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Abstract

The Sainte-Marguerite-3 hydroelectric generating station, a 882 MW facility, required the impoundment of a 315 km² reservoir. As expected, 7 years after the impoundment, fish mercury levels increased by factors ranging from 6 to 8 according to the main fish species, to 0.78 µg g⁻¹ (ww) in 400-mm Lake Whitefish and to 1.89 µg g⁻¹ in 700-mm Northern Pike. Fish consumption and mercury exposure surveys of local populations were carried out in 1997, before impoundment, and in 2006, 8 years after the beginning of filling. Compared to pre-impoundment conditions, non-native fishers consumed significantly more local fish on a monthly basis, while native Innu fishers consumed significantly less fish, for reasons unrelated to the mercury issue. The average hair mercury concentration remained unchanged for the non-native fish consumers at 0.9 µg g⁻¹, while it decreased significantly from 0.9 to 0.5 µg g⁻¹ for native fish consumers. For both native and non-native women of child-bearing age, the average hair mercury levels remained unchanged at 0.4 µg g⁻¹.

Introduction

The impoundment of large hydroelectric reservoirs causes significant although temporary increases in fish total mercury (Hg) concentrations (Lucotte *et al.*, 1999). The development of the Sainte-Marguerite-3 (SM 3) hydroelectric facility required the impoundment of a 315 km² canyon-type reservoir on Québec's North Shore region, which was filled from 1998 to 2002. The reservoir is located about 90 km from the city of Sept-Îles and the native Innu communities of Uashat and Mani-Utenam.

Fish mercury levels were monitored, fish consumption guides were distributed, and mercury exposure and fish consumption surveys were carried out, before and after impoundment, on native Innu and non-native populations consuming local fish.

As expected, fish mercury levels increased 6 to 8 fold in the main fish species. **Figure 1** shows that average mercury concentrations reached 0.78 µg g⁻¹ (ww) in 400-mm Lake Whitefish (7 years after the beginning of impoundment), and 1.89 µg g⁻¹ in 700-mm Northern Pike (after 10 years).

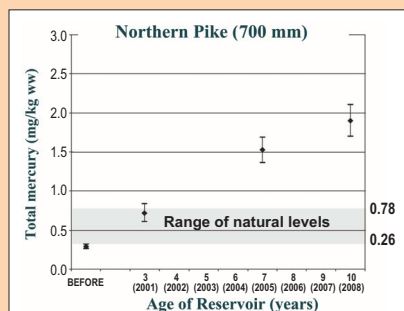
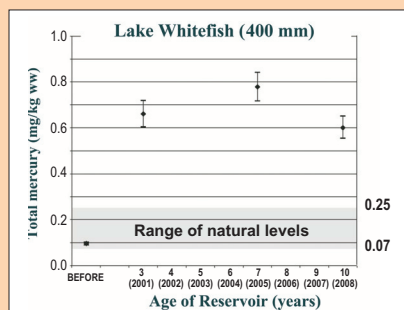
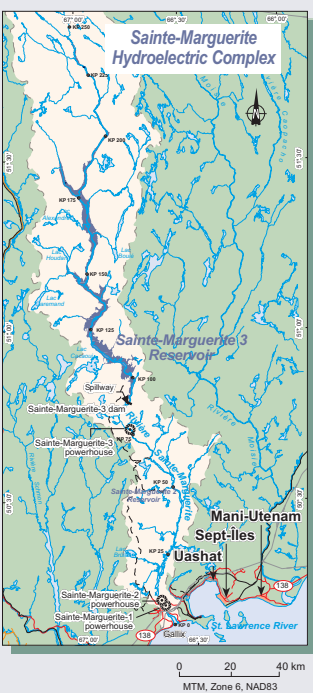
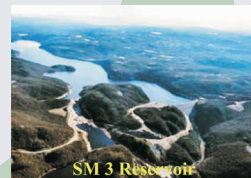


Figure 1: Monitoring of mercury levels in consumption size fish of SM 3 Reservoir

Materials and Methods

Fish consumption habits were determined by a questionnaire containing 26 questions and 98 sub-questions related to fish species captured, fishing sites, and fish consumption, during the previous 12-month period. This questionnaire was administered before (in 1997) and 8 years after the beginning of impoundment of the SM 3 Reservoir (in 2006). A total of 184 participants (77 native Innus and 107 non-natives) responded in 1997, and 125 participants (35 Innus and 90 non-natives), in 2006. The 2006 campaign focused on land users (members of fishing associations, cottage owners and trapline holders), estimated at 504 non-natives and 47 Innus.

Mercury exposure was determined by total Hg hair measurements, expressed in µg g⁻¹ ww. A total of 136 hair samples were thus obtained in 1997 (56 Innus and 80 non-natives), and 112 hair samples were collected in 2006 (33 Innus and 79 non-natives). For both surveys, men and women of different age classes were targeted: 18 to 34, 35-44, 45-54 and 55+.

Total Hg concentrations in hair samples were determined by the standard CVAAS method. Three separate hair segments of 1 cm were analysed on each hair sample. Results presented in Tables 2 and 3 correspond to the arithmetical means obtained for the three segments.



Sainte-Marguerite Fish Consumption Guide

Results

The local Innu population living in Uashat and Mani-Utenam communities showed a slight, although significant, reduction in fish consumption after impoundment, with an average of 2.1 fish meals per month in 2006, 8 years after the impoundment of the SM 3 Reservoir, compared to 2.3 meals per month in 1997 (Table 1). For the non-native population of Sept-Îles, consumption of fish captured in the area increased significantly after impoundment, to an average of 2.6 meals per month, compared to 1.8 meals per month in 1997. The preferred species in 2006 remained Brook Trout for both populations. Most consumed fish were caught in natural lakes, but 17% of the Innu and 36% of the non-native participants consumed fish from the water bodies affected by the project (mostly Northern Pike).



Drying of the fish before smoking



Lake Whitefish



Northern Pike

Table 1: Average number of local fish meals consumed per month by local populations, before and after the impoundment of the SM 3 Reservoir.

Population	Before (1997)			After (2006)		
	N	Mean	(S-D*)	N	Mean	(S-D*)
Innu of Uashat and Mani-Utenam	77	2.3	(0.4)	35	2.1**	(0.4)
Non-Natives of Sept-Îles	107	1.8	(0.2)	90	2.6**	(0.3)

* Standard deviation

** Significant difference (p-value < 0.05)

Table 2 shows that mercury exposure of the non-native population of Sept-Îles remained unchanged, with a mean hair total Hg concentration of 0.9 µg g⁻¹ (ww). For the Innu population of Uashat and Mani-Utenam, mercury exposure actually decreased after impoundment, to 0.5 µg g⁻¹ total Hg (hair concentration), compared to 0.9 µg g⁻¹ in 1997. These values are all well below the recognized threshold of health effects for adults in general, of 0.9 µg g⁻¹ total Hg hair concentration (WHO, 1972; 2004).

Table 2: Mercury exposure of local populations before and after the impoundment of the SM 3 Reservoir (Total Hg in 3 cm hair segments, in µg g⁻¹ ww).

Population	Before			After		
	N	Mean	(Range)	N	Mean	(Range)
Innu of Uashat and Mani-Utenam	56	0.9	(<0.1 - 4.2)	33	0.5*	(<0.1 - 1.9)
Non-Natives of Sept-Îles	80	0.8	(<0.1 - 3.4)	79	0.9	(<0.1 - 10)

* Significant difference (p-value < 0.05)

Table 3 shows that mercury exposure obtained after impoundment of the SM 3 Reservoir also remained low for women of child-bearing age for both populations surveyed. Indeed, a mean value of 0.4 µg g⁻¹ total Hg hair concentration was measured, with individual values ranging from <0.1 to 1.3 µg g⁻¹. These values are also well below the recognized threshold of health effects for the fetus of 14 µg g⁻¹ maternal-hair total Hg (WHO, 1972; 2004).

Table 3: Mercury exposure obtained after the impoundment of the SM 3 Reservoir (in 2006) for women of both populations surveyed (Total Hg in 3 cm hair segments, in µg g⁻¹ ww).

Women	2006		
	N	Mean	(Range)
Child-bearing age (18 to 39 years)	13	0.4	(<0.1 - 1.3)
Other women (40 years and older)	80	0.7	(<0.1 - 1.9)

Discussion

Our results show no increases in mercury exposure of local populations after the impoundment of the SM 3 Reservoir, despite 6 to 8 fold increases in fish total Hg levels. Accordingly, the simple application of fish Hg increase factors is clearly not useful to predict future Hg exposure of local fish consumers. Health risk assessment methods related to the consumption of fish in the context of hydroelectric reservoir projects must also take into account fish consumption habits, preferred fish species and fisher intention of harvesting reservoir fishes (Schetagne *et al.*, 2008).

In the case of the SM 3 Reservoir facility, the preferred fish species of the local populations remained Brook Trout, a non-piscivorous species that does not prosper in large reservoir habitats, where large predators such as Northern Pike are abundant.

Conclusion

- The SM 3 development did not increase mercury exposure of local fish consumers. Mercury exposure remained well below recognized threshold of health effects for adults in general and for the fetus
- Although the temporary increases in fish mercury levels represent a theoretical health risk, fish consumption habits in Québec make its occurrence highly improbable
- Communication programs and fish consumption guides developed with local public health institutions show that the potential health risk can be managed efficiently



Smoking of the fish

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