 Fluoride Vol.27 No.4 220-226 1994

IMPACT OF ARTIFICIAL FLUORIDATION ON SALMON SPECIES IN THE NORTHWEST USA AND BRITISH COLUMBIA, CANADA

Richard G Foulkes and Anne C Anderson
Abbotsford BC, Canada, and Bellingham WA, USA

SUMMARY: A review of literature and documentation suggests that concentrations of fluoride above 0.2 mg/L have lethal (LC_{50}) effects on and inhibit migration of "endangered" salmon species whose stocks are now in serious decline in the US Northwest and British Columbia. Fluoride added to drinking water, "to improve dental health", enters the fresh water eco-system, in various ways, at levels above 0.2 mg/L. This factor, if considered in "critical habitat" decisions, should lead to the development of a strategy calling for a ban on fluoridation and rapid sun-setting of the practice of disposal of industrial fluoride waste into fresh water.

Key words: British Columbia; Fluoride; Toxicity; Salmon species; US Northwest.

Introduction

In the US Northwest, species of salmon using the Snake-Columbia River system, are listed as "endangered". On the North Thompson River of British Columbia, Canada, sperm banks are being employed to preserve salmon species. Proposed water diversion on the Nechako River, in British Columbia, may threaten the internationally important Fraser River fishery. (See Map).

Joseph Cone, writing in the quarterly magazine, *The New Pacific*, in January 1994, reported that the annual migration of salmon in the Snake-Columbia River system had declined over the past century from an estimated 10-16 million to 2 million in 1991. He pointed out that "the problem is enormously complex - biologically, administratively and economically".

His article and reports in the media have stressed the problems with harvesting; loss of habitat through poor forestry practices, livestock and human settlement; and dams built for power and irrigation. Little emphasis is placed on the effects of pollution of water by toxic substances such as fluoride.

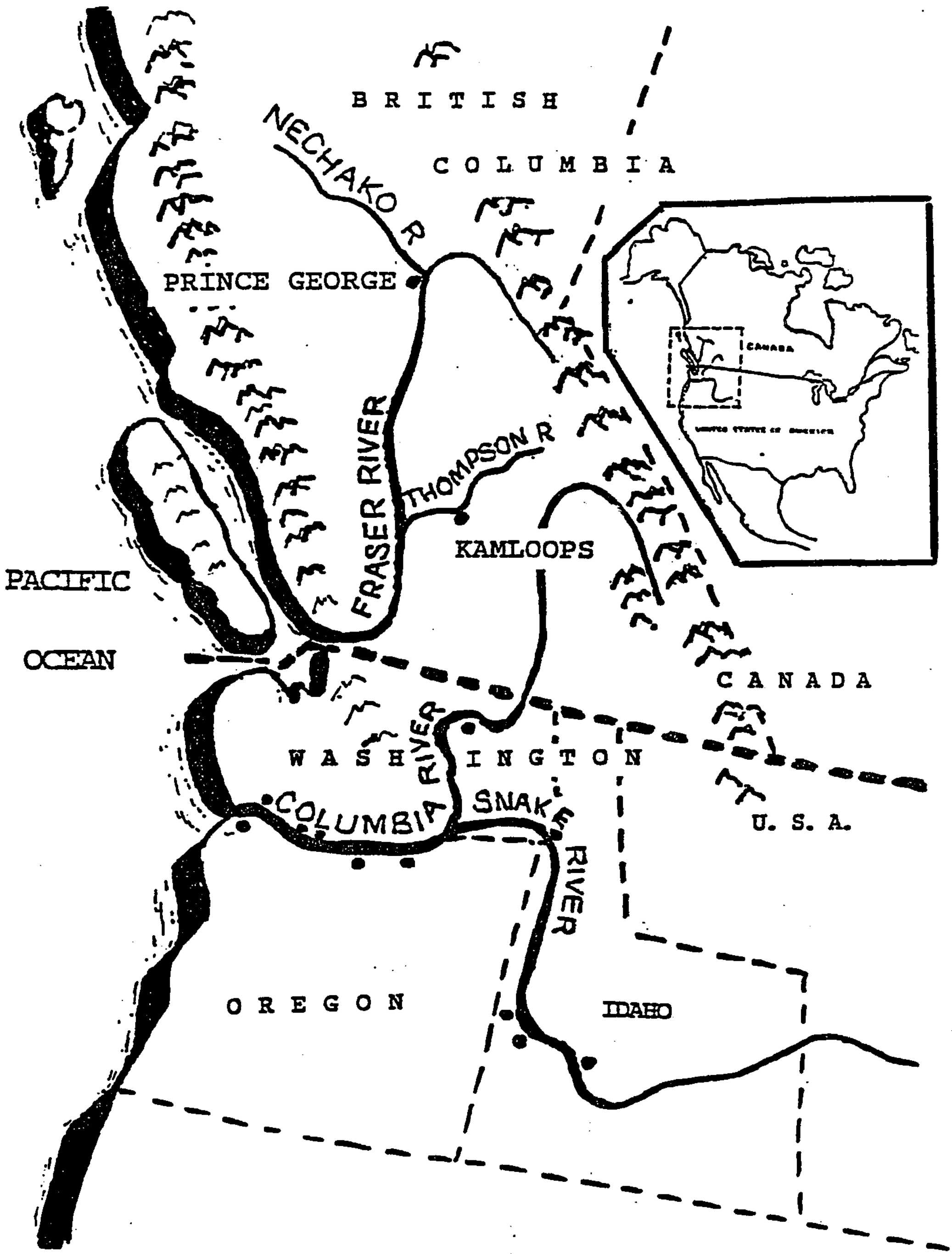
The aluminum industry is the chief beneficiary of power dams on the Columbia River system, and it is the fluoride wastes from smelters that first come to mind as sources of fluoride pollution. However, there is another potential source of contamination - the artificial fluoridation of community water supplies for the avowed purpose of improving dental health.

Fluoride and "critical habitat"

In discussions of "critical habitat" for endangered salmon species, *all* of the possible components must be evaluated. This study examines the possibility that artificial fluoridation of drinking water in communities along the course of salmon rivers is a factor to be included.

PO Box 278, Abbotsford BC, Canada V2S 4N9.
Presented at the XXth Conference of the International Society for Fluoride Research, Beijing, China, September 1994.

MAP OF THE AREAS



"Safe level" questioned

The US Environmental Protection Agency (EPA) (1) and the Province of British Columbia (BC) (2) adhere to a "permissible level" of 1.5 ppm (1.5 mg/L) for fluoride discharged into fresh water. BC's "recommended guideline" is currently 0.2 mgF/L; but this does not have the force of legislation. Neither the BC Ministry of the Environment nor the Washington State Department of Ecology requires fluoride estimations for sewer effluent permits as it is considered that fluoride is not significantly toxic to aquatic life in concentrations expected in discharges (3,4).

A review of the literature and other documents, such as court transcripts, reveals that levels below 1.5 mgF/L have been shown to have both lethal and other adverse effects on salmon.

"Evidence" presented by the EPA and other government bodies responsible for the environment suggests that harm can come to aquatic life only at concentrations that far exceed those in discharges from fluoridated cities. Both Groth (5) and Warrington (6) point out that many factors influence susceptibility of fish to fluoride: temperature; water hardness; pH; chloride concentration; and, the strain, age, and physiological and reproductive condition of the fish.

Groth points out that there are serious problems with "laboratory" experiments as opposed to "field" studies. In the former, "... many of the organisms tested for fluoride toxicity did not experience effects until levels of fluoride higher than those which might realistically be encountered in the environment were attained." Groth concluded that the finding can be misleading: the techniques of measurement may be inadequate to detect effects, and these may be at the population rather than the individual level (5).

There are studies showing the effect of temperature and hardness. Angelovic and others (7) showed lethal effects on rainbow trout related to temperature. Using sodium fluoride at the same degree of hardness (estimated at 44 by Warrington (6)), the 240-h LC_{50} at 7.2°C was found to be 5.9-7.5 mgF/L; at 12.8°C, 2.6-6.0; and, at 18.3°C, 2.3-7.3 mgF/L. Neuhold (8) reported the same result for 12.8°C and the same degree of hardness. Pimental and Bulkley (9), using a constant temperature of 12°C, found that the 96-h LC_{50} for rainbow trout with hardness levels, in mg/L, of 17, 49, 182 and 185 was associated with fluoride levels, in mg/L, of 51, 128, 140 and 193 respectively.

Warrington (6) in British Columbia, where the softness of major salmonid watercourses is the rule, combined the findings of Angelovic (7), and of Pimental and Bulkley (9) to calculate that the chronic threshold for rainbow trout at 12° and water hardness of 10 mg/L (calcium carbonate) is 0.2 mgF/L.

In a field study, Damkaer and Dey (10) demonstrated that high salmon loss (Chinook and Coho) at John Day Dam on the Columbia River, 1982-1986, was caused by the inhibition of migration by fluoride contamination from an aluminum smelter 1.6 km above the dam. The average daily discharge of fluoride in 1982 was 384 kg. This was associated, at the dam, with a fluoride concentration of 0.5 mg/L and a migration time of more than 150 hours and a 55% loss. In 1983, discharge was reduced to 107 kg/day. This was associated with a reduction of concentration to 0.17 mgF/L and the migration time to less than 28 hours with a loss of 11%. In 1985, fluoride discharge of 49 kg/day was accompanied by a concentration of 0.2 mgF/L and a salmonid loss of 5%.

Damkaer and Dey confirmed the cause-and-effect relationship by means of a two-choice flume for fluoride gradient salmon behaviour tests. These determined that the "critical level" was 0.2 mgF/L.

It is interesting that the Damkaer and Dey study was not available at the time of Warrington's review.

There are other studies that indicate that fluoride at levels below 1.5 mg/L have lethal and other adverse effects on fish. Delayed hatching of rainbow trout occurred at. 1.5 mgF/L (11); brown mussels died at 1.4 mgF/L (12); an alga (Porphyria tenera) was killed by a four-hour fumigation with fluoride with a critical concentration of 0.9 mgF/L (13); and, levels below 0.1 mgF/L were shown to be lethal to the water flea, Daphnia magna (14). These latter two studies suggest that salmon species may be affected by fluoride induced reduction of food supply.

Documents used in the Court case involving Meader's Trout farm in Pocatello, Idaho, in 1961 (15) contain evidence that between 1949 and 1950 trout damage and loss was related to fluoride contamination due to rain washing air-borne particles from leaves into hatchery water, at levels as low as 0.5 mgF/L.

Therefore, there is evidence that the "safe level" of fluoride in the fresh water habitat of salmon species is not 1.5 mg/L; but, 0.2 mg/L. Is this concentration exceeded by fluoridated communities on the banks of water-courses serving as salmon habitat?

Fluoride levels in water and sewer systems

In fluoridated areas, drinking water, obtained from surface water with an average fluoride concentration of 0.1-0.2 mg/L (16), is raised to the "optimal" level of 0.7-1.2 mgF/L by the addition of sodium fluoride, hydrofluosilicic acid, or sodium silicofluoride.

Fluoride, in community drinking water, enters the fresh water ecosystem in various ways. Surface run-off from fire-fighting, washing cars, and watering gardens may enter streams directly or through storm sewers at "optimal" concentration, 0.7-1.2 mgF/L. Most enters during waste water treatment.

Masuda (17) studied a large number of cities and calculated the concentrations in waste water that were *in excess* of the concentration present in the cities' water supplies. In raw sewage, this was 1.30 mgF/L; primary treatment reduced this slightly to 1.28 mgF/L; secondary treatment to 0.39 mgF/L. Singer and Armstrong (18) found 0.38 mgF/L in *unfluoridated* sewage and 1.16-1.25 mgF/L in *fluoridated* sewage.

It is clear that, in the case of artificially fluoridated communities, the concentration of fluoride in both surface run-off and sewer effluent exceeds 0.2 mgF/L.

The concentration of fluoride in receiving waters depends on a number of factors: background level (*i.e.*, concentration above effluent outlet); concentration of community water before fluoridation; amount of fluoride added; and, the rates of flow of production, discharge, and receiving water.

Studies show that elevated concentrations in fresh water receiving fluoridated effluent may persist for some distance. Bahls (19) showed that the effluent from Bozeman Montana of 0.6-2.0 mgF/L discharged into the East Galletin River did not return to the background level of 0.33 mgF/L for 5.3 km. Singer and Armstrong (18) reported that a distance of 16 km was required to return the Mississippi River to its background level of 0.2 mg/FL after receiving the effluent of 1.21 mgF/L from Minneapolis-St Paul.

Although dilution reduces *concentration* over distance, the *amount* of fluoride in effluent is either deposited in sediment locally or is carried to the estuary where it may persist for 1-2 million years (16) or may re-contaminate if dredging were to take place.

Sewage sludge, a product of secondary treatment systems must contain high concentrations of fluoride. However, this is not measured, routinely, in the jurisdictions that were contacted for this study. This also, when spread on agricultural land, including forests, is a hazard in the "critical habitat" of salmon species.

During application, aerosols are created that may be ingested by animals or contaminate surface water. The sludge adds toxic substances to the soil. Fluoride can move into ground water and the run-off of soil particulates may enter streams that play a role in the life cycle of salmon.

Effluent from fluoridated cities is also discharged into tidal waters. Sea water has been shown to have a higher concentration of fluoride than unpolluted surface water (16). This concentration of 1.35-1.4 mgF/L is *total* fluoride. Ionic fluoride is 0.4-0.7-mgF/L and a similar amount is bound in ionic form to magnesium (20).

A more meaningful measure of fluoride pollution in sea water is the ratio of fluorine to chlorine (normally, 10^{-5}:1). Contaminated rivers flowing into an estuary, as well as direct discharge of effluent, can elevate the amount of fluoride. The possible effects on salmon species are left for future review.

Discussion

More research, especially field study, is required. However, from information that is available, 0.2 mgF/L in the fresh water ecosystem in the US Northwest and British Columbia appears to be the appropriate safe level for salmon species rather than 1.5 mgF/L currently accepted. Artificially fluoridated communities discharge fluoride into this ecosystem at levels that exceed this from surface run-off, sewage effluent and, probably, from the agricultural use of sludge.

Decreases in water volume and/or flow velocity have the potential to increase fluoride concentration. Increased water temperature will enhance fluoride toxicity.

Fluoridation deserves to be looked at as a component of "critical habitat" along with the more publicized factors.

A review of *Fluoridation Census 1985* published by the US Department of Health and Human Services (21) shows that along the course of the Snake River from the Idaho-Wyoming border to its junction with the Columbia River in Washington State, there are three water systems fluoridated at 1.0 mgF/L. Eight artificially fluoridated water systems are located on the banks of the Columbia from the Canadian border to the mouth. That is, a total of 11 artificially fluoridated communities are located along the Columbia-Snake River system into which they release fluoride. Does this play a role in the catastrophic decline in salmonid stocks in this once highly productive ecosystem?

The declining salmon returns to the North Thompson, especially of Chinook and Coho, is threatening the existence of species. The City of Kamloops, which contributes run-off and sewage effluent to the North Thompson, is artificially fluoridated. Could this fluoride contribute to migration delay, as occurred at the John Day Dam? Could the decline be related to loss of basic feed or hatching abnormalities associated with toxic levels of fluoride? Effluent levels in Kamloops have been measured at 0.6-1.2 mgF/L by employees of the City (personal communication) but no field studies on the effect on salmon species have been carried out.

The Fraser River of British Columbia begins in the Rocky Mountains, north of the origins of the Columbia. The Fraser travels west to the City of Prince George, where it is joined by the Nechako River carrying water from the western portion of the Province. From there, it flows south to enter the Strait of Georgia after it is joined by numerous tributaries, the largest of which is the Thompson River.

Prince George, like Kamloops, is artificially fluoridated.

Does fluoride from Prince George contribute to reported declines in Chinook and Coho stocks in the Nechako? If the diversion of water from the Nechako River, as proposed in the "Kemano II" hydroelectric project, takes place and lowers the water level, slows the flow and raises the temperature of the Nechako-Fraser River system, will the fluoride from both Prince George and Kamloops be enhanced in its toxic effects not only on Chinook and Coho but on other salmon species such as the Sockeye upon which fishers of both the US and Canada depend?

Conclusion

The decline in salmon stocks, especially Chinook and Coho, is a major economic problem for both commercial and sport fisheries. "Critical habitat restrictions" are currently (April 1994) being formulated. Fluoride pollution should be included.

There are many questions. But, until evidence to the contrary, based on *impartially* conducted field studies, is available, the "criteria level" of fluoride, in fresh water, to protect salmon species in the US Northwest and British Columbia, should be 0.2 mgF/L. Acceptance of this level would condemn both the direct metering into fresh water of fluoride wastes from such activities as smelting and phosphate fertilizer manufacture and the entry of fluoride after its deliberate addition to community water supplies.

The strategy for eliminating unacceptable levels of fluoride from the "critical habitat" of Northwest Pacific salmon consists in the immediate banning of artificial fluoridation and the rapid sunsetting of the current disposal practices of fluoride-producing industries.

References

1 *Water Quality Criteria 1972*. Environmental Protection Agency (USEPA) Committee on Water Quality Criteria, Environmental Studies Board, 1973.

2 Recommended BC Health Branch Water Quality Standards. British Columbia Department of Health Services and Hospital Insurance, 1969.

3 Letter from J O'Riordan, Assistant Deputy Minister, British Columbia Ministry of Environment, 22 July 1993.

4 Letter from Ray Hennekey, Washington State Department of Ecology. February 23, 1993.

5 Groth III E. An evaluation of the potential for ecological damage by chronic low-level environmental pollution by fluoride. *Fluoride 8* (4) 224-240 1975.

6 Warrington PD. *Ambient Water Quality Criteria for Fluoride*. Technical Appendix. British Columbia Ministry Of Environment, 1990.

7 Angelovic JW, Sigler WF, Neuhold JM. Temperature and fluorosis in Rainbow trout. *Journal. Water Pollution Control Federation 33* 371-381 1961.

8 Neuhold JM, Sigler WF. Effects of sodium fluoride on carp and Rainbow trout. *Transactions. American Fisheries Society 89* 358-370 1960.

9 Pimental R, Bulkley RB. Influence of water hardness on fluoride toxicity to Rainbow trout. *Environmental Toxicology and Chemistry 2* 381-386 1983.

10 Damkaer DM, Dey DB. Evidence for fluoride effects on salmon passage at John Day Dam, Columbia River, 1982-1986. *North American Journal of Fisheries Management 9* 154-162 1989.

11 Ellis MM, Westfall BA, Ellis MD. *Determination of Water Quality*. Research Report 9. Fish and Wildlife Service, Department of Interior, Washington DC 1948 pp 81-82.

12 Hemens J, Warwick RJ, Oleff WD. Effect of extended exposure to low fluoride concentration on estuarine fish and crustacea. *Progress in Water Technology 7* 579-585 1975.

13 Ishio S, Makagawa H (1971). Cited in: Rose D, Marier J. *Environmental Fluoride 1977*. National Research Council of Canada, Ottawa 1977 p 30.

14 Dave G. Effects of fluoride on growth, reproduction and survival in Daphnia magna. *Comparative Biochemistry and Physiology 78c* (2) 425-431 1984.

15 US Court Of Appeals, Ninth Circuit (Pocatello, Idaho) No 17059 (1961): Food and Machinery and Chemical Corporation and J R Simplot Co. vs W S and Ray Meader. Exhibit (Table 1) August 25 1961.

16 Carpenter R. Factors controlling the marine geochemistry of fluorine. *Geochimica et Cosmochimica Acta 33* 1153-1167 1969.

17 Masuda TT. Persistence of fluoride from organic origins in waste waters. *Developments in Industrial Microbiology 5* 53-70 1964.

18 Singer L, Armstrong WD. Fluoride in treated sewage and in rain and snow. *Archives of Environmental Health 32* 21-23 1977.

19 Bahls LL. Diatom community response to primary waste water effluent. *Journal. Water Pollution Control Federation 45* 134-144 1973.

20 Miller GW. Effect of fluoride on higher plants. *Fluoride 26* (1) 3-22 1993. (Table 1, p 5)

21 *Fluoridation Census 1985*. US Department of Health and Human Services. Public Health Service, 1988.

