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Abbreviations

AI	adequate intake
CICI	Context and Implementation of Complex Interventions
CRHA	Calgary Regional Health Authority
CWF	community water fluoridation
HTA	health technology assessment
MAC	maximum acceptable concentration
PHAC	Public Health Agency of Canada
ppm	parts per million
UL	upper limit

Introduction

Dental caries is a common public health problem in Canada,¹ and it affects about 57% of children aged six to 11 years and 59% of adolescents aged 12 to 18 years.² It has been estimated that the prevalence of coronal caries and the prevalence of root caries for Canadian adults aged 19 years and older is 96% and 20.3%, respectively.² Dental caries can result in pain, infection, premature tooth loss, and misaligned teeth.³ Untreated dental caries in children are associated with poor overall growth, iron deficiency, behaviour problems, low self-esteem, and a reduction in school attendance and performance.⁴⁻⁹ In pregnant women, periodontal diseases are risk factors for preterm low birth weight.^{10,11} By adulthood, about 96% of Canadians have experienced dental caries.² In 2018, the cost of dental services was estimated to be approximately \$17 billion in Canada, about \$461 per Canadian, based on total national health expenditure estimated from both the private sector (\$15.2 billion) and public sector (\$1.8 billion).¹² Poor oral health is experienced by Canadians who cannot access regular dental care, including lower income families with no insurance, seniors in long-term care, new immigrants, and Indigenous peoples.^{2,13}

Fluoride is a negative ion (F^-) of the element fluorine (F_2).¹⁴ The term fluoride also refers to compounds containing F^- , such as sodium fluoride (NaF), calcium fluoride (CaF_2), fluorosilicic acid (H_2SiF_6), or sodium fluorosilicate (Na_2SiF_6).¹⁴ In water, these compounds dissociate to release F^- .¹⁴ Fluoride compounds exist in soil, air, plants, animals, and water.¹⁵ Epidemiological studies in the 1930s and 1940s found that people living in areas with high naturally occurring fluoride levels in water had lower incidence of dental caries (i.e., cavities and tooth decay), a chronic and progressive disease of the mineralized and soft tissue of the teeth. This finding led to the controlled addition of fluoride to community drinking water with low fluoride levels in order to prevent dental caries.^{16,17} In 1945, Brantford, Ontario, was the first city in Canada and the third city in the world to implement drinking water fluoridation.^{18,19}

Fluoride helps to prevent dental caries both systemically (pre-eruptive or before the teeth emerge) and topically (post-eruptive or on the tooth surface).^{20,21} The systemic effect occurs through the incorporation of ingested fluoride into enamel during tooth formation, which strengthens the teeth, making them more resistant to decay.²¹⁻²³ The major sources of systemic fluoride are fluoridated water and foods and beverages prepared in areas with fluoridated water.^{24,25} Fluoride from other sources such as toothpaste, mouth rinses, gels, varnishes, or foams provides a topical effect (unless swallowed) through direct contact with exposed tooth surface; this increases tooth resistance to decay against bacterial acid attack by inhibiting tooth de-mineralization, facilitating tooth remineralization, and inhibiting the activity of bacteria in plaque.²⁶ As well, after being absorbed systemically, a small portion of fluoride is excreted into the saliva where it provides a topical effect from the continuous bathing of saliva over the teeth.²⁷ Evidence has suggested that CWF is associated with a decrease in dental caries, a decline in numbers of hospital attendances for general anesthesia and tooth extractions, and a reduction in the cost of dental treatment in children.²⁸⁻³⁴

Daily intake levels of fluoride in humans vary depending on many factors, these include sources of fluoride (water, foods or beverages, or dental products), levels of fluoride in water or foods, the amount of water or food consumed, and individual characteristics and habits.¹⁴ About 75% to 90% of ingested fluoride is absorbed through the gastrointestinal tract, and up to 75% of the absorbed fluoride is deposited in calcified tissues (such as bones and teeth) in the form of fluorapatite within 24 hours.^{35,36} The rest is excreted primarily in the urine, with

small amounts excreted in perspiration, saliva, breast milk, and feces.^{35,36} In 2007, a dietary survey of the Canadian population estimated that the average intake of fluoride in children aged one to four years old in fluoridated and non-fluoridated communities was 0.026 mg/kg/day and 0.016 mg/kg/day, respectively.¹⁴ The average dietary intake of fluoride in adults 20 years and older ranged from 0.038 mg/kg/day to 0.048 mg/kg/day in fluoridated communities, and ranged from 0.024 mg/kg/day to 0.033 mg/kg/day in non-fluoridated communities.¹⁴ Based on the average daily dietary fluoride intakes in fluoridated areas (i.e., 0.7 to 1.1 ppm) in Canada and US, the recommended adequate intake (AI) of fluoride from all sources that is sufficient to prevent dental caries is 0.05 mg/kg/day, irrespective of age groups, sex, and pregnancy status.^{37,38} The tolerable upper limit (UL) value for infants through children aged eight years is 0.10 mg/kg/day.³⁷ The UL for children older than eight years and for adults including pregnant women is 10 mg/day.³⁷

According to the 2010 Health Canada *Guidelines for Drinking Water Quality*, the maximum acceptable concentration (MAC) of fluoride in drinking water is 1.5 ppm (parts per million or mg/L), while the optimal level of fluoride in drinking water is recommended to be 0.7 ppm (reduced from the previous range of 0.8 ppm to 1.0 ppm) for providing optimal dental health benefits and minimizing dental fluorosis.¹⁵ MAC was determined with moderate dental fluorosis as the end point of concern.¹⁵ Thus, community water fluoridation (CWF) in Canada is the process of controlling fluoride levels (by adding or removing fluoride) in the public water supply to reach the recommended optimal level of 0.7 ppm and to not exceed the maximum acceptable concentration of 1.5 ppm.¹⁵ Most sources of drinking water in Canada have low levels of naturally occurring fluoride.¹⁵ According to a Canadian survey conducted between 1984 and 1989, the average, provincial, naturally occurring fluoride levels in drinking water ranged from less than 0.05 ppm in British Columbia and Prince Edward Island, to 0.21 ppm in Yukon.¹⁵ The provincial and territorial data on drinking water in 2005 provided by the Federal-Provincial-Territorial Committee on Drinking Water showed that the average fluoride concentrations in fluoridated drinking water across Canada ranged between 0.46 ppm and 1.1 ppm.¹⁵ As of 2017, about 38.7% of Canadians were exposed to CWF for the protection of dental caries.³⁹ The decision to fluoridate drinking water is not regulated at the federal, provincial, or territorial levels, but rather the decision is made at the municipal level and is often taken by means of a community vote (i.e., by referendum or plebiscite).¹⁴

While public and dental health agencies and organizations, and about 60% of Canadians, view CWF as an effective and equitable means of improving and protecting the dental health of populations, there continues to be opposition, resistance, and skepticism about CWF, especially in terms of human and environmental health.⁴⁰⁻⁴² There are a variety of different perspectives on CWF, some of which centre on the scientific evidence of dental benefit,^{42,43} while others include the availability of alternative oral public health programs or interventions that avoid perceived concerns of CWF.^{43,44} Alternative publicly funded oral public health programs, such as school-based topical fluoride varnishes, though available, are not consistent across Canadian jurisdictions.⁴⁵⁻⁴⁷ Importantly, the available programs are not universal in nature and mainly target high-risk populations.^{45,46} Furthermore, public health programming is often targeted toward youth, excluding the adult and elderly populations. CWF, in contrast, is an intervention that reaches a broader population, so long as persons drink from municipal water supplies. Still, others cite potentially harmful side effects of fluoridation, for example, fluorosis, thyroid function, lowered average intelligence quotient (IQ) in populations, and negative environmental impact^{14,48} as motivation for water fluoridation cessation. Additional concerns include possible relationships between industry and fluoridation.^{14,48} Finally, an unsettled tension exists around the ethics of CWF in terms of

distribution of benefits to all persons who consume fluoridated tap water, removing (or making very difficult) the ability to “choose” fluoridation.^{43,49-51}

It is within this context that some municipalities are choosing to cease water fluoridation, leading to its decline.³⁹ Notably, large Canadian cities such as Calgary, Quebec City, Windsor, Moncton, and Saint John have discontinued their water fluoridation programs in recent years.⁵²⁻⁵⁴ Other municipalities have also discontinued CWF across provinces and territories since 2012.³⁹ Although the total percentage of Canadians with access to CWF has increased from 2012 (37.4%) to 2017 (38.7%), some provinces and territories have shown a significant decline in fluoridated water system coverage.³⁹ As of 2017, the provinces and territories with the fewest municipalities with CWF systems include British Columbia, Quebec, New Brunswick, Newfoundland and Labrador, and Yukon.³⁹ The impact of the CWF cessation on dental health is unclear.

Policy Question

This Health Technology Assessment (HTA) is intended to provide guidance to policy and decision-makers at the municipal levels to help orient discussions and decisions about water fluoridation in Canada. The HTA seeks to address the following policy question: Should community water fluoridation be encouraged and maintained in Canada? The analytic framework informing this HTA is presented in Appendix 1.

Objectives

The aim of this HTA is to inform the policy question through an assessment of the effectiveness and safety,⁵⁵ economic considerations,⁵⁶ implementation issues,⁵⁷ environmental impact,⁵⁸ and ethical considerations⁵⁹ for CWF. An analysis of the evidence related to these considerations comprises different chapters of the HTA, each with specific and different research questions and methodologies. The following report presents the Implementation Issues Analysis. Other sections have been published separately.

Research Question

The HTA addressed the following research questions:

Review of Dental Caries and Other Health Outcomes

1. What is the effectiveness of community water fluoridation (fluoride level between 0.4 ppm and 1.5 ppm) compared with non-fluoridated drinking water (fluoride level < 0.4 ppm) in the prevention of dental caries in children and adults?
2. What are the effects of community water fluoridation cessation (fluoride level < 0.4 ppm) on dental caries in children and adults compared with continued community water fluoridation (fluoride level between 0.4 ppm and 1.5 ppm), the period before cessation of water fluoridation (fluoride level between 0.4 ppm and 1.5 ppm), or non-fluoridated communities (fluoride level < 0.4 ppm)?
3. What are the negative effects of community water fluoridation (at a given fluoride level) compared with non-fluoridated drinking water (fluoride level < 0.4 ppm) or fluoridation at different levels on human health outcomes?

Economic Analysis

4. From a societal perspective, what is the budget impact of introducing water fluoridation in a Canadian municipality without an existing community water fluoridation program?

5. From a societal perspective, what is the budget impact of ceasing water fluoridation in a Canadian municipality that currently has a community water fluoridation program?

Implementation Issues

6. What are the main challenges, considerations, and enablers related to implementing or maintaining community water fluoridation programs in Canada?
7. What are the main challenges, considerations, and enablers related to the cessation of community water fluoridation programs in Canada?

Environmental Assessment

8. What are the potential environmental (toxicological) risks associated with community water fluoridation?

Ethical Considerations

9. What are the major ethical issues raised by the implementation of community water fluoridation?
10. What are the major ethical issues raised by the cessation of community water fluoridation?
11. What are the major ethical issues raised by the legal, social, and cultural considerations to consider for implementation and cessation?

The Implementation Issues Analysis addressed research questions 6 and 7.

Methods

Data Collection

Literature Search

The literature search for implementation considerations was performed by an information specialist using a search strategy that was peer-reviewed according to the PRESS (Peer Review of Electronic Search Strategies) checklist (<https://www.cadth.ca/resources/finding-evidence/press>). The search strategy is available on request.

Published literature relevant to implementation or cessation of CWF programs in Canada was identified by searching the following bibliographic databases: MEDLINE (1946–) and Embase (1974–), via Ovid; Cumulative Index to Nursing and Allied Health Literature (CINAHL) via EBSCO; and PubMed. The search strategy used both controlled vocabulary, such as the National Library of Medicine’s MeSH (Medical Subject Headings), and keywords. The main search concepts were fluoridation and fluoride in water.

Search filters were applied to limit retrieval to studies relevant to implementation issues in Canada. Retrieval was not limited by publication date, but was limited to the English or French language. The initial search was completed on November 15, 2017. Regular alerts were established and will continue to be conducted to update the searches until the publication of the final report.

Grey literature (literature that is not commercially published) was identified by searching relevant sections of the *Grey Matters* checklist (<https://www.cadth.ca/grey-matters>), which includes the websites of regulatory agencies, HTA agencies, clinical guideline repositories, systematic review repositories, patient-related groups, and professional associations.

Google was used to search for additional Web-based materials. These searches were supplemented by reviewing the bibliographies of key papers and through contact with appropriate experts and industry.

Targeted Stakeholder Consultations and Feedback

To inform the scope, literature search, and the findings of the Implementation Issues Analysis, consultations with willing and available stakeholders in the field of CWF and oral health were conducted. Stakeholders included individuals involved in local public health, those involved in the delivery of municipal water, those working with federal health agencies, and academics in the field of CWF. The Implementation Issues Analysis aims to gather information around relevant implementation considerations for CWF. These considerations may contain policies, funding, and dental care practices relevant to providers and patients, including considerations for special groups of patients, such as those in rural or remote settings or those of low socio-economic status. As such, the questions asked of stakeholders related to these issues and the consultations took a semi-structured approach. Following are the example questions that helped shape initial conversations with stakeholders; as the conversations were semi-structured, the questions were used only as a guide, with other topics being explored if raised as important by the stakeholders (notes were taken and reviewed to determine how they provided additional information to the literature). Stakeholder feedback will also be solicited by posting a draft version of this report on CADTH's website, and by emails to subscribers to CADTH's mailing lists.

1. What is the policy landscape of CWF in Canada (i.e., what policies support/impede the addition of fluoride to water in Canada)?
2. From your perspective, what are the barriers and supports for CWF in general, but also for specific groups of people or settings?
3. How is the decision made to implement a CWF program, and how is this operationalized?
4. Who are the various interests, actors involved in CWF in Canada (nationally, provincially, and municipally)?
5. Alternatively, what are the barriers and supports for the discontinuation of water fluoridation programs? How is the decision made to discontinue these programs and how is this operationalized?
6. What do you perceive are the information gaps in this area, if any? How do clinicians, publics, and decision-makers get their information on CWF?

Screening and Selecting

English- and French-language reports that described implementation and context issues, including challenges and enablers associated with CWF (and its cessation programs) were eligible for inclusion. All study designs and report types were eligible for inclusion.

There was no date limit for the publications, but the search was limited to Canadian studies. Articles were deemed relevant and included for summary if they reported information on the implementation and context domains, according to INTEGRATE-HTA's Context and Implementation of Complex Interventions (CICI) framework.⁶⁰

Data Extraction

From each relevant article, the bibliographic details (i.e., author and date of publication), implementation issue under review, and other relevant study information pertaining to barriers or facilitators (e.g., clinical setting, geographical setting) were captured by one reviewer.

Data Analysis

Consultation data and findings from the literature were organized into categories based on the domains of implementation and context identified by the CICI framework.⁶⁰ The framework provides a method for assessing the context and implementation issues related to complex health interventions, and to explore the interaction of different domains. It is intended to be used by producers of HTAs, or organizations commissioning and using HTAs.

Using this framework, four domains of implementation — “provider,” “organization and structure,” “policy,” and “funding,” as well as the additional domain of “public” — were used to further guide the categorization of identified strategies, barriers, or supports as they relate to the implementation of CWF across the various levels of health care service delivery. The domains of context — “socio-economic,” “socio-cultural,” “setting,” “political,” “legal,” “geographical,” “ethical,” and “epidemiological” — were also used to guide the categorization of information.

Data, from consultations and the literature, were read through for initial familiarization before coding. Data were coded by one researcher. Data could be coded to more than one domain, if relevant. The information from all sources was summarized narratively and presented by domain. The summary includes a brief description of the domain and how the identified issues relate to CWF programs.

Results

Literature Search

The literature search yielded 275 citations, of which 32 publications (e.g., observational studies, position papers, editorials, and essays) were identified for inclusion.^{17,41,42,51,61-87} Ten additional publications^{13,15,39,88-94} were included after being identified through conversations with stakeholders.

Consultations

After the initial review of the literature, two targeted stakeholder consultations were conducted (in March 2018) to gain further insight into CWF programs in Northern Canada (specifically in Nunavut and the Northwest Territories), as well as clarity on the Public Health Agency of Canada’s environmental scan of CWF.³⁹ The distribution of a survey, as identified in the protocol, was not needed due to the wealth of literature and the opportunity for targeted consultations.

Domains of Implementation

The CICI framework describes implementation as “an actively planned and deliberately initiated effort with the intention to bring a given object into policy and/or practice.”⁶⁰ This effort is generally enacted by individuals and organizations with active and organized plans

to promote a certain intervention or adopt a new practice.⁶⁰ The following explores the findings within the domain of implementation for CWF programs, with the goal of highlighting implementation issues that would impact policy decisions at different levels of the health care system, including health care providers and providers of CWF, system organization and structure, policy, funding, and public perspectives.

Provider

Provider refers to the characteristics of those who deliver the intervention (e.g., roles and responsibilities).⁶⁰ Investment in CWF programs will require resources and training, both at the initiation of CWF and for its prolonged maintenance. This domain looks at two different kinds of providers — the providers of water and the providers of oral health services (e.g., dentists and public health professionals).

Provider of Water

The majority of Canadians (88.9%) get their water from municipal water supplies (i.e., water that comes through pipes to their homes from the city water supply), while 10.5% of Canadians get their water from private wells, and the remainder (0.6%) have their water hauled into the community (e.g., water trucked into the community).⁸⁹ CWF is only available to Canadians who drink from municipal water supplies, whether this is piped into their homes or hauled into their communities. The domain of setting explores, by province or territory, some communities that have implemented or ceased CWF programs in recent years.

Health Canada drinking water guidelines¹⁵ have established the MAC for fluoride in drinking water at 1.5 ppm. The optimal level of fluoride for drinking water, as stated on the Health Canada website, is 0.7 ppm.⁹⁰ Provinces and territories also have their own guidelines and standards for drinking water; for example, Ontario's standards (created in 2006) recommend that the concentration of fluoride in drinking water be within the range of 0.5 ppm to 0.8 ppm.⁹¹

Local governments make the decision to fluoridate water (an issue discussed in greater detail in other sections of this review), while federal, provincial, and territorial governments set guidelines for fluoridation.⁸³ Municipalities with fluoridated drinking water adjust the levels of fluoride to fall within the parameters set out by both Health Canada and their own provincial or territorial guidelines.

Municipalities providing fluoridated water to their constituents must consider several things. In the article by Tchouaket et al.,⁸⁵ which models the economics of fluoridating water in Quebec, the authors use a logic model to outline necessary inputs for water fluoridation. While their view may be an oversimplification of the whole process (i.e., they do not consider the factors leading up to the decision to fluoridate or not, or the resources for public health campaigns), it provides an overview of the inputs and intended societal benefits of CWF. When considering the initiation of water fluoridation programs, the inputs include the infrastructure and equipment to be used (e.g., water treatment plants, plumbing in homes, etc.), the chemical products used to fluoridate water, and the professionals needed to initiate and maintain water fluoridation programs. These professionals include water treatment plant operators, technicians, public health dentists, and those who perform laboratory inputs for testing water and monitoring the levels of fluoride. Water treatment plant operators must be certified, a process that includes training and examinations.^{93,94} The activities for this logic model are water fluoridation and the promotion of oral health. Intended benefits included

improved oral health, reduction in oral health costs, and indirect benefits (such as less time missed from work and school for things like dentist appointments).⁸⁵

Another consideration is the need to ensure a consistent application of fluoride to maintain a steady concentration of fluoride in the water, as well as factors that may prevent that from happening. For example, maintenance of infrastructure could mean that fluoride is not added to the water during certain repair periods,^{68,70} or operator error could lead to under-fluoridation (i.e., not fluoridating to the optimal levels set out by Health Canada).⁶² A 1980 water fluoridation status report from the Canadian Dental Association noted that under-fluoridation may be an attempt to appease those opposed to fluoridation.⁶² There may also be a need for more careful monitoring of levels of fluoride in the water being supplied. One study of British Columbia's drinking water and supply management practices found that a small number of locations (three out of 12 locations that fluoridated their water) did not monitor the outgoing levels of fluoride.⁸⁶ The recommendation from these authors was that fluoride-level monitoring should be conducted daily.⁸⁶

In summary, not all Canadians have access to municipal water supplies. For those that do, there are regulations set forth by Health Canada regarding optimal levels of fluoridation, and it is the responsibility of municipal governments to decide whether CWF programs will be implemented, not implemented, or ceased. When implementation occurs, there are technical requirements for municipal water systems and resources that are required to carry out CWF.

Provider of Health Services

Many professional groups and organizations support (i.e., have position statements, studies, or reports) CWF, though there are differences in thresholds and standards for the concentration of fluoride in water. The groups include Health Canada,⁹⁰ the Canadian Dental Hygienists Association,⁷¹ the Canadian Pediatric Society,⁸⁴ the Canadian Dental Association,^{82,90} the Canadian Medical Association,⁹⁰ and the Public Health Agency of Canada (PHAC).⁹⁰ However, it should be noted there are groups of Canadians that oppose CWF, often with regional chapters, such as Fluoridation-Free Ottawa or British Columbia's Health Action Network Society.⁹⁵

Different organizations in Canada have different roles and perspectives when it comes to CWF. For example, Health Canada's perspective on CWF concerns the safety of fluoridated water, while PHAC promotes CWF as a measure to improve oral health, and provides information and fact sheets on fluoride and CWF, and supports communities making decisions regarding CWF.

It was noted in a position statement by the Canadian Pediatric Society that primary care providers should be aware of the access to fluoridated water for the Indigenous communities in their service areas.⁷² Presumably this is to better tailor oral health services to those populations, especially as it relates to offering other fluoride treatments. This goal is outlined in the Canadian Task Force on the Periodic Health Examination (1995) clinical practice guideline paper, which recommends the use of water fluoridation for the prevention of dental caries, and does not recommend the use of fluoride supplements for children who have access to fluoridated water.⁷⁷ The Canadian Pediatric Society statement also noted that Indigenous communities should be provided with information regarding CWF, as well as the resources necessary to implement CWF if they so choose (e.g., financial support and training for water operators), and more generally, that advocating for community drinking water should be done for and by Indigenous communities.⁷²

There may also be a role for health professionals in the care of those exposed to high levels of fluoride in their water. One case study (published in 1995 by Boyle and Chagnon) of a couple exposed to high levels of fluoride (between 5 ppm and 28 ppm) in their well water over a period of decades (in the Gaspé region of Quebec), suggested that water specialists (e.g., hydrogeochemists and groundwater hydrologists) could help determine a risk assessment model for skeletal fluorosis that could be used by health officials.⁶¹ The aim of this would be to monitor those exposed to high levels of fluoride to mitigate possible health concerns.

Health providers, as well as other stakeholders, have a role in offering oral health programs outside of CWF. Rowan-Legg (2013) lists provincial or territorial publicly funded oral health programs offered to children.⁶⁴ This is explored in more detail in the section on setting, where provincial and territorial snapshots of CWF are provided.

In summary, providers of health services should be aware of the fluoridation status and the oral health status of the people they are serving as this may help them be more effective and tailor services.

Organization and Structure

The organization and structure domain refers to the policies, guidelines, networks, and organizational cultures through which an intervention occurs.⁶⁰ The issue of CWF brings together groups and people with common goals (whether it is in support or opposition of CWF programs) who work together to further their cause.

In the reviewed literature, there was an emphasis on health care agencies and professional associations working together to promote fluoridation, and the notion that the leadership for this collaboration may need to come from a specific group tasked with promoting fluoridation.⁸¹ This was well outlined in a case study from Calgary, Alberta — the paper by Pryce (1999)⁸² looked at the 1998 municipal vote in Calgary regarding water fluoridation, and the actions taken by those who were supportive of adding fluoride. The Calgary Regional Health Authority (CRHA) organized the creation of a fluoride education steering committee with three essential objectives: to build partnerships with relevant stakeholders; to educate health professionals; and to educate the public. To address the issue of partnerships, endorsements for water fluoridation were obtained from the Canadian Dental Association, the Alberta Dental Association, the Calgary and District Dental Society, the Alberta Dental Hygienists' Association, the Department of General Pediatric Consultants, and pediatric dentists from the Alberta Children's Hospital.⁸² The creation of a manual discussing the most recent fluoridation research became the foundation for educating health professionals and the public. Education sessions were also held to help educate CRHA staff. More targeted education materials (such as pamphlets and newsletters) were also used to reach health professionals. Several media were used to reach members of the public, including print materials, a fluoride information phone line, a fluoride website, social marketing campaigns, and media coverage.

On the alternative side, those opposed to water fluoridation (two vocal groups called the Health Action Network Society, and Calgarians for Choice) also organized themselves leading up to the plebiscite. They had well-known experts come speak to city council about water fluoridation, and also used media coverage and print materials to educate the public. There was also a group of people who tried to mount legal action against the CRHA to stop its CWF promotional activities, though this group was unsuccessful.⁸² The outcome of the

1998 vote was to continue with fluoridation; it was not until 2011 that Calgary decided to stop fluoridating its water.⁴¹

The 2017 Public Health Agency report entitled *The State of Community Water Fluoridation across Canada*³⁹ highlights the variability of reporting across Canada. Much of the information in the report is obtained from ministries of health or ministries of the environment.³⁹ Some jurisdictions (though it is not specified which ones in particular) collected and reported detailed information on all communities, regardless of fluoridation status, whereas others could only provide information on fluoridated communities.³⁹ Information on wells with naturally occurring fluoride was also difficult to obtain as wells are typically located on private property and are not subjected to government monitoring.³⁹

Coordination across organizations could provide more accurate information on the fluoridation status of communities and private wells, which in turn could help inform health care professionals about the sources of fluoride a person may be exposed to (i.e., aid in understanding oral health needs of both individuals and populations).

A 2016 paper by McLaren⁷⁹ also highlights the variability across Canada in reporting fluoridation status. The paper looked at postal codes (as a means of geographic location) to classify fluoridation status. One of the findings was that it was not easy to obtain information on fluoridation status — seven provinces were represented in the study, but only four were able to provide information on the communities in their jurisdiction with fluoridated water, or direct the author to resources in their area which could provide this information.⁷⁹ The author, in discussion with provincial representatives (no further information was provided about these persons) stated that “this reflects limitations on data-sharing across ministries or agencies, such that databases that could link public water systems to postal codes may be incomplete, inaccessible or simply not exist.”⁷⁹ The potential merits of a more cohesive system were reported to be that dental professionals are better able to tailor their practices based on a patient’s exposure to fluoride in their water. Under a more cohesive system this information would be more readily available not only to health professionals, but also to members of the public.⁷⁹ The Water Fluoridation Reporting System in the United States⁹² and databases from New South Wales in Australia were provided as examples of systems Canada could follow.⁷⁹

In summary, the issue of CWF brings together groups and people with common goals — they work together to further their cause (whether in support of CWF or in opposition of CWF). Additionally, a coordinated surveillance system for CWF across Canada may enable better data collection and a clearer picture of the fluoridation status of individual communities.

Policy

Policy refers to the government, public, and organizational processes and measures that may influence the implementation of the intervention — in this case, CWF programs.⁶⁰

Policy issues that emerged in the review focused on several key points. These points included rural health issues in oral health policy in general (not specific to water fluoridation); the creation of legislation regarding water fluoridation, and for cessation of water fluoridation; and the policy decision to spend money on other oral health programs.

In regards to rural oral health policy, the authors of the paper by Crocombe et al.⁶⁵ undertook an analysis of oral health policies from eight English-speaking Organisation for Economic Co-operation and Development countries, examining the extent to which the

policies address rural oral health concepts. In the Canadian oral health policy (*A Canadian Oral Health Strategy — 2005-2010*), the concept of rural oral health issues was infrequently mentioned.⁶⁵ While CWF is not specifically addressed in this document, the nature of inequities in oral health among rural populations was framed as an issue of “social access,” and focused on the cultural barriers between clients and services providers, especially for Indigenous peoples and people of low socio-economic status.⁶⁵ The Ethics section of this HTA explores these issues in more detail.

Two examples reviewed in the literature are historic in regards to changes to legislation to accommodate water fluoridation. In one example, Winnipeg began fluoridating its water in December 1956; however, the city supplied water to surrounding municipalities.⁶³ Prior to the initiation of fluoridation, new provincial legislation was enacted and the consent of the other municipalities was needed to fluoridate the water supply.⁶³ In another example, there were changes in how fluoridation could be introduced in communities and how it was discussed in the public sphere. The government of Ontario, in 1959, appointed a royal commission to explore water fluoridation.⁶³ The commission was in favour of water fluoridation and recommended that municipalities should be allowed to introduce fluoridation without a referendum (i.e., water fluoridation was not a violation of civil liberties, but was a “technical medical issue”).⁶³ The Government of Ontario then passed legislation that allowed municipalities to enact water fluoridation unless there was a petition signed by 10% of the electorate requesting a referendum on the issue.⁶³

According to McLaren and Petit, policy must also consider the trade-offs between the prevention of dental caries and the risk of fluorosis, especially for those who have access to other sources of fluoride, such as toothpastes.⁸⁰ An example of a trade-off between a general public health program like CWF and more specific health programs was most evident in the case study of Calgary’s decision to stop fluoridating water in May 2011; the city redirected funds that was previously used for CWF toward targeted dental programs, specifically addressing oral health needs in children from low socio-economic communities.⁸⁰ The money saved from cessation of water fluoridation (\$750,000) was redistributed to targeted programs (i.e., Calgary Urban Project Society, and the Alex Community Health Centre).⁸⁰ Some limitations to this approach were noted from the perspective of the study authors; foremost that the funds were reallocated on a one-time basis and that in times of economic downturn, non-profits are typically the first to experience cut-backs; the second concern was that these programs target only a subsection of the population (as opposed to the assumed universal nature of water fluoridation) and it can be hard to reach members of the target population; additionally, targeted programs are unlikely to address social inequities.⁸⁰ The authors argued for an emphasis for the policy-maker to consider the most vulnerable of populations (e.g., those of low socio-economic status and those with limited access to resources) when making decisions.⁵¹ The Ethics section of this HTA explores these issues (e.g., assumed universality of CWF) from different perspectives.

In summary, policies should consider the risk-benefit of CWF. Policy can also be a tool to support CWF (e.g., make it easier for provinces to enforce CWF). More generally, there exists a lack of policy regarding the oral health of rural populations.

Funding

The funding domain refers to both the long- and short-term mechanisms by which an intervention receives monetary support, from any source (e.g., government, non-government organizations, private sector funders, etc.).⁶⁰

Few studies discussed the particulars of funding for CWF; though, many acknowledged that oral health is primarily funded privately by individuals (i.e., out of pocket) and through private insurance.^{69,71,78,84} The Budget Impact Analysis of this HTA provides a more detailed look at the economics of CWF programs.

As a generalization, given that municipalities decide and fund CWF in Canada, the 2010 essay by Carstairs commented that wealthy provinces with large urban centres are more likely to have water fluoridation compared with less wealthy provinces with larger rural populations.⁶³ For example, even though Carstairs stated that the government of Saskatchewan has heavily promoted CWF,⁶³ its population is largely dispersed and fluoridation is not common.^{39,63}

According to Carstairs, some provinces can encourage the fluoridation of water by providing municipalities with the funds necessary to purchase equipment.⁶³ However, this has not always meant that municipalities will fluoridate, as very few municipalities (13 municipalities based on data from 2002 to 2010) in Quebec are fluoridated even though the costs of fluoridation supplies and the cost of installing equipment are covered by Quebec's Ministry of Health and Social Services.⁸⁵ It was noted by Carstairs that while fluoride itself is not very costly, the resources needed to deliver CWF are more expensive (e.g., human resources, staffing, monitoring, etc.).⁶³ Even still, professional groups such as the Canadian Association of Dental Hygienists recommend that provinces and territories invest more money into CWF programs.⁷¹

The literature review also highlighted the potential from some individuals to accrue personal costs while avoiding the consumption of fluoridated water. In one case study, a couple in rural Nova Scotia had high levels of fluoride (between 5 ppm and 28 ppm) in their well water, and after the husband suffered severe fluorosis, the couple began consuming bottled water to deter any further health effects.⁶¹ While the example comes from a couple whose water was high in fluoride, to the point where one partner suffered from skeletal fluorosis, it may also apply to those who do not wish to consume any fluoridated water. It was also noted by Boyle and Chagnon that routine radiology for groups at risk (in this case rural populations) was cost prohibitive, but that medical care for those with skeletal fluorosis was also costly as the patient had to be transferred to a larger centre for medical follow-up.⁶¹

The literature review also brought to light the cost associated with alternatives to water fluoridation. The Canadian Pediatric Society, for example, argued that even if other interventions (e.g., fluoride tablets for children under the age of 12) are cost-saving,⁶⁷ there is an issue with compliance, which may limit the effectiveness of such interventions.^{67,75}

In summary, the responsibility of funding CWF lies with local government; however, the burden of paying for oral health care primarily falls on the individual. This can create a disconnect between who funds preventive health measures and where the benefits are realized.

Public

The public domain refers to contextual issues around public discourse about CWF and populations of special interest.

Almost half of Canadians are aware of CWF, so when conversations around CWF arise, it is unlikely that all citizens are engaged in the conversation, as only a subset are aware of this intervention. Quinonez (2009)⁴² conducted a telephone survey of 1,005 Canadians (identified by random digit dialling) and surveyed them on questions related to water

fluoridation; 45% of this sample had heard of CWF, mainly from print and electronic media. Of those who had heard of CWF, many (79.5%) understand that it is used to prevent dental caries, with the majority (63.0%) believing it to be safe and the majority (59.7%) believing it to be effective. A total of 62.4% of those who had heard of CWF were supportive of it.⁴² According to this survey, an increase in age, income, and education was associated with an increased awareness of CWF.⁴² Those who visit the dentist regularly and those with larger incomes were more likely to support CWF, while those who pay for dental care out of pocket, women, and those with young children were less likely to support CWF.⁴² A key limitation with telephone surveys is that they may not appropriately capture a relevant sample of the population (e.g., respondents must have access to a phone, the ability to communicate over phone, etc.) and therefore the generalizability of the results are uncertain. Further, some results may not be stable over time.

Several papers identified children as a special population regarding fluoride exposure and oral health.^{64,74,78,84,86} Children are frequently mentioned because of the systemic effect of fluoride before permanent teeth have come in (i.e., the pre-eruptive effect) — which is not relevant to other populations — in addition to the topical effect fluoride has on teeth that have already emerged (i.e., the post-eruptive effect).⁷⁸ Ensuring that children receive what is considered the optimal level of fluoride is therefore of concern to many stakeholders. Children may be exposed to fluoride in the drinking water at their schools.⁷⁴ Juurlink⁷⁵ suggested fluoridating school water above the optimal concentration to ensure children receive an effective dose of fluoride; however, this was not mentioned in other publications or by stakeholders, and outcomes of this proposed approach are uncertain. In addition to fluoride from schools, there was the recognition that children are exposed to other sources of fluoride, such as in soft drinks and juices made with fluoridated water;⁶⁴ however, these products typically have high sugar contents, which can be detrimental to oral health. Because of these additional sources of fluoride, participants in a workshop with public and children's health experts recommended that any fluoride supplementation be limited to children three years of age and older living in areas with less than 0.3 ppm in the water supply.⁶⁴

Other special populations of interest also emerged from the review, for which special consideration may also be warranted when implementing a CWF program. Indigenous children were identified as having a higher rate of dental caries than the general pediatric population, in addition to facing more barriers to receiving dental care.⁸⁴ The difference in oral health and access to dental care was noted for both Indigenous children from remote communities and those from urban areas.⁸⁴

Another group that may require special consideration are new Canadians. Compared with children born in Canada, new Canadians could face barriers like language, difference in culture, lack of finances, and navigating a new health system; these can all impact their access to dental care.⁸⁴

Persons, especially children, with special needs were also identified as an important group of interest.^{77,84} Children with special needs may have poorer oral health in general, but also could face barriers such as distance from a centre specialized in pediatric care, cost of care, and shortage of pediatric dentists.⁸⁴

Finally, the working poor were identified as a special population.⁸⁴ Working status may make these individuals ineligible for public dental programs, their jobs may not have benefits, and other costs (e.g., food and housing) may take priority over dental visits.⁸⁴

In summary, this section highlights several populations of special interest; children, persons with special needs, Indigenous children, new Canadians, and the working poor are particularly relevant in conversations around CWF as they experience special oral health needs. There may be particular needs for these communities, which should be considered when making decisions regarding CWF programs. This is also not an exclusive list of special populations, and CWF may be relevant to other groups such as seniors, persons in assisted living, or others who may rely on others for personal care and hydration.

Domains of Context

The domains of context refer to the components that interact, modify, or change the environment in which an intervention takes place or is implemented.⁶⁰ The INTEGRATE-HTA CICI framework describes context as the active and unique factors that interact with these domains, and help to understand an appropriate and jurisdiction specific implementation strategy.⁶⁰ The following explores context and domains that were likely to impact on the implementation or cessation of CWF in a particular jurisdiction.

Socio-Economic

The socio-economic domain explores the relationship between economic resources and a community's ability to access the intervention of interest.⁶⁰ Socio-economic status impacts one's ability to access oral health care; differences in oral health may be related to income disparity.

A recurrent theme in the socio-economic domain was oral health status as it relates to income disparity. People of low socio-economic status usually have less access to private oral health benefits, and there is an apparent disparity in oral health status between high- and low-income Canadians.^{69,71,74} Context about the oral health of Canadians, and how people access and pay for dental services, adds to our understanding of the context in which CWF takes place, and may influence decision-making regarding its use.

Reasons for this disparity were briefly explored within the reviewed literature. Oral health care is paid for in one of four ways in Canada — people may pay for dental care directly out of pocket, through private dental insurance, through third-party insurance (i.e., insurance through their employer), or through public dental programs (e.g., Veterans' Affairs Non-Insured Health Benefits).⁸⁴ Persons with low income typically have less insurance, while also experiencing the greatest burden of disease.⁸⁴ Rowan-Legg⁸⁴ stated that based on survey data from 2007 to 2009, 32% of Canadians did not have dental insurance; and when considering persons within a lower income bracket, 50% of these persons did not have dental insurance. Those without insurance have also been found to be less likely to visit a dentist.⁷¹

Associations or possible links between community-wide socio-economics and CWF were not explored directly. It is uncertain whether places experiencing economic downturn view or enact CWF differently than those of stable or growing economic security. Regardless, the socio-economic status of a community, and its relationship with oral health status, may be important to consider when making decisions around CWF.

Socio-Cultural

Conversations around the socio-cultural issues related to fluoridation typically revolve around concerns with fluoridation, the barriers to fluoridation, and the sources of information

that exist for the public. Much of this literature was supportive of fluoridation, though some cited a need to address the concerns of those opposed to fluoridation.

The context of how water fluoridation was initiated in Canada, even in the beginning, has involved controversy and opposition.^{41,63,81} In an editorial by Musto, and an essay by Carstairs, differences in the perception of the nature of fluoridation emerged as a possible explanation for opposition: compared with interventions like water chlorination, which is aimed at preventing contagious and fatal diseases, fluoridation is protective in preventing dental caries — a non-fatal, non-contagious condition.^{63,81} A 1972 position paper by the Canadian Pediatric Society commented that some people have expressed the feeling that chlorination overcomes a danger, while fluoridation medicates water.⁶⁷ Carstairs has also raised the argument, from the view of anti-fluoridationists, that care for children's teeth is the responsibility of parents, not of government.⁶³ There is also some discussion as to whether dental caries would be more appropriately controlled by a healthier diet and less sugar.⁶³ There are many different perspectives to take into account when considering policies around fluoridation, to consider the history of this public health intervention in Canada, and how the history shapes the current views and opinions of individuals and organizations.

From the public perspective, some general barriers to CWF that emerged from the literature review are:

- A public awareness of the shortcomings and fallibility of government (e.g., Three Mile Island disaster, Mississauga train accident, etc.) that might extend to fluoridation and the decision by governments to fluoridate water.^{62,81}
- A desire from consumers for more natural foods, as well as environmental concerns around additives to foods and environmental pollutants, and the view that fluoride is not compatible with these desires.^{62,81}
- The freedom for choice and the feeling that fluoridation violates this principle.⁶² This issue is explored more in the Ethics section of this HTA, as well as the ethics domain of this review.
- A need for organized and funded government support, laws, and legislation concerning fluoridation and promoting fluoridation. This includes a hesitancy from government officials to act on the issue of fluoridation (most probably due to the sensitive nature of this topic), whether for implementation or cessation.⁶²
- Active resistance from interest groups that tend to be well-organized and well-supported, that oppose fluoridation. Historically, these groups are typically the most vocal in raising the desire to stop fluoridation.⁶²

Exploring the context in which fluoridation is discussed in public forums allows for a more fulsome exploration of the concerns around fluoridation. The worries of individuals are many and varied, and so are the sources of information on fluoridation. Podgorny and McLaren (2015) examined Web pages enabled with comments to explore the public discourse around water fluoridation in Calgary, specifically the harms and risks associated with fluoridation.⁴¹ More generally, this gives insight into the use of the Internet, especially forums allowing public comments, as a vehicle for conversation around fluoridation and as a source of information to the public.

The majority of sources (55 sources in total) were online newspaper or magazine articles (50%), blogs (19%), public discussion forums (15%), opinion pieces or letters to the editor (8%), and other sources (e.g., videos, websites, interviews) (8%). To be included as a source, there had to be the capacity to comment on the source, and there had to be

comments (i.e., articles with no comments were not included). The bias of the sources was not evaluated.⁴¹

Many comments (42.3% of comments reviewed) did not provide evidence for claims made, and when scientific literature was cited, these papers often had methodological concerns, as determined by Podgorny and McLaren.⁴¹ The authors stress the need for appraisal of new scientific literature, and to communicate the results and assessment to the public.

Podgorny and McLaren explored a list of concerns as to why people do or do not support fluoridation, and also advocate that communication strategies cannot be dismissive of concerns (i.e., scientific literature is not the only reason people may or may not be supportive of CWF programs, and communication strategies should be cognizant of this).⁴¹ The following list presents thematic groups of concerns about fluoride:

- generic toxic or poisonous
- generic unhealthy or damaging to health
- dental harms (e.g., fluorosis)
- behavioural and cognitive (e.g., attention deficit hyperactivity)
- generic harms to children and the elderly
- animals, environment, and aquatic life
- bones and skeleton (e.g., skeletal fluorosis)⁶³
- endocrine system (e.g., pineal gland)
- cancer^{62,63,81}
- brain and central nervous system (e.g., brain and central nervous system neurotoxin)
- urinary system (e.g., bladder)⁶³
- immune system (e.g., allergy)⁶³
- digestive system
- other (e.g., diabetes, genetic harms, hair loss)
- respiratory system
- pregnancy and related.⁴¹

The types of sources of information cited in online comments, ordered by frequency were: no evidence or person viewed as an expert; generic reference to research; websites, including YouTube; personal experience; government report or organization, including government acts and regulations; study or article in peer-reviewed journal; personal research and reading; product label; documentary, magazine, or book; non-governmental or non-profit organization; newspaper.⁴¹

An editorial by Musto⁸¹ hypothesized about the timing of pro-fluoridation communications, while echoing that the mass media is an important source of information for the public. Writing from a health communication perspective, Musto states that early communication may raise fluoridation as an issue of possible public vote, while communication during a fluoridation campaign can raise awareness of concerns around fluoridation or emphasize the proposed value of fluoridation.⁸¹ The editorial argues that endorsement of fluoridation by the media has been considered a vital component of success in pro-fluoridation campaigns.⁸¹

Education on the issue of CWF was also considered important. When fluoridation was first introduced in Brantford (the first city to be fluoridated in Canada), an education campaign

was conducted to stress the poor condition of children's teeth, with fluoride as a measure to mitigate this. After this campaign, public demand for fluoridation became strong, and several community organizations began to support CWF.¹⁷ Education of the public, community officials, and health workers (e.g., physicians would be able to promote CWF at patient visits) was also stressed in the article by Juurlink.⁷⁵ There is uncertainty about the extent to which media campaigns in the current age may influence personal beliefs; in the early days of CWF programs, education may have played a larger role, and potentially the gains in knowledge about CWF programs from the media would be marginal today.

Setting

The domain of setting encompasses the physical and organizational structure of the environment in which an intervention takes place.⁶⁰ In regards to CWF programs, this domain encompasses issues related to water fluoridation in rural and urban areas, and based on provincial and territorial jurisdictions.

One concept raised by several sources was that rural areas often have less access to fluoridated water,^{65,75,87} and people living in rural areas may be less aware of CWF in general⁴² and may have less access to oral health care (e.g., fewer dentists and oral health specialists).^{65,87} One possible explanation as to why rural areas may have reduced access to fluoridated water is that the cost is prohibitive. One study stated that it was six times more costly (per person) to fluoridate an area with fewer than 5,000 people than an area with more than 20,000 people.⁸⁷

Issues related to implementing CWF may also differ for northern or remote communities. Many identified issues related to CWF in northern communities relate to capacity, such as issues around employment, community capacity building, education, and literacy (stakeholder, personal communication, March 9, 2018).

PHAC provides a map (using 2017 data) of the population of each province and territory that currently has fluoridated water; specifically, this refers to optimally fluoridated water (within the Health Canada–recommended range).⁸⁸ Levels of CWF range from 0% in Yukon to 71.1% in Ontario.^{39,88} Much of this information was obtained from ministries of the environment for each of the provinces and territories (stakeholder, personal communication, March 2, 2018). Information on CWF and fluoride in well water is collected by departments of environment and reported back to departments of health (stakeholder, personal communication, March 2, 2018).

The report also details what percentage of Indigenous communities within each jurisdiction have access to fluoridated water systems; only communities with a Municipal Transfer Agreement (which gives them access to other municipal water sources) have access to CWF.³⁹ The following percentages of people with access to CWF in Indigenous communities (see results by jurisdiction) may be an overestimate as some CWF systems experience interruptions in service, and access to fluoridated water may vary across the community.³⁹

The following explores access to CWF by province and territory. It should be noted that though the data were accurate at the time of the studies, the state of water fluoridation in Canada is in constant flux and current data may be different than reported here. Similarly, information about publicly funded dental programs for children, which are subsequently listed, is accurate as of 2013.⁸⁴

Alberta

According to 2017 data, 42.4% of Albertans have access to fluoridated water.^{39,88} It is estimated that 6.4% of Indigenous persons in the province have access to CWF.³⁹ As previously stated, Calgary has had a complex history with CWF, and as of 2011 the city no longer fluoridates its water.^{41,79,80} Since 1967, the city of Edmonton has fluoridated its water.^{78,79,83} Water fluoridation in Edmonton is contracted to EPCOR; the company runs two water treatment plants in the city.⁷⁹ The city of Red Deer also fluoridates its water, a process that began in 1957.⁷⁸ In 2012, the town of Okotoks discontinued fluoridation.³⁹

For access to oral health care, Alberta's publicly funded dental programs for children include Alberta Child Health Benefit, Family Support for Children with Disabilities, children and youth in foster care, and Assured Income for the Severely Handicapped.⁸⁴

British Columbia

Just over one per cent (1.2%) of people in British Columbia have access to fluoridated water.^{39,88} For Indigenous persons, it's estimated that 0% have access to CWF.³⁹ The city of Vancouver does not fluoridate its water.⁷⁸ This means that communities that are served by the Metro Vancouver watershed are also not fluoridated (e.g., Richmond and Coquitlam).⁷⁹ In 2014, the town of Sparwood and the city of Prince George discontinued water fluoridation.³⁹ Cranbrook introduced water fluoridation in 1966, and in 2014 a referendum was held where residents voted to continue water fluoridation.⁷⁹ The areas of Williams Lake and Quesnel are not fluoridated. While Williams Lake implemented fluoridation in 1969, it was stopped in 2005 fluoridation due to equipment upgrades, and in 2011 a referendum was held in which it was voted that water fluoridation not be reinstated.⁷⁸

British Columbia's publicly funded dental programs for children include Healthy Kids and Dental Benefits Program for Children and Youth in Foster Care.⁸⁴

Manitoba

The percentage of Manitobans with access to fluoridated water is 69%.^{39,88} It is estimated that 1.4% of Indigenous persons in the province have access to CWF.³⁹ Winnipeg has fluoridated its water since 1956.⁷⁹ Since 2011 the communities of Flin Flon, Churchill, Pilot Mound, Melita, The Pas, Virden, and Reston have discontinued water fluoridation.³⁹

In terms of access to oral health care, Manitoba also has several publicly funded dental programs for children, including Health Services Dental Program, S.M.I.L.E. plus program (based out of the Winnipeg regional health authority), Healthy Smile Happy Child, and Free First Visit Program (from the Manitoba Dental Association).⁸⁴

New Brunswick

Similar to British Columbia, 1.2% of New Brunswick is fluoridated.^{39,88} For Indigenous persons located within the province, it was estimated that 3.6% have access to CWF.³⁹ The city of Moncton implemented water fluoridation in 1970;⁷⁸ however, this was discontinued in 2012.^{39,41} Dieppe, Riverview, and Saint John have also discontinued water fluoridation.³⁹

The province of New Brunswick's publicly funded oral health program provides dental care to low-income families.⁸⁴

Newfoundland and Labrador

In Newfoundland and Labrador, 1.5% of people have access to fluoridated water.^{39,88} For Indigenous persons in the province, it was estimated that 0% have access to CWF.³⁹ The city of St. John's does not fluoridate its water.⁷⁹ Gander discontinued water fluoridation in 2010.³⁹ However, most private water and community sources comes from wells, which may have a level of naturally occurring fluoride (detailed data on well water was not available or not provided).⁸³

The publicly funded dental program for children in Newfoundland is the Children's Dental Health Program.⁸⁴

Northwest Territories

According to 2017 data, 64.9% of the population of the Northwest Territories has access to fluoridated water.^{39,88} The estimate is the same for Indigenous persons within the territory given that the majority (52%) of persons living in the Northwest Territories are of Indigenous background.³⁹ In Inuvik Region (the western part of the Northwest Territories), Inuvik was the only community out of the 13 communities in the region to provide fluoridated water; additionally, many of these communities are accessible only by air, with the exception of Fort McPherson, Inuvik, and Tsiigehtchic.⁷⁶ The communities of Fort Liard, Nahanni Butte, Whati, and Wrigley have wells with naturally occurring fluoride (detailed data on well water was not available or not provided).³⁹

The Non-Insured Health Benefits Program (for First Nations and Inuit persons) is the publicly funded oral health program in the Northwest Territories.⁸⁴

Nova Scotia

In Nova Scotia, 46.9% of the population has fluoridated water.^{39,88} It is estimated that 20% of Indigenous persons in the province have access to CWF.³⁹ Water fluoridation in Nova Scotia began in the 1970s, and the Nova Scotia Department of Health Promotion and Protection supports the practice.⁸³ However, the community of Truro does not fluoridate its water.⁷⁹ From October 2016 to October 2017 the municipality of East Hants was not fluoridated due to an issue with a pump malfunction.³⁹

Nova Scotia has two publicly funded programs that provide dental care to children, the MSI Children's Oral Health Program and the Mentally Challenged Program.⁸⁴

Nunavut

According to the 2017 PHAC report, 28.8% of the population of Nunavut has access to fluoridated water.^{39,88} The estimate is the same for Indigenous persons within the territory given that the majority (86%) of persons living in Nunavut are of Indigenous background.³⁹ In 2016 in Rankin Inlet, the practice of water fluoridation was temporarily discontinued due to "purported workers' safety issues."³⁹

Similar to the Northwest Territories, the Non-Insured Health Benefits Program (for First Nations and Inuit persons) provides access to publicly funded oral health care services.⁸⁴

Ontario

As already stated, Ontario has the largest percentage of the population with access to fluoridated water (71.1%).^{39,88} It is estimated that 1.2% of Indigenous persons in Ontario have access to CWF.³⁹ The largest contributor to the high level of fluoridation is likely

metropolitan Toronto (including the city of Toronto, Etobicoke, North York, Scarborough, and surrounding municipalities), which is fluoridated, and has been since 1963.⁷⁸ Since 1965 the city of Ottawa has also been fluoridated.⁷⁹ Other communities that fluoridate their water include Simcoe,⁷⁹ Oakville,⁷⁹ Port Severn,³⁹ and the District Municipality of Muskoka.³⁹ The Region of Durham also has several communities that fluoridate their water (e.g., Ajax, Brooklin, Oshawa, Pickering, and Whitby); however, not all follow this practice (e.g., Clarington).⁷⁸

Several communities have discontinued the practice of CWF. The communities of Windsor, LaSalle, Tecumseh, New Tecumseth-Tottenham, Lake of Bays, Huntsville, Kirkland Lake, Amherstburg, Kingsville, Nairn, Hyman, McDougall, Parry Sound, and Cornwall all discontinued the practice of CWF.³⁹ The Niagara Region discontinued water fluoridation in 1999.^{78,83} Waterloo discontinued CWF in 2010, and neighbouring Kitchener has never fluoridated its water.⁷⁸ Coburg does not fluoridate its water.⁷⁸ Thunder Bay is not fluoridated, but has an education program on CWF intended for a public audience.⁸³ The city of Kingston does not fluoridate its water.⁷⁹

In a study of Ontario fluoridation systems, considerably fewer rural systems were fluoridated (three out of 17), compared with urban systems (14 out of 17); out of the 17 rural systems, 11 had suboptimal (i.e., below the Ministry of Environment, Conservation and Parks optimal range) levels of fluoride.⁸⁷

Ontario has had several publicly funded dental programs for children, including Healthy Smiles, the Ontario Disability Support Program, the Assistance for Severely Disabled Children, and the Children in Need of Treatment program.⁸⁴ As of January 1, 2016, these programs have been integrated and are now part of Healthy Smiles Ontario.⁹⁶

Prince Edward Island

In Prince Edward Island, 24.4% of the population has access to fluoridated water.^{39,88} No Indigenous communities have access to CWF in PEI.³⁹ CWF in Charlottetown and the Canadian Forces Base in Summerside began in 1968.⁸³ There are also school-based dental programs that focus on the prevention of dental caries by the application of topical fluoride.⁸³

The publicly funded dental programs for children in Prince Edward Island include Children's Dental Care Program, Pediatric Specialist Services Dental Program, preventive orthodontic clinic, and the Early Childhood Dental Initiative.⁸⁴

Quebec

According to the PHAC report, 2.5% of the population of Quebec has access to fluoridated water.^{39,88} It is estimated that 0% of Indigenous communities in the province have access to CWF.³⁹ The city of Montreal does not fluoridate its water.

In Quebec, two publicly funded programs provide dental care to children; *régie de l'assurance maladie du Québec* and the Children's Dental Care Program.⁸⁴

Saskatchewan

According to 2017 data, 39.6% of the people of Saskatchewan have access to fluoridated water.^{39,88} It is estimated that 2.4% of Indigenous persons have access to CWF in Saskatchewan.³⁹

The publicly funded dental programs for children in Saskatchewan include Family Health Benefits, Supplementary Health Program, and Public Health Services Dental Clinic (out of the Saskatoon Health Region).⁸⁴

Yukon

In Yukon, 0% of the population, including Indigenous persons, has access to municipally fluoridated water; however, it's reported that the total population of Yukon has access to naturally fluoridated well water.^{39,88} In discussion with one of the authors of the PHAC report,³⁹ it was clarified that everyone in Yukon is exposed to some level of fluoride through naturally fluoridated well water, but the level of fluoride was less certain (stakeholder, personal communication, March 2, 2018).

The Children's Dental Health Program by Yukon Health and Social Services provides publicly funded dental services to children living in the territory.⁸⁴

Political

The political domain refers to issues of power, interest, and assets related to a specific intervention; this can relate to particular policies and political authorities, including governance and leadership specific to the intervention of interest, in this case CWF programs.⁶⁰

Fluoride is a politically controversial topic, with strong feelings both for water fluoridation and against water fluoridation. Decisions to fluoridate are made by municipal governments, while adhering to provincial and federal guidelines.⁴¹ The process may require a referendum to fluoridate water, or constituents may petition to have a referendum on the issue, but in other cases, city councils can independently make the decision to fluoridate water. There is also a difference in outcome depending on how the decision to fluoridate, or not to fluoridate, is made. Some generalizations about the decision around fluoridation were made in the literature, based on trends in how municipalities decided to address fluoridation. As discussed in the review by Musto and the essay by Carstairs, most generally, when the question of fluoridation is put to the public, the outcome is often not to fluoridate.^{63,81} Carstairs in particular found that when fluoridation was a matter of public vote, the votes were generally close (no overwhelming majority either for or against CWF).⁶³ On the other hand, while centralized decision-making bodies (e.g., municipal councils) do not frequently address the issue of fluoride unless prompted for some reason, when they do look at fluoride, they have been noted to be more likely to adopt it.⁸¹

Several political tools have been used to enhance the use of CWF programs, though these did not always lead to municipalities being fluoridated. For example, for a short period of time, Quebec had mandated CWF throughout the province (it was mentioned in the funding section that even with a financial subsidy, few municipalities in Quebec are fluoridated); New Brunswick similarly retained the ability to order municipalities to implement CWF.⁶³ There was no case of any province mandating CWF in all municipalities.

According to Hamilton's review on the politics of fluoride, there may be the feeling from politicians that it is most appropriate to err on the side of caution for this topic, and there is a hesitancy to address fluoride as part of a general aversion to doubt and risk.⁶⁹ Additionally, a reluctance on the part of elected officials to act on fluoridation (at provincial and municipal levels of government) was noted to often accompany discussions of CWF.⁶² As an example of this risk aversion, fluoridation was less likely to be implemented in the 1970s when concerns around chemicals were high, as compared with the 1950s and 1960s when

implementing fluoride was more common.⁶³ It then becomes important to understand how the issue of fluoridation is raised within councils, and how the decision is being made. For example, councils will often hear from experts on both sides of the issue; however, there may be a reluctance from dentists to participate in the debate on water fluoridation as one author reports the arguments are emotionally charged, and dentists feel their views are not listened to.⁶⁹

The implementation literature outlines several case studies looking at the political factors related to CWF. The Calgary City Council vote in May 2011 to cease water fluoridation was preceded by several plebiscites (some of which included a “heated” debate) aimed at ceasing CWF, none of which had previously passed.⁸⁰ Factors involved in the 2011 city council vote were seen to be the costs associated with infrastructure upgrades, veteran councillors who made efforts to revisit fluoridation, new councillors and a new mayor, and very limited public engagement.⁴¹

The issue of CWF was also raised in Timmins in 1991 where fluoride was voted on by the public, and supported (10,922 to 8,432 in favour); however, the referendum was dismissed on a technicality based on how the petition was submitted to council.⁶⁹

The implementation literature looked very briefly at voting patterns and demographics related to voting on CWF programs. Negative votes were found to sometimes be interpreted as an act of resistance, especially when there are negative feelings toward science or government.⁸¹ Negative votes may also be due to confusion; for example, when there has been confusion around fluoridation and chlorination. There is little education around what fluoride is, and the messaging from health professionals has been interpreted as arrogant and read as if there is an assumption that there is no legitimate concern regarding this issue, which is believed to also further limit effective communication on this topic.⁸¹ Many voters have been socialized to expect debate around issues, and understand there are two sides (or more) to every argument; when faced with information or controversy of which they had been previously unaware, one author suggests that voters may err on the side of caution and vote against fluoridation.⁸¹

Legal

The legal domain encompasses the rules and regulations (regarding rights and the interests of society) necessary to implement interventions.⁶⁰

One reference was made to legal issues related to CWF in the reviewed literature. One explicit example was the case in Calgary where a group of people unsuccessfully tried to mount legal action against the CRHA to stop its activity on water fluoridation.⁸² No other examples of legal issues were identified in this review, although that should not be taken to mean that legal issues are not relevant to CWF.

Geographical

The geographical domain refers to the physical landscape, ecology, and natural resources of the location in which an intervention takes place (e.g., climate; land use, including urbanization; altitude; etc.).⁶⁰

Captured under the geographical context of water fluoridation is the environmental impact. A separate section of this HTA takes an in-depth look at the environmental impact of CWF, and these themes are important to consider when making an implementation or cessation decision.

The Environmental Issues section reports that concentrations of fluoride are variable depending on the source (e.g., surface water, groundwater) and the surrounding geographical characteristics (e.g., geological makeup of the region). An example of a region with naturally high levels of fluoride in its ground water was discussed in the paper by Boyle and Chagnon,⁶¹ which reported a case of skeletal fluorosis in a man who consumed water from a well in rural Nova Scotia (this case study has been referenced in other sections of this report). Levels of fluoride found in the groundwater of this region, the Maritime Carboniferous Basin, reached upward of 5.0 mg/L¹ and were not recommended for consumption.⁶¹

The Environmental Issues section also discusses how fluoride is ubiquitous in the environment. Even those living in communities with non-fluoridated water may see some effect of fluoride by consuming food and beverages produced and processed with fluoridated water, for example.⁷³ This has been referred to as the “halo effect.”⁷³ The strength of this halo effect (i.e., its impact on dental caries) was not quantified or discussed in great length in the literature. However, because of the ubiquity of fluoride, there is not as strong a demarcation between fluoridated and non-fluoridated communities as there might have been when water fluoridation was first introduced in Canada.

One Canadian author suggested the people in warmer climates may consume more water, which may influence their exposure to fluoride.⁷⁰ Though it was uncertain how applicable this is to Canada as no specific literature was identified to describe whether this hypothesis had been studied in a Canadian context.

Ethical

The ethical domain is concerned with the principles, beliefs, and behaviours of individuals and institutions specific to the health intervention.⁶⁰ In this HTA there is a separate section that provides an ethical analysis of CWF implementation and cessation that should be referred to for a more fulsome discussion on this topic. Several ethical concepts regarding water fluoridation are relevant to implementation and cessation decisions, and a brief overview of some of these issues is provided here.

The issues surrounding the ethics of fluoridation, as seen in the implementation literature, often considered the balance of potential harms and potential benefits (which are explored in the Review of Dental Caries and Other Health Outcomes section of this HTA). Additionally, the balance between economic harms and benefits were also raised (e.g., cost of fluoridating, cost of caries, and cost of fluorosis — explored in the Budget Impact Analysis section of this HTA). A common argument was that the addition of fluoride violates civil liberties and that there should be an individual right to choose an intervention,^{51,62,63,75,81} but some saw this violation as justifiable and equitable from a societal perspective (i.e., considering those that cannot afford other sources of fluoridation).^{51,78} There was also the view that there is a public demand for freedom of choice,⁶² and for some that fluoride is viewed as a medication, therefore fluoridating water violates a person’s right to choose whether they accept this medical intervention.⁷⁵ The issue of more targeted interventions was also raised; for example, a consideration was made for interventions that are less intrusive on an individual’s ability to choose their health care interventions and work toward the same outcome (e.g., targeted dental programs for improving oral health).⁸⁰

McLaren and Petit⁸⁰ explored the different perspectives on the concept of equity as it relates to fluoridation, using fluoridation in Calgary as a case study. They raise four arguments surrounding CWF:

- fluoridation is equitable (i.e., it's cost-effective and reaches a large number of people)
- poor children cannot afford alternatives (i.e., cost associated with dental services, either for caries or fluorosis, and cost for bottled water while homeowners pay for municipal water)
- fluoridation is good for poverty (i.e., persons living in poverty may not be able to comply with alternatives to fluoride, and the divisive attitude toward social class differences)
- fluoridation and poverty are not connected (i.e., the costs of fluoridation does not solve issues of socio-economic disparity, and some might find the poverty–fluoridation argument to be offensive).⁸⁰

Access emerged as another area of ethical consideration. For those supportive of CWF, the issue that all Canadians do not have access to fluoridated water is concerning. For example, Indigenous persons living on a reserve have far less access to CWF compared with other Canadians,^{39,72} which was seen as especially troublesome considering Indigenous children are at high risk for dental caries.⁷² If CWF is determined to be an essential service, the issues of access and equity would need to be considered.

Fluoridation is an upstream intervention (in theory an intervention that reaches everyone in the community); however, authors have commented that it does not address the social determinants of health that lead to disparities in oral health. It has been suggested that a more targeted approach could address some of these determinants, but the program being delivered may further stigmatize individuals (e.g., accessing a targeted program may identify individuals as being low income and be further stigmatizing).⁸⁰ When deciding on a fluoridation strategy, consideration must also be given to the ethical issues regarding alternatives to CWF (e.g., more targeted programs such as fluoride rinses).

Epidemiological

The epidemiological domain refers to the demographics of the individuals and populations relevant to the health intervention, including disease conditions and burden of disease.⁶⁰ The Review of Dental Caries and Other Health Outcomes section of the HTA more fulsomely explores issues of epidemiological importance. This section highlights findings from the implementation literature, and how this domain is being discussed in this area.

One of the arguments around fluoridation (from both sides of the issue) is the link between fluoride and dental caries. McLaren and Emery and Ismail et al. have hypothesized that this may be due to the halo effect, but also to the increased use of other forms of fluoride, such as fluoridated toothpaste and topical fluorides.^{73,78} However, The Review of Dental Caries and Other Health Outcomes of this HTA found that the protective effect of CWF was observed even after accounting for a background of toothpaste use. McLaren and Emery also hypothesized that the increased awareness of oral health may have led to a decrease in the incidence of dental caries.⁷⁸ Without addressing some of the social determinants of health, authors have commented that it's simplistic to assume that fluoridating the water will address the issues of dental caries in all populations, especially those of low socio-economic status. For example, Ismail et al. stated that water fluoridation is still cost-effective and a worthwhile intervention, but it may no longer be the cornerstone of public health programs.⁷³ They assert that water fluoridation may not be necessary in communities with low rates of dental caries.⁷³

The argument from those opposed to fluoridation is that CWF is not effective at reducing dental caries^{75,81} and there is an overall lack of belief that dental caries are a serious health problem, which some have suggested could be due to decreased incidences of dental caries over time.⁷⁵ The Review of Dental Caries and Other Health Outcomes of this HTA explores the data regarding CWF and dental caries in more detail; this argument is not consistent with the findings of that section, which demonstrated a protective effect from CWF and recognized dental caries as a health concern.⁵⁵ The Review of Dental Caries and Other Health Outcomes also concluded that dental fluorosis prevalence may increase with increasing water fluoride levels, though dental fluorosis of “aesthetic concern” among Canadian children is rare.

Discussion

As outlined under implementation and context in this section, CWF programs are complex, with many stakeholders and issues to consider. The organization of CWF programs is multi-level, with involvement and different roles and responsibilities from municipal, provincial or territorial, and federal government. Those responsible for setting regulations are often different than those who decide whether CWF programs will be implemented (or ceased), and are also often different than those who pay for oral health care. Within the realm of oral health care, there are dentists and public health professionals whose interest is in the oral health of individuals and populations, and public and private insurers responsible for paying for oral health care. In terms of municipal water delivery, there are water treatment personnel, engineers, and city staff; and then there are members of the public. Any one of these stakeholders can view CWF programs favourably or not. This means that perspectives on CWF programs differ based on the individual, their experience, and their context. Thus, the landscape in which CWF programs are enacted, delivered, or ceased is complex and context-dependent.

Part of this context, beyond the many stakeholders involved and their different perspectives, is the issue that CWF programs are available to those who use municipal water supplies; and not every municipal water supply is fluoridated. The setting and geographical domains explore the access to municipally fluoridated water across Canada, and this differs based on setting (e.g., rural populations are typically less fluoridated compared with urban areas) and jurisdiction. Decisions around CWF programs then must also include consideration for the setting and region, as feasibility will differ from place to place.

Conversations around CWF will have to consider the socio-economic disparity that exists among Canadians, especially how that relates to oral health status and how Canadians access dental care. There are different health needs for individuals, and for certain populations of interest (i.e., children, persons with special needs, recent migrants to Canada, etc.). CWF decisions should consider the oral health status, and burden of dental caries, in the region in which the program is implemented or ceased.

There are limitations to this review, the first being the scope of the review. This HTA has only considered Canadian literature and discussions with stakeholders located within Canada. While this may make the information more transferable to a Canadian context, there may be information from other countries that is also applicable, but that was not captured in this review. This review also only considered CWF programs, and not other public health dental programs (i.e., this was not a fulsome review of all public health interventions to address dental caries).

Additionally, much of the literature focused on the benefits of water fluoridation and the context around water fluoridation in the political and public sphere; there was less information on the cessation of water fluoridation and the perspective of those opposed to water fluoridation. Reasons for the lack of literature around cessation are uncertain, but perhaps were limited to case studies such as the discontinuation of CWF in Calgary. This may also change over time as research looks to the effects of CWF cessation.

The landscape of water fluoridation is also changing, and the information captured within this report may not reflect the current landscape (e.g., fluoridation status of cities), or may become outdated in the near future.

Conclusion

This report describes implementation issues. As noted, separate reports on the assessment of dental caries and other health outcomes,⁵⁵ economic considerations,⁵⁶ environmental impact,⁵⁸ and ethical considerations⁵⁹ for CWF are available as part of the full HTA review on this topic.

This review explored the literature regarding CWF programs (including both the implementation and the cessation of these programs), and discussed the findings as it related to the domains of implementation and domains of context from the INTEGRATE-HTA CICI framework.⁶⁰ Gaps in the literature were supplemented with conversations with targeted stakeholders. Overall, the context in which CWF takes place is nuanced and ever changing. There are many different stakeholders from all levels of government, public health, and the general public who may have very different opinions on water fluoridation. Then there are the issues of access, distribution, and oral health disparity. These issues add levels of complexity and context, which need to be weighed in decisions about CWF programs.

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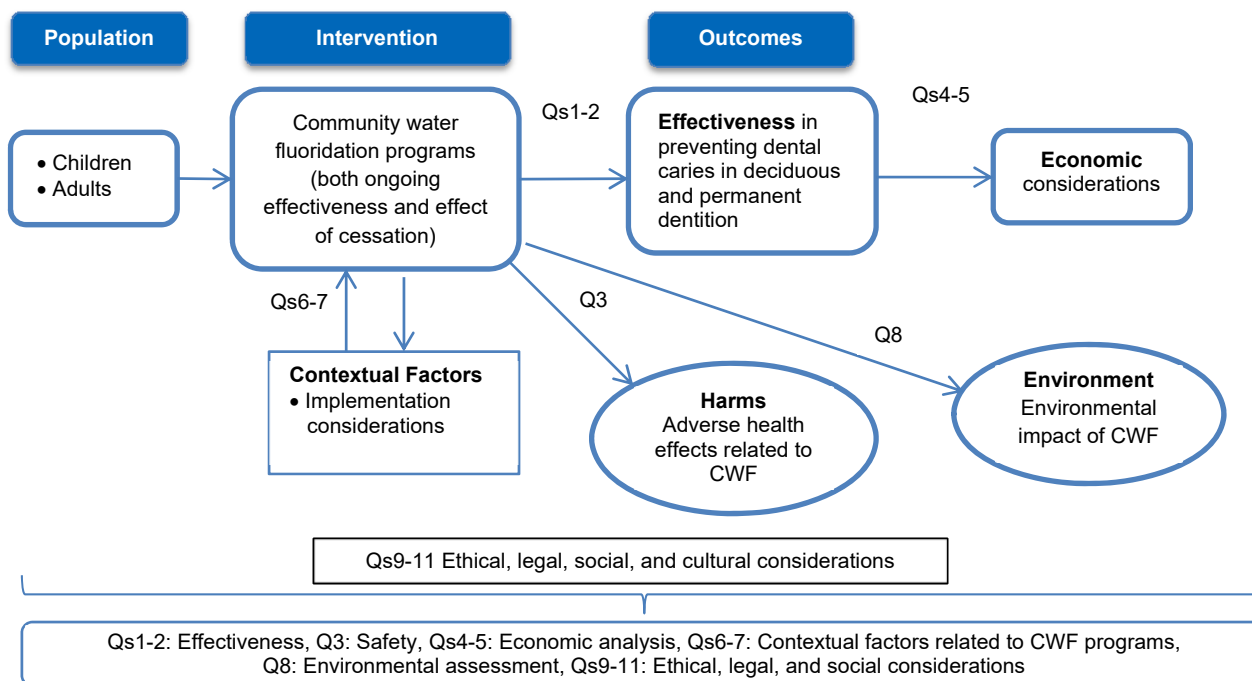
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Appendix 1: Analytical Framework

Policy Question: Should community water fluoridation be encouraged and maintained in Canada?



Research Questions	Methods
Q1. What is the effectiveness of community water fluoridation compared with non-fluoridated drinking water in the prevention of dental caries in children and adults?	Update of two published systematic reviews
Q2. What are the effects of community water fluoridation cessation compared with continued community water fluoridation, the period before cessation of water fluoridation, or non-fluoridated communities on dental caries in children and adults?	
Q3. What are the negative effects of community water fluoridation (at a given fluoride level) compared with non-fluoridated drinking water (fluoride level < 0.4 parts per million) or fluoridation at different levels on human health outcomes?	
Q4. What is the budget impact of introducing water fluoridation in a Canadian municipality without an existing community water fluoridation program from a societal perspective?	Budget impact analyses
Q5. What is the budget impact of ceasing water fluoridation in a Canadian municipality that presently has a community water fluoridation program from a societal perspective?	
Q6. What are the main challenges, considerations, and enablers to implementing or maintaining community water fluoridation programs in Canada?	Consultations with targeted experts and stakeholders
Q7. What are the main challenges, considerations and enablers to the cessation of community water fluoridation programs in Canada?	Narrative summary of the published and grey literature Survey on implementation issues related to community water fluoridation

Research Questions	Methods
Q8. What are the potential environmental (toxicological) risks associated with community water fluoridation?	Narrative summary of the published and grey literature Qualitative risk assessment
Q9. What are the major ethical issues raised by the implementation of community water fluoridation?	Review of the bioethics literature and analysis of ethical issues raised by reports answering Qs1-8
Q10. What are the broader legal, social, and cultural considerations to consider for implementation and cessation?	
Q11. What are the major ethical issues raised by the cessation of community water fluoridation?	