



Community Water Fluoridation in Canada – Trends, Benefits, and Risks

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Summary

- Fluoride has been added to public drinking water in Canadian communities since the 1940s as a means of preventing tooth decay.
- Dental fluorosis is a known adverse effect of excessive fluoride exposure during tooth formation. Fluorosis ranges from barely noticeable whitish striations in the enamel to severe pitting and brownish staining. In general, the prevalence of dental fluorosis in communities with water fluoridation is higher in comparison to non-water fluoridated communities.
- No evidence was found for an association between water fluoridation and any of the following adverse outcomes: bone mineral density, bone fractures, bone cancer, or cancer in other body tissues.
- The best available evidence supports the finding that water fluoridation reduces the prevalence of dental caries, although this benefit of fluoridation may be limited due to multiple sources of exposures to fluoride that are now available to the public.

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- Although many major health organizations support water fluoridation, the trend across Canadian communities has been a decreasing uptake in water fluoridation or discontinuation.

Introduction

Dental caries (i.e., tooth decay) is the demineralization and dissolution of the hard tissue of teeth.¹ It can result in loss of tooth structure and discomfort. If untreated, dental caries can lead to severe pain and to bacterial infection. Infection may result in loss of dental function and tissue necrosis, requiring tooth extraction, and may progress to acute systemic infection.² Inflammatory periodontal diseases have been associated with such chronic health conditions as cardiovascular disease, diabetes and rheumatoid arthritis, although these associations are inconclusive and remain under investigation.²

Fluoride is known to act in a variety of ways to prevent and arrest tooth decay.⁴ Topical mechanisms of fluoride include inhibiting

bacterial metabolism, inhibiting demineralization, and enhancing remineralization.³ Fluoride primarily affects the surface of the tooth after it has erupted, especially when low concentrations of fluoride are consistently maintained in the mouth.^{3,4}

Fluoride is found in all natural waters in varying concentrations.⁵ Community water fluoridation is the addition of a controlled amount of fluoride in public water supplies to promote health through the prevention of dental caries.⁶ In Canada, fluoride was first added to public drinking water in the 1940s to prevent tooth decay.⁸ As water fluoridation was shown to be effective in preventing and controlling dental caries, new products containing fluoride were developed, including toothpaste and mouth rinse.³ Additionally, processed beverages and food including tea now contain small amounts of fluoride, especially if they are processed with fluoridated water.³ Communities may also receive fluoride through the “halo” or “diffusion” effect from exposure to processed foods and beverages made from fluoridated water.⁷ As a result, Canadians have increased exposure to multiple sources of fluoride.

Community water fluoridation is recognized as the single most effective public health measure to prevent tooth decay and was listed by the Centers for Disease Control in the top ten greatest public health achievements of the 20th century.⁸ Despite this success, the appropriateness of community water fluoridation is often the subject of intense public debate regarding its benefits or risks.^{6,9}

The purpose of this evidence review is two-fold: 1) Evaluate the literature on the health benefits and risks of community water fluoridation; and 2) Describe the current trends in Canada and identify gaps and lessons learned that will inform public health professionals.

Methods

A literature search was completed in March 2012 and May 2013 based on electronic resources available from the University of Guelph library and research and reports from national and international public health and dental organizations including the World Health Organization, Centers for Disease Control and Prevention, Health Canada, Public Health Agency of Canada, and the Canadian Dental Association. The inclusion criteria for the literature review addressed

the following topics: mechanism for action of fluoride in oral health; benefits and health risks of water fluoridation; and cost-effectiveness and public opinion in Canada. Seventy-one references were identified and 44 were included (see Appendix A).

Results and Discussions

Health Benefits

Studies have shown that fluoridated drinking water reduces the number of cavities in children’s teeth.^{3,10-13} Early studies from the 1940s through the 1960s, including the original trials in Brantford, Ontario, showed the strongest effect of water fluoridation, in which dental caries were reduced by 50 to 60% in children.^{3,12} Since the 1970s, research on fluoridation has been complicated by the availability of other sources of fluoride. By the mid-1980s, the relative effectiveness of community water fluoridation had declined as studies found the difference in the prevalence of dental caries among those consuming fluoridated and non-fluoridated water had narrowed.^{3,14,15} Recent systematic reviews of studies on community water fluoridation noted relatively few high quality studies^{4,13} but concluded that the best available evidence supports water fluoridation reducing the prevalence of dental caries.^{4,11,13,16-18} It has been noted that the magnitude of the effect is not large in absolute terms, as described below.⁴

Children are the subjects for the majority of water fluoridation research studies. The meta-analysis by McDonagh et al. (2000) showed that water fluoridation reduced the average prevalence of dental caries in children by 14.6%.¹³ Oral health is determined by the total number of decayed, missing, or filled teeth (DMFT). A higher DMFT score of 2.25 teeth was found in control areas when compared to communities with fluoridated water systems, suggesting that fluoridation is associated with improvement in DMFT scores.¹³ Similarly, in a cross-sectional study of 16,508 Australian children from 2002–2005, an interaction effect was found in which water fluoridation reduced the impact of consumption of sugar-sweetened beverages on the frequency of dental caries.¹⁹

Griffin et al. (2007) evaluated studies on the effectiveness of water fluoridation in adult populations. The relative risk of caries in adults who were lifelong residents of fluoridated communities was 0.65 (95% CI: 0.49-0.87) compared to adults

who were lifelong residents of non-fluoridated communities.²⁰ The preventable fraction was 27.2% (95% CI: 19.4%-34.3%) meaning approximately 27% of caries cases could have been prevented if community water was fluoridated compared to not being fluoridated.²⁰

From a public health perspective, an advantage of providing fluoride at a population level is that it benefits all residents served by community water supplies.²¹ Additionally, fluoridation does not rely on individual compliance with health recommendations, and therefore removes barriers around poor compliance or limited access.¹¹ Population level intervention ensures all socioeconomic sectors of the population can be reached, notably those with limited access to preventative dentistry.¹¹ There is mounting evidence for the role of fluoridation in reducing disparities in caries that are related to the social determinants of health.^{4,13,15,22,23} However, greater efforts beyond community-level fluoridation are required to continue to reduce oral health inequalities.^{24,25}

Additionally, a number of studies show a positive cost-benefit analysis for community water fluoridation. An economic evaluation combining eleven studies which had used cost benefit, cost effectiveness or cost utility analyses, concluded that fluoridation of community water is a cost-saving intervention.²⁶

Health Risks and Concerns

Fluorosis

The known adverse effects of excessive fluoride exposure (from drinking water, or in combination with exposure to fluoride from other sources) range from mild dental fluorosis to crippling skeletal fluorosis.⁵

Dental fluorosis is a set of defects of enamel associated with hypoplasia or hypomineralization of dental enamel and dentine as a result of excessive ingestion of fluoride during tooth formation.⁴ Fluorosis ranges from barely noticeable whitish striations in the enamel to severe pitting and subsequent staining (brownish discolouration).⁴ There are no health concerns associated with mild fluorosis.^{27,28} The majority of dental fluorosis is categorized as very mild or mild and is not considered to be of aesthetic concern.^{11,16} Moderate to severe fluorosis can reduce tooth aesthetics due to the pitting and staining of the

tooth surface.¹¹ Severe fluorosis can negatively affect tooth quality and function.²⁹

Dental fluorosis only occurs during development of the enamel and becomes apparent upon eruption of the teeth; therefore the risk period for fluorosis is usually limited to children aged eight and younger.³ The development of fluorosis is strongly associated with cumulative fluoride intake during enamel development.^{3,13} Severity of fluorosis depends on the dose, duration, and timing of fluoride intake.³ The excessive use of multiple dental products containing fluoride (e.g., toothpastes and mouth rinses), infant formula with fluoride, and fluoride dietary supplements are all risk factors for fluorosis.^{4,15}

Dental fluorosis is more prevalent in communities with fluoridated water compared to those without fluoridated water. Dental fluorosis has generally increased since the 1950s, with non-water fluoridated communities having the larger increase.^{4,30,31} A systematic review by McDonagh et al. (2000) found the odds of very mild through severe fluorosis was 2.05 times higher in fluoridated compared to non-fluoridated areas (95% CI: 1.75-2.39) and the odds of fluorosis of aesthetic concern in fluoridated areas was 2.29 times greater than non-fluoridated areas (95% CI: 1.68-3.12).³² In comparison to an area of relatively low fluoride content of 0.4 ppm, the difference in proportion of the population with dental fluorosis was not statistically significant at 0.7 ppm (9.3%; 95% CI: -1.9-20.6). However, the differences in proportions increased to 15.7% (95% CI: 4.1-27.2) and 18.9% (95% CI: 7.2-30.6) when comparisons were made with areas having fluoride levels of 1.0 and 1.2 ppm, respectively. However, there was no statistical difference in the proportion of the population with fluorosis of aesthetic concern when comparing areas having fluoride levels of 0.4ppm to 0.7, 1.0 or 1.2 ppm.³² A 1990 study of Quebec adolescents, aged 11–17 years, living in fluoridated Trois-Rivières had a higher prevalence of dental fluorosis (45.6-58.0%) compared to adolescents living in non-fluoridated Sherbrooke (30.1-31.1%).³³ Identified risk factors were consumption of fluoridated water and fluoride tablets.³³ However, the 2007 Health Canada expert review states, “The actual prevalence of moderate dental fluorosis in Canada is low, and all evidence suggests that since 1996 there has been an overall decreasing trend of dental fluorosis in Canada.”³⁴ However, Health Canada did not make reference to this claim in the 2010 technical document for fluoride.²⁷

Skeletal fluorosis is a crippling disease associated with chronic exposure of ≥ 10 mg of fluoride per day for at least 10 years.⁴ Skeletal fluorosis is not a public health concern in Canada, as skeletal fluorosis is extremely rare in North America.²⁸

Other Health Concerns

Fluoride (like many other nutrients and substances) is an acute poison in large doses; however, toxic levels cannot be reached by drinking fluoridated water.⁴ In a review that included both acute and chronic effects, the Federal-Provincial-Territorial Committee on Drinking Water within Health Canada concluded in 2010 that the current maximum acceptable concentration of 1.5 mg of fluoride per litre of drinking water is unlikely to cause adverse health effects, including cancer, bone fracture, immunotoxicity, reproductive/developmental toxicity, genotoxicity, and/or neurotoxicity.²⁷ The most recent literature and systematic reviews of water fluoridation and health effects which assessed primarily observational studies published between 1944 and 2006 also found no compelling, consistent evidence for the association between water fluoridation and any of the following adverse outcomes: bone mineral density, bone fractures, or cancer in bones or other body tissues.^{4,11,13,16}

The systematic review by McDonagh et al. found the validity of most of the studies on fractures related to exposure to fluoride was low and a meta-analysis suggested no association between community water fluoridation and hip fracture incidence. The evidence on other bone outcomes was extremely limited.¹³

McDonagh et al. evaluated 26 studies in a systematic review that examined the association between exposure to fluoridated water and cancer incidence and mortality. All the studies were rated as low or moderate quality.¹³ Overall, the review found no clear association between water fluoridation and overall cancer incidence or mortality, bone cancers, or thyroid cancer.¹³ This finding supports a previous literature review of studies from 1994 to 1999 which concluded that “there is no reason to believe that exposure to fluoridated water increases the risk of cancer in the bones or other body tissues.”⁴ More recently, an ecological study of osteosarcoma incidence rates between 1999 and 2006 in American children and adolescents aged 5–19 years found no association with community fluoridation status within sex- and age-specific categories.³⁵

According to McDonagh et al., the quality of studies on water fluoridation and mental health outcomes such as IQ, impaired mental functioning, and Alzheimer’s disease was low, and it was concluded that there was insufficient evidence on any particular neurocognitive outcome to conclude there was any effect from water fluoridation.¹³

Current Status in Canada

1. Trends

Some major health organizations that support drinking water fluoridation include: The World Health Organization; Centers for Disease Control; Health Canada; Public Health Agency of Canada; Canadian Dental Association; and Canadian Medical Association.^{3,10,36-39}

In Canada, provincial and territorial governments regulate the quality of drinking water in their jurisdictions. The fluoridation of drinking water supplies is a decision that is made by each municipality, in collaboration with the appropriate provincial or territorial authority. This decision may also be taken in consultation with residents, often in the form of a referendum or plebiscite.¹⁰ For example, water fluoridation for the city of Calgary was introduced in 1991. A 1998 plebiscite upheld the water fluoridation policy, despite anti-fluoridation activities.⁴⁰ The issue of fluoridation may also arise when local councils must decide about updating the water treatment and water fluoridation infrastructure.^{41,42}

An expert panel convened by Health Canada in 2007 recommended adopting a level of 0.7 mg/L as the optimal target concentration for fluoride in drinking water, which would prevent excessive intake of fluoride through multiple sources of exposure.³⁴ As of 2010, Health Canada recommends an optimal concentration of fluoride in drinking water of 0.7 mg/L to promote dental health. The maximum acceptable concentration, which is deemed not to pose a risk to human health, remains at 1.5 mg/L.¹⁰

Data from 2007 show that 45% of Canadians receive fluoridated water from their community water supply. This percentage varies widely across provinces and territories from zero percent in Yukon and Nunavut to 76% in Ontario (see Appendix B).⁴³ In an examination of Canadian water fluoridation history, Carstairs (2010) noted that historically, fluoridation was more

likely in provinces where the decision to fluoridate was left to the municipality, and a referendum was not required.⁴⁴ Wealthier provinces with bigger cities were more likely to fluoridate their water supply than poorer provinces with a large rural population, in part due to cost effectiveness.⁴⁴ In provinces with a strong health food movement (including Quebec and British Columbia) fluoridation of community water is less likely to be accepted.⁴⁴

Between 2005 and 2007, the percentage of Canadians who had access to fluoridated drinking water increased from 42.6 to 45.1%.⁴³ Since 2007, a number of large cities have discontinued fluoridation, including Quebec City, Calgary, Waterloo, and Moncton. The trend in Canada has been a decreasing uptake in water fluoridation.¹² On the other hand, some cities have recently voted in favour of continuing fluoridation, including Toronto, Hamilton, and Lethbridge. (See Appendix C).

2. Public Opinion

A 2009 study by Quiñonez and Locker examined public opinions of community water fluoridation in Canada using a national telephone interview survey (participation rate of only 3% based on random digit dialling).⁴⁵ Although the study sample was not necessarily representative, 45% of adult respondents surveyed had heard or read about community water fluoridation and of those that knew about fluoridation, 80% understood its intended use and 60% believed it was both safe and effective. Notably for public health, 62% supported the idea of having fluoride added to their local drinking water.⁴⁵ Respondents with higher income and those who have had regular dentist visits are more likely to support fluoridation. Those with children and those who had public dental insurance were less likely to support fluoridation.⁴⁵

3. Opposition to Fluoridation

In Canada, the decision to implement or discontinue water fluoridation is often put to a referendum or plebiscite (a direct vote for all members of the electorate on an important public question). Plebiscites are more likely to fail than pass, not only due to the issue of fluoridation itself but also due to the nature of plebiscites, which are most often defeated due to poor voter turnout.¹² Opposition to water fluoridation may have a scientific base or be an ethical issue.

Opponents to fluoride argue that the effectiveness of water fluoridation to prevent dental caries is questionable.^{9,46} Compared to the original studies done on water fluoridation, more recent studies are unable to show any significant effect of water fluoridation on dental caries when comparing to non-fluoridated communities.^{12,15} Canadians now have more sources of fluoride compared to 60 years ago. This complicates the research process to determine the effectiveness of water fluoridation.

Challengers of water fluoridation point out that there are alternative sources of fluoride individuals can add to their dental routine if they want to obtain exposure to fluoride (e.g., fluoride dietary supplements, home fluoridation units, fluoridated toothpaste, and fluoride topical application from the dentist).⁹ They also express concern about exposure beyond recommended maximum concentrations because of exposure to multiple sources.⁶

Opponents to fluoridation claim it causes harm to individuals. A known health consequence is fluorosis. Other health outcomes suspected to be associated with community water fluoridation include: heart disease, cancer, birth defects, kidney problems, skeletal changes, allergies, goiters, ulcers, anemia, and spontaneous abortion. However, these associations are not supported by the scientific literature.^{9,46}

Other arguments against adding fluoride to drinking water that do not relate to human health include the following concerns: fluoride is toxic to the environment; fluoridation compromises the purity of our water because it is not natural; fluoridation is a violation of civil liberties and people should not have to consume a substance against their will, even if it has positive health benefits; and, anti-trust arguments against the government in general.⁹

Gaps

There are a number of current gaps in the literature concerning water fluoridation relevant to Canadian public health professionals:

- Given the increasing number of Canadian communities changing their fluoridation status, there is need for studies that follow the health status of the community before and after changes in water fluoridation.

- Epidemiological studies would benefit from better exposure assessment and estimates of body burden to fluoride from a variety of sources, including community water supplies, to ascertain whether recommended limits are exceeded.
 - Research on the impacts of dental fluorosis on quality of life is needed.
 - There are few case studies of effective public health communication campaigns regarding fluoridation in Canada in the published literature. With so many communities addressing the fluoridation issue in the past 10 years, and the expectation of this issue to continue, sharing communication and campaign strategies and results would benefit public health professionals.
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Conclusion

Community water fluoridation is effective at preventing dental caries, although the magnitude of the effect of fluoridation on improving dental health appears to be diminishing due to multiple sources of fluoride, better dental care and personal oral hygiene. Although community water fluoridation is an effective method of removing variation in individuals' dental health behaviours and ensuring all members of the population have access to fluoride at a safe concentration, it will remain a public health issue due to ethical considerations and concerns of excessive exposures to fluoride. Acknowledgements

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Appendix A – Methodology

A literature search was conducted in January and February 2012 and updated through to the beginning of May 2013. The electronic literature search primarily made use of the University of Guelph's "Primo Central" search engine. Key databases included PubMed, Wiley Online Library and CabDirect.

Search terms included iterations and synonyms of "drinking water fluoridation," "health impacts" and "Canada." Additional searches for fluoridation "cost-effectiveness" and "public opinion" were also conducted.

The literature reviewed for this report addresses the following topics only:

- Fluoride's mechanism of action in oral health
- Benefits of water fluoridation
- Health risks of water fluoridation
- Cost-effectiveness
- Public opinion in Canada and opposition to fluoride

Additionally, existing research and reports from leading organizations were accessed through the Internet to identify relevant data and research. Organizations searched included: the World Health Organization, the Center for Disease Control, Health Canada, Public Health Agency of Canada, and the Canadian Dental Association.

Reference lists from selected systematic reviews and studies included in this review were manually searched for additional relevant articles.

All papers identified by the search were initially screened for relevance using the title and/or abstract. Literature was restricted to only those written in the English language involving human subjects. There were no date limitations imposed, but more recent studies and reviews were favoured. There were no design limitations, but preference was for more rigorous study design and systematic reviews. Higher interest was paid to research from Canada; additionally, research from the United States of America, the United Kingdom, Australia and other similar countries were deemed to be relevant. Fifty-five references were found and thirty-seven were included.

All references obtained by the above methods were entered and managed in RefWorks and EndNote, web-based bibliographic management services (www.refworks.com) (www.myendnoteweb.com).

Appendix B: Provincial and Territorial Estimates for Community Water Fluoridation Coverage in 2007

Province/Territory	Total Population	Population with fluoridated water	Population without fluoridated water	Percent with fluoridated water	Percent without fluoridated water
British Columbia	4,113,000	152,241	3,960,759	3.7%	96.3%
Alberta	3,290,350	2,457,406	832,944	74.7%	25.3%
Saskatchewan	968,157	356,096	612,061	36.8%	63.2%
Manitoba	1,148,401	803,116	345,285	69.9%	30.1%
Ontario	12,160,282	9,229,015	2,931,267	75.9%	24.1%
Quebec	7,546,131	489,420	7,067,711	6.4%	93.7%
New Brunswick	729,498	188,607	540,891	25.9%	74.2%
Nova Scotia	913,462	519,031	394,431	56.8%	43.2%
Prince Edward Island	135,851	32,174	103,677	23.7%	76.3%
Newfoundland/Labrador	505,469	7,572	497,897	1.5%	98.5%
Nunavut	29,474	0	29,474	0.0%	100.0%
Northwest Territories	41,464	23,400	18,034	56.4%	43.6%
Yukon	30,372	0	30,372	0.0%	100.0%
Canada	31,611,911	14,258,078	17,364,803	45.1%	54.9%

This information was collected from Provincial or Territorial Environment Ministries and then verified by the Dental Directors of each province and territory. The Ministries of Environment provided detailed data on the community fluoridated, or the water plants well as population numbers.

Appendix C – Partial listing of municipalities from grey literature sources that have recently voted on fluoridation

Canadian cities that have discontinued fluoridation or voted against uptake since 2000:	Approximate Population ⁴
Athabasca, AB	3,000
Calgary, AB	1,215,000
Drayton Valley, AB	7,000
Slave Lake, AB	6,800
Taber, AB	6,800
Golden, BC	3,700
Kamloops, BC	85,000
Lake Cowichan and Williams Lake, BC	14,000
Churchill, MB	300
Dieppe, NB	23,000
Moncton, NB	70,000
Amherstburg, ON	21,000
Cobalt, ON	1,000
Dutton-Dunwich, ON	4,000
Dryden, ON	8,000
Lakeshore, ON	35,000
Thunder Bay, ON	146,000
Waterloo, St. Jacobs and Elmira, ON	113,000
Welland, Pelham, and parts of Thorold, ON	65,000
West Elgin, ON	5,000
Gatineau, QC	265,000
Quebec City, QC	516,000
Meadow Lake, SK	5,000
Some municipalities that have recently voted in favour of continuing fluoridation (2009 or more recent):	
Lethbridge, AB	83,000
Cape Breton, NS	102,000
Halton Region, ON	502,000
Hamilton, ON	520,000
Toronto, ON	2,615,000

⁴ Statistics Canada. 2011 Census Profile of Population collected from <http://www12.statcan.gc.ca/census-recensement/2011/dp-pd/prof/index.cfm?Lang=E>⁴⁷

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