during the 1950's. Minamata disease has never been detected or reported in Canada.

The mercury content of fish has increased in several reservoirs in Canada and elsewhere (Green, 1990; Jackson, 1988; Johnson *et al.*, 1991; Bodaly *et al.*, 1984; Abernathy and Cumbie, 1977), but has not been observed in fish from Alberta reservoirs (e.g. Alberta Environmental Centre, 1989). The mechanism for increased mercury uptake by fish appears to be based on enhanced activity of methylating bacteria and other microorganisms in freshly inundated soil (Cox *et al.*, 1979; Jackson, 1988, 1991). The rate of methylation and subsequent uptake by fish and other aquatic species depends on numerous factors, including redox potential of the sediment, binding of Hg^{2+} to sulphides, binding of organic mercury (OHg) to FeOOH and MnOOH, microbiological activity, pH of the sediment and overlying water, mercury concentrations in water, temperature, and trophic conditions (Jackson, 1988, 1993; Berman and Bartha, 1986; Curtis, 1974; Hakanson, 1980). Since each of these factors will vary from reservoir to reservoir, the extent of mercury accumulation in fish is also variable. In the more serious cases where concentrations in fish muscle tissue exceed the guideline of 0.5 mg kg^{-1} (Health and Welfare Canada, 1990), human consumption of fish has been limited or totally restricted.

2.2 Objectives

The overall study objectives have not changed since the project was initiated. They include:

Primary - assess changes in the concentration of mercury in the muscle tissue of fish over a five year period in the Oldman Dam Reservoir, the Oldman River above and below the reservoir, and the Crowsnest River.

Secondary - conduct supplementary inventory studies of fish populations in the reservoir and surrounding rivers.

Fish collected during the first and second year of the study (1991 and 1992) carried mean mercury concentrations that were always <0.5 mg kg^{-1}, regardless of species or site (Alberta Environmental Centre, 1993 and 1994). The THg concentration in the 1992 collections were generally within the bounds of THg estimates for the same species in 1991 (Alberta Environmental Centre, 1993) and 1986 (Alberta Environment, 1989). This specific report provides interim data for the 1993 fish collections, and comparisons with data from the 1992 fish collections.

3 CONDUCT OF STUDY

3.1 Good Laboratory Practice

The principles of Good Laboratory Practice (GLP) were followed during 1993, and will continue to be used throughout the duration (5 years) of the study. Compliance with GLP is intended to ensure the quality and integrity of data generated for safety testing regarding human consumption of fish tissue and possible litigations.

Guidance for GLP (including animal care and use, and data and sample tracking) is outlined in Standard Operating Procedures (Aquatic Biology Branch, 1991). These procedures are consistent with those outlined by other agencies (Federal Register, 1983; National Health and Welfare, 1989).

3.2 Project Team

The project team responsible for the execution of the protocol, which was formed in 1991, has gone through some changes in 1994 as listed below:

J.W. Moore	Biological Sciences Division (Project Leader until August 1994)
K.L. Smiley	Biological Sciences Division (Field Collection)
L.Z. Florence	Physical and Engineering Sciences Division (Statistical Design and Analysis)
S.Wu	Physical and Engineering Sciences Division (Project Collaborator and Project Leader since August 1994, Analytical Methods)
D.S. Lucyk	Physical and Engineering Sciences Division (Laboratory Supervision and analysis until March 31, 1994).

All data and reports generated by this team are subject to the AEC review process.

3.3 Study Design and Sampling Methods

A complete description of the study design and sampling methods used in 1993 is outlined in Protocol 2440-DL2/P3 "Oldman River Dam: Mercury in Fish - 1993" Protocol. Copies of this protocol are available from the following address:

Central Records Office, Alberta Environmental Centre, Vegreville, AB, T9C 1T4, telephone (403) 632-8319.

The study design and sampling methods are consistent with those used during 1991 and 1992 (Alberta Environmental Centre, 1993 and 1994).

3.4 Method and Quality of Mercury Analysis

A complete description of the methods used to determine total and organic mercury is available from the Alberta Environmental Centre (1993). Analytical quality for the 1993 data is described in Wu *et al.* (1994), also available from the following address:

Central Records Office, Alberta Environmental Centre, Vegreville, AB, T9C 1T4, telephone (403) 632-8319.

4 RESULTS

4.1 Species Inventory

A total of 135 fish was caught from the six sites (Figure 1, Table 1). Sites I and II (upstream of the reservoir) yielded 34.1% of the catch, Sites III and IV (within the reservoir) 48.1%, and Sites V and VI (downstream of the reservoir) 17.8%.

Among the sport fish collected, bull trout *Salvelinus confluentus*, rainbow trout *Oncorhynchus mykiss*, and mountain whitefish *Prosopium williamsoni* made up 11.1%, 17% and 49.6% of the catch, respectively, while the corresponding frequency for white sucker *Catostomus commersoni* and longnose sucker *Catostomus catostomus* were 6% and 16.3%, respectively. No northern pike (*Esox lucius*) or burbot (*Lota lota*) were caught from any sites in 1993.

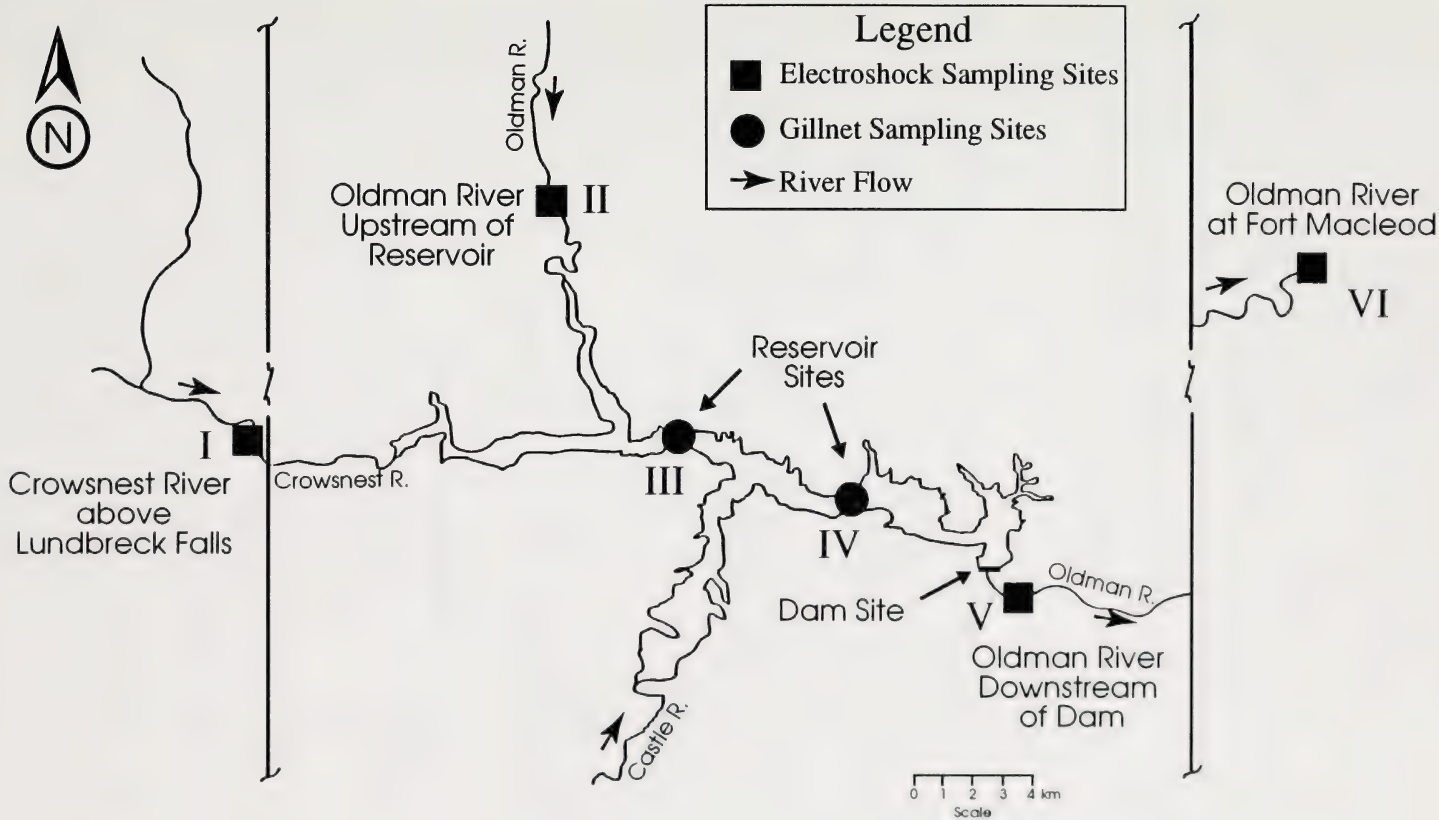

Figure 1. Collection sites I-VI

Table 1. Distribution of 1993 fish catch

CATCH NUMBER / SPECIES	SITE*						TOTAL NUMBER	PERCENT
	I	II	III	IV	V	VI		
Bull Trout	-	2	4	9	-	-	15	11.1
Longnose Sucker	-	7	3	10	2	-	22	16.3
Mountain Whitefish	15	5	23	9	5	10	67	49.6
Rainbow Trout	15	2	1	-	5	-	23	17
White Sucker	-	-	1	5	2	-	8	6
TOTAL NUMBER	**30**	**16**	**32**	**33**	**14**	**10**	**135**	
PERCENT	**22.2**	**11.9**	**23.7**	**24.4**	**10.4**	**7.4**		**100**

*Site I - Crowsnest River (upstream)
Site II - Oldman River (upstream)
Site III - Reservoir, West Basin
Site IV - Reservoir, Central Basin
Site V - Oldman River, Below Dam
Site VI - Oldman River, Fort MacLeod

4.2 Total Mercury Concentrations in Fish Muscle Tissue

Mean THg concentrations in fish were always <0.5 mg kg^{-1}, regardless of species or site (Appendix 1). Mountain whitefish generally contained the smallest concentrations, followed by rainbow trout. Although variable, concentrations of total mercury in bull trout were generally higher than those of any other species. These trends were the same as observed in the 1992 collections (Alberta Environmental Centre, 1994).

4.3 Organic Mercury Concentrations in Fish Muscle Tissue

Organic mercury (OHg) analysis were performed for all fish having total mercury (THg) concentrations above 0.4 mg kg^{-1} in 1992 collection. During the 1993 collection and analysis of fish tissues, only three total mercury concentration were above 0.4 mg/kg; therefore the costly organic mercury analysis was not performed. The organic mercury fraction (OHg/THg•100) ranged from 92-104% among species and from 87-100% among sites for the first year's study (1991) of this project (Alberta Environmental Centre, 1993). The average organic fraction of total mercury ranged from 89-96% among species or among sites for the second year (1992) (Wu et al., 1993).

4.4 Comparison of 1993 and 1992 Data at Different Sites

Table 2 shows the comparisons of means of THg between 1993 and 1992 collections at each site. The means were reported as raw, untransformed estimates; analyses of variance and comparisons between years are done using $\log_{10}$ transformed THg and fish fork length in order to account for the distribution of these two variables and stabilize variances among sites. With the exception of rainbow trout at site I, no statistically significant increases or decreases in average THg were detected for each species at each site at the 0.05 level of significance. The significant increase in THg found in rainbow trout, site I, can not be attributed to the impoundment since this population was collected above Lundbreck Falls in Crowsnest River (Fig. 1). However, we caution that our ability to detect significant differences was reduced in those cases where small numbers of samples were collected. For example, the rainbow trout catch for site II in 1992 and 1993 was 4 and 2 respectively, for site III, was 1 each year, for site IV, was 4 and 0 respectively, and for site VI was 1 and 0 respectively. These deficiencies are sometimes inevitable in this sort of field survey.

Table 2. Means of THg (± SD, in parentheses). Where "n/a", only one fish was caught. Comparisons between years, by species, among sites, was done using log transformed data adjusted for fish size (fork length, when caught).

Species	Year	Site					
		I	II	III	IV	V	VI
Bull Trout	1992	--	0.273	0.328	0.400	0.339	--
		--	(0.1236)	(0.0493)	(0.1629)	(0.0451)	--
	1993	--	0.366	0.2310	0.310	--	--
		--	(0.1846)	(0.0571)	(0.0827)	--	--
Longnose Sucker	1992	--	--	0.223	0.238	0.338	0.337
		--	--	(0.0444)	(0.0547)	(0.0801)	(0.1733)
	1993	--	0.334	0.225	0.251	0.302	--
		--	(0.0469)	(0.1018)	(0.0662)	(0.0148)	--
Mountain Whitefish	1992	0.035	0.114	0.100	0.172	0.112	0.154
		(0.0118)	(0.0548)	(0.0702)	(0.0829)	(0.0313)	(0.0648)
	1993	0.044	0.148	0.123	0.175	0.135	0.140
		(0.0191)	(0.0698)	(0.0785)	(0.0635)	(0.0471)	(0.0562)
Rainbow Trout	1992	0.032	0.120	0.346	0.334	0.238	0.315
		(0.0094)	(0.1186)	n/a	(0.1427)	(0.135)	n/a
	1993	0.042[a]	0.044	0.159	--	0.182	--
		(0.0202)	(0.0021)	n/a	--	(0.0630)	--
White Sucker	1992	--	--	0.193	0.196	0.322	0.345
		--	--	(0.0729)	(0.0455)	(0.1580)	(0.1755)
	1993	--	--	0.174	0.208	0.307	--
		--	--	n/a	(0.0291)	(0.0071)	--

[a] No statistically significant differences were detected between years for any speices, except RBT, site 1, which cannot be attributed to the Oldman Dam.

5 DISCUSSION

The limnological conditions in the reservoir and Oldman River downstream of the reservoir are still dynamic and will likely not stabilize for several years. Although, the 1993 season was the third year of this five-year project, discretion must still be taken when interpreting these results. Prior to the 1992 collection in October 1992, the reservoir's operational volume had been maintained at about 60% of its total capacity for only three months. From then to the 1993 collection in October, the reservoir operational volume had been continuously maintained at 80-90% of its total capacity (Alberta Environmental Protection, 1994). As changes occur in physical and chemical conditions of the sediments and water column, the availability of organic mercury to aquatic organisms will also change as previously discussed (Alberta Environmental Centre, 1994).

The most significant feature of the 1993 data is that for each species at each site where THg data was available, mean THg concentrations were consistently low and <0.5 mg kg^{-1} (Table 2). The second significant feature is that for each species at sites inside the reservoir and on the Oldman River downstream or upstream of the reservoir, where mean THg data were available, no significant increase or decrease was detected at the $\leq$0.05 significance level between 1993 and the 1992 collections. However, we caution that the overall sample size was significantly lower in 1993 compared to 1992 and the sample design sizes were not achieved for most species at most sites. These restrictions have hampered our ability to detect possible significant differences in comparing mean THg concentrations. Nevertheless, the 1993 results remain a good indication of the general trend of THg residues in fish muscle tissue in the Oldman River reservoir and surrounding rivers. The observed trend that THg residue in fish remained unchanged from 1992 to 1993 may be partially attributed to the fact that about 440 hectares of riparian forest (including all trees and shrubs over about 3m in height) and about 150,000 cubic meter topsoil (representing most of the higher quality topsoil) were removed from the inundated area of the reservoir. (Nilson, 1994; Mahoney, 1994; Hardy Associates [1978] Ltd., 1986).

The variation in THg concentrations for the same species among sites in the Oldman River basin may be due to a number of factors or combination of factors of both natural and anthropogenic origins. Examples of these factors are: i) rate of methylation of mercury as the river becomes more eutrophic moving downstream; ii) methylation of mercury as the river warms moving downstream, iii) changes in the physical and chemical properties of sediments, resulting in increased mobilization of inorganic and organic mercury; iv) change in the diet of fish, and v) sampling artifacts.

This database will be enlarged over the next two years of the study. The project team will continue to work toward meeting the sampling goals of the protocol in the next two years.

In conclusion, THg residues in fish collected during 1993 from the reservoir and surrounding rivers remained low and posed no threat to human consumers of fish. Where sufficient data permitted comparisons, THg concentrations in the 1993 collections were generally similar with determinations made for the same species in the 1992 collections.

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Appendix 1. Summary of mercury concentration in fish in Oldman River Dam area in 1993

Site	Species*	Year	Length			Total Mercury[§]			N of Total Mercury ≥0.5 (mg kg^{-1})
			N	Fork Length (cm)		N	Concentration (mg kg^{-1})		
				Mean	Range		Mean	Range	
Site I Crowsnest River, above Lundbreck Falls	MNWH	1993	15	32.4	27.5-36.8	15	0.044	0.002-0.074	0
	RNTR	1993	15	25.5	17.6-31.5	15	0.042	0.017-0.086	0
Site II Oldman River, upstream of reservoir	BLTR	1993	2	39.8	38.2-41.4	2	0.355	0.235-0.496	1
	MNWH	1993	5	35.3	32.3-40.1	5	0.148	0.080-0.266	0
	RNTR	1993	2	29.4	20.1-38.6	2	0.045	0.043-0.046	0
	LNSC	1993	7	43.5	38.0-46.7	7	0.334	0.273-0.417	0
Site III Reservoir, west basin	BLTR	1993	4	26.2	22.4-34.0	4	0.231	0.174-0.290	0
	LNSC	1993	3	26.8	25.1-29.6	3	0.225	0.144-0.339	0
	MNWH	1993	23	20.7	15.7-26.8	23	0.123	0.014-0.262	0
	RNTR	1993	1	21.3	21.3-21.3	1	0.159	0.159-0.159	0
	WHSC	1993	1	36.0	36.0-36.0	1	0.174	0.174-0.174	0
Site IV Reservoir, central basin	BLTR	1993	9	30.7	19.3-49.9	9	0.310	0.158-0.443	0
	LNSC	1993	10	32.1	24.5-39.8	10	0.251	0.173-0.366	0
	MNWH	1993	9	25.4	21.5-34.1	9	0.175	0.070-0.307	0
	WHSC	1993	5	38.7	34.3-43.9	5	0.208	0.181-0.256	0
Site V Oldman River, immediately below dam	LNSC	1993	2	43.4	42.1-44.7	2	0.303	0.292-0.313	0
	MNWH	1993	5	30.0	26.4-35.5	5	0.135	0.101-0.216	0
	RNTR	1993	5	32.9	26.8-35.5	5	0.182	0.105-0.256	0
	WHSC	1993	2	37.5	34.2-40.7	2	0.307	0.302-0.312	0
Site VI Oldman River, Fort Mcleod	MNWH	1993	10	34.3	27.0-40.3	10	0.140	0.077-0.251	0

[§] Analysis performed by snipping subsampling procedure

* BLTR - Bull Trout
LNSC - Longnose Sucker
MNWH - Mountain Whitefish
RNTR - Rainbow Trout
WHSC - White Sucker