

**Drinking water fluoridation in Canada:
Review and synthesis of published literature**

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SUMMARY

Objective: To review and synthesize the published literature on drinking water fluoridation in Canada.

Methods: We searched seven interdisciplinary databases. Search terms included iterations and synonyms of “drinking water fluoridation” and “Canada”. We screened articles for relevance based on titles and abstracts. Approximately 115 of the 281 citations were retrieved and read in full.

Findings: Main findings may be summarized as follows:

- Evidence for the effectiveness of drinking water fluoridation in the prevention of dental caries in Canada exists. The strongest evidence is from the original trials (e.g., Brantford-Sarnia-Stratford) in the 1940s through 1960s. These original trials were impressive for their adherence to a rigorous research protocol.
- Since the 1970s, research on drinking water fluoridation has been complicated by the widespread availability of other sources of fluoride, most notably fluoride toothpaste. As such, more recent evidence on fluoridation is weaker than the earliest findings, though on balance it supports more than it refutes the effectiveness of the intervention.
- Existing research consistently shows an association between exposure to drinking water fluoridation and increased risk of dental fluorosis. Case studies of fluorosis in communities with high levels of fluoride in drinking water illustrate the critical importance of monitoring fluoride concentrations, particularly in rural areas with weaker infrastructure.
- Although there is some indication that exposure to fluoridation may have some benefit for bone density, on balance there is no clear evidence for an association between drinking water fluoridation and health outcomes other than dental outcomes.
- To conduct research on the health impact of drinking water fluoridation, it is essential to have accurate information on exposure, including a) length of residence in the community; and b) use of other sources of fluoride. This has implications for oral health surveillance across multiple Canadian jurisdictions.
- Although resistance to fluoridation is sometimes thought to be a recent phenomenon, well-defined opposition to fluoridation has in fact existed as long as fluoridation itself.
- Many arguments have been put forth by those opposed to fluoridation, ranging from the relatively innocuous “it’s not effective” to the more apocryphal “communist plot” and “aluminum company conspiracy”. Part of the power of the anti-fluoride movement is that some of the arguments – e.g., potential harm to the environment and aquatic life – cross ideological lines and have proponents in both the political right and left.
- We identified a large amount of material on local circumstances surrounding plebiscites or referenda. While this information may be helpful for communities undergoing a vote, it is important to recognize that fluoridation plebiscites are more likely to fail than to pass, which reflects characteristics of fluoridation and characteristics of plebiscites.
- Contrasting with the failure of most fluoridation plebiscites is the observation, from public opinion polls, that a majority of Canadians are in favour of, or at least not opposed to, fluoridation. This suggests that anti-fluoridationists are over-represented among voters at plebiscites, and it speaks to the success of the anti-fluoridationists in persuading otherwise undecided or non-voters to vote no.
- From an ethical point of view, drawing on principles of beneficence, autonomy, and truthfulness, the controversy over fluoridation may be un-resolvable.

Knowledge gaps:

- Surveillance. The amount of published research on the impact of drinking water fluoridation on oral health in Canada pales in comparison to the number of communities that have implemented (and in some cases discontinued) the intervention. Although we cannot discount the possibility that data from these communities exist and simply have not been published, it appears that the research opportunity provided by community changes in fluoridation status has often been left unexploited. Surveillance systems at national, provincial, and municipal levels would facilitate ongoing research on the effects of fluoridation.
- Oral health inequities. Considering that one of the main arguments put forth for continuing fluoridation is that it is a practical and effective way to provide fluoride to all (including those who cannot afford or access dental care and other sources of fluoride), we detected a surprising lack of research on the implications of drinking water fluoridation for inequities in oral health in Canada.

Limitations of the review:

- Articles were identified for review and inclusion based on titles and, if available, abstract. Therefore, we may have missed documents that provided insight into fluoridation if it was not a prominent objective of the study.
- Although we were careful to select databases that index older volumes of key journals, the nature of retroactive indexing is such that some older documents may have been missed. Nonetheless, our identification and inclusion of several documents from the 1950s and 1960s suggests that our search was reasonably comprehensive.
- The scope of our review was academic and professional journals (including but not limited to peer-reviewed sources). Therefore we did not seek out other important information sources such as organizational reports, unpublished documents in the “grey literature”, and media items. Of these sources, we believe that documents from provincial and municipal governments, and local health regions, would be particularly informative.
- On the whole, the materials reviewed tended to be favourable or neutral towards fluoridation, suggesting that our methods may not have adequately captured the anti-fluoridation literature. To ensure a fair hearing of both sides of the debate, it will be important to identify the sources of the anti-fluoridation literature and to include it in comprehensive syntheses.

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Drinking water fluoridation in Canada: Review and synthesis of published literature

Impetus and Objective

On Monday February 7, 2011, Calgary City Council voted 10-3 to discontinue fluoridation of the public drinking water. The City's water had been fluoridated since 1991, following a successful plebiscite in 1989. The highly-polarized debate surrounding Calgary's recent decision echoed circumstances elsewhere in Canada and in other countries. In the wake of Calgary's decision, and following an opportunity as public health scientists to speak publically on the issue (McLaren et al. 2011), we were approached by the Public Health Agency of Canada to undertake a thorough and systematic look back on drinking water fluoridation in Canada since its inception in 1945, and take stock of the research and other materials published in academic and professional journals during this time period.

Oral health is an important component of overall health. Oral health problems can impair people's ability to eat, speak, and interact with others; and pain and infection from oral diseases can cause physical discomfort as well as social and economic consequences (e.g., when one cannot work or otherwise participate fully in society due to oral health problems, perhaps due to inability to access appropriate treatment) (Health Canada 2010). Dr. P. Cooney, Health Canada's Chief Dental Officer, states that dental disease is the number one chronic disease among children and adolescents in North America (Rabb-Waytowich 2009). Oral health has also been linked with health conditions such as diabetes and respiratory diseases (<http://hc-sc.gc.ca/hl-vs/oral-bucco/index-eng.php>).

Although national data are limited, those that exist suggest dramatic improvements in oral health outcomes among Canadians during recent decades. For example, the prevalence of dental caries on permanent teeth of Canadian children age 6-11 declined from 74% in 1970/72 (based on the Nutrition Canada Survey) to less than 25% in 2007-2009 (based on the Canadian Health Measures Survey) (Health Canada 2010). Likewise, significant declines in edentulism among adults (having no natural teeth) have occurred: while 16% of the Canadian population (age 15+) was edentate in 1990 (based on the Health Promotion Survey), this proportion had dropped to 9% by 2003 (based on the Canadian Community Health Survey) (Miller & Locker 2005). These improvements have been attributed in part to widespread fluoridation of drinking water across the country (Millar & Locker 2005; Health Canada 2010).

Despite these improvements, however, oral health problems remain. Among children age 6-11 years in the Canadian Health Measures Survey (2007-2009), nearly 57% were affected by dental caries (Health Canada 2010). Further, socioeconomic inequalities in oral health outcomes exist. For example, dental caries prevalence and severity were higher (worse) among children from families with lower parental education and who do not have private dental insurance (Health Canada 2010). According to data from the 2007/8 Canadian Community Health Survey, the percentage of people (age 12+) reporting "excellent or very good mouth and tooth health" increased linearly with increasing household income decile (Sharpe & Murray 2010). These two findings (i.e., persistence of oral health problems among children, and socioeconomic inequalities in oral health outcomes) are often drawn upon to make a case for the continued fluoridation of drinking water. The argument is that drinking water fluoridation is a practical and effective way to ensure exposure to fluoride for everyone – including those most vulnerable (i.e., children, and those with limited socioeconomic resources). Ensuring full and equitable access to preventive dental health measures such as fluoride is particularly important when, as is the case in Canada, dental health services are not part of the public health care system. It has been estimated

that only approximately 6% of all dental expenditures in Canada are publically funded (Health Canada 2010).¹ Universal access to preventive dental health measures such as fluoridation may help to offset the inequitable access to dental health treatment services.

Our objective was to review and synthesize the published literature on drinking water fluoridation in Canada. We focused on materials published in academic or professional journals, including but not limited to peer-reviewed material. The review was deliberately broad so that we could capture diverse aspects of the issue, including effectiveness research, public opinions, descriptions of plebiscites, other forms of analysis, and letters; all pertaining to drinking water fluoridation in Canada.

Methods

We searched the following interdisciplinary databases: Medline, Embase, Global Health, CAB Abstracts, Canadian Business and Current Affairs (CBCA), Cinahl, and Canadian Periodicals Index (CPI). Some of these databases (Medline, Embase, Cinahl) are standard resources for health literature syntheses; others (Global Health, CAB, CBCA, CPI) were selected because of their Canadian focus and/or because they captured journals (including older issues) known to be important to this subject matter (i.e., Journal of the Canadian Dental Association; Canadian Journal of Public Health). Search terms included iterations and synonyms of “drinking water fluoridation” and “Canada”. No date or design limitations were imposed, and both English- and French-language documents were sought. The full search strategy is provided in Appendix A.

The search yielded 281 citations. Based on review of title and/or abstract, 115 citations were deemed potentially relevant, including 11 French-language documents. All 115 were retrieved and reviewed, and approximately 90 are included in our synthesis below. In line with our search strategy, citations retrieved were diverse in format, and included: full-length empirical peer-reviewed articles, commentaries, discussion pieces, historical analyses, editorials, letters to the editor, and news briefs. Below, we summarize and synthesize the content of these documents.

Synthesis of findings

A. Historical overview

The history of fluoride from an oral health perspective dates to the early 20th century, when “peculiar, permanent staining of the teeth” (called the “Colorado Stain”, Bellemare et al. 1979) was observed by American dentist Dr. F.S. McKay at his practice in Colorado Springs in 1901. Several years of his own field research led McKay to suspect an unidentified (at the time) agent in the public water supply as responsible for the staining, which he and Dr. G.V. Black labeled “mottled enamel” in an article published in *Dental Cosmos* in 1916 (Crawford 1995; Hutton 1956). McKay also observed that, amongst his practice, “rampant decay is almost unknown”, and a large proportion of individuals pass through the teenage years and into adulthood with no decay (Smith 1946). Around the same time, a dentist in Bauxite, Arkansas, Dr. F.L. Robertson, noted mottling among his patients in this town which was owned by the Aluminum Company of America (ALCOA). A chemist with ALCOA was able to identify high concentrations of fluoride in the water supply in Bauxite, as well as in Colorado Springs, thus confirming the etiological agent of mottled enamel (CDC 1999).

¹ A main exception is Quebec, where all children (under age 10) are covered by a public insurance plan that includes examination and certain treatments (Ismail et al. 1990; Health Canada 2010; www.ramq.gouv.qc.ca)

Epidemiological research ensued, including a major research effort led by the U.S. Public Health Services' newly-formed National Institute of Health (NIH). In 1931, the NIH hired dental surgeon Dr. T. Dean to conduct a major study of mottled enamel. As early as 1932 Dean observed that individuals living in an area where mottled teeth were observed demonstrated lower caries incidence (CDC 1999). In 1942, two publications from the American Academy for the Advancement of Science (including one authored by Dean) first raised the possibility of adding a fluoride compound to public water supplies to reduce caries incidence (Hutton et al. 1951; Connor 1970). In 1945, the first experiments in artificial fluoridation of community drinking water began: first in Grand Rapids, MI (which was fluoridated at 1.0 parts per million [ppm] and compared against Muskegon [not fluoridated] and nearby Aurora [naturally fluoridated at 1.4ppm]) (Bellemare 1979), and followed shortly thereafter in Newburgh, NY (compared to non-fluoridated Kingston NY), and Brantford, ON, Canada (described below) (Dunton 1967; Smith 1946).

As outlined below, results of the initial water fluoridation experiments in Brantford and elsewhere were striking, and led to the implementation of fluoridation in many other Canadian communities (Rabb-Waytowich 2009) and endorsement of fluoridation by many medical, dental, and public health organizations. In 1966, the Minister of National Defense approved fluoridation at all Canadian armed services bases (JCDA 1966). By 1986, ten of the 17 Canadian cities with populations of at least 200,000 had adopted fluoridation – the major exceptions including Montreal, Vancouver, Quebec City, and Calgary (Crawford 1995). Table 1 and Figure 1 show the progression of fluoridation adoption in Canada. During this time, evidence of fluoridation's effectiveness in preventing and reducing tooth decay accumulated. For example, a 1985 report by a Joint Working Group convened by the Fédération Dentaire Internationale (FDI) -- World Dental Association and the World Health Organization (WHO) provided "overwhelming evidence" that many highly industrialized countries have experienced large decreases in caries prevalence and severity among children and adolescents (Clovis 1988). The effects of fluoride were determined to be dual: via a pre-eruptive (during tooth formation) systemic effect, and a post-eruptive (after the tooth erupts through the gums) topical effect, primarily on the smooth surfaces of teeth.

As evidence of fluoridation's effectiveness increased, so too did its accolades. In an article published in *Science* in 1982, fluoridation was identified as "one of the four greatest mass preventive health measures of all time", alongside vaccination, water purification, and milk pasteurization (Musto 1987). In anticipation of fluoride's 21st anniversary in 1966, dentists rallied for a commemorative Canadian postage stamp (Postmark Brantford, 1969). Celebratory publications appeared acknowledging fluoridation's 25th and 50th anniversaries (Connor 1970; Crawford 1995). The U.S. Centers for Disease Control and Prevention (CDC) identified drinking water fluoridation as one of the top 10 public health achievements in the United States during the 20th century (<http://www.cdc.gov/mmwr/preview/mmwrhtml/00056796.htm>). A large number of medical, dental, and public health organizations and societies have formally endorsed water fluoridation, including the WHO, the CDC, Health Canada, the Public Health Agency of Canada, Canadian Dental Association, and the Canadian Medical Association (Rabb-Waytowich 2009).

In contrast to the earliest fluoride experiments, subsequent evidence of effectiveness has been more equivocal. A main reason for this trend is the availability of other forms of fluoride exposure, such as the "spectacular increase in the use of fluoride toothpaste" starting in the 1970s (Clovis 1988), which has made it more difficult to isolate exposure to fluoride from drinking water and attribute benefits to that source. Other complicating factors include topical fluoride treatment at the dentist, naturally-occurring low levels of fluoride in some water supplies, fluoride consumed through food prepared or

manufactured in fluoridated regions, increased awareness of the importance of oral health, and improved oral hygiene (Rabb-Waytowich 2009; Gray 1987).

Throughout fluoridation's history, resistance to the public health measure and polarized debate have been constants. These debates are particularly apparent during municipal fluoridation plebiscites, a partial chronology of which is provided in Table 2. The prominence of contemporary debates gives the impression that skepticism about and resistance to fluoridation is a recent phenomenon. In fact, as we discuss below, opposition to fluoridation has existed as long as fluoridation itself. Although some of the arguments fuelling the anti-fluoridation movement have come and gone, others have been remarkably consistent throughout its 66 year history (Rabb-Waytowich 2009; Carstairs & Elder 2008).

B. Drinking water fluoridation and health outcomes in Canada: what do we know?

We identified a number of empirical studies examining the impact of fluoridation on various health outcomes, including oral health (e.g., dental caries, fluorosis) and other health outcomes (e.g., bone health). Generally speaking, these studies were based on a quasi-experimental design whereby fluoridated communities were compared with non-fluoridated communities, or with an earlier or later time period when the community's fluoridation status was different. It is important to note that, as with many public health interventions, a randomized controlled trial design is not possible in these circumstances and thus our best evidence accrues from quasi-experimental studies with measurement and adjustment (design or statistical) for possible confounding variables.

I. Oral health outcomes

In the following paragraphs we summarize studies that examined oral health outcomes associated with fluoridation. In general, studies provided data on a variety of oral health indicators, such as mean number of decayed / missing [extracted] / filled teeth (DMFT) per child (often presented separately for deciduous and permanent teeth), percent of children with no caries, tooth mortality, and status of tooth surfaces. Typically, the pattern of findings is consistent across these different indicators, and for brevity of presentation we often provide examples of findings (e.g., numbers from consecutive surveys) for just one indicator. We begin with Ontario and with Brantford in particular, and then proceed across the country by province according to the chronological order of the study period from earliest to most recent. In this section we also include the small number of cost-benefit studies encountered.

ONTARIO

Upon implementation of drinking water fluoridation in June 1945, Brantford, Ontario (population 36,000) became the first city in Canada, and the third city in the world, to do so. The instigators of fluoridation in Brantford were W. Linscott (Brantford's school dental officer) and W.L. Hutton (medical officer of Brant County Health Unit), who in 1942 convened a meeting to discuss the "appalling amount of dental caries" among schoolchildren in Brantford (Postmark Brantford 1969; Connor 1970). After ascertaining that the water source, the Grand River, did not contain natural fluoride (Hutton 1951), Linscott and Hutton set about acquiring local support for water fluoridation and securing necessary approvals both locally and provincially. During the ensuing two year period, support for the initiative was obtained from local dental and medical societies, the two boards of education, the Board of Trade, Rotary, Kiwanis, and other service clubs, and labor unions. In 1944, local Council approved fluoridation, on recommendation from the provincial board of health (Postmark Brantford 1969; Connor 1970). The provincial Department of Health provided the technical assistance of an engineer, and the

Public Utilities Commission agreed to add the fluoride and to pay for the cost of the chemicals. On June 20, 1945, fluoride was first added to Brantford's water supply, with an initial concentration of 1.0ppm.

From the beginning, a great deal of attention was devoted to ensuring that the Brantford experiment was set up as a proper research study (Connor 1970; Hutton et al. 1951). Baseline data were collected during Spring 1945: a dental survey of all school children (age 5-16) who had had "continuous residence" (i.e., born and raised) in Brantford. Each child was examined using a mouth mirror and sharp explorer method, and the caries experience (i.e., diseased teeth, missing/extracted teeth, and filled teeth, for both deciduous and permanent teeth) for each child was recorded. Subsequent annual surveys were completed using the same methods and, impressively, the same dentist to ensure consistency. Hutton et al. (1951) presents annual survey data from 1945 (pre-fluoridation) through 1950. The overall reduction in mean caries experience during this time period was 31% (from 7.7 to 5.3), and ranged from 11% among 11-year-olds (6.4 to 5.7) to 54% among 5-year-olds (5.7 to 2.6). Even greater improvements were apparent at the 8-year follow up (Hutton et al. 1954). By 1953, the overall reduction in caries was 39.2% for deciduous teeth (among children age 5-11) and 53.7% for permanent teeth (among children age 6-16). Estimated cost of fluoridation was 17 cents per capita in 1948 and 12.6 cents per capita in 1949 (Hutton et al. 1951). In 1949, the Brantford Fluorine Committee made a decision to increase the dosage of fluoride from 1.0 to 1.2ppm (Hutton et al. 1951).

In 1948, the "Brantford experiment" was bolstered by the addition of two comparison communities. Seeing the value of the research opportunity, the Department of National Health and Welfare (Research and Statistics Division and Dental Health Division) began a parallel and independent study of Sarnia, Ontario which was not fluoridated, and Stratford, Ontario, in which the water source that had been in use since 1917 was naturally fluoridated at 1.2ppm - 1.6ppm² from an underground fluoride deposit (Hutton et al. 1956; Brown et al. 1956; Brown 1951; Smith 1946). These cities were known to be otherwise quite similar to Brantford. Once again, adherence to a rigorous research protocol was emphasized, and the survey methods and procedures used in Sarnia and Stratford were the same as those used in Brantford. The methods were written up in a document produced by the Department of National Health and Welfare entitled "A Suggested Methodology for Fluoridation Surveys in Canada".

Brown et al. (1956) present data for the three communities from 1948 to 1955. Overall, findings indicated that caries prevalence fluctuated at a high level over time in Sarnia (not fluoridated), fluctuated at a low level in Stratford (naturally fluoridated), and dramatically improved in Brantford. For example, among 6-8 year olds, the mean number of decayed, missing, or filled permanent teeth per child was 1.60 (1948) and 1.88 (1955) in Sarnia; 0.41 (1948) and 0.67 (1955) in Stratford, and 1.41 (1948) and 0.69 (1955) in Brantford (Brown et al. 1956). The authors comment that "the children born in Brantford since fluoridation began now exhibit the same degree of resistance to dental caries as those of the corresponding age group in Stratford, where water containing about 60% more fluoride than the Brantford water has been consumed during the past 38 years". Earlier, Brown (1951) had presented preliminary data from the 1948 and 1951 surveys. In addition to a reduction in caries in Brantford that was not apparent in Sarnia, survey data on oral hygiene suggested a higher number of Brantford children in the "good" oral hygiene range than in Sarnia or Stratford.

Mottling of teeth was also recorded as part of the dental examinations in the Brantford experiment. Brown et al. (1956) reports that "a small percentage of the native children in Stratford have mild mottling of the enamel, which in no case is unsightly, and is detectable only by an experienced examiner". Also, "a few cases of mild mottling, barely detectable even on close examination, were seen

² Different concentrations were reported in different documents, ranging from 1.2 to 1.6ppm.

in Brantford”. Notably, “enamel opacities ... were also observed in a small number of children in [non-fluoridated] Sarnia”. No cases of “ill-effects” were observed, based on reports made at a meeting of medical staff at Brantford General Hospital (Brown et al. 1956).

In summary, the rigorous research protocol surrounding the Brantford experiment allowed reasonably strong conclusions to be drawn about fluoridation’s impact on oral health outcomes. By all accounts, the caries improvements observed in Brantford were striking, and the timing of the improvements aligned with expectations based on knowledge of children’s age, tooth development, and implications of exposure. One possible confounding variable is the better oral hygiene observed in Brantford by Brown (1951); however he emphasizes the preliminary nature of those data. Data, or opportunity to report on, tooth mottling and other consequences of fluoridation were available, and these information sources did not indicate any problems or concerns.

Aside from the Brantford experiment, we located some published data on the oral health impact of fluoridated drinking water in two other Ontario communities: Ingersoll and Toronto. Although there appeared to be an intention to evaluate the oral health impact of fluoridation in a third community, Paris, Ontario (Dunton 1967), this effort encountered problems and no oral health data for Paris were apparent in our results. We also located some pertinent statistics for other regions in Ontario, and for Ontario as a whole.

The research in Ingersoll was part of the Department of National Health and Welfare’s plan to extend the Brantford-Sarnia-Stratford study to other communities across Canada, including those with naturally fluoridated water at a level of 1.0ppm or higher. In Ingersoll (population 6,500), the water source is naturally fluoridated at approximately 1.7ppm. Dental health outcomes of born-and-raised Ingersoll children were examined using the same methods and examiner as used in the Brantford-Sarnia-Stratford study. Brown and Poplove (1964) report data from a 1962 survey of 6-11 year old Ingersoll children, and compare these to 1957 data from Brantford, Sarnia, and Stratford. It was found that children in Ingersoll, like children in Brantford and Stratford, had dental caries rates much lower than in non-fluoridated Sarnia. Some small differences amongst the three fluoridated communities were found, which in many cases favored Ingersoll. The authors suggest that these differences may reflect the greater concentration of fluoride in the Ingersoll water than elsewhere, but acknowledge that other explanations could not be ruled out. No cases of “unsightly mottling” were observed in Ingersoll in the 1962 data (Brown & Poplove 1964).

Six documents (two empirical articles, one editorial, and three news briefs) were located that speak to the dental health impact of fluoridation in Toronto, which began in September 1963. By all accounts, notable dental health improvements were observed among Toronto children. For example, data from kindergarten children (age 5) indicated a reduction in mean caries per child from 2.5 in 1958 (pre-fluoridation) to 1.3 in 1968 (Toronto has record low ... JCDA 1970). Among 9-year-olds, the number who had never suffered tooth decay increased by 50% between 1963, when fluoridation began, and 1968. A report from Etobicoke stated that “no side effects such as mottling” had been observed in that borough (Fluoride cuts caries in Toronto .. JCDA 1970). According to a report published by the University of Toronto’s Department of Community Dentistry and the Toronto Department of Public Health, a gradual improvement in child oral health was observed since fluoridation; for example, among children age 5-9, by 1976 almost three times as many children experienced no tooth decay compared with pre-fluoridation (Hargreaves 1976). Data from 1964, 1971, 1982, and 1986 presented by Lee and Goettler (1988) illustrate the gradual improvement over time. For example, among children 9 years of age, the mean DMF teeth per child was 2.1, 1.2, 0.9, and 0.7 in the four consecutive surveys. Lee and

Goettler (1988) also report that the cost of fluoridation was 29 cents per person per year. Finally, Lewis et al. (1972) report on data from 1,741 kindergarten children (age 5 years) stratified according to the timing of their birth relative to Toronto's commencing of fluoridation. Children's dental services were recorded, and it was observed that treatment expenses declined over the time period marked by the implementation of fluoridation. For example, average dental costs for the 250 children born 20 months before fluoridation started were approximately \$63 per child, versus approximately \$34 per child among the 304 children born 14 months after fluoridation (Fluoride cuts dental costs ... JCDA 1971; Lewis et al. 1972).

McFarland and Klooz (1992) provide, for each region in Ontario, the percent of the population receiving fluoridated water (artificially or naturally) and dental health statistics (DMF rate for 13-year-olds, and 1991 per capita expenditures for the Ministry of Health-funded Children in Need of Treatment dental program). Overall, approximately 64% of the population of Ontario was receiving fluoridated water at the time. A significant inverse linear relationship was observed, such that as the percent of the population exposed to fluoridated water by region increased, the DMF rate decreased. The treatment cost data were not associated with either DMF or water fluoridation exposure, which is consistent with previous findings showing that decreases in decay or DMF do not necessarily translate into reduced treatment costs.

More recently, Rabb-Waytowich (2009) cites additional Ontario data from regional health units. For example, the caries rate for children in Kitchener (not fluoridated, 0.1ppm naturally occurring fluoride) is 44%, while it is 33% in neighboring Cambridge (not fluoridated, 0.3ppm naturally occurring fluoride) and 32% in neighboring Waterloo (fluoridated since 1967). In the Simcoe Muskoka District Health Unit, where most communities are not fluoridated, the rate of decay among children age 5-13 is consistently higher than for Ontario as a whole (approximately 76% of the Ontario population was exposed to fluoridation in 2007) (Rabb-Waytowich 2009).

PRAIRIE PROVINCES

Moose Jaw, Saskatchewan began fluoridating its water in 1953, to a concentration of 1.0ppm. Chegwin (1962) presents survey data from 1952 (pre-fluoridation) and 1959. Surveys were based on public school children (age 6-14) who were born and raised in Moose Jaw, and identical methods were used in the two surveys. Significant improvements to oral health were observed over this time period. For example, the percent reduction in average DMF teeth per child was 60% for 6-8 year old children (from 2.4 to 0.95), 32% for 9-11 year old children (from 4.1 to 2.8), and 25% for 12-14 year old children (from 8.0 to 6.0). The authors note that these significant improvements were observed despite a 15-month period during 1955-56 during which fluoridation was (unintentionally) not in place, and an additional 3 month period during which fluoride concentration was lower than intended (fluctuating between 0.4 and 0.8ppm).

Brandon, Manitoba began fluoridating its drinking water in March 1955, to a concentration of 1.0ppm. Dental health examinations and surveys were conducted pre-fluoridation and annually thereafter, following the same methods used in the Brantford-Sarnia-Stratford study. All eligible (i.e., born and raised in Brandon) children were examined (Connor 1961). Connor (1961) presents data from 1955 and 1960, which reveal significant improvements in several oral health indicators. For example, the mean DMF teeth per child decreased from 1.9 to 0.8 among children age 6-8, from 4.6 to 2.9 among children age 9-11, and from 7.4 to 5.8 among children age 12-14. Connor (1963) updated the findings to include data from the 1962 dental survey, which again revealed marked improvements for all age groups

of children. As in other studies (e.g., the Brantford experiment), improvements were especially prominent for children age 6-8 (the youngest age group studied), which is to be expected considering that they have the most potential to benefit from the intervention (as their first permanent teeth were starting to come in when fluoridation was first implemented). Further, these studies clarified that improvements were evident for overall tooth health as well as for molars and incisors separately. This speaks to the dual protective benefit of fluoride: it exerts an effect both prior to calcification and eruption (the molar data), as well as post-eruption (the incisor data). Connor (1963) also indicated that “certain minor enamel opacities which are found in both fluoride and non-fluoride areas were reported”, suggesting that “no mottling that could be ascribed to fluoride was detectable”.

As part of a comparison of dental health outcomes in Montreal and Edmonton (also described below), Payette et al. (1982) present dental health data for Edmonton children from 1966 (pre-fluoridation; fluoridation began in Edmonton in 1967) and 1979. Among a representative sample of Edmonton children age 6-17, marked reductions in caries were observed over time, in both primary and permanent teeth. For example, among 7-year olds, caries prevalence decreased from 5.2 to 3.2 in primary teeth, and from 1.4 to 0.5 in permanent teeth, between 1967 and 1979.

Clovis et al. (1988) examined caries experience among schoolchildren (grade 6, age 12) in two adjacent Alberta communities: Camrose (non-fluoridated) and Wetaskiwin (fluoridated at a concentration of 1.08ppm), in 1984. An earlier report, from 1963 (Castaldi 1963, cited in Clovis 1988), had indicated a higher mean DMFT among children (age 11) in non-fluoridated Camrose (6.1) than in fluoridated Wetaskiwin (2.3), and since that report there had been a dramatic decline in caries in Camrose, the reasons for which were not clear. Clovis et al.’s (1988) aim was to determine whether Wetaskiwin’s oral health advantage over Camrose was still apparent, in light of Camrose’s improvement. A crude comparison of oral health indicators (DMFT, DMFS) in the two communities indicated no significant differences (e.g., mean DMFT of 2.4 in Camrose versus 2.8 in Wetaskiwin). However, when length of residence was taken into account, differences favoring Wetaskiwin were apparent. For example, within Wetaskiwin, those with longer residence (>5 years) had a lower DMFT than those with a shorter residence (<=5 years): 2.3 and 3.4 respectively. Comparing those with longer residence in Wetaskiwin with those with longer residence in Camrose revealed 17% fewer surface caries in Wetaskiwin (mean = 2.8) than in Camrose (mean = 3.4), though the difference was not statistically significant.

QUEBEC

Based on a 1977 provincial dental health survey, Lussier (1981) presented dental health data for 13-year-old children in Quebec, in comparison to data from other provinces (B.C., Alberta, Manitoba, and Ontario) gathered at a similar time (e.g., 1976-1978) (Stamm et al. 1980, cited in Lussier 1981). The mean “CAO” score (cariées, absentes, obturées) in Quebec was 8.5, which is considered “very high” according to a World Health Organization classification. In comparison, the mean score was 7.5, 4.7, 5.4, and 4.4 in B.C., Alberta, Manitoba, and Ontario, respectively. The provincial CAO scores correlated inversely with provincial fluoridation rates, such that the high mean score in Quebec corresponds to the low proportion of the population exposed to fluoridation (17% in 1980) relative to other provinces. Bellemare (1981) also describes data from the 1977 provincial survey, as part of a broader discussion on fluoridation. He focused on the comparison between children in Montreal (not fluoridated) and children in Laval, which had been fluoridated since 1958. Among 7 to 9 year olds in Laval, there were 46% fewer dental caries in permanent teeth relative to children the same age in Montreal (Demirjian et al. 1977; cited in Bellemare 1981).

Payette et al. (1982) presented data from a 1979 survey of dental caries and related outcomes (e.g., dental treatment procedures) for representative samples of children age 6-17 years in Montreal (not fluoridated) and Edmonton (first fluoridated in 1967). Caries data for primary teeth (for children age 6-11) and permanent teeth (for children age 6-17) were provided. The same examination methods were used in the two locations. The authors reported consistently higher caries rates in Montreal than in Edmonton children at each age, such that the oral health of Montreal children in 1979 was similar to and in some cases worse than that of children in Edmonton pre-fluoridation, in 1966. This was particularly apparent for permanent teeth; for example, caries prevalence among permanent teeth of 11-year-olds was 4.4 for children in Montreal in 1979, 2.4 for children in Edmonton in 1979, and 4.3 for children in Edmonton in 1966 (pre-fluoridation). Children in Montreal also had a higher rate of extractions, particularly after age 13 years, and a higher rate of untreated caries, than the Edmonton children.

Tessier (1987) presented data from children age 6-7 in Windsor, Quebec from a 1977 survey (prior to fluoridation) and from 1986. These data were further compared against data from children in Richmond, Quebec, a comparison community with a similar sociodemographic profile and a fluoride rinse program in schools but non-fluoridated drinking water. Caries rates were almost identical in the two communities in 1977 (8.2 in Windsor, 8.3 in Richmond). Declines between 1977 and 1986 were observed over time in both communities, favoring Windsor which saw a 61.8% reduction in caries rate (decrease in mean caries index from 8.3 to 3.2 among 56 lifelong residents) compared to a 34.4% decline in caries rate in Richmond (decrease from 8.2 to 5.4 among a sample of 85).

Lee and Goettler (1988) present dental health data from Montreal children in 1984, and compare it with data from four consecutive dental health surveys of children in Toronto (1964, 1971, 1982, 1986). Overall, the authors make the point that the dental health of children in Montreal, which has never had fluoridated drinking water, is similar to the dental health of Toronto children prior to that city's decision to begin fluoridation in 1963. For example, among 11-year old children, the mean DMF teeth per child in Toronto was 4.0 (1964), 2.2 (1971), 1.7 (1982), and 1.4 (1986). Among 11-year old Montreal children in 1984, the mean DMF was 3.7. We note that the Montreal data presented in this study is attributed to a personal communication (Dr. M. Tannenbaum, n.d.).

Ismail et al. (1990) investigated dental health indicators among students (age 11-17 years) living in Sherbrooke, Quebec (non-fluoridated) and Trois-Rivieres (fluoridated). They make reference to a previous study (Payette 1987, cited in Ismail et al. 1990) which showed an average difference of 2 DMFT between children in fluoridated versus non-fluoridated regions of Quebec, favoring those in the fluoridated regions. In addition to dental health indicators, Ismail et al. (1990) analyzed other data including socio-economic status (public or private school) and reported use of fluoride tablets. The authors report that caries patterns by fluoridation exposure differ by socio-economic status. For public school students, caries outcomes in Trois-Rivieres (fluoridated) were significantly lower (better) than in Sherbrooke (non-fluoridated). For example, mean DMFS was 8.8 in Trois-Rivieres versus 9.9 in Sherbrooke. The opposite was found for private school students (i.e., better outcomes in non-fluoridated Sherbrooke (mean DMFT = 6.6) than in fluoridated Trois-Rivieres (mean DMFT = 7.4). Because of an inconsistent history of fluoridation in Trois-Rivieres, analyses were re-run stratified by age, to better classify exposure. The authors found that the effect of water fluoridation was most pronounced for 15-17 year olds in public schools, and conclude that the findings suggest a role for drinking water fluoridation in alleviating socioeconomic inequalities in oral health. Fluorosis was also examined, and prevalence was found to be significantly higher in fluoridated Trois-Rivieres (55%) than in Sherbrooke (31%). However, when asked whether they liked the color of their child's teeth, parents of children with

fluorosis did not differ from parents of children without fluorosis, suggesting that the implications of differences in fluorosis prevalence may be minimal. The authors highlight that these findings were observed despite Quebec's unique child dental program, whereby all children up to age 12 (at the time) were covered by a dental insurance plan for examination and certain treatments.

We identified two studies that estimated the cost-effectiveness of water fluoridation in Quebec. The first, a conference abstract by Tessier et al. (1984) for which no follow-up article could be located estimated the cost-effectiveness of water fluoridation in four cities in Quebec. They concluded that in Montreal (the most densely-populated of the four cities), the benefits would exceed the costs in five years, while in Amos (the least densely-populated of the four cities), this would take eight years. O'Keefe (1994) built upon Tessier et al.'s (1984) earlier study to forecast whether water fluoridation in Montreal would still be cost-effective. Amongst the target population of residents of Montreal who receive City water, the authors note that 31.5% are considered economically disadvantaged, and may therefore be most likely to benefit from fluoridation. Under the assumptions set out by the authors, they conclude that fluoridation would "clearly" be cost-effective for Montreal, with an estimated savings of \$17.36 for every QATY gained (quality-adjusted tooth year). Recognizing the sometimes arbitrary nature of assumptions in economic modeling, the authors re-estimated their models for various scenarios of costs and benefits. They conclude that "for all but the most extreme situations", water fluoridation would be a cost-effective public health measure for Montreal.

ATLANTIC PROVINCES

To determine whether Truro, Nova Scotia, should implement fluoridation, Ismail et al. (1993) examined data from a cross-sectional survey and dental exam in 1991 of children in grades 5 and 6 in Truro (non-fluoridated) and in Kentville, a nearby town that had been fluoridated since at least 1977. Additional data included parent reports about their child's exposure to fluoride since birth, including the water supply, use of fluoride supplements, and use of other fluoride products. This information enabled the authors to develop a reasonably clear indicator of exposure to fluoride via different sources, which is an important methodological issue for fluoridation research in an era characterized by many potential sources of fluoride. Although oral health indicators appeared better in the fluoridation group than in the non-fluoridation group, most differences were not statistically significant (e.g., mean DMFS [decayed, missing, filled surfaces] of 4.2 and 3.5 in the non-fluoridated and fluoridated group, respectively). The prevalence and mean level of dental fluorosis was significantly higher in the fluoridated group (e.g., mean number of fluorosed tooth surfaces was 4.5 among those who drank non-fluoridated water during the first six years of life and 9.6 among those who drank fluoridated water during the first six years of life). There was an inverse association between father's education status and certain oral health outcomes, but this association was not tested separately in fluoridated versus non-fluoridated groups.

Based on the presence of moderate fluorosis among children in Rigolet, Labrador (population 600), which was observed during a routine dental visit to the community, Ismail and Messer (1996) examined the association between fluorosis and exposure to well water which had been determined to contain a high concentration of fluoride. A dental exam was conducted in 1993, and children were classified according to their age in 1983 when the well first started being used as the primary drinking water source. Among 48 lifelong residents of Rigolet, the authors found a "quite clear" relationship between age at first exposure and fluorosis, whereby those who were less than 1 year of age on December 1, 1983, had higher odds of fluorosis (e.g., at least 2 teeth with fluorosis) according to the 1993 dental exam, than those who were 4 years or older on December 1, 1983 (OR = 4.8). Due to the small sample size it was not possible to take other variables into account.

BRITISH COLUMBIA

Published studies of British Columbia communities identified in this review focus on two sets of comparisons in which one community is fluoridated and the other is not. The comparisons are: Kelowna (fluoridated) versus Vernon (not fluoridated), and Comox/Courtney/Campbell River (voted to discontinue fluoridation in 1992) versus Kamloops (voted to continue fluoridation in 1992).

Clark et al. (1995) report on caries outcomes among school-age children and adolescents in Kelowna (fluoridated at 1.2ppm) and Vernon (not fluoridated, 0.1ppm naturally occurring fluoride). A total of 1,131 children were selected from a random sample of schools which were stratified by socioeconomic status (based on family income and real estate value of the area). Six schools were selected in each community. Kelowna and Vernon were selected because local dental health authorities had expressed interest and a desire to participate. For the primary outcome variable (D1D2MFS³), the crude prevalence was 2.4 in non-fluoridated Vernon and 1.9 in fluoridated Kelowna, a 17% difference favoring the fluoridated community. By incorporating additional data on the use of fluoride supplements, the authors were able to identify a group with lifelong exposure to fluoridated water (with no fluoride supplements) and a group with no exposure to systemic fluoride, either through water or through supplements. Comparison of these two groups revealed a larger difference than the crude comparison: a 35% difference in dental health indicators favoring the fluoridated community (mean D1D2MFS = 2.53 vs. 1.65). Social inequalities in caries were observed whereby caries prevalence was higher among children whose parents had lower, versus higher, education; however the magnitude of the inequality was similar in the two communities (i.e., did not vary by fluoridation status).

Using the same data as above (school children in Vernon and Kelowna), Clark et al. (1993) reported on fluorosis in the two communities. Fluorosis was measured using the Tooth Surface Index of Fluorosis (TSIF) tool on which scores range from 0-7 with 0 being no fluorosis. Across the full sample, 40% had no fluorosis, 52% had a score of 1, and 8% had a score of 2-6 (no one had a score of 7). The prevalence of fluorosis was significantly higher in fluoridated Kelowna (65%) than in non-fluoridated Vernon (55%). Although parents' concerns about their child's teeth appearance increased with increasing fluorosis score, only very few parents overall expressed concern.

Four studies focused on school children in Comox/Courtney and Campbell River (which discontinued fluoridation based on a 1992 referendum) and Kamloops (which voted in 1992 to continue fluoridation). Data were collected in 1993/4, 1996/7, and 2002/3 and included both longitudinal and cross-sectional data from children in grades 2, 3, 5, 6, 8, 9, 11, and 12. Two studies focused on caries outcomes, and the other two focused on fluorosis, as follows.

Based on the 1993/4 and 1996/7 data, Maupomé et al. (2001a) reported that the prevalence of caries (based on the cross-sectional data) decreased over time in Comox/Courtney and Campbell River (where fluoridation was discontinued) but stayed the same in Kamloops (contrary to intuition). Caries incidence (based on the longitudinal data) did not differ between the communities, but when surfaces at risk were studied in detail, Comox/Courtney and Campbell River (which discontinued fluoridation) had a higher incidence than Kamloops (e.g., caries incidence [D1D2MFS] after 3 years for 5 and 6 year olds was 0.63 in Comox/Courtney and Campbell River, and 0.50 in Kamloops). To build upon this study (2001a), which focused on aggregate change over time, Maupomé et al. (2001b) analyzed tooth surface

³ D1D2MFS is an index of decayed, missing, and filled tooth surfaces which scores incipient and cavitated lesions separately (Clark et al. 1995).

progression and reversal changes over time among lifelong residents in the two communities, using the longitudinal data. Although overall progression and reversal rates were low, reflecting low levels of caries, the authors observed that the odds of both smooth surface and pit and fissure progression (adverse outcomes) in Comox/Courtney and Campbell River (which discontinued fluoridation) was significantly higher than the odds in Kamloops (OR=2.4 and OR = 1.23 for smooth surface and pit and fissure, respectively).

Clark et al. (2006) examined fluorosis in Comox/Courtney and Campbell River following cessation of fluoridation in 1992. They used data from the 1993/4, 1996/7, and 2002/3 surveys. Fluorosis scores (based on the Thylstrup-Fejerskov Index [TFI]) were found to be higher in 1993/4 than in the two follow-up surveys. This is consistent with a decrease in fluorosis following cessation of fluoridation; however, the authors observed that exposure to fluoride from other sources also declined during the time period. For example, far fewer children were taking fluoride supplements in 2002/3 than in the previous surveys. In an earlier study, Maupomé et al. (2003) examined fluorosis in relation to other sources of fluoride. They included children from both communities whose maxillary anterior permanent teeth had undergone maturation and mineralization prior to 1992, when both communities had fluoridation in place. The authors found that approximately one-third of the whole sample had some degree of fluorosis, which was mild or very mild in the vast majority of cases. TFI maximum scores in aesthetically important teeth were more prevalent in cases of high fluoride exposure from various sources. Aside from community of residence, predictors of fluorosis included an early start to brushing with fluoride toothpaste (i.e., between first and second birthdays), use of fluoride supplements, and having a college-educated father.

II. Other outcomes

Aside from publications focused on fluoridation in relation to dental caries and fluorosis, we identified four publications which report on the association between exposure to drinking water fluoridation and health outcomes not directly related to oral health: one on diseases of the circulatory system and neoplasms, one on osteosarcoma (a form of cancer) and two on bone health. Like the oral health studies above, the following studies are based on a quasi-experimental design whereby populations exposed to fluoridation are compared with populations not exposed, or populations are compared prior to and after a change in fluoridation status.

Based on suggestions that fluoridation is associated with higher rates of mortality for a) diseases of the circulatory system and b) neoplasms, Lee and Goettler (1988) present standardized mortality rate data for these two outcomes for residents of Toronto during the period 1951 to 1986. Toronto began fluoridating its water in 1963. For circulatory diseases, there was a steady downward trend in mortality rates over the time period. The pattern for neoplasms was relatively stable over the time period. There was no indication of any change in the patterns around or after 1963 when fluoridation began, suggesting no association between fluoridation and these outcomes.

Hrudey's (1990) study is based on prior animal research on fluoride and osteosarcoma which, despite equivocal findings (described below), yielded media attention with provocative claims such as "fluoride from your tap water may cause cancer". Using data from the Alberta Cancer Board's population-based cancer registry, Hrudey (1990) examined cases of osteosarcoma in Edmonton, fluoridated since 1967, and Calgary, not fluoridated until 1991. The data did not reveal any differences in osteosarcoma rates between Edmonton and Calgary (e.g., incidence rate per 100,000 was 0.29 in Calgary and 0.27 in Edmonton), even when urban/rural designation and age cohort were taken into

account. The authors concluded that, based on evidence to date, there is no link between fluoridation and osteosarcoma among Albertans.

Studies by Suarez et al. (1993) and Arnold et al. (1997) focus on bone health. Because sodium fluoride therapy has been used as a treatment for osteoporosis, exposure to fluoride in drinking water may have a protective effect for bone density. However, some studies have shown an increased risk of hip fracture among individuals undergoing sodium fluoride therapy, raising the hypothesis that exposure to fluoride in drinking water could increase risk for hip fractures. The postulated mechanism is an increase in bone mass caused by fluoride, which increases bone fragility.

To examine whether exposure to fluoride in drinking water increases risk for hip fracture, Suarez et al. (1993) compared hip fracture hospitalization rates in Edmonton (fluoridated since 1967) and Calgary (not fluoridated, during the time frame of the study) between 1983 and 1987. They found that, for women, and for men and women combined, there was no difference in hip fracture hospitalization rates between the two cities. For men, the rate was significantly higher in Edmonton than in Calgary, which is consistent with the increased risk conferred by exposure to fluoride in the drinking water; however, the effect was small (e.g., relative risk of 1.12 for men age 45+). Although adjustment for confounding variables was not performed, authors emphasize the similarities between the two cities. They conclude, based on the results of the study, that “fluoridation of drinking water has no major impact, beneficial or deleterious, on the risk of hip fracture”.

Arnold et al. (1997) examined the effect of exposure to fluoridated drinking water on bone density, by comparing young women (female university student volunteers) in Regina (non-fluoridated) and Saskatoon (fluoridated at 1.0ppm since 1954). Young women were selected because fluoride has been found to absorb more rapidly in growing bone than in adult bone. Based on several exclusion criteria (e.g., length of residency) and comparison of measured covariates, samples of women in the two cities were determined to be very similar. The authors found that women raised in Saskatoon (fluoridated) had significantly higher bone mineral density values than women raised in Regina at two sites in the lumbar spine (11.9% difference at total anterior-posterior lumbar spine and 7.6% difference at volumetric L3), but there were no significant differences between the samples for the total body or the proximal femur measurements. The results support a site-specific protective effect of exposure to fluoride in the lumbar vertebrae, and are consistent with studies showing an absence of a protective effect of fluoride on hip fractures, such as Suarez et al.’s study above.

C. Plebiscites: ethics, process, and public opinion

On balance, the evidence summarized above and elsewhere suggests that drinking water fluoridation is i) at least somewhat effective in preventing tooth decay, and ii) does not appear to be harmful to our health. Contrasting with this summary is the observation, made by several authors in our review, that community fluoridation plebiscites (in which an electorate votes yes or no to the decision to begin, or to continue, fluoridation) fail far more often than they pass. This situation draws attention to the dynamics of plebiscites and the arguments brought forth by those opposed to fluoridation. We identified several documents speaking to these issues, which we summarize in the paragraphs below.

We begin by considering descriptions and analyses of local plebiscites. Although the decision to implement fluoridation rests with municipalities, the outcome of municipal plebiscites will depend, in

part, on guidelines set in place at the provincial level. Carstairs and Elder (2008) describe how provinces differed in terms of their fluoridation legislation⁴, at the time of their 2008 paper:

- In New Brunswick, Manitoba, and Saskatchewan, it is up to the municipality to decide whether or not to fluoridate.
- In Ontario, the decision is left to the municipality, unless 10% of the electorate petitions for a referendum.
- In New Brunswick, communities can decide to fluoridate after holding a vote.
- In Alberta, municipalities are required to hold a plebiscite. Initially, provincial legislation required a 66.6% majority to pass; in 1966 this was amended to allow fluoridation with a 50% majority.
- In British Columbia, communities can decide to fluoridate after holding a vote. A 60% majority is needed to pass.
- In Newfoundland/Labrador and Prince Edward Island, there is no provincial legislation pertaining to fluoridation.
- In Quebec, there was no legislation until 1975, when the province mandated compulsory fluoridation throughout the province (it was the only province to do so). This legislation was suspended shortly thereafter in 1977.

Description and/or analysis of local plebiscites were located for municipalities in Ontario (Thorold, Pembroke, and Toronto), Alberta (Calgary and Edmonton), and British Columbia (Vancouver, Squamish, and Comox/Courtney). As well, circumstances have been described in Winnipeg and Montreal.

ONTARIO

Discussions of plebiscite circumstances in Ontario were located for Toronto, Thorold, and Pembroke. As noted above and elsewhere (Hargreaves 1976), permissive provincial legislation gives Ontario communities the power to fluoridate water supplies unless 10% of voters petition for a plebiscite, which must then be passed by simple majority.

Sturgeon (1958) describes events surrounding a 1957 plebiscite in Thorold, Ontario. The plebiscite concerned the continuation of drinking water fluoridation, which had begun in 1952. The plebiscite was prompted by a petition signed by over 600 people (comprising more than 10% of voters) requesting a vote to determine continued fluoridation of Thorold's drinking water. Methods employed by opponents (e.g., meetings held, newspaper ads, "Thorold Citizens Committee" formed) and counter-measures (endorsement of fluoridation by physicians and dentists, door to door canvass, paid advertisements, presentations, etc) are described. In the end, Thorold voted in favor of continued fluoridation: 1,359 to 756. The authors estimate that the most important contribution to the outcome was the letter of endorsement signed by all physicians and dentists in the community. They also acknowledge the important role of the American Medical Association's endorsement of fluoridation, which was released a few days before the plebiscite.

On December 6, 1976, Pembroke, Ontario (population 17,500) voted 3,760 to 3,410 in favor of fluoridation (Ringland 1978). Two previous attempts had been unsuccessful: fluoridation was defeated

⁴ Originally in Canada, the term plebiscite referred to a vote in which the results were not binding, whereas in a referendum the results were binding. Often the two terms are used interchangeably, and in this review we use whichever term was used in the paper being summarized.

by a large margin in 1972, and by a narrow margin in 1974. The 1976 success was attributed to “an effective, well-run campaign headed by a hard-working committee”. Three months prior to the election, the Pembroke Dental Society formed the Pembroke Fluoridation Committee, which included representation from health professionals and the general public. The Committee developed and executed a plan characterized by an “aggressive, high-profile campaign”. To fund the campaign, local businesses were approached, and their response was “enormously encouraging”. Campaign material was largely local in flavor and included information from other communities in the Ottawa Valley area that had implemented fluoridation. Although anti-fluoridation groups appeared and were vocal, they were “few in number and lacked organization” (Ringland 1978).

According to Crawford (1993), “no fluoride controversy in Canada drew more attention or press coverage than the eight-year „debate” that galvanized the city of Toronto”. Although Metro Toronto City Council approved fluoridation in 1955, a constellation of events delayed the implementation until 1963 (Carstairs 2010). First, the Council of Forest Hill (one of Toronto’s municipalities) announced that it would take Metro Toronto to court to prevent fluoridation, on the grounds that it violated people’s individual rights. In response, the Ontario Court of Appeal prohibited Toronto from fluoridating its water. Although Metro Toronto appealed, the Supreme Court of Canada agreed that water fluoridation fell outside of the purview of the existing Municipal Act. In 1959, the Ontario government appointed a Royal Commission to investigate water fluoridation. In 1961, the commission came out in favor of fluoridation, concluding that “the fluoridation of municipal supplies would not be a denial of any fundamental or basic civil right or liberty which the Legislature in its wisdom should seek to preserve” (Musto 1987). They recommended that the decision to fluoridate be left to the municipalities without a referendum required. Later that year, the Ontario government passed legislation noted above (whereby municipalities make the decision to fluoridate unless 10% of the electorate petitions for a referendum), and Toronto City Council voted to implement fluoridation. Almost immediately, those opposed to fluoridation self-organized, and a petition to request a referendum was assembled and presented. The plebiscite was held in December 1962, and fluoridation passed with 50.7% in favor. The City was divided geographically and demographically in its votes: Toronto and the older municipalities tended to vote against it, while suburbs populated by young families (e.g., North York, Etobicoke, and Scarborough) voted in favor (Carstairs 2010).

Rabb-Waytowich (2009) comments on more recent municipal circumstances in Ontario. She reports that, since 2008, at least eight communities in Ontario underwent votes (by Council and/or the electorate) to discontinue fluoridation. Municipal councils voted to continue fluoridation in Hamilton, Tottenham, and Atikoken. Dryden and Niagara voted not to restart fluoridation, by referendum and Council vote respectively. Halton and Norfolk councils, while awaiting the final report of the Federal-Provincial-Territorial committee on drinking water, voted to continue fluoridation in the meantime. Halton, as well as Toronto, opted to lower the fluoride concentration to 0.6ppm. Waterloo, fluoridated since 1967, held a plebiscite in conjunction with their 2010 municipal election. The outcome of that plebiscite was that the Waterloo electorate voted to discontinue fluoridation, with 50.3% opposed.

ALBERTA

Although University of Alberta researchers produced some of the first significant research on fluoridation, Alberta was slower than some other provinces to implement the public health measure (Clarke & Castaldi 1961), which was partly due to early provincial legislation.

Following publication of the early results from the Brantford experiment in the early 1950s, a recommendation was made to Edmonton City Council to begin fluoridation in that city. No provincial legislation was in place at the time, so an amendment to Alberta's Public Health Act was made in 1952 stipulating that a plebiscite was required before a community could fluoridate, and that the measure must be endorsed by a 66.6% majority (Clarke & Castaldi 1961; Watson 1990). This early provincial legislation proved a significant barrier to implementing the intervention: in Edmonton, four plebiscites were held between 1957 and 1964. Although in three of four instances over 60% voted in favor, the measure did not pass because it was short of the 66.6% required majority. In April 1966 another amendment to the provincial Public Health Act was made, which changed "two-thirds" to "majority" (i.e., 50%) (Watson 1990). Fluoridation began shortly thereafter in Edmonton, in 1967.

Circumstances of plebiscites in Edmonton were described by Fish et al. (1965) and Watson (1990), who highlight factors other than provincial legislation that hindered fluoridation uptake. Although virtually all scientific, medical, and dental associations were in favor of fluoridation, along with prominent researchers at the University of Alberta, and the *Edmonton Journal*, significant anti-fluoridation activity occurred. There were at least two active anti-fluoridation organizations in Edmonton during the 1950s and 1960s: the Noralta Civil Rights Committee, and the Fluoridation Information Bureau (aka the Fluoridation Educational Bureau), which later became the Edmonton Pure Water Association. Ms. Cornelia Wood, long-standing MLA for Stony Plain during the 1940s-1960s, was actively opposed to fluoridation, and the Edmonton Local Council of Women expressed their opposition to fluoridation in 1953. The Social Credit Party of Alberta, which was responsible for implementing the 66.6% provincial legislation in 1952, announced their opposition to fluoride in 1962. Fish et al. (1965) studied voter turnout and characteristics at Edmonton's 1959 plebiscite, which was held in conjunction with a municipal election. A random sample of 356 Edmonton adults were interviewed on (among other things) issues related to fluoridation. Findings indicated that those who held more extreme views on fluoride (positive or negative) were more likely to vote than those who were indifferent or undecided. The authors concluded that, based on their findings, the decision at the 1959 plebiscite (majority in favor, but not enough to pass) was made by a small minority of the population that was not representative of the larger population. They also speculated that the tendency for voters to be older may give the anti-fluoridation position an advantage, since older individuals may be more skeptical of fluoridation (Fish et al. 1965).

Fluoridation in Calgary was discussed by Carstairs (2010), Clarke and Castaldi (1961), Pryce and Smorang (1999), and Rabb-Waytowich (2009). Carstairs (2010) comments that, along with Toronto, Calgary has a history of "particularly heated" fluoride debates. The City has been through six plebiscites: in 1957, 1961, 1966, and 1971, the electorate voted "no" to fluoride. In 1989 the vote passed with 53% in favor (fluoridation began in 1991), and a plebiscite over the continuation of fluoridation in 1998 passed with 55% in favor.

Carstairs (2010) discusses the context and circumstances surrounding Calgary's past plebiscites. An interesting fact about the first plebiscite, in 1957, is that the City's Medical Officer of Health, Dr. W.H. Hill, was opposed to fluoridation and actively campaigned against the measure, on the basis of fluoride's alleged toxicity. It is also interesting to note that, during at least the first three Calgary plebiscites (1957, 1961, and 1966), and in direct contrast to its position today, the *Calgary Herald* newspaper was staunchly supportive of fluoridation and promoted it consistently, even going so far as to condemn fluoridation's opponents as "irresponsible and unscientific". By the third plebiscite, in 1966, provincial legislation had been changed from 66.6% to 50% majority, but still the pro- vote was not sufficient to pass. One more defeat (in 1971) occurred before the measure finally passed in 1989. The

1989 referendum was partly prompted by a group of students at a local high school, who had studied fluoridation in their grade 11 science class. The Calgary Board of Health endorsed their request. Although popular mayor Ralph Klein voted against the decision, Council agreed to hold the referendum and fluoridation passed with 53% of voters in favor. Fluoridation began in Calgary in 1991.

In 1997, Calgary City Council was approached by citizens who were concerned about the safety of fluoridation, based on “new evidence” (Pryce & Smorang 1999). In response, the City sponsored an expert panel to review research on effectiveness and safety of fluoridation that had been published since the city’s last plebiscite in 1989. The members of the panel were selected for their expertise in science related to fluoridation, such as bone health, pediatric and community health, toxicology, environmental design, and biostatistics. The Calgary Regional Health Authority (CRHA) committed to following the recommendations of the panel, whatever they were. Four of five panel members agreed that there was not sufficient evidence on which to make changes to Calgary’s existing fluoridation policy. Although the fifth panel member’s conclusions initially differed only slightly from the other four, they became increasingly negative over time. Thus, although the panel as a whole recommended continuing fluoridation, and CRHA endorsed this position, the City nonetheless recommended that a plebiscite be held in conjunction with the 1998 municipal election. As in other plebiscites, vocal and well-organized groups emerged that were in favor of fluoridation (e.g., medical, dental, and public health organizations) and that were opposed (two in particular: the Health Action Network Society [HANS] and “Calgarians for Choice”). In the end, the Calgary electorate voted 55% in favor of continuing fluoridation, and it was recommended that, to prevent future plebiscites, CRHA should regularly review research pertaining to fluoridation and communicate this research to the public (Pryce & Smorang 1999).

BRITISH COLUMBIA

In British Columbia, a plebiscite requires 60% support to pass (Warner 1972; Carstairs & Elder 2008). According to Rabb-Waytowich (2009), although the B.C. Ministry of Health Services supports fluoridation, less than 4% of the B.C. population currently drinks fluoridated water. Discussions of BC plebiscite circumstances were found for Vancouver, Squamish, and Comox/Courtney.

Warner (1972) examined the “communication dynamics” during the period leading up to a 1968 plebiscite in Vancouver. Although an analysis of the news media (newspaper) during 1967 and 1968 revealed significant support for fluoridation, the Vancouver electorate voted just 54% in favor, which was not enough to pass. As in other circumstances, a pro-fluoridation position was taken by prominent groups in the community, including medical and dental organizations, as well as City Council. Warner (1972) suggests that this pro-fluoride group came to resemble a “power bloc”, to which certain sectors of the population (who were undecided about fluoride) reacted negatively. Although a unified position on behalf of medical and dental professionals and associations may be important, Warner (1972) cautions that its effect may vary across the population: presenting a reassuring stance for those who are already in favor of fluoride, but potentially alienating those who are undecided and who may be, for other reasons, resistant to government and other power bloc structures.

Clark and Hann (1989a, 1989b) examined the fluoridation plebiscite in Squamish, BC which coincided with the November 1988 BC municipal elections. The question put to vote was whether to continue fluoridation of the community’s drinking water, which had been in place for nearly 20 years. With the timing prompted by the need to replace fluoridation infrastructure, the issue was brought forth by an alderman who had taken an interest in the topic. One year prior, the same alderman had raised the issue but council at that time decided to continue fluoridating based on the recommendation of local

health professionals. This second time, Council decided to put the issue to public vote. Leading up to the vote, local health professionals and academics publicized their support in the newspaper and canvassed the community, encouraging people to vote. The sense was that the community was generally in favor of fluoridation. Aside from the one alderman who instigated the vote, there was only one anti-fluoridation event: a public meeting led by Dr. John Lee, a noted anti-fluoridationist from the U.S. Turnout at the meeting was poor, and of those who attended, many were reportedly not from Squamish. The pro-fluoridationists found that “it was easy to draw upon the experience of others who had previously debated or dealt with Dr. Lee”. At the vote, 73% voted in favor of continued fluoridation – a clear margin. The success was attributed to “good local support from the public health community and local dentists and physicians, and a poorly conceived effort from the opposition”.

Finally, Emerson and Clark (1993) describe the events surrounding a referendum on February 15, 1992 in Comox and Courtney BC, in which the community voted out fluoridation after 20 years. As in Squamish, the decision to hold a vote was facilitated by the need to replace fluoridation infrastructure. When this need became public, local anti-fluoridationists became organized and vocal about their desire to see fluoridation discontinued, drawing mainly on (faulty) evidence that fluoride causes cancer. The referendum was deemed necessary because Comox, whose Council had endorsed a pro-fluoride position, and Courtney, which had adopted an anti-fluoride stance, share a water system. Although, as elsewhere, the health professional and academic community presented a united pro-fluoride front, only 48% of the electorate voted to continue fluoridation: not enough to pass. The failed vote was viewed as surprising because of two things: first, during the lead-up to the referendum, the results of Clark et al. ‘s (1995) study showing that children in fluoridated Kelowna, BC, had 34% less dental decay than children in non-fluoridated Vernon were publicized. Second, prior to the referendum, a public opinion poll taken by the University of British Columbia’s Faculty of Dentistry showed that, of decided voters, 60% indicated being in favor, which suggests that those opposed to fluoride were over-represented among voters at the referendum. Overall, the authors suggest that “the tactics of the anti-fluoridationists to create controversy and doubt in the minds of voters had its desired effect” and “suggests that the public can be easily scared into making decisions that are not in the communities’ best interest”.

OTHER REGIONS

Carstairs (2010) describes fluoridation circumstances in Winnipeg, where fluoridation passed easily, and in Montreal, where fluoridation has undergone much controversy but has never been implemented (the Montreal circumstances were also analyzed by Charland 1992)..

Amongst Canadian cities, Winnipeg was one of the earliest to adopt fluoridation, and this occurred at a time when, relatively speaking, there was limited concern about potential risks of the measure. In response to an initial recommendation to fluoridate made by Winnipeg City Council’s Committee on Health in 1952, the main point of opposition was its cost. Because Winnipeg’s water supply served other municipalities as well, it was necessary to a) gain the consent of those other municipalities and b) develop new provincial legislation. These two things were achieved, and Winnipeg began fluoridation in 1956. Although anti-fluoride groups emerged during the four years between the initial recommendation and implementation, “the anti-fluoride movement slowly disappeared” and fluoridation was ultimately implemented with little resistance in that city (Carstairs 2010).

In contrast, fluoridation has had a volatile history in Montreal. The public health measure was first recommended in the early 1950s by Montreal’s Medical Officer of Health, but the City’s long-standing mayor, Jean Drapeau, was strongly opposed (Carstairs 2010). Although Drapeau believed in

fluoridation's effectiveness in preventing tooth decay, he resisted on the grounds of infringement of personal liberties. In the late 1960s, the provincial government first became involved, by recommending water fluoridation throughout the province. In 1972, the Liberal government's Minister of Health and Social Welfare introduced a bill that would have mandated fluoridation across the province. The bill was opposed by various groups including a health food consumers group, environmental groups, and the Federation of Quebec Women, and on the basis of this opposition the proposed legislation was withdrawn. The bill was renewed however in 1975, by the provincial Liberal Government. There was strong support for the bill from the group representing physicians in Quebec (Roy 1975), which cited reducing tooth decay and reducing fragility fractures and osteoporosis among fluoride's benefits. This support, coupled with the Liberals' large majority, enabled the legislation to pass easily in 1975.

Upon their election in 1976, however, the Parti Québécois suspended the fluoridation legislation (Carstairs 2010). The suspension was fueled in part by opposition groups who highlighted health and environmental concerns about fluoridation. Although the legislation remained suspended, municipalities were permitted to introduce fluoridation if they wished, with the province providing financial support. Montreal Mayor Drapeau resigned from politics in 1986, and a left-leaning Montreal Citizen's Movement promised to fluoridate the city if elected. They won by a large majority, and plans to implement fluoridation in Montreal were announced in 1987. Debate ensued, an interesting aspect of which was Quebec's opportunity, via fluoridation, for "rattrapage" or "catching up", which echoed political debates during the Quiet Revolution of the 1960s. Nonetheless, despite signs of public support for fluoridation, the Community Development Standing Committee, which had decided to hold hearings on the issue, voted against the proposal, and fluoridation in Montreal has never been implemented (Carstairs 2010).

Plebiscites: why do they fail?

Although the outcomes of plebiscites reflect unique local and provincial circumstances, there are certain factors in common from which lessons may be learned. For example, Emerson and Clark (1993) highlight that anti-fluoridation groups are well-organized and often well-funded, and therefore it is important to organize those in favor of fluoridation as early as possible, including engaging local decision-makers, securing the support of the local media, etc. Musto (1987) notes that, although active support of health care and professional organizations is crucial, it may be that leadership for the "pro" movement should come from elsewhere and be separate from the health and academic sectors. Hawkins (2009) agrees that while health professionals and academics should be public supporters, things may backfire if these groups are viewed negatively as an elitist power bloc. Bowen (1974) offers several suggestions for maximizing the likelihood of achieving a vote in favor of fluoridation: set up a citizen's committee, which should include health professionals, members of the general public, a pharmacist, a nutritionist, and a lawyer; try to obtain the support of local media; plan and execute an information campaign; and have fluoridation literature prepared and be ready to answer questions.

In some contrast to the frequent failure of fluoridation plebiscites, we identified two empirical studies of public opinions about fluoridation, which suggest that the majority of various Canadian populations are supportive of, or at least not opposed to, fluoridation. Levallois (1998) reports the findings of a telephone survey of a random sample of residents living in fluoridated and non-fluoridated municipalities in the Quebec City Region. Residents were sampled from two fluoridated municipalities: Quebec (fluoridated since 1976) and Sillery (fluoridated since 1991), and from two non-fluoridated municipalities: Sainte-Foy and Lévis. Overall, knowledge of the main benefits of fluoride was relatively low, and was similar (19-20% knowledgeable) in the two regions. Knowledge of fluorosis was very

low, and also similar (2-3%) in the two regions. Interestingly, individuals' knowledge of their community's water fluoridation status was low: of respondents in the fluoridated areas, only 50% knew that their water was fluoridated; of respondents in the non-fluoridated areas, 35% thought (incorrectly) that their water was fluoridated. Although opposition to fluoride was slightly higher in the fluoridated regions (22%) than in the non-fluoridated regions (18%), the opposition was clearly a minority in both regions. Quiñonez and Locker (2009) conducted a telephone survey of a random sample of Canadians. They found that approximately one in two adults surveyed knew about community water fluoridation. Of those who knew about it, a majority (60%+) believed that it is safe and effective, and would support it. Respondents with higher income and those who visited the dentist more regularly were more likely to support community water fluoridation, and those with children and those who had public dental insurance were less likely to support community water fluoridation.

The observation that the public appears to be more supportive of fluoridation than not, coupled with the contrasting observation of frequent failure of plebiscites, suggests value in analyzing the anti-fluoride position, as a number of authors have done. Some authors (Hamilton 1992; Musto 1987) focus on societal changes over time, to explain growing anti-fluoride sentiment. Musto (1987), for example, notes growing public awareness of the political process, and skepticism thereof, as key reasons for voter opposition to fluoridation. He also highlights growing public concern about environmental toxins (e.g., as causes of cancer), and increasingly prominent social norms around assertion of individuality and freedom of choice. The focus on recent societal trends to explain growing anti-fluoride sentiment accords with historical analyses that highlight the 1950s as a period characterized by belief and trust in science and experts (Carstairs & Elder 2008; Hanlon et al. 2011), which gave way to the influx of neoliberalism in the 1970s and 1980s (and continuing today) characterized by, among other things, a trend of decreasing government involvement in social and economic aspects of life (Sewell 2009). These trends have led, in some cases, to a hesitancy among elected officials to act on fluoridation issues, and the failure of legislation in many cities to promote and enable fluoridation (Water Fluoridation in Canada, a Status Report, 1980). Although a focus on societal trends gives an impression that anti-fluoride sentiment is a recent phenomenon, other authors have highlighted that opposition to fluoride has existed as long as fluoridation itself (e.g., Carstairs & Elder 2008; Sutton & Amies 1958; Hawkins 2009). Musto (1987) notes that the first large-scale confrontation against fluoridation and defeat of proposed fluoridation in a referendum occurred in Wisconsin in 1950.

A number of arguments have been put forth over time to support opposition to fluoridation. Some have been short-lived, while others have endured throughout the history of this public health measure. We present these arguments here, in no particular order.

1. The effectiveness of water fluoridation to prevent tooth decay is questionable.

This argument highlights the equivocal nature of some recent fluoridation studies, relative to the early fluoride trials (e.g., Maupome et al. 2001), but it also extends to methodological critiques of the early trials (e.g., Sutton & Amies 1958). For example, the Brantford trial has been criticized for using the mirror and probe method to check for caries rather than X-rays, and also on the grounds that Brantford children allegedly had better oral hygiene habits than children in neighboring communities, and these better oral hygiene habits explain the caries improvements observed (Carstairs & Elder 2008).

It is true that evidence of the effectiveness of fluoridation in preventing tooth decay in recent studies is less striking than evidence from earlier studies, which largely reflects the influx of other sources of fluoride. Nonetheless, the evidence remains, on balance, supportive of fluoridation's effectiveness.

Hawkins (2009) notes that since 1997 there have been 18 major reviews examining fluoridation, including an expert panel convened by Health Canada in 2007. These reviews have consistently found that fluoridation is effective in reducing the risk of tooth decay, and is the most cost-effective way of providing the benefits of fluoride to communities.

2. There are alternative ways to get fluoride.

According to this argument, drinking water fluoridation is not necessary because there are several other ways that individuals can, on their own accord, obtain adequate exposure to fluoride. It is also argued that providing fluoride through water is a slippery slope which will ultimately lead to the delivery of other, potentially dangerous products including drugs, through our water supply (Carstairs & Elder 2008). Because there are other ways to get fluoride, it is possible to avoid the slippery slope.

Several documents in our review discuss alternatives to water fluoridation, such as supplements (tablets or drops), home fluoridation units, and topical application of fluoride at a dental clinic. Disadvantages of these alternatives, relative to fluoridation, are also discussed; for example, use of supplements in children relies on diligent parental adherence, which may vary unfairly across the population. Also, recommendations for fluoride supplements vary depending on exposure to fluoridated water, and a study in Quebec found that a sizeable proportion of GPs and pediatricians (who prescribe supplements) did not know the water fluoridation status of their patients' communities, which resulted in just 21% prescribing supplements appropriately (Vallée et al. 1993). Cited disadvantages of topical application of fluorides at dental clinics include: 1) it presents an unsustainable burden (time and capacity) on dental professionals; and 2) not everyone visits the dentist regularly; for example, Vallée et al. (1993) cite survey data indicating that less than 30% of children age 6 or younger in Quebec visit the dentist at recommended intervals. Overall, it is argued that fluoridation is more efficient, less expensive, and more equitable than these other fluoride delivery modes (Fluoridation or fluoride supplements ... CMAJ 1972; Are there alternatives ... JCDA 1969; Dawson 1965).

3. Fluoridation is a Communist plot

The relatively short-lived Communist plot argument holds that fluoridation was instigated by Communists to make people docile and therefore amenable to a takeover. By way of context for this argument, Watson (1990) articulates that the initial fluoridation trials took place amidst an atmosphere of uncertainty. During the Cold War period following World War II, there was near-hysterical concern about security and the possibility of Communist subversion. Water fluoridation was thought to be the medium by which the subversion would occur.

Carstairs and Elder (2008) note that most people opposed to fluoridation eventually backed away from this argument because they realized that it was far-fetched and endorsement could lead to one being subject to ridicule.

4. Fluoridation is an aluminum company conspiracy

This argument, also relatively short-lived (with some exceptions⁵), is based on the idea that aluminum companies used fluoridation as a way to get rid of sodium fluoride, which is an unwanted byproduct of aluminum processing that is expensive to dispose of properly (Carstairs & Elder 2008). Carstairs and

⁵ In response to our editorial on fluoridation in the Calgary Sun (McLaren et al. 2011) we received one response that invoked this idea.

Elder (2008) note that there is no evidence that aluminum companies ever promoted fluoridation or that they made much money from producing fluorides to be used for water fluoridation.

5. Fluoridation causes harm to individuals

Fluoridation has been argued to cause myriad health consequences. Aside from fluorosis (whose association with fluoridation is acknowledged by those supportive of and opposed to fluoridation), it has been argued that fluoridation causes or has been associated with heart disease, cancer, birth defects, kidney problems, skeletal changes, violent allergies, goiters, ulcers, anemia, and abortion (Carstairs & Elder 2008).

Concerns about the possible health consequences of fluoridation have existed as long as fluoridation itself. For example, at the time of the Brantford experiment in the 1940s and 1950s there was concern about the possible accumulation of fluoride in the body (Smith 1946). When Hutton, one of the instigators of the Brantford experiment, was approached with this concern, he responded by sharing the results of a report produced by the U.S. Health Service on the topic, which showed that fluorine in urine is proportional to fluorine in water, and that fluorine at sub-toxic levels (i.e., the levels found in drinking water) does not accumulate in the body (Smith 1946).

Since the inception of fluoridation, research has accumulated on its health consequences. Hawkins (2009) comments on 18 major reviews of fluoridation since 1997. These reviews, which comprise critical appraisal of research by experts, have found no evidence that fluoridation is linked with cancer, bone disease, kidney disease, birth defects, or other adverse health effects (Hawkins 2009; Analyzing selected criticisms ... JCDA 1981). One of these reviews was the Expert Panel convened by Health Canada in 2007, which found no evidence to link fluoride with increased risk of cancer, bone fracture, immunotoxicity, reproductive/developmental toxicity, genotoxicity, or neurotoxicity (Rabb-Waytowich 2009; Health Canada 2007). Skeletal fluorosis was identified by the panel as an adverse consequence which is likely to occur if an individual ingests 10 mg of fluoride per day for 10 years or more. The panel found no health concerns associated with mild or very mild fluorosis. Although the presence of moderate fluorosis is considered to be a marker of excessive fluoride (cosmetic end point versus toxicological end point), the panel members note that the prevalence of moderate fluorosis in Canada is low and decreasing, which probably reflects reductions in use of fluoride supplements. To ensure the accuracy and appropriateness of position statements, medical and dental professions that endorse fluoridation continually monitor this research. For example, in response to concern about health consequences of fluoridation, Swan (2005) notes that “the Canadian Dental Association is always scanning the latest fluoridation research, and according to the generally accepted body of scientific knowledge, there has been no proven association between cancer rates in humans and optimal levels of fluoride in drinking water”.

Arguably, the most frequently-cited alleged health consequence of fluoridation is cancer. We therefore believe it is appropriate to describe two studies that were referenced in documents in our review, which seem to have been particularly important in promulgating a fluoridation-cancer link. First, a cancer bioassay on fluoride was undertaken by the U.S. National Cancer Institute and the National Toxicology Program during 1977-1987. The results of this animal research were that some cases of osteosarcoma were observed among male rats exposed to the two highest fluoride doses: 4 of 80 exposed to 79 mg/L and 1 of 50 exposed to 45 mg/L of fluoride. No cases were observed among the control rats or the female rats. For a number of reasons, a panel convened to review these findings unanimously concluded that the evidence of carcinogenic activity of sodium fluoride in male rats was “equivocal” (cited in

Hrudey et al. 1990). Second, a study by Yiomouyannis and Burk (1977) reported higher cancer rates among humans in fluoridated than in non-fluoridated cities. Re-examination of these data by several prominent organizations (e.g., U.S. National Cancer Institute, the British Royal Statistical Society, and Canada's Ministry of Health and Welfare) led to their rebuke based on the argument that the authors did not adequately account for confounders including different socio-demographic attributes of the two populations (Yiomouyannis & Burke 1977, cited in Bellemare 1981). Once this was done, the authors conceded that no differences in cancer were apparent (Bellemare 1981).

6. Fluoridation is toxic for the environment

This argument holds that fluoride is a dangerous pollutant with potential to endanger aquatic life (Carstairs and Elder 2008). This argument was bolstered by an event in 1967 in Dunnville, Ontario, in which fluoride pollution from a fertilizer plant damaged crops and animals (Carstairs & Elder 2008). This argument emerged against the backdrop of growing concern about environmental pollutants and their implications for human health outcomes, the publication of Rachel Carson's *Silent Spring* in 1962, and the ensuing emergence of the modern environmental movement.

The main response to this argument is that controlled water fluoridation represents only one small part of the total cycle of fluorides (Analyzing selected criticisms ... JCDA 1981), and that there are far more harmful pollutants, in far higher quantities, with much greater consequences for the environment than drinking water fluoridation, such as emissions from industry and transportation.

7. Fluoridation is not natural

The claim that fluoride is an unnatural chemical that compromises the purity of water was a frequently reported argument in the early days of fluoridation, in the 1950s and 1960s (Carstairs & Elder 2008). In part, this argument – which is related to the environmental argument above – stems from health food store owners and naturopathic health practitioners who were amongst the first anti-fluoridationists, on the grounds of its alleged impurities. These groups believed that illness in general and oral health problems in particular reflected aspects of modern life such as a refined-food diet, and that a return to natural foods and natural ways of living was a more suitable remedy to health problems than adding chemicals to the water (Carstairs & Elder 2008).

Importantly, this argument, along with #6 (toxic to the environment) appealed to left-leaning members of electorates, whereas others (e.g., #8 below) appealed particularly to those on the political right. Thus, part of the overall power of the anti-fluoridation movement is that it crosses ideological lines.

8. Fluoridation is an infringement on personal freedom

According to this well-known argument, fluoridation is perceived as a violation of civil liberties, or in other words, an infringement of personal freedom. In its extreme form, fluoridation has been equated with Nazi wartime atrocities such as forced experimentation on humans (Carstairs & Elder 2008). In its more subdued and typical form, this position emphasizes the inappropriateness of using such a fundamental resource as drinking water as a medium for the delivery of a product for which public support is not unanimous.

Typically, the response to the infringement to personal freedom position by those in favor of fluoridation is twofold (e.g., McNally & Downie 2000): First, it is argued that some infringement upon personal freedom is justified when the well-being of vulnerable groups is at stake. For example, fluoride is argued

to be a practical and effective means of ensuring access to fluoride among children, and among those with limited socioeconomic resources who may not otherwise have access to preventive dental care and treatment. Second, the point is made that in countries such as Canada, there is a core set of values which allows for infringement of individual rights in certain instances such as mandatory vaccination, fortification of foods with essential nutrients, and routine testing for certain genetic diseases at birth (McNally & Downie 2000).

However, these arguments do not necessarily stand up to a robust ethical analysis. Cohen and Locker (2001) analyze the ethics of fluoridation, focusing on bioethics principles of autonomy, beneficence, and truthfulness. They argue that, in the case of fluoridation, it may in fact be impossible to resolve the conflict between beneficence and autonomy, because beneficence depends on whose notion of “good” or “well being” is applied. If beneficent acts are to benefit the recipients of the intervention (which is the case for fluoridation), then the basis for the goodness of the intervention must fall to the values of autonomous individuals. Truthfulness refers to the obligation of scientists and health professionals to tell the truth so that autonomous individuals may weigh the benefits and harms. Cohen and Locker (2001) note that while evidence of the benefits of fluoridation may once have been very clear, this is no longer the case, and an intervention cannot ethically be justified on the basis of historical evidence. They also argue that, in the scientific literature, the harms are not always presented in a balanced manner, for example with fluorosis typically described as a “cosmetic” concern. They conclude that, in the absence of a full account of benefits and risks, communities cannot currently make a properly-informed decision about fluoridation (whether and to what extent).

9. Fluoridation is implemented by governments and scientists, and they cannot be trusted

A final argument, related to others above, is that fluoridation is an effort devised by “elite” groups in societies (governments, scientists, and health professionals), and that these groups cannot always be trusted to make the appropriate decisions. In general, this position is rooted in suspicion of large organizations, including medical and dental professions, as well as large corporations. It is argued that the science behind fluoridation may be biased by these affiliations; for example, “fluoridation is only practiced in English-speaking countries because of pharmaceutical lobbying and collusion with the medical profession” (Dilancea 2003). Past instances of tragedies in science and medicine are raised, such as deaths attributed to the polio vaccine or birth deformities attributable to thalidomide (Carstairs & Elder 2008). Foulkes (2007) characterizes fluoridation as a paradigm that endures due to backing by prominent authorities (e.g., WHO, CDC, Health Canada), rather than based on scientific evidence, and Charland’s (1992) analysis concludes that fluoridation controversy reflects a failure of the authority of science and the public health “complex”. Musto (1987) hypothesized that those who vote “no” in fluoridation plebiscites may be expressing a negative attitude towards science and government, and alienation from social and political life, rather than unique resistance to fluoridation per se.

Overall, although some anti-fluoride arguments have come and gone (e.g., the Communist plot, the aluminum company conspiracy), resistance to fluoridation has existed as long as fluoridation itself, and certain aspects of the position have endured: questioning the contemporary effectiveness, concern about possible harms, and the perceived threat to individual freedom (Musto 1987; McLaren et al. 2011; Rabb-Waytowich 2009). These consistent arguments have certainly contributed to the tendency of fluoridation plebiscites to fail. In addition to these arguments, some authors have highlighted other attributes which have contributed to fluoridation’s controversial nature and the outcomes of fluoridation plebiscites; for example:

- Fluoridation is used for the prevention of tooth decay which is, in general, a non-contagious and non-fatal condition. This lessens the urgency of preventive measures, from the public's perspective (Carstairs & Elder 2008)
- Unlike other public health interventions that are known to be effective and are therefore mandated (e.g., water chlorination), decisions about fluoridation are made by local governments. Federal and provincial governments can provide guidance and legislation, but ultimately they cannot dictate a municipality's fluoridation circumstances (a notable exception being the province of Quebec's short-lived legislation mandating community drinking water fluoridation) (Hawkins 2009; Rabb-Waytowich 2009)

Also pertinent to understanding the outcomes of fluoridation plebiscites are characteristics of plebiscites themselves. Bonham (1993) argues that plebiscites, whatever their focus, are extremely difficult to win, for the following reasons:

- Plebiscites act as "lightening rods", allowing various strong emotions to be expressed;
- Despite the media's obligation to be balanced, it is more newsworthy to cover dramatic negative events, such as faulty research on which the fluoridation-cancer link was drawn;
- There is an unequal burden of pro versus con. In a plebiscite, the proponents are tasked with creating confidence in all aspects of the issue, while the opponents only need to raise one concern or doubt.
 - The potential leverage of the opposed side is especially apparent when considering the results of public opinion surveys showing that baseline knowledge about fluoridation is low, as demonstrated in public opinion surveys (Quiñonez & Locker 2009; Levallois 1998; Bellemare 1981).
 - Musto (1987) offers a "confusion hypothesis" to explain voter behaviour at plebiscites: namely, voters who are faced with an apparent controversy may vote for the safer option (apparently endorsed by the anti-fluoridationists), even if they were initially in favour of fluoride.

Thus, in contrast to the evidence base on fluoridation which, on balance, shows that the measure is a) effective and b) does not cause harm, the fluoridation trend in Canada is characterized by decreasing uptake and municipal decisions to discontinue. This appears to reflect characteristics unique to fluoridation, as well as characteristics of the plebiscite mechanism by which many fluoridation decisions are made.

SUMMARY OF FINDINGS

- Evidence for the effectiveness of drinking water fluoridation in the prevention of dental caries in Canada exists. The strongest evidence is from the original trials (e.g., Brantford-Sarnia-Stratford) in the 1940s through 1960s. These original trials were impressive for their adherence to a rigorous research protocol.
- Since the 1970s, research on drinking water fluoridation has been complicated by the widespread availability of other sources of fluoride, most notably fluoride toothpaste. As such, more recent evidence on fluoridation is weaker than the earliest findings, though on balance it supports more than it refutes the effectiveness of the intervention.
- Existing research consistently shows an association between exposure to drinking water fluoridation and increased risk of dental fluorosis. Case studies of fluorosis in communities with high levels of fluoride in drinking water illustrate the critical importance of monitoring fluoride concentrations, particularly in rural areas with weaker infrastructure.
- Although there is some indication that exposure to fluoridation may have some benefit for bone density, on balance there is no clear evidence for an association between drinking water fluoridation and health outcomes other than dental outcomes.
- To conduct research on the health impact of drinking water fluoridation, it is essential to have accurate information on exposure, including a) length of residence in the community; and b) use of other sources of fluoride. This has implications for oral health surveillance across multiple Canadian jurisdictions.
- Although resistance to fluoridation is sometimes thought to be a recent phenomenon, well-defined opposition to fluoridation has in fact existed as long as fluoridation itself.
- Many arguments have been put forth by those opposed to fluoridation, ranging from the relatively innocuous “it’s not effective” to the more apocryphal “communist plot” and “aluminum company conspiracy”. Part of the power of the anti-fluoride movement is that some of the arguments – e.g., potential harm to the environment and aquatic life – cross ideological lines and have proponents in both the political right and left.
- We identified a large amount of material on local circumstances surrounding plebiscites or referenda. While this information may be helpful for communities undergoing a vote, it is important to recognize that fluoridation plebiscites are more likely to fail than to pass, which reflects characteristics of fluoridation and characteristics of plebiscites.
- Contrasting with the failure of most fluoridation plebiscites is the observation, from public opinion polls, that a majority of Canadians are in favour of, or at least not opposed to, fluoridation. This suggests that anti-fluoridationists are over-represented among voters at plebiscites, and it speaks to the success of the anti-fluoridationists in persuading otherwise undecided or non-voters to vote no.
- From an ethical point of view, drawing on principles of beneficence, autonomy, and truthfulness, the controversy over fluoridation may be un-resolvable.

KNOWLEDGE GAPS:

- Surveillance. The amount of published research on the impact of drinking water fluoridation on oral health in Canada pales in comparison to the number of communities that have implemented the intervention. Although we cannot discount the possibility that data from these communities exist and simply have not been published, it appears that the research opportunity provided by community changes in fluoridation status has often been left unexploited. Surveillance systems at national, provincial, and municipal levels would facilitate ongoing research on the effects of fluoridation.

- Oral health inequities. Considering that one of the main arguments put forth for continuing fluoridation is that it is a practical and effective way to provide fluoride to all (including those who cannot afford or access dental care and other sources of fluoride), we detected a surprising lack of research on the implications of drinking water fluoridation for inequities in oral health in Canada.

LIMITATIONS OF THE REVIEW:

- Articles were identified for review and inclusion based on titles and, if available, abstract. Therefore, we may have missed documents that provided insight into fluoridation if it was not a prominent objective of the study.
- Although we were careful to select databases that index older volumes of key journals, the nature of retroactive indexing is such that some older documents may have been missed. Nonetheless, our identification and inclusion of several documents from the 1950s and 1960s suggests that our search was reasonably comprehensive
- The scope of our review was academic and professional journals (including but not limited to peer-reviewed sources). Therefore we did not seek out other important information sources such as organizational reports, unpublished documents in the “grey literature”, and media items. Of these sources, we believe that documents from provincial and municipal governments, and local health regions, would be particularly informative.
- On the whole, the materials reviewed tended to be favourable or neutral towards fluoridation, suggesting that our methods may not have adequately captured the anti-fluoridation literature. To ensure a fair hearing of both sides of the debate, it will be important to identify the sources of the anti-fluoridation literature and to include it in comprehensive syntheses.

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Table 1. Some major events in the history of drinking water fluoridation in Canada

Year	Event
1901	Initial observation of “peculiar” tooth staining by McKay among clients at his Colorado Springs dental practice.
1916	McKay and Black’s publication on “mottled enamel” in <i>Dental Cosmos</i>
1930	Chemists at ALCOA (Aluminum Company of America) identify fluoride as the etiologic water-born agent causing tooth mottling
1932	T. Dean, dental surgeon at National Institute of Health, observed association between mottled teeth and lower caries incidence
1942	Publications from the American Academy for the Advancement of Science (including one authored by Dean) first raised the possibility of reducing caries incidence by adding fluoride to public water
1945	Fluoridation began in Brantford Ontario (also in Grand Rapids, Michigan and Newburgh, New York). Annual dental surveys commence.
1948	Department of National Health and Welfare instigate annual dental surveys in two comparison communities: Sarnia (not fluoridated) and Stratford (naturally fluoridated at >1 ppm).
1952	Sudbury (ON) begins fluoridating drinking water
1953	Oshawa (ON) begins fluoridating drinking water
	Moose Jaw (SK) begins fluoridating drinking water
	JCDA published its first editorial endorsing fluoridation.
	CDA endorsed fluoridation of Canadian water supplies
1954	CMA endorses controlled fluoridation of communal water
1955	Pointe-Claire (QC) begins fluoridating drinking water
	Saskatoon (SK) begins fluoridating drinking water
	Brandon (MB) begins fluoridating drinking water
1956	Halifax (NS) begins fluoridating drinking water
	Winnipeg (MB) begins fluoridating drinking water
1957	Dorval (QC) begins fluoridating drinking water
	Joliette (QC) begins fluoridating drinking water
1958	Laval (QC) begins fluoridating drinking water
1959	Ontario provincial government appoints Royal Commission to investigate water fluoridation
1961	Ontario’s Royal Commission comes out in favor of fluoridation, declaring that it is not a violation of civil liberties but a technical medical issue.
1962	Trois-Rivières (QC) begins fluoridating drinking water
1963	Toronto (ON) begins fluoridating drinking water
1964	Royal Commission on Health Services recommended that every community across Canada be provided with the necessary funds to fluoridate its water.
1965	Ottawa (ON) begins fluoridating drinking water
1966	CDA recommends that provinces enact legislation to make fluoridation of communal water mandatory.
1967	Waterloo (ON) begins fluoridating drinking water
	London (ON) begins fluoridating drinking water
	Hamilton (ON) begins fluoridating drinking water
	Edmonton (AB) begins fluoridating drinking water
	Fluoride pollution from a fertilizer plant in Dunnville, ON, damaged crops and animals
1968	Charlottetown and CFB-Summerside (PEI) begin fluoridating water

1969	Windsor (ON) begins fluoridating water
1970	Moncton (NB) begins fluoridating drinking water
1971	Canada's National Research Council publish report "Environmental Fluoride", which argues that Canadians living in fluoridated communities were approaching dangerous levels of consumption (first time)
1972	Canadian Pediatric Society recommends fluoridation of all Canadian municipal water supplies
1973	CDA cut back on pro-fluoridation advocacy
1975	Quebec provincial government (Liberal) passed legislation mandating fluoridation
1976	Provincial Council of Women of British Columbia passed a resolution opposing fluoridation.
1977	Canada's National Research Council publish report "Environmental Fluoride", which argues that Canadians living in fluoridated communities were approaching dangerous levels of consumption (second time)
	CDA refutes the NRC report
	Quebec government changed its 1975 policy and allowed municipalities to make own decisions re: drinking water fluoridation
	Environmental Health Directorate investigates fluoride-cancer link and concludes no statistically significant differences in death rates from any type of cancer in fluoridated and un-fluoridated communities.
1978	Quebec City begins fluoridating drinking water
	Windsor (QC) begins fluoridating drinking water
	Canadian Environmental Health Directorate of Dept National Health and Welfare report re: fluoride and cancer: concluded no differences in rates of death from cancer in fluoridated vs. non-fluoridated areas.
1979	Province of Quebec's Consultative Committee on the Environment submitted its report, which concluded that fluorides were accumulating in the environment and that not enough was known about the health impact of fluoride. Recommended that fluoridation be permanently suspended.
	CPHA published "A Criteria Document in Support of a Drinking Water Standard for Fluoride". An advisory committee was set up by CPHA to sift through increasing amount of research about fluoride (from Canada and elsewhere) and to recommend an acceptable drinking water standard for Canada. Report was broad in scope and included one chapter on "fluoride and human health" which discusses the "reputed carcinogenicity of fluoride" and its role re: dental caries.
	National Council of Women in Canada votes to withdraws its support of water fluoridation (133-118)
1991	Calgary begins fluoridating drinking water
1992	Comox-Courtney and Campbell River discontinue fluoridation
2007	Health Canada releases findings and recommendations from the Fluoride Expert Panel. The panel recommends fluoridation concentration of 0.7 ppm (reduced from previous range of 0.8 to 1.0 ppm).
2008	Hamilton city council votes (9-7) to continue fluoridation (no plebiscite)
	Quebec City votes to discontinue fluoridation
	Dorval resumed fluoridation after 5 year hiatus
2011	Calgary City Council votes (10-3) to discontinue fluoridation (no plebiscite)

Sources: Crawford 1995, Hutton et al. 1951, Dunton 1967; Sherrington 1979; Musto 1987; "Fluoridation comes to Moncton" JCDA 1970; JCDA 1966; Carstairs & Elder 2008; Carstairs 2010;

Fluoridation or fluoride tablets, CMAJ 1972; Smith 1949; CDC 1999; Rabb-Waytowich 2009; Water fluoridation in Canada ...” JCDA 1980; McKee 1979; Vallée et al. 1993; Bellemare 1981; Lussier 1981.

Notes: Vancouver and Montreal never implemented drinking water fluoridation.

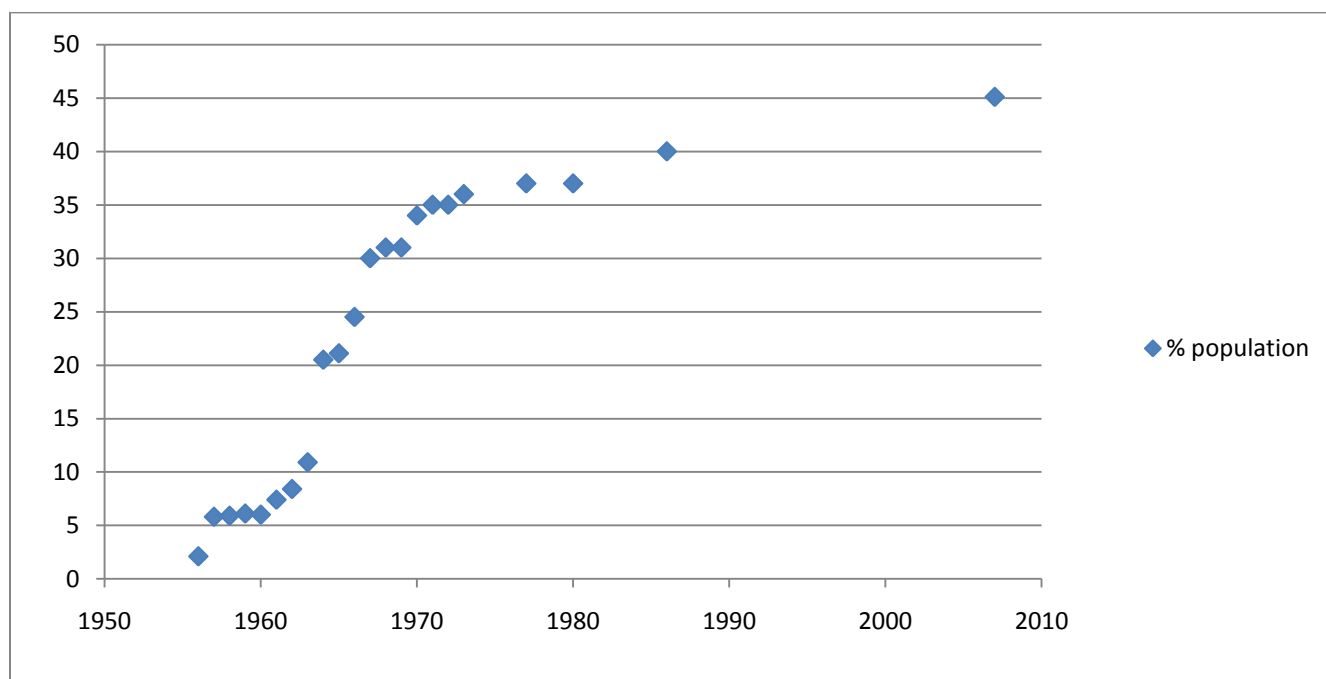
Table 2. An incomplete history of fluoridation plebiscites in Canadian municipalities

Year	Location	Vote to begin or continue?	Outcome
1957	Thorold, ON	Begin	1,359 to 756 in favor (passed)
	Medicine Hat, AB	Begin	Over 50% in favor (not passed – needs 66.6%)
	Red Deer, AB	Begin	Over 66% in favor (passed)
	Innisfail, AB	Begin	72% in favor (passed)
	Calgary, AB	Begin	51% against (not passed – needs 66.6%)
	Edmonton, AB	Begin	64.6% in favor (not passed – needs 66.6%)
1959	Lethbridge, AB	Begin	63% opposed (not passed – needs 66.6%)
	Medicine Hat, AB	Begin	Over 60% opposed (not passed – needs 66.6%)
	Cold Lake, AB	Begin	Over 66% in favor (win, but as of C&C 1961 had not been implemented)
	Fairview, AB (Peace River Health Unit)	Begin	82% in favor (passed)
	Edmonton, AB	Begin	55.7% in favor (not passed – needs 66.6%)
	Devon, AB	Begin	Over 66 2/3 % in favor (passed)
1960	Hinton, AB	Begin	60.3% in favor (not passed – needs 66.6%)
1960	Bowness, AB (Mountview Health Unit)	Begin	54.4% opposed (not passed – needs 66.6%)
1961	Edmonton, AB	Begin	61.6% in favor (not passed – needs 66.6%)
	Calgary, AB	Begin	Less than 50% in favor (not passed – needs 66.6%)
1962	Toronto, ON	Begin	51.7% in favor (passed)
1964	Edmonton, AB	Begin	65% in favor (not passed – needs 66.6%)
1966	Calgary, AB	Begin	45.5% in favor (not passed – needs 50%)
1966	Edmonton, AB	Begin	Passed
1967	Charlottetown, PEI	Begin	Passed
1968	Vancouver BC	Begin	54% in favor (not passed – needs 60%)
1970	Virden, Manitoba	Begin	793 to 234 in favor
1971	Calgary, AB	Begin	Not passed – needs 50%
1972	Pembroke, ON	Begin	Defeated by a large margin
1974	Pembroke, ON	Begin	Defeated by narrow margin
1976	Pembroke, ON	Begin	3,760 to 3,410 in favor
1988	Squamish, BC	Continue (had started almost 20 years before)	73% in favor (passed – will continue fluoridation)
1989	Calgary, AB	Begin	53% in favor (passed)
1992	Comox & Courtney, BC	Continue (had started 20 years	48% in favor (not passed – needs 60% in BC – will discontinue fluoridation)

		earlier)	
	Kamloops, BC	Continue (had started in 1961)	Passed – will continue fluoridation
1998	Calgary, AB	Continue	55% in favor (passed – will continue fluoridation)
2001	Kamloops, BC	Continue	37% in favor (not passed – needs 60% in BC – will discontinue fluoridation)
2010	Waterloo, ON	Continue (had started in 1967)	49.3% in favor (not passed – will discontinue fluoridation)

Sources: JCDA 1970 “Manitoba community votes for fluoride”; Crawford 1993; Sturgeon 1958; Ringland 1978; Clarke & Castaldi 1961; Fish et al. 1965; Watson 1990; Warner 1972; Clark & Hann 1989a; Clark & Hann 1989b; Emerson & Clark 1993; Carstairs 2010; Rabb-Waytowich 2009; Maupomé et al. 2003; Goldstein 1970.

Figure 1. Chronology of percent of Canadian population exposed to controlled drinking water fluoridation



Sources: Crawford (1995); Fluoridation in Canada 1966 (JCDA 1966); Rabb-Waytowich 2009; JCDA 1966; JCDA 1970 “6.6 million Canadians ...” JCDA 1981; “Water fluoridation in Canada ...1980”; Goldstein 1970.

Appendix A
Drinking water fluoridation search strategy (March 1, 2011)

MEDLINE (OVID 1946 to 2011)

1. Fluoridation/
2. exp Fluorides/
3. Water Supply/
4. 2 and 3
5. (drink* adj5 water adj5 fluorid*).tw.
6. (fluoridation or fluoridization).tw.
7. 1 or 4 or 5 or 6
8. exp canada/
9. (canada or canadian or british columbia* or alberta* or saskatchewan* or manitoba* or ontario* or quebec* or nova scotia or newfoundland or new brunswick or northwest territories or yukon).tw.
10. 8 or 9
11. 7 and 10
12. limit 11 to (english or french)
13. limit 12 to animals
14. limit 12 to (animals and humans)
15. 13 not 14
16. 12 not 15
17. limit 16 to clinical trial, all
18. 16 not 17

EMBASE (OVID 1980 to 2011)

1. fluoridation/
2. exp fluoride/
3. drinking water/
4. 2 and 3
5. (fluoridation or fluoridization).tw.
6. (drink* adj5 water adj5 fluorid*).tw.
7. 1 or 4 or 5 or 6
8. exp canada/
9. (canada or canadian or british columbia* or alberta* or saskatchewan* or manitoba* or ontario* or quebec* or nova scotia or newfoundland or new brunswick or northwest territories or yukon).tw.
10. 8 or 9
11. 7 and 10
12. limit 11 to animal studies
13. limit 11 to animals
14. 12 or 13
15. 11 not 14
16. limit 15 to (english or french)

Global Health (OVID 1910 to 2011)

1. fluoridation/
2. exp fluorides/
3. exp drinking water/ or water supply/

4. 2 and 3
5. (drink* adj5 water adj5 fluorid*).tw.
6. (fluoridation or fluoridization).tw.
7. 1 or 4 or 5 or 6
8. exp canada/
9. (canada or canadian or british columbia* or alberta* or saskatchewan* or manitoba* or ontario* or quebec* or nova scotia or newfoundland or new brunswick or northwest territories or yukon).tw.
10. 8 or 9
11. 7 and 10

CAB Abstracts (OVID 1910 to 2011)

1. fluoridation/
2. exp fluorides/
3. exp drinking water/
4. water supply/
5. 3 or 4
6. 2 and 5
7. (fluoridation or fluoridization).tw.
8. (drink* adj5 water adj5 fluorid*).tw.
9. 1 or 6 or 7 or 8
10. exp canada/
11. (canada or canadian or british columbia* or alberta* or saskatchewan* or manitoba* or ontario* or quebec* or nova scotia or newfoundland or new brunswick or northwest territories or yukon).tw.
12. 10 or 11
13. 9 and 12

Canadian Business and Current Affairs (CBCA Proquest)

1. LSU (fluoridation)
2. (drink*) and (water) and (fluorid*) [Citation/Indexing]
3. (fluoridation or fluoridisation)[Citation/Indexing]
4. 1 or 2 or 3
5. Limit 4 to scholarly journals

CINAHL (EBSCO)

1. (MH "Fluoridation")
2. (MH "Water Supply") AND (MH "Fluorides+")
3. TI ((fluoridation or fluoridization)) or AB ((fluoridation or fluoridization))
4. TI ((drink* and water and fluorid*)) or AB ((drink* and water and fluorid*))
5. 1 or 2 or 3 or 4
6. (MH "Canada+")
7. (canada or canadian or british columbia* or alberta* or saskatchewan* or manitoba* or ontario* or quebec* or nova scotia or newfoundland or new brunswick or northwest territories or yukon)[All Fields]
8. 6 or 7
9. 5 and 8
10. Limit 9 to peer reviewed

Canadian Periodical Index (Gale)

1. KE (fluoridation or fluoridization)
2. KE (drink* and water and fluorid*)
3. 1 or 2
4. Limit 3 to peer reviewed