Key Issues:
9- Public Health
5- Water Quality

Climate Zone:
Df: Severe, with precipitation in all seasons

Subjects:
- Management of the Issue of Mercury in Hydroelectric Reservoirs

Effects:
- Reduction of health risks to native Cree Indians pursuing traditional activities of fishing and hunting, as well as to sport fishers.

Project Name: La Grande Hydroelectric Complex
Country: Canada

Implementing Party & Period
- Project: Hydro-Québec
1971 - 2000
- Good Practice: Hydro-Québec, Cree of Québec and Government of Québec
1978 -

Key Words:
Mercury, Reservoirs, Public Health, Monitoring, Information tools, Consumption advisories

Abstract:
The development of hydroelectric reservoirs causes temporary increases of mercury levels in fish which may pose health risks to regular fish consumers. A management program has been implemented to reduce health risks related to mercury exposure which includes : the signing of the James Bay Mercury Agreement, the study of the source and fate of mercury in Northern Québec; the monitoring of mercury levels in fish and of the Cree exposure to mercury, public information campaigns and fish consumption advisories.

1. Outline of the Project

The James Bay territory, located in Northern Québec, Canada, lies between the 48th and 55th North parallels and covers 350 000 km2 (135 187 sq. mi.). The La Grande hydroelectric complex, contained within this territory, was constructed to produce electric power. The total installed capacity of the complex is 15 238 MW. The two-phase project comprises eight generating stations and required the impounding of eight reservoirs with a total surface area of 12 953 km2, including 10 809 km2 of flooded terrestrial area.

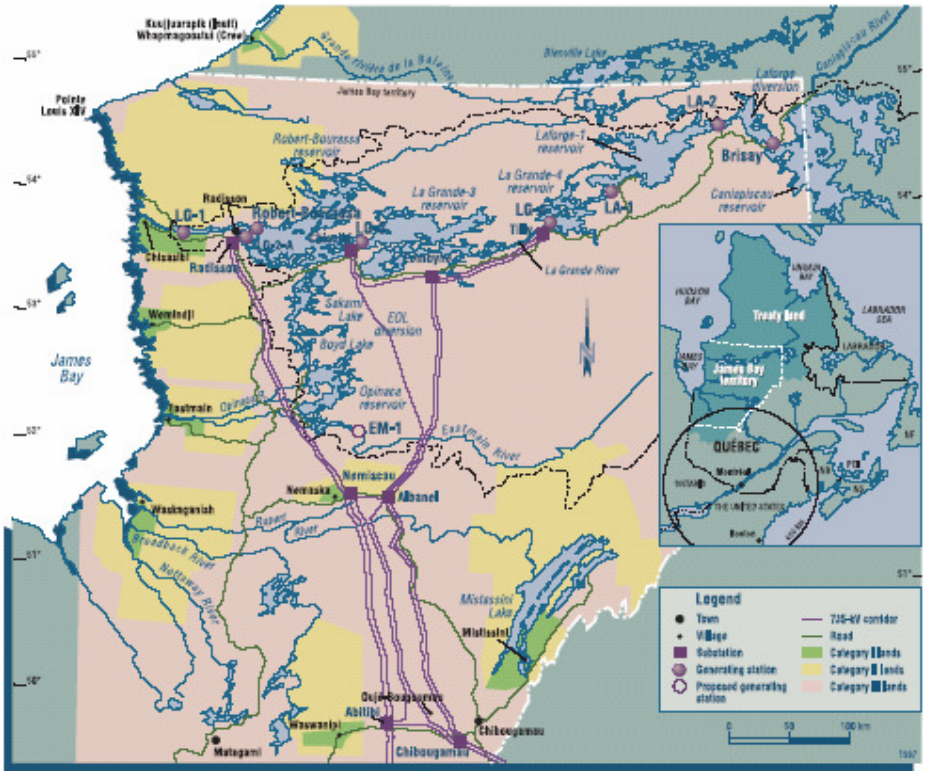

Figure 1: Location map of the La Grande Hydroelectric project

2. Features of the Project Area

The topography of the territory is the result of the passage of glaciers and can be divided into three zones : a coastal plain, 150 km wide, with scattered peat bogs and clay deposits; a hilly plateau covered by a large number of lakes; and finally, at the eastern end, rougher terrain. The whole region is part of the Canadian Shield, one of the oldest known geological formations composed of igneous and metamorphic rock. The climate is of the cold continental type, characterized by highly contrasting seasons. The annual average temperature is around -4°C. The hydrological regime is governed by rain and snow : heavy spring floods from snowmelt; decreased summer runoff and rain-induced fall flood; winter low water season which begins in November and follows through May. Waters are well oxygenated, highly transparent, poorly mineralized, low in nutrients and typically oligotrophic.

The territory, which includes all or part of the drainage basins of six large rivers, is home to some 11 200 Cree Indians, belonging to eight communities scattered across the region and the community of Whapmagoostui located just outside its northern boundary.

3. Major Impacts

Since the project began, regular monitoring has been conducted on the main parameters of the new ecosystems in the developed basins, such as water quality, fish, and mercury levels in the flesh of fish. Mercury levels in five fish species were monitored over a 20 year period : the non piscivorous lake whitefish (*Coregonus clupeaformis*) and longnose sucker (*Catostomus catostomus*) and the piscivorous

northern pike (*Esox lucius*), walleye (*Stizostedion vitreum*) and lake trout (*Salvelinus namaycush*). In reservoirs, concentrations in all species increased rapidly after impoundment, peaking after 5 to 9 years in non-piscivorous fishes, and after 10 to 13 years in piscivorous species, then significantly and gradually declined. Peak concentrations reached levels 3 to 7 times those measured in surrounding natural lakes. Concentrations in the non-piscivorous species have returned to levels typical of natural lakes 10 to 19 years after impoundment. In the piscivorous northern pike, the rate of decline, which begins after 15 years, strongly suggests that natural concentrations are reached between 20 to 30 years after impoundment. These increases in fish mercury levels considerably reduce the number of fish meals that can be eaten on a monthly basis, without exceeding the level of mercury exposure considered safe by public health authorities.

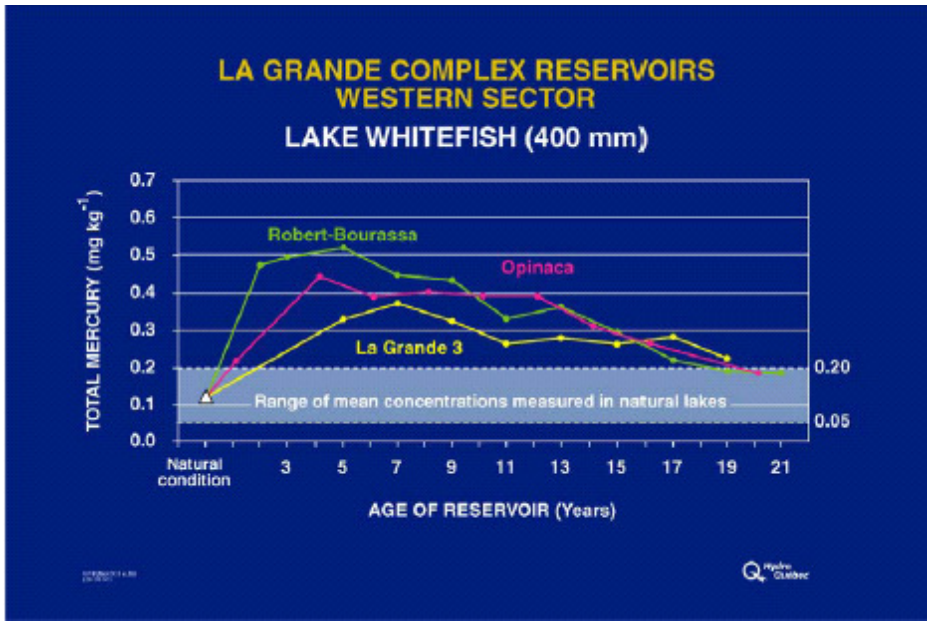

Figure 2: Temporary increases of mercury levels in a non piscivorous fish of the La Grande complex

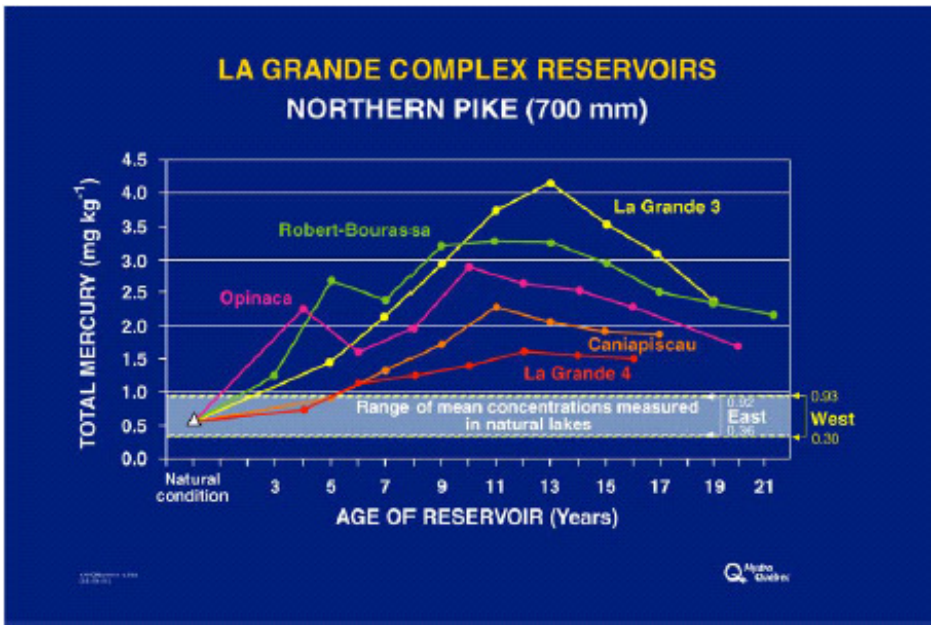

Figure 3:Temporary increases of mercury levels in a piscivorous fish of the La Grande complex

4. Mitigation Measures

At the onset of the La Grande Hydroelectric Project, the mercury issue related to reservoirs was virtually unknown. It was only stated in the literature that fish from some reservoirs had elevated mercury concentrations. Background mercury levels in fish were thus determined before impoundment of the first reservoir of the complex and an exploratory campaign carried out 2 years after the flooding of the first reservoir justified regular monitoring of mercury levels in fish of the modified environments of the La Grande Region. The Native Cree Indians were informed as soon as monitoring revealed significant increases of mercury levels in fish.

Hydro-Québec's Corporate research Program on mercury

Hydro-Québec established a Mercury Research and Management Program to address the issue of increasing mercury levels in fish caused by hydroelectric developments. The cost of this Corporate Research Program, initiated in 1990 and currently ongoing is approximately 1M$ per year. The following activities were included in this program:

- monitoring of mercury levels in fish of modified environments of the La Grande complex;
- development of models predicting mercury levels in fish of reservoirs;
- assessment of risks to piscivorous fauna;
- the study of the sources and fate of mercury in natural environments and hydroelectric reservoirs of Northern Québec (within a university-industry Environmental Chair);
- the study of intensive fishing as a means to reduce mercury levels in fish of natural lakes and reservoirs (within a university-industry Environmental Chair);
- assessment of the health risks and benefits associated with the consumption of La Grande Region fish;
- participation in a Canadian Department of Fisheries and Oceans study of the production of methylmercury in experimental reservoirs.

A number of these studies were carried out in collaboration with Government Organizations such as the Canadian Wildlife Service and the National Science and Engineering Research Council of Canada (which supported part of the funding of the Environmental Chair).

The James Bay Mercury Agreement

In addition to its Corporate research program on mercury, Hydro-Québec also negotiated the signing and implementation of the James Bay Mercury Agreement between the Government of Québec, the Cree of Québec and Hydro-Québec. The overall objective of this Agreement was to reduce the health risks and provide for remedial measures allowing the Cree to carry on their traditional hunting and fishing activities and maintain their way of life. This 10 year Agreement (1987-1996), with a total budget of 18 M$ of which 12 M$ was paid by Hydro-Québec, dealt with Health, Socio-cultural and Environmental aspects of the mercury issue. For each of these aspects, research, monitoring and mitigation were investigated and carried out when approved by a steering committee composed of representatives from Hydro-Québec (2), the Crees (2) and the Government of Québec (2).

The monitoring of mercury levels in fish of the La Grande Territory was continued, under this Agreement, by Hydro-Québec which was responsible for the environmental monitoring. Monitoring of the Cree exposure to mercury was carried out by the Cree Regional Board of Health and Social Services

of James Bay, which was responsible for the health aspects.
A critical review of potential mitigation measures aimed at reducing the increases of mercury levels in fish of young reservoirs failed to reveal any realistic solution, for various reasons including potential harmful side effects and economic and technical impracticability of all measures when it comes to their scale of application. The Steering Committee quickly reoriented its activities towards remedial measures aimed at reducing health risks by providing means to facilitate low mercury bush food harvesting and consumption:

- subsidies for family and community fishing in natural lakes;
- subsidies for coastal fisheries of anadromous species;
- wildlife enhancement schemes;
- schemes to increase harvesting of migratory waterfowl, etc.

Appropriate biological monitoring of the fisheries was also financed in order to avoid over harvesting.
Information tools, such as booklets, maps and videos, were developed and information campaigns were carried out in the Cree communities to explain the mercury issue and the health risks and benefits related to fish consumption. Fish consumption advisories were also distributed to Cree sport and subsistence fishers, according to exposure criteria of the Cree Regional Board of Health and Social Services of James Bay.

Figure 4: Information campaigns in Cree Communities

Figure 5: Information tool produced in French, English and Cree, in the form of a table mat

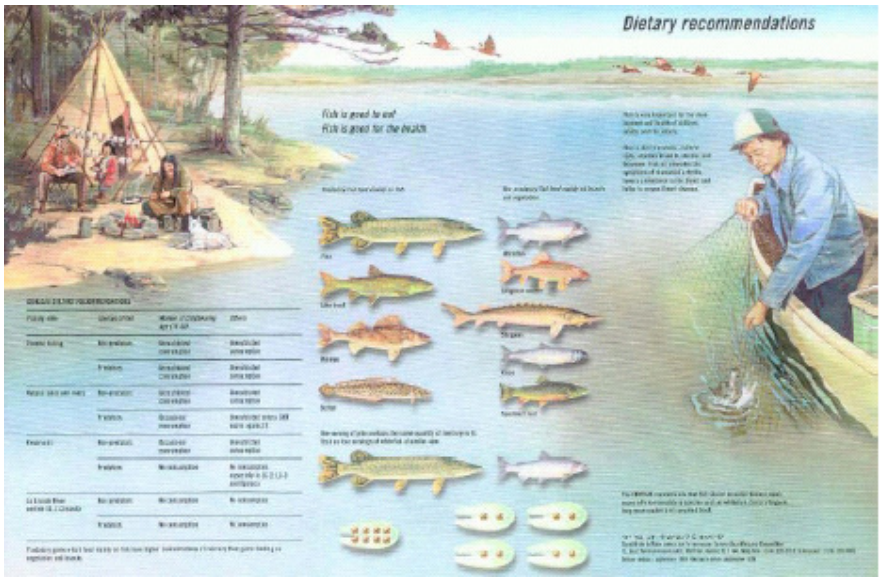

Figure 6: Fish consumption advisories

5. Results of the Mitigation Measures

The management of the mercury issue through Hydro-Québec's Corporate Research Program and through the activities of the James Bay Mercury Agreement produced a number of very important results. It enabled Hydro-Québec's Environmental Department to be considered amongst world leaders in mercury research related to hydroelectric developments as demonstrated by the publication of a Monograph on the sources and fate of mercury in natural environments and hydroelectric reservoirs of Northern Québec (Lucotte *et al.*, 1999).

Hydro-Québec's Corporate Research Program permitted a comprehensive understanding of the biogeochemical processes involved in the production of methylmercury in reservoirs and its transfer to fish. It also established the magnitude and duration of the post-impoundment increase of mercury levels in fish and permitted the development of mathematical models predicting mercury concentrations in reservoir fish.

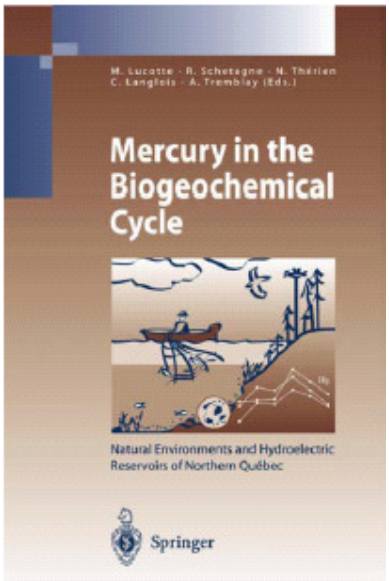

Figure 7:Mercury Monograph

The responsible manner by which the mercury issue was addressed by Hydro-Québec facilitated the governmental approval of a number of recent hydroelectric projects by demonstrating that the mercury issue, and its potential health risks to fish consumers, can be adequately managed through appropriate monitoring and compensation type remedial measures, as well as through information and communication campaigns informing fishers on the health risks and benefits of fish consumption.

Description

This Monograph presents an exhaustive view of what is known about the biogeochemical cycling of mercury in hydroelectric reservoirs as well as in natural aquatic systems of the boreal forest region of Northern Québec (Canada). Presented in the form of 14 peer reviewed papers, addressing the issue of mercury in natural lakes, terrestrial environments, hydroelectric reservoirs and fish eating wildlife, with an overall synthesis. It marks the conclusion of over 10 years of studies carried out by universities, governmental institutions and industries, using the latest and most appropriate sampling and analytical procedures. It also presents results of over 20 years of monitoring of mercury levels in reservoir fishes.

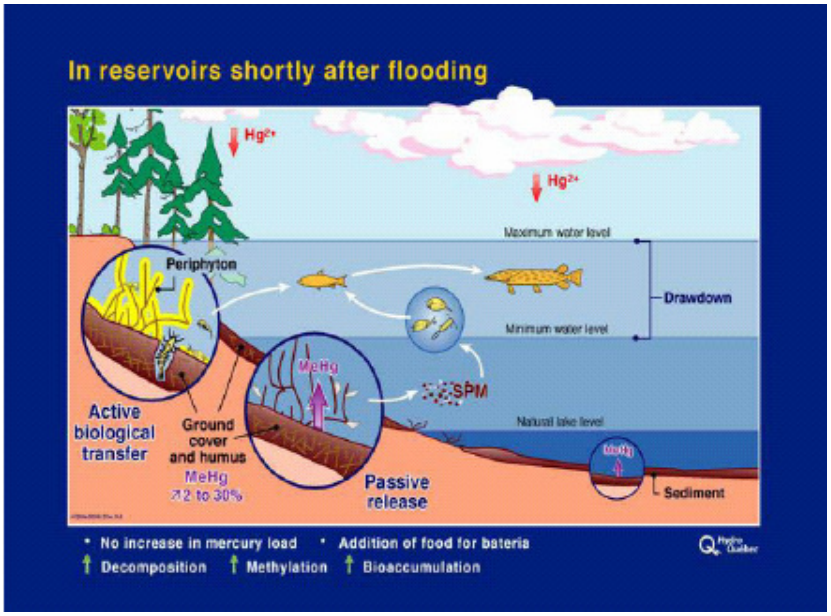

Figure 8: Processes involved in the temporary increase of methylmercury production and transfer in reservoirs

For each new project, fish consumption advisories for non-native sport fishers were also prepared in collaboration with Québec Public Health agencies according to Canadian and provincial exposure criteria.

Figure 9: Fish consumption advisories in the form of maps distributed to sport fishers

The mitigation measures selected and financed by the James Bay Mercury Steering Committee, under the Mercury Agreement, encouraged traditional hunting and fishing activities, offered benefits to the entire community, and were compatible with sound management of the environment's natural resources.
In general, replacement fisheries, both in lakes and coastal areas, were the most favored by the Cree communities affected by the mercury problem at the La Grande complex. This measure fulfilled some of the objectives of these remedial measures favoring fishing activities and the consumption of fish. In fact, non-piscivorous species of fish, which present low levels of mercury contamination, were found in the largest proportions, accounting for over 80% of total catches. Piscivorous species, known for higher mercury levels, accounted for 20% of total catches. Hence, non-piscivorous species of fish constitute a high-quality source of food. In addition, social links were fostered between the Cree through fishing activities, the redistribution of fish within the community, and the hosting of events such as the traditional celebration at Fort George Island. Through the biological monitoring of fish populations, Cree communities were able to see how their fisheries were evolving and were able to recommend measures, such as increasing gill net mesh sizes, to prevent any risk of over harvesting. The conclusion may be drawn that the implementation of the mitigation measures program has contributed to a reduction in the Cree's exposure to mercury while maintaining their traditional hunting and fishing activities (Chevalier *et al,*. 1997).

Figure 10: Subsistence fishing : Cree showing his catch.

6. Reasons for Success

The management of the mercury issue at the La Grande Complex was a true success because Hydro-Québec took immediate action, informed rapidly all those concerned and sought collaboration and partnerships to properly address the issue.
At the onset of the development of the hydroelectric potential of the La Grande Region, the phenomenon of temporary increases of mercury levels in fish as a result of flooding terrestrial environments was unknown. However, shortly before the impounding of the first La Grande reservoir, it was reported that fish of some reservoirs had elevated mercury levels. Hydro-Québec immediately initiated a study to document this new issue at the La Grande Complex.
As soon as monitoring of fish mercury levels confirmed significant increases, the Cree and the Government of Québec were immediately informed of the issue and the James Bay Mercury Agreement

was signed to study the problem and money was provided for mitigation measures to reduce impacts on subsistence and sport fishers.

Hydro-Québec elaborated a comprehensive research program, and partnerships were initiated with Canadian universities and Government research centers to study the issue and seek mitigation measures. The results of studies and monitoring were regularly published in peer reviewed scientific journals. The Québec Environment Ministry was continuously forwarded data from monitoring of mercury levels in fish which were incorporated in its *Consumption Guide for Freshwater Sport Fishes*.

7. Outside Comments

Hydro-Québec was congratulated and set as an example of Corporate Involvement by Canadian Government agencies, such as the Canadian Environmental Assessment Agency, for maintaining, with continued efforts for more than 20 years, its Environmental Effects Monitoring Program at the La Grande Complex, of which the follow-up of mercury levels is an important part. Furthermore, Public Health researchers commended Hydro-Québec for the thorough manner with which it carried out the monitoring of mercury levels in fish at the La Grande Complex.

The mitigation efforts and public communication activities carried out under the James Bay Mercury Agreement received praise by numerous Canadian and American Public Health representatives. Public representatives, which were consulted during the design stages, gave very positive comments concerning the Fish consumption Guide produced for the Gros Mécatina Region.

The monograph on mercury also received very positive comments from numerous Canadian and American researchers.

8. Further Information

8.1 References

1) Chevalier, G., Dumont, C., Langlois, C., Penn, A., 1997. Mercury in northern Québec : role of the mercury agreement and status of research and monitoring. *Water, Air and Soil Pollution*, vol. 97 (1977), p 53-61.
2) Lucotte, M., Schetagne, R., Thérien, N., Langlois, C., Tremblay, A., 1999. *Mercury in the Biogeochemical Cycle : Natural Environments and Hydroelectric Reservoirs of Northern Québec.* Berlin : Springer. 334 p.

8.2 Inquiries

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