

# Report of the Fairbanks Fluoride Task Force

**DRAFT**  
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## Chapter 1

# Introduction

In response to concerns expressed by community members, on February 8, 2010, the Fairbanks City Council passed a resolution (Appendix A) establishing a committee charged with the responsibility to examine evidence related to fluoridation of public water supplies and to provide the City Council with a report containing analysis and recommendations. The committee was to obtain documentation provided by both proponents and opponents of fluoridation and to supplement this documentation with information from other appropriate sources. The committee was to make its final report to the City Council by early July, 2010, but the committee was unable to meet this deadline due to the complexity of the assignment and the schedules of the committee members.

The committee, referred to in this report as the Fairbanks Fluoride Task Force (FFTF), is composed of the following members:

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The FFTF met for the first time on March 4, 2010, and continued to hold public meetings approximately twice a month through March 8, 2011. At the invitation of the FFTF, both proponents and opponents of fluoridation of the Fairbanks water system (operated by Golden Heart Utilities) made presentations at the March 16, 2010, meeting. Public testimony was received at each of the ten public meetings during the period March 16, 2010, through June 22, 2010. Numerous comments and pieces of information were submitted to the FFTF electronically. Members of the FFTF supplemented this information with relevant articles from the professional literature and results of personal interviews and research.

All documents and information received by the FFTF during the period in which public testimony was being accepted are cited on the References section of the FFTF website ([www.ci.fairbanks.ak.us/boardscommissions/fluoridetaskforce/fluoridetaskforcereferencematerials.php](http://www.ci.fairbanks.ak.us/boardscommissions/fluoridetaskforce/fluoridetaskforcereferencematerials.php)). While FFTF members considered the entire body of information submitted and collected, only some of the materials listed on the References website were used in preparing this report. Those materials are listed as references at the end of this report. There is a massive amount of relevant information on this topic. For example,

in 2008, C. A. Yeung did a review of the efficacy and safety of fluoridation that began with over 5,000 relevant citations. The approach the FFTF took to assessing and using this information was to rely on reviews and studies published between 2000 and 2008 to assess the evidence for and against fluoridation of drinking water as it existed up to 2008 and to supplement this body of literature with key professional articles published in the last several years.

Although the FFTF examined all aspects of water fluoridation, it focused most of its review of the literature on exposure of individuals to fluoride, the efficacy of fluoridated water in caries prevention, and the risks associated with consumption of fluoride. While the task force's major concerns were about populations exposed to 0.7 to 1.2 parts per million (ppm) fluoride in their water supplies, it did examine and consider evidence related to populations receiving both higher and lower concentrations of fluoride in their drinking water. The FFTF's review and analysis of relevant information was organized around the topics that became the chapters of this report. After a series of discussions and work sessions in which all members voiced their observations and concerns about each of the topics, assignments were made to individual task force members for lead responsibility in producing an initial draft of each chapter. The entire task force was subsequently engaged in the process of chapter revision that led to first this draft report, which went out for public review, and the subsequent final report, which will be submitted to the City Council (all members of the FFTF remain involved, even though two of them—Drs. Taylor and Stolzberg—were in the Lower Forty-eight during the report drafting and revision process).

Some technical terms and abbreviations are used throughout this report. In an attempt to make the report more readable for the general public, a few key definitions are given below:

**concentration:** the relative content of a component, often expressed as amount in a given volume (e.g., ppm)

**DMFS:** decayed, missing, and filled surfaces in permanent teeth

**DMFT:** decayed, missing, and filled permanent teeth

**dmft:** decayed, missing, and filled deciduous (baby) teeth

**dose:** measured quantity of an agent to be taken at one time

**g (gram):** 0.001 kg

**kg (kilogram):** a basic unit of mass and weight equal to 2.2 pounds

**mg (milligram):** 0.001 g

**L (liter):** a basic unit of volume equal to about a quart

**LD<sub>50</sub> (lethal dose, 50%):** dose of a toxin required to kill 50% of a group of test organisms

**ppm (parts per million):** a unit of concentration, defined for this report as one mg/L

## Chapter 2

# Recommendations

The Fairbanks Fluoride Task Force makes the following recommendations:

1. Primarily because (1) the ground water used for Fairbanks public water contains an average of 0.3 ppm fluoride, and (2) higher concentrations of fluoride put non-nursing infants at risk, the task force recommends that supplemental fluoridation of the Fairbanks public water supply be terminated. The task force further recommends that the Fairbanks community be informed of possible dental health implications from not fluoridating the water.

*Rationale:* Not fluoridating Fairbanks water will reduce the fluoride content from 0.7 ppm to 0.3 ppm, which is the fluoride concentration of the raw water used by Golden Heart Utilities (GHU). This will reduce, but not eliminate, the risk of significant incidence and severity of fluorosis, especially fluorosis associated with the use of GHU water to prepare infant formula. Doing so will also address ethical concerns raised during the task force's public testimony. However, the effect of this reduction in fluoride concentration on the caries rate in the Fairbanks community, while most likely small, is unknown and unpredictable. Those who depend on 0.07 ppm fluoride in tap water for their dental health need to be informed of the possible adverse consequences to their dental health caused by reducing the fluoride content of Fairbanks tap water from 0.07 ppm to 0.3 ppm and of the measures that can be taken to address these possible adverse consequences.

The task force has made this recommendation to terminate fluoridation of GHU water with full knowledge of and respect for the positions of the American Dental Association (ADA), the Centers for Disease Control and Prevention (CDC; part of the U.S. Department of Health and Human Services), and the World Health Organization in support of fluoridation of public water supplies. While the task force members agree that water fluoridation may be an important element of an effective dental health program in many communities, the majority of members are not convinced that it is necessary in Fairbanks because of the fluoride content of the city's ground water and the alternate sources of fluoride available in the community. Five task force members, with various degrees of conviction, support this recommendation, while one member supports continuing fluoridation at 0.7 ppm.

2. The Fairbanks City Council's decision-making process on fluoridation should involve representatives of the Fairbanks North Star Borough government.  
*Rationale:* An estimated 25% of area residents who receive GHU water reside outside the city limits.

3. Local dentists and physicians should be encouraged to provide their patients with up-to-date information on the benefits and risks associated with fluoride.  
*Rationale:* If nothing else, the recent notice that the secretary of the U.S. Department of Health and Human Services has proposed a new recommendation on fluoridation of public water supplies indicates that the citizenry should be informed about the state of contemporary research findings and analysis related to the role of fluoride in dental health. All of the members of the task force

went into this project with incomplete and in some cases incorrect information about the issue. We suspect that we are not unique in that respect.

4. The Fairbanks City Council should encourage the local school system to review and modify, as appropriate, its approach to providing education about good dental health practices.

*Rationale:* The local schools have an excellent opportunity to help all families in the community to learn about and to implement good dental health practices, which can include optional opportunities for topical fluoride treatment (in the form of rinses and toothpaste, for example) as well as techniques for minimizing unnecessary and/or unwanted exposure to fluoride.

## Chapter 3

# History of Fluoridation of Public Water Supplies

### Fairbanks

A version of Fairbanks City Code dated July 1, 1959, contained a section (Article III, Section 10.301) that authorized and directed the Municipal Utilities System to develop and implement a fluoridation plan that fulfilled the requirements of the Alaska Department of Health. A slightly rewritten version of Article III, Section 10.301 of the City Code was adopted on January 12, 1960, and on August 21, 1962, the mandated fluoridation of city water was implemented in the city of Fairbanks. In 1996, the city water plant was sold by the Municipal Utilities System to Golden Heart Utilities (GHU). The fluoridation program continued under the auspices of GHU, and in 1999 the rewritten Fairbanks General Code (FGC 82-1) continued the mandate for fluoridation under the administration of Golden Heart Utilities. The present version of the Fairbanks City Code retains the language of Section 82-1 as it existed in 1999.

The only formal attempts to discontinue the fluoridation program took place in 2008. On February 25 of that year a proposed ordinance to prohibit the addition of fluoride to the GHU water supply failed in a vote of the City Council. In July 2008, a city resident submitted an application for an initiative proposing that FGC 82-1 be repealed and reenacted to read:

Fluoride should not be added to City community water systems. Water utilities that own or operate community water distribution systems in the City shall not add fluoride, in any form, to the water system. All water utilities owning or operating community water systems in the City shall conduct periodic water quality testing.

The required signatures were not submitted by the deadline of August 12, so the initiative did not go on the October ballot. The city took no additional action on the fluoridation issue until February 8, 2010, when the City Council passed Resolution No. 4398, establishing a task force to research issues related to the fluoridation of the municipal water supply.

### United States

In the early 1900s, research, largely by dentist Frederick McKay and Dr. G. V. Black of the Northwestern University Dental School, documented that many residents in several areas of the western U.S. had mottled teeth and, in severe cases, brown stains (“Colorado brown stain”) on their permanent teeth. McKay also noticed that the mottled teeth were resistant to decay. By the 1930s it had been determined that these conditions (today known as fluorosis) were caused by high concentrations of fluoride (ca. 4–14 ppm) in drinking water. In the ensuing years, Dr. H. Trendley Dean conducted a series of epidemiological studies and reported that (1) fluoride concentrations of up to 1.0 ppm in drinking water did not cause the more severe forms of dental fluorosis and (2) a correlation existed between fluoride levels in drinking water and reduced incidence of dental decay

(Dean et al., 1941). Dean's work led Dr. Gerald Cox and associates to publish in 1939 the first paper in which fluoridation of public water supplies was proposed (Cox et al., 1939).

In the 1940s, four classic, community-wide studies were carried out to evaluate the addition of sodium fluoride as a caries-reduction strategy in Grand Rapids, MI; Newburgh, NY; Brantford, Ontario; and Evanston, IL. Based on the overwhelmingly positive evaluations of these pilot studies by scientists and dental professionals, water fluoridation programs were instituted in a number of large U.S. cities in the following two decades. In addition, alternative methods of administering fluoride to combat caries were developed, the most notable being the introduction of fluoridated toothpaste in 1955.

However, as water fluoridation programs spread, so did opposition to the practice. In 1965, the first lawsuit in the U.S. contesting the legality of fluoridation of public water supplies was settled by the New York State Supreme Court, which denied the plaintiff's case "at least until some proof is advanced that fluoridation has harmful side effects" (Graham and Morin, 1992, p. 215). In the ensuing years a number of lawsuits contesting fluoridation of public water supplies have been pursued, but in no case have the plaintiffs been successful in stopping the practice (see Legal/Ethical Issues, chapter 4).

The relevant federal, state, and professional organizations have endorsed and promoted the fluoridation of public water supplies for the past fifty years. As a result, in 2008, forty-six of the country's fifty largest cities provided fluoridated water, and approximately 60% of the U.S. population consumed fluoridated water (Fagin, 2008). The U.S. Public Health Service (USPHS) has set a goal of "at least 75% of the U.S. population served by community water systems should be receiving the benefits of optimally fluoridated water by the year 2010" (U.S. Department of Health and Human Services [HHS], 2000, p. 205). However, the actions of communities on this front are mixed. One summary (Juneau Fluoride Study Commission, 2006) indicates that from 1998 to 2005 approximately two hundred communities in the U.S. moved to fluoridated water or decided to retain it while approximately one hundred chose to discontinue the practice. The situation in Alaska roughly mirrors the national picture. In 2006, 64% of the Alaska population received fluoridated water, up from 47% in 1993 (Whistler, 2007). However, today's statewide figure may be below that of 2006 because Juneau discontinued its fluoridation program in January 2007.

## **International**

According to the British Fluoridation Society (British Fluoridation Society, 2010), over 400 million people in sixty countries were served by fluoridated public water supplies in 2004. Countries and geographic regions with extensive water fluoridation programs include the U.S., Australia, Brazil, Canada, Chile, Columbia, Ireland, Israel, Malaysia, New Zealand, Hong Kong, Singapore, Spain, and the United Kingdom. However, especially during the period of 1970 to 1993, Japan and a number of European Countries (Federal Republic of Germany, Sweden, Netherlands, Czechoslovakia, German Democratic Republic, USSR, and Finland) discontinued water fluoridation programs. In 2003, Basel, Switzerland, ended its water fluoridation program, and in 2004 Scotland rejected plans to fluoridate water supplies.

In most or all of these situations, dental health continued to improve following cessation of water fluoridation (Ziegelbecker, 1998), presumably due to factors including enhanced dental hygiene programs, fluoride-containing table salt, fluoridated toothpaste, and improved diets. There are data to support the contention that in recent years caries rates in many areas have declined irrespective of the concentrations of fluoride in water supplies. World Health Organization (WHO) data (Peterson, 2003: Fig. 7) indicate substantial declines in DMFT among twelve-year-olds in developed countries (from about 4.7 to about 2.5) during the period 1980 to 1998 but little change among this age group in developing countries (from about 1.8 to about 2.3). Nevertheless, the World Health Organization continues to consider community water fluoridation to be an effective method to prevent dental caries in adults and children. However, it recognizes that other approaches, including fluoridated salt and milk fluoridation, have “similar effects” ([www.who.int/oral\\_health/strategies/cont/en/index.html](http://www.who.int/oral_health/strategies/cont/en/index.html)). It also recognizes the value of fluoridated toothpaste and fluoride-containing mouth rinses and gels.

For Alaska communities, perhaps the most relevant international situation is that in the neighboring country of Canada. According to the Health Canada website ([www.hc-sc.gc.ca](http://www.hc-sc.gc.ca)), each Canadian municipality retains the authority to decide on fluoridation of its water supply, and in 2005, 43% of the Canadian population was served by fluoridated water supplies (Federal-Provincial-Territorial Committee on Drinking Water, 2009). The Guidelines for Canadian Drinking Water Quality set a maximum allowable fluoride concentration of 1.5 ppm in drinking water, a level at which Health Canada believes there are no undue health risks (Health Canada, 2010). Although Canadian provincial and territorial governments regulate the quality of drinking water in their jurisdictions, Health Canada has recommended to communities wishing to fluoridate their water supplies that “the optimal concentration of fluoride in drinking water to promote dental health has been determined to be 0.7 mg/L” (Health Canada, 2010).

## **The Controversy**

From the very beginning of efforts to implement water fluoridation programs in 1945, there has been controversy (Connett et al., 2010). By the 1950s the sides were pretty well drawn. On one side were dentists and scientists from government and industry, who promoted the addition of fluoride to drinking water as a protection against dental decay. On the other side were mostly activists who contended that water fluoridation was essentially compulsory mass medication, thus a violation of individual rights, and that the risks of fluoridation had not been studied adequately. The advocates of fluoridation won the argument, in part by ridiculing the unlikely arguments of some of the opponents (e.g., the John Birch Society, which contended that fluoridation was a communist plot to poison the citizens of the USA).

A series of court cases from the mid-1960s through the mid-1980s established that local and state governments have the constitutional authority to implement fluoridation programs. These decisions were based largely on the principle that the “government interest in the health and welfare of the public generally overrides individual objections to health regulation” (American Dental Association [ADA], 2005, pp. 47–49). In light of these decisions, the argument against “compulsory mass medication” has emphasized ethical rather than legal issues (see, for example, Bryson, 2004).

During this same period, a number of scientific investigations into potential adverse effects of drinking fluoridated water were undertaken. None of these studies produced results that were universally accepted as demonstrating serious adverse health effects of water containing “optimal levels” of fluoride ion (0.7 to 1.2 ppm). However, a number of them raised significant questions about potential risks by showing some adverse health effects at fluoride concentrations of greater than 2 ppm (for example, Kurttio et al., 1999; Freni, 1994).

Around the turn of the century, a comprehensive review of the scientific literature related to water fluoridation was undertaken under the auspices of York University in the United Kingdom. The report from this review (McDonagh et al., 2000), often referred to as the York Report, noted the generally poor quality of the evidence for both beneficial and adverse effects of fluoridation. The resulting uncertainties about the benefits and risks of consuming fluoridated water fueled the controversy in that it allowed each side to discount the opposition’s arguments because of the “poor quality” of the evidence on which positions were based. While there are many examples of the arguments put forward by the two sides, two representative accounts are an antifuoridation article by Colquhoun (1998) and a profluoridation article by Armfield (2007).

Another key review of the effects of fluoride in drinking water was published by the U.S. National Academy of Sciences in 2006 (National Research Council, 2006). This review and associated recommendations were focused on EPA standards for drinking water (Maximum Contaminant Level, MCL, of 4 ppm and Secondary Maximum Contaminant Level, SMCL, of 2 ppm) and did not directly address the USPHS regulations on the lower concentrations in fluoridated public water supplies in the U.S. (0.7 to 1.2 ppm). Nevertheless, the report contains information and data relevant to the safety of fluoridated water. Evidence in the scientific literature led the review committee to conclude that water containing 4 ppm fluoride “puts children at risk for developing severe enamel fluorosis” and was “not likely to be protective against bone fracture” (National Research Council, 2006, p. 2). This review also contains analyses of a number of other adverse health effects that have been alleged to be related to fluoride ingestion, but the authors found that these allegations were either not supported by good evidence or required further study before any meaningful conclusions could be drawn. As with the York Report, the uncertainties about the risks of fluoride-containing water (compounded, in this case, by uncertainties about how conclusions based on consideration of fluoride concentrations of 2 ppm or higher relate to lower concentrations) have given both advocates and opponents of fluoridation data and arguments that they have selectively employed in supporting their opposing positions.

As time has gone on, particularly since the publication of the York and National Research Council reports, a number of professionals with expertise in dental health and toxicology have joined the opposition to fluoridation. They include dental researchers who were originally supporters of fluoridation (e.g., Colquhoun, 1998; Limeback, 2000), dentists (e.g., Osmunson, 2010a), and EPA employees (e.g., Thiessen, 2006, 2009a, 2009b, 2010; Hirzy, 2000). A “Professionals’ Statement to End Fluoridation” ([www.fluoridealert.org/prof\\_statement.pdf](http://www.fluoridealert.org/prof_statement.pdf)) had over three thousand signers as of July 2010 (although many of the signers are not identified with respect to their areas of expertise, so it is not clear that all these “professionals” have expertise in relevant areas). However, professional and governmental organizations remain supportive of water fluoridation, and it appears that the vast majority of dental health practitioners continue to support it.

There is no shortage of information; the literature search for a recent review of the efficacy and safety of fluoridation turned up over five thousand citations. However, after application of exclusion/inclusion criteria related to the quality of the research and after review of the full text of each remaining article, the author of the review selected just seventy-seven citations for inclusion (Yeung, 2008). Why has so much of the fluoridation literature been deemed to be of less than high quality? There are at least four difficulties inherent in these studies:

1. as with all epidemiological studies, those focused on the safety and efficacy of water fluoridation are complicated by a multitude of confounding variables (e.g., Taubes, 2006), not the least of which is the tremendous variability in water consumption and related fluoride dose of individuals (EPA, 2004);
2. in many cases the data cannot be interpreted without the application of sophisticated statistical methods, and even then statistical correlations do not necessarily imply causative relationships (e.g., Sigfried, 2010);
3. some of the alleged adverse effects of fluoride are associated with very rare conditions (e.g., osteosarcoma), making it difficult to detect small, but potentially significant, differences in study populations;
4. the results from studies with laboratory animals are often not complicated by confounding variables, but their relevance to humans and the concentrations of fluoride in public water supplies is often difficult to determine (Hayes, 2008, pp. 330–332).

In recent years, the difficulties associated with critical evaluation of research findings and associated conclusions have been exacerbated by the widespread use of the internet as a medium for distributing information and opinions. The opponents of fluoridation in particular have used the internet to advance their arguments and point of view. Although many of these sites contain useful information and cogent arguments, the sites and the information on them are not uniformly of high quality. In many instances it is difficult to evaluate the quality of material posted on websites focused on fluoride and fluoridation without a fairly thorough knowledge of the peer-reviewed literature.

While these scientific issues continue to be debated, it appears that within the general public the major concern is related to ethics, not quality of the research on benefits and adverse effects of water fluoridation. Thus, many opponents of water fluoridation would remain opposed to “mass medication” even if the safety and efficacy of the practice were clearly documented. So, today the controversy continues unabated. The situation is described quite well in a recent journal article:

Plans to add fluoride to water supplies are often contentious. Controversy relates to potential benefits of fluoridation, difficulty in identifying harms, whether fluoride is a medicine, and the ethics of a mass intervention. We are concerned that the polarised debates and the way that evidence is harnessed and uncertainties glossed over make it hard for the public and professionals to participate in consultations on an informed basis. (Cheng et al., 2007, p. 699)

## Findings

Throughout the United States, and in many countries around the world, the incidence of tooth decay has decreased significantly over the past several decades. Although claims have been made that adding fluoride to drinking water has been one of the main reasons for this decline, the data indicate that in many countries and communities progress in preventing caries has been made without fluoridated water.

For many years professional organizations and federal, state (including Alaska), and local governments in the United States have promoted the fluoridation of public water supplies, and these organizations and relevant government agencies still strongly support the practice. However, there has also been opposition to the practice since its inception in the 1940s. Although it appears that the vast majority of dental practitioners and researchers still support fluoridation of municipal water supplies, it also seems that the number of practitioners and researchers who oppose the practice has increased. At this time the claims most often cited by opponents of fluoridation of water supplies are:

- lack of definitive evidence for efficacy,
- evidence indicating risk of adverse effects, and
- ethical issues related to mass medication.

## Chapter 4

# Legal and Ethical Issues

As indicated by testimony to the Fairbanks Fluoride task Force, legal and ethical issues are perhaps the biggest concerns of the local residents who are opposed to fluoridation of Fairbanks' public water supply. The testimony received by the task force was overwhelmingly against fluoridation. During the ten task force meetings at which public testimony was invited, sixty-two testimonies were presented by thirty individuals (at the extremes eighteen individuals presented testimony just once, and one individual submitted testimony on six different occasions). The positions of the testifying individuals, as described by themselves or ascertained by the task force from their nature of the testimonies, were twenty-six against fluoridation, three in favor, and one with no clearly stated opinion. The major concerns voiced by the opponents of fluoridation were:

1. Toxic and harmful effects of fluoride
2. Lack of high-quality evidence that fluoride in public water supplies effectively prevents dental caries
3. Unethical aspects of “mass medication”
4. Fluoridation of public water supplies interferes with freedom of choice, infringes on individual rights, and results from an overreach of governmental powers.
5. The risk that fluoridation of public water supplies may do more harm than good

While testimony and evidence on all five of these concerns were presented to the task force, concerns 3, 4, and 5 were highlighted for the task force by both the frequency and passion of testimonies related to them. They have also been voiced in the larger debate over water fluoridation. The “mass medication” argument is that fluoridation of public water supplies administers medication to an unaware and in some cases, unwilling public (see, for example, [www.fluoridedebate.com/question34.html](http://www.fluoridedebate.com/question34.html); Cross and Carton, 2003). The “individual rights” concern (#4) is related to the previous concern in that it questions governmental authority to implement the “mass medication” (Cross and Carton, 2003). The concern that water fluoridation may do more harm than good brings into the argument the “first, do no harm” precept of medical ethics. This precept basically says that in a given situation it may be better to do nothing if the action to be taken may cause more harm than good.

The legal concerns brought to the task force were considered in light of a rather lengthy history of legal challenges to fluoridation of public water supplies (Graham and Morin, 1999). Although fluoridation has been challenged numerous times in at least thirteen states, and while cases decided primarily on procedural grounds have been won and lost by both proponents of and opponents to fluoridation, no final ruling in any of these cases has stopped a proposed fluoridation program or ruled in favor of elimination of an existing program (Block, 1986; ADA, 2005; Pratt et al., 2002). In the process, the U.S. Supreme Court has declined to review fluoridation cases at least thirteen times (ADA, 2005).

In contrast to the legal question, which has repeatedly been addressed by the courts, the ethical issues remain problematic. On the one hand, opponents of fluoridation cite concerns about the propriety of forced “massed medication” and the integrity of at least some of the individuals and organizations that promote the practice (see, for example, Bryson, 2004; Cheng et al., 2007; Connett et al., 2010). On

the other hand, some proponents have argued that those who potentially have the most to gain from fluoridation of public water supplies—the economically and educationally disadvantaged and those with limited access to proper health care—do not have a voice in the development of health policies and practices unless those in power are looking out for their interests (McNally and Downie, 2000). Cohen and Locker (2001), observe that the conflict between beneficence of water fluoridation and autonomy remains unresolved and that “there appears to be no escape from this conflict of values, which would exist even if water fluoridation involved benefits and no risks” (p. 578). Further, they argue that although recent studies indicate that water fluoridation continues to be beneficial, critical analysis indicates that the quality of evidence provided by these studies is generally poor. Thus, they argue that from an ethical standpoint, past benefits of fluoridation cannot be used to justify continuation of the practice, and they call for new guidelines that “are based on sound, up-to-date science and sound ethics” (p. 579).

## Chapter 5

# Exposure

Fluorine, which exists in its elemental form as fluorine gas, is one of the most reactive elements. Its chemical reactivity is characterized by its propensity to accept electrons and to undergo reduction to the fluoride ion. While elemental fluorine is found in just one form, the fluoride ion exists in a number of compounds, including the common minerals fluorapatite and fluorite. Fluorine is also found in a group of compounds called “organic fluorides,” compounds in which fluorine is chemically bonded to carbon. Some pharmaceuticals, consumer products, and pesticides are organic fluorides.

Concerns about the safety and efficacy of artificially fluoridated water revolve around one species, the fluoride ion—often referred to in this report as fluoride. Fluoride is easily absorbed in the human alimentary tract, is distributed to most—if not all—tissues, and is cleared from the blood and tissues by uptake into bone and by excretion (Whitford, 1996; National Research Council, 2006). It is capable of inhibiting certain enzymes (Scott, 1983, p. 166; National Research Council, 2006) and of affecting bacterial metabolism, including reducing the capability of plaque-forming bacteria to produce acid (Featherstone, 2000; Jones et al., 2005), which is the bacterial product responsible for caries. Given that fluoride has these biochemical properties, it is not surprising to find that it is toxic. The acute toxic dose of fluoride is 5 to 10 grams for a 155-pound person (Hodge and Smith, 1965; ADA, 2005). More precise determinations of toxicity have been performed with pure chemicals and laboratory rats, and these studies indicate that sodium fluoride is about ten times less toxic than sodium cyanide and about fifty times more toxic than sodium chloride (table salt).

The fluoride-containing compound of most interest in the Fairbanks situation is sodium fluorosilicate, the compound that Golden Heart Utilities (GHU) uses to fluoridate the water it distributes. Sodium fluorosilicate is toxic; for rats its  $LD_{50}$  is 125 mg/kg (that is when laboratory rats were given single doses of 125 mg of sodium fluorosilicate per kg of body weight, 50% of the test animals died). According to the National Institute of Health’s TOXNET website (<http://toxnet.nlm.nih.gov/cgi-bin/sis/search/a?dbs+hsdb:@term+@DOCNO+770>), the acute toxic dose of sodium fluorosilicate for a human is between 3.5 and 35 grams. However, the low concentration of this compound in treated water (around 1.5 mg per liter) ensures that there is no acute toxicity threat associated with the treated GHU water. Nevertheless, concerns have been voiced about risks related to the use of sodium fluorosilicate in water fluoridation programs. In particular, a correlation was reported between use of sodium fluorosilicate to fluoridate water in various locales in the state of New York and levels of lead in the blood of children residing in these communities (Masters and Coplin, 1999; Masters et al., 2000). However, this correlation was not verified in a subsequent study (Macek et al., 2006). Furthermore, a causative link between the use of sodium fluorosilicate and elevated lead levels in blood of children who consume the fluoridated water would require that sodium fluorosilicate incompletely dissociates when it dissolves in water, a proposition put forward by Westendorf (1975) but which is inconsistent with the best contemporary evidence (Urbansky, 2002).

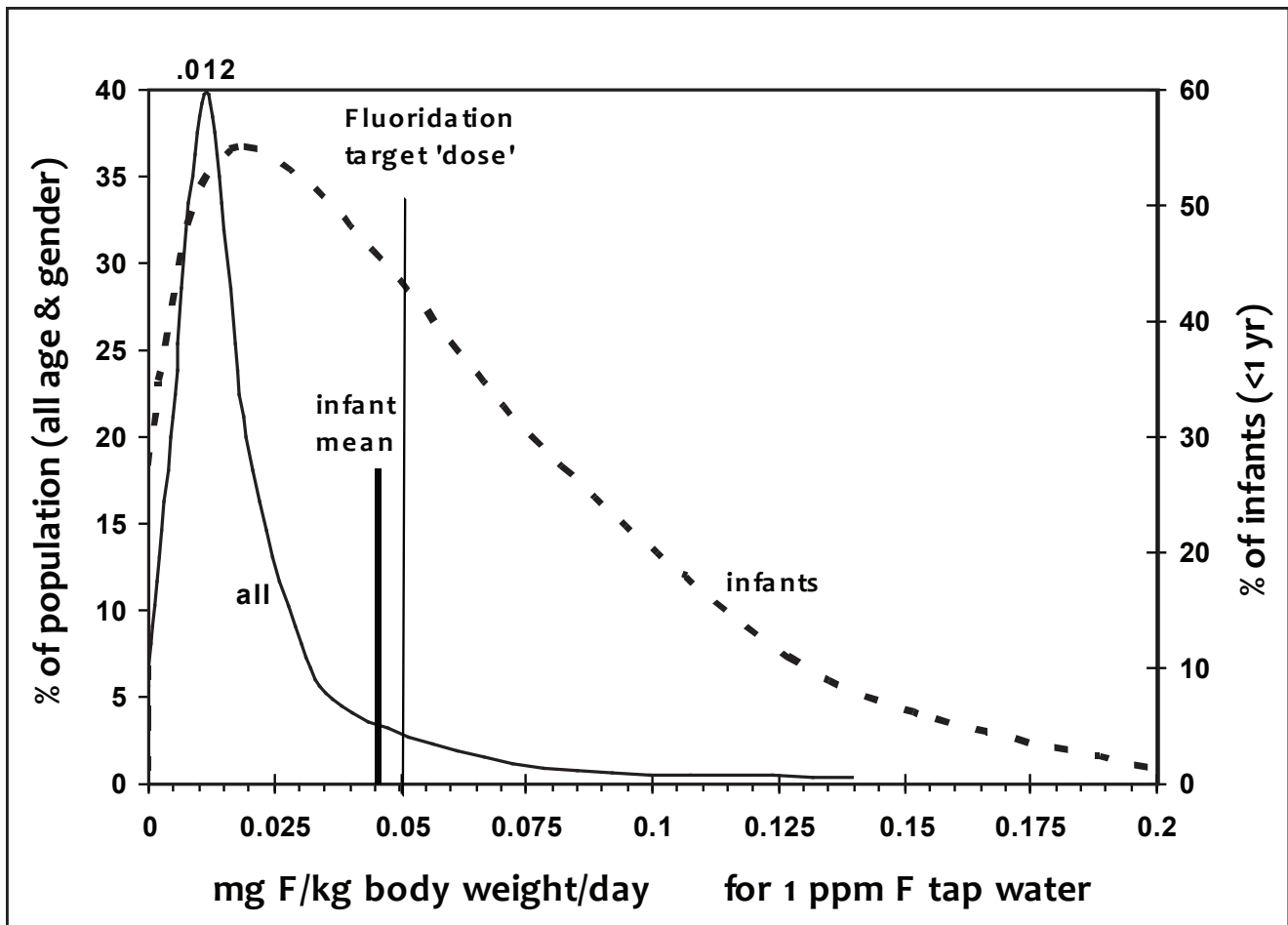


Figure 5.1. Fluoride consumption from tapwater distribution for total population (dark, solid curve and scale on left and for infants (dashed curve, scale on right). Note that only a small proportion of the population receive the target dose from tap water and that a large proportion of infants receive a dose considerably higher than the target dose. Graph constructed from data in EPA (2000).

Because fluoride is found in a number of common minerals, it is not surprising to find that it is present in many natural water systems. The concentration of fluoride in the oceans is approximately 1.3 ppm (Turekian, 1969). In the United States, fluoride concentrations in wells, lakes, and rivers range from undetectable to 16 ppm (National Research Council, 2006). For example, Lake Michigan's fluoride level is 0.17 ppm, wells in Arizona have concentrations up to 7 ppm, and groundwater in Bauxite, Arkansas, has up to 14 ppm fluoride (ADA, 2005). In Alaska, a voluminous DEC data sheet (Alaska Department of Environmental Conservation, 2010) demonstrates that although many natural water systems around the state have undetectable levels of fluoride, one area (Wales) has 2 ppm fluoride in groundwater, and several sources of groundwater in the Fairbanks area have from 0.1 to 0.3 ppm fluoride. An independent study of forty-six residential wells in the Fairbanks area by the U.S. Geological Survey showed a range of 0.1 to 1.6 ppm fluoride (USGS, 2001).

A major source of exposure to fluoride for many Americans, including those who receive GHU water, is drinking water. While this exposure is clearly related to the concentration of fluoride in

the water, it is important to distinguish between *concentration* and *dose*. The amount of fluoride (dose) an individual receives from drinking water depends on the concentration of fluoride in the water and the amount of water consumed. Thus an individual who drinks one liter of water containing 0.5 ppm fluoride receives the same dose of fluoride as another individual who drinks two liters of water containing 0.25 ppm. Various surveys have found that the amount of drinking water consumed by individuals varies considerably. For example, an EPA report (2004) states that the results from surveys done in the 1990s indicate that very young children consume an average of about 0.3 liter of drinking water per day and adults about 1 liter as opposed earlier EPA and WHO estimates of 1 L and 2 L, respectively. More importantly, the ranges of consumption are enormous: among the study subjects, infants less than one year old had water consumptions ranging from 0.03 liter to 1.5 liters, and the range among adults was from 0.1 liter to over 4 liters. The situation is further complicated by the fact that certain metal ions present in many water supplies can react with fluoride ions (before consumption) in a way that alters the uptake of fluoride from drinking water by humans (Institute of Medicine, 2000; Urbansky, 2002). For example, in seawater about one-half of the total fluoride is actually present as the  $MgF^+$  complex ion (Bethke, 1996). Therefore, it is very difficult to determine how much fluoride any individual actually consumes from drinking water on a daily basis. Furthermore, “average consumption” is meaningful for a relatively small segment of the population (see Fig. 5.1 for one representation of the situation).

Agencies of the U.S. federal government, taking into account information that documents the adverse effects of human consumption of large doses of fluoride, have issued regulations and recommendations on the concentrations of fluoride ion in drinking water. The U.S. Environmental Protection Agency (EPA) has set a maximum contaminant level (MCL) for fluoride at 4 ppm and a secondary maximum contaminant level (SMCL) of 2 ppm (to provide a margin of safety against development of fluorosis from exposure to fluoride in drinking water—see Chapter 7). In 1962 the U.S. Public Health Service adopted standards that call for fluoride concentrations between 0.7 ppm and 1.2 ppm in public water supplies that have been “artificially fluoridated” or have “adjusted” levels of fluoride. This range of concentrations was selected based on estimates of water consumption that take into account differences based on climate and the assumption that people in warmer climates drink more tap water than do residents in cooler climates.

In January 2011, just as the Fairbanks task force was finalizing the first draft of its report and recommendations, two federal agencies initiated formal processes to change policy and regulations related to fluoride exposure. In early January, the secretary of the U.S. Department of Health and Human Services (HHS) issued a notice that HHS was seeking public comment on a proposed new recommendation that communities that are fluoridating or choose to fluoridate their public water supplies adjust the fluoride concentration to 0.7 ppm ([http://www.hhs.gov/news/press/2011pres/01/pre\\_pub\\_frn\\_fluoride.html](http://www.hhs.gov/news/press/2011pres/01/pre_pub_frn_fluoride.html)). This recommendation is based on the considerations that (1) scientific evidence indicates that water fluoridation is effective in preventing dental caries, (2) fluoride in drinking water is now just one of several sources of fluoride, (3) the prevalence and severity of dental fluorosis has increased in recent years, and (4) the water consumption of children and adolescents is independent of ambient temperatures. At this writing, the HHS action is limited to initiating the public comment period and does not constitute a formal change in the HHS recommendation. A few weeks later, the EPA initiated a “Registration Review” of the pesticide sulfuryl fluoride. This chemical, used for controlling insect pests in a variety of stored agricultural products, breaks

down during application to release fluoride ions. Although the fluoride residue from sulfuryl fluoride contributes negligibly to the fluoride exposure of individual humans, this proposal is based on the EPA's assessment that "aggregate fluoride exposure is too high for certain identifiable subpopulations in the United States, in particular children under the age of seven who live in areas with higher fluoride concentrations in drinking water resulting from natural background sources" (EPA, 2011; Office of Pesticide Programs, 2011). Under the Federal Food, Drug, and Cosmetic Act, EPA must withdraw sulfuryl fluoride under these circumstances; and the action initiated at this point (invitation for public comment) is the first step in the withdrawal process.

The exposure of a given individual in the Fairbanks area to fluoride from drinking water is very difficult to assess because of the various sources of drinking water available in the area. However, for the purposes of this report, we will focus on individuals who are served by the Golden Heart Utilities water system. This distribution includes about 30,000 people (approximately 6,500 hookups) in the city of Fairbanks and an additional 10,000 or so individuals (approximately 2,200 hookups, including several water delivery services) in the surrounding area served by College Utilities. Until January of 2011 the drinking water supplied to these individuals contained, on average, 1.0 ppm fluoride. The GHU records examined by the task force demonstrated that over an extended period of time, the range of fluoride concentration in the distributed water was from 0.8 to 1.1 ppm. The variability in the concentration of fluoride was principally (maybe entirely) due to the fluctuation in fluoride concentration in the feed water for the GHU process—averaging 0.3 ppm but ranging from 0.1 to 0.5 ppm. In response to the HHS action described in the previous paragraph, in January of 2011 GHU reduced the concentration of fluoride in distributed water from 1.0 ppm to 0.7 ppm. Thus the GHU fluoridation process presently raises the fluoride concentration from about 0.3 ppm in the groundwater to 0.7 ppm in the distributed water.

The process used by GHU to produce water containing 0.7 ppm fluoride is one of the two most common approaches used elsewhere in the United States. A calculated amount of sodium fluorosilicate (SFS) is added to the raw water in a rather sophisticated treatment process. The SFS originates at KC Industries in Mulberry, Florida, where it is obtained from the domestic phosphate fertilizer industry. Each lot of SFS is analyzed and verified as meeting or exceeding American Water Works Association standards of purity before it is shipped. The material used by GHU is shipped from Florida by truck and container ship to Univar in Anchorage then by truck to Fairbanks. Univar has on record the certificates of assurance for the purity of each lot of SFS that it receives (R. Holland, personal communication). A member of the Fairbanks Fluoride Task Force conducted a laboratory analysis of a sample of SFS provided by GHU and found it to be impressively pure (Table 5.1). When used in the fluoridation process, the calculated concentrations of metal ions added from the SFS are in the parts per trillion range, well below limits set by the EPA. While there are no guarantees against accidents in which fluoride levels in distributed water could rise to a dangerous point, the GHU fluoridation process is well run and has controls in place to provide a high level of assurance of safe operation. Each year since 2006 GHU has received a "Water Fluoridation Quality Award" from the Alaska Oral Health Program (Alaska Division of Public Health). The fluoride concentration in drinking water is measured three times each day, and the concentrations of eleven metals and radionuclides are analyzed on schedules that range from every three to nine years.

Table 5.1a. Major elemental components of a random sample of KC Industries' sodium fluorosilicate<sup>a</sup>

Element	Weight %	Element	Weight %
Silicon	14.8	Fluorine	60.3
Sodium	24.9	Chlorine	0.24

Table 5.1b. Trace elements in a random sample of KC Industries' sodium fluorosilicate<sup>a</sup>

Element	ppm	Element	ppm
Aluminum	25	Arsenic	<4
Barium	<5	Bromine	132
Cobalt	<1	Chromium	<1
Copper	<5	Iron	35
Iodine	35	Nickel	<2
Phosphorous	34	Lead	<1
Antimony	<5	Thorium	<0.5
Vanadium	<1	Tungsten	<2
Zinc	<2		

Table 5.1c. Approximate concentrations of elements added to Fairbanks water after the fluoride concentration has been adjusted to 0.7 ppm

Element	ppm	Element	ppm
Silicon	0.1	Fluorine	0.4
Sodium	0.2	Chlorine	0.002
Element	ppt <sup>b</sup>	Element	ppt <sup>b</sup>
Aluminum	21	Arsenic	<4
Barium	<4	Bromine	11
Cobalt	<1	Chromium	<1
Copper	<4	Iron	28
Iodine	28	Nickel	<1
Phosphorous	28	Lead	<1
Antimony	<4	Thorium	<0.4
Vanadium	<1	Tungsten	<1
Zinc	<2		

a. Analysis by XRF at the University of Alaska Fairbanks, Advanced Instrumentation Lab

b. R. Newberry, analyst

ppt = parts per trillion

Exposure of individuals to fluoride from dental products was not an issue when fluoridation of public water supplies was first introduced in the 1940s. Fluoridated toothpaste became commercially available in 1955, and it rapidly became widely accepted as an agent for caries prevention. However, inadvertent intake of fluoride from toothpaste can be a problem, especially with children who may have poor control of the swallowing reflex. Detailed studies of fluoride ingested by children from swallowing toothpaste have led to ingestion estimates ranging from 0.1 to 0.4 mg per brushing

(Ophaug et al., 1985; Levy and Zarei-M. 1991; Rojas-Sanchez et al., 1999). A USPHS report (Institute of Medicine, 2000) summarized the findings by concluding that an average of about 0.3 mg of fluoride is introduced with each episode of tooth brushing in young children. Additional, and highly variable, amounts of fluoride may be ingested by individuals who take fluoride supplements (e.g., drops) or receive topical fluoride application by dental professionals.

Many foods and beverages contain detectable amounts of fluoride. The USDA National Fluoride Database on the fluoride content of a wide range of beverages and foods (USDA, 2004) contains an extensive list. Table 5.2 contains some representative entries.

*Table 5.2. Fluoride concentrations in selected foods and beverages available in the United States. Adapted from USDA National Fluoride Database of Selected Beverages and Foods (2004) and Lalumandier and Ayers (2000).*

<b>Food or Beverage</b>	<b>Mean (ppm)</b>	<b>Standard Deviation</b>	<b>Range (ppm)</b>
Dairy Products	0.25	0.38	0.02–0.82
Grain and Cereals	0.42	0.40	0.08–2.01
Potatoes	0.49	0.26	0.210–0.84
Leafy Vegetables	0.27	0.25	0.21–0.84
Fruits	0.06	0.03	0.02–0.08
Sugar and Substitutes	0.28	0.27	0.02–0.78
Tea (brewed)	3.7	0.6	2.6–5.3
Soda Pop or Cola	0.5	0.1	0.05–0.8
Bottled Water <sup>a</sup>	NA	NA	0.02–0.94

a. An analysis of bottled water available in Scotland found some European bottled waters to contain nearly 6 ppm (MacFayden et al., 1982).

Part of the variation in fluoride concentrations in foods reflects differences in plant metabolism (for example, tea leaves seem to sequester higher concentrations of fluoride than do the leaves of lettuce or kale). However, one notable aspect of the range of fluoride concentrations in prepared foods is what is called the “halo effect”—the result of the use of fluoridated water to prepare foods and beverages (Griffin et al., 2001). Thus, the fluoride content of processed foods and beverages reflects, in large part, the fluoride concentrations in the water used in their processing.

While the halo effect is manifested in a variety of products, perhaps the most obvious is bottled water, a product of special interest to residents of communities with fluoridated water supplies because it provides an alternative to tap water. The fluoride content of bottled water is regulated by law (see National Research Council, 2006), and it can contain up to 2.4 ppm fluoride with no requirement for a statement of fluoride content on the label, unless fluoride has been added. The large range of allowable concentrations of fluoride and the lack of a requirement for notification of fluoride content clearly compromises the utility of bottled water (as opposed to distilled water) as an alternative to fluoridated community water.

A final source of fluoride, or at least fluorine in some form, is from the air. This is largely due to trace amounts of pesticides and other industrial chemicals in the atmosphere. For the most part the

fluoridated substances in the air are organic fluorides rather than the fluoride ion found in water, dental products, foods, and beverages. Although our knowledge of the fate of fluorine from organic fluorides as the result of metabolism in the human body is very limited, it seems unlikely that the “fluoride” that comes from atmospheric sources adds significantly to the fluoride ion burden in humans.

Various estimates of the total fluoride exposure of individuals in the United States have been made, but the most comprehensive effort is probably that of an NRC committee (National Research Council, 2006). Tables 5.3 through 5.5, below, were constructed by the Fairbanks Fluoride Task Force from data in that report. The NRC committee’s estimates of fluoride exposure from water were based on estimates of water consumption (EPA, 2000), which had been used in many of the studies considered by the committee. Because updated estimates of water consumption are now available (EPA, 2004), the task force substituted the updated estimates of water consumption and repeated the calculations used to construct Tables 5.3 through 5.5. The results are displayed in Tables 5.6 through 5.8.

Table 5.3. Estimated fluoride exposure (mg/kg body weight/day) of U.S. populations on water with 1.0 ppm fluoride, based on water intakes estimated in NRC (2006)

Population	water <sup>a</sup>	toothpaste <sup>b</sup>	background food <sup>b</sup>	pesticides & air <sup>b</sup>	total exposure <sup>c</sup>	% from water
Nursing infant	.0260		.0046	.0019	.033	79
Non-nursing Infant	.0860		.0114	.0019	.099	87
1–2 year old	.0314	.0115	.0210	.0020	.066	48
3–5 year old	.0292	.0114	.0181	.0012	.060	49
6–12 year old	.0202	.0075	.0123	.0007	.041	49
13–19 year old	.0152	.0033	.0097	.0007	.029	52
20–49 year old	.0196	.0014	.0114	.0006	.033	59
50+ year old	.0208	.0014	.0102	.0006	.033	63

a. Assuming all water, tap plus other, at 1.0 ppm

b. NRC (2006), Table 2-9

c. NRC (2006), Table 2-11

Table 5.4. Estimated fluoride exposure (mg/kg body weight/day) of U.S. populations on water with 0.7 ppm fluoride, based on water intakes estimated in NRC (2006)

Population	water <sup>a</sup>	toothpaste <sup>b</sup>	background food <sup>b</sup>	pesticides & air <sup>b</sup>	total exposure <sup>c</sup>	% from water
Nursing infant	.0182		.0046	.0019	.025	73
Non-nursing Infant	.0602		.0114	.0019	.074	81
1–2 year old	.0220	.0115	.0210	.0020	.056	39
3–5 year old	.0204	.0114	.0181	.0012	.051	40
6–12 year old	.0141	.0075	.0123	.0007	.035	40
13–19 year old	.0106	.0033	.0097	.0007	.024	44
20–49 year old	.0138	.0014	.0114	.0006	.027	51
50+ year old	.0146	.0014	.0102	.0006	.027	54

a. Calculated from Table 5.3, assuming all water, tap plus other, at 0.7ppm NRC (2006)

b. NRC (2006), Table 2-9

c. NRC (2006), Table 2-11

Table 5.5. Estimated fluoride exposure (mg/kg body weight/day) of U.S. populations on water with **0.3 ppm fluoride**, based on water intakes estimated in NRC (2006)

Population	water <sup>a</sup>	toothpaste <sup>b</sup>	background food <sup>b</sup>	pesticides & air <sup>b</sup>	total exposure <sup>c</sup>	% from water
Nursing infant	.0078		.0046	.0019	.014	56
Non-nursing Infant	.0258		.0114	.0019	.039	66
1–2 year old	.0094	.0115	.0210	.0020	.044	20
3–5 year old	.0088	.0114	.0181	.0012	.040	22
6–12 year old	.0061	.0075	.0123	.0007	.027	23
13–19 year old	.0046	.0033	.0097	.0007	.018	26
20–49 year old	.0059	.0014	.0114	.0006	.019	31
50+ year old	.0062	.0014	.0102	.0006	.018	34

a. Calculated from Table 5.3, assuming all water, tap plus other, at 0.3ppm

b. NRC (2006), Table 2-9

c. NRC (2006), Table 2-11

Table 5.6. Estimated fluoride exposure (mg/kg body weight/day) of U.S. populations on water with **1.0 ppm fluoride**, based on water intakes estimated by EPA in 2004

Population	water <sup>a</sup>	toothpaste <sup>b</sup>	background food <sup>b</sup>	pesticides & air <sup>b</sup>	total exposure	% from water
Nursing infant	.017		.0046	.0019	.024	71
Non-nursing Infant	.055		.0114	.0019	.068	81
1–2 year old	.029	.0115	.0210	.0020	.064	45
3–5 year old	.026	.0114	.0181	.0012	.057	46
6–12 year old	.017	.0075	.0123	.0007	.038	45
13–19 year old	.014	.0033	.0097	.0007	.028	50
20–49 year old	.018	.0014	.0114	.0006	.032	56
50+ year old	.018	.0014	.0102	.0006	.030	60

a. Calculated from Table 5.3, assuming all water, tap plus other, at 1.0ppm

b. NRC (2006), Table 2-9

Table 5.7. Estimated fluoride exposure (mg/kg body weight/day) of U.S. populations on water with **0.7 ppm fluoride**, based on water intakes estimated by EPA in 2004

Population	water <sup>a</sup>	toothpaste <sup>b</sup>	background food <sup>b</sup>	pesticides & air <sup>b</sup>	total exposure	% from water
Nursing infant	.012		.0046	.0019	.019	63
Non-nursing Infant	.039		.0114	.0019	.052	75
1–2 year old	.020	.0115	.0210	.0020	.055	36
3–5 year old	.018	.0114	.0181	.0012	.049	37
6–12 year old	.012	.0075	.0123	.0007	.033	36
13–19 year old	.010	.0033	.0097	.0007	.024	42
20–49 year old	.013	.0014	.0114	.0006	.026	50
50+ year old	.013	.0014	.0102	.0006	.025	52

a. Calculated from Table 5.4, assuming all water, tap plus other, at 0.7ppm

b. NRC (2006), Table 2-9

Table 5.8. Estimated fluoride exposure (mg/kg body weight/day) of U.S. populations on water with **0.3 ppm fluoride**, based on water intakes estimated by EPA in 2004

Population	water <sup>a</sup>	toothpaste <sup>b</sup>	background food <sup>b</sup>	pesticides & air <sup>b</sup>	total exposure	% from water
Nursing infant	.0051		.0046	.0019	.012	43
Non-nursing Infant	.017		.0114	.0019	.030	57
1–2 year old	.0087	.0115	.0210	.0020	.043	20
3–5 year old	.0078	.0114	.0181	.0012	.039	20
6–12 year old	.0051	.0075	.0123	.0007	.026	20
13–19 year old	.0042	.0033	.0097	.0007	.018	23
20–49 year old	.0054	.0014	.0114	.0006	.019	28
50+ year old	.0054	.0014	.0102	.0006	.018	30

a. Calculated from Table 5.5, assuming all water, tap plus other, at 0.3 ppm

b. NRC (2006), Table 2-9

Several things must be kept in mind when interpreting the data in these tables:

- The average intakes of water are based on two different estimates of water consumption (NRC, 2006; EPA, 2004). The following pairs of tables allow direct comparison of the overall estimated exposures based on the differences in estimates of water intake: Tables 5.3 and 5.6, Tables 5.4 and 5.7, Tables 5.5 and 5.8.
- The range of water intakes among individuals is quite large.
- For simplicity of calculation, the estimated intake of fluoride from water assumes that all water has the fluoride concentration indicated in each table. This clearly is not the case for someone who uses several sources of water (for example, well, public system, and bottled) on a regular basis. This assumption, coupled with the range of fluoride concentrations in commercial bottled water, injects quite a bit of uncertainty into the results of these calculations.
- The estimated amounts of fluoride ingested by individuals from toothpaste are for individuals who regularly brush twice daily with fluoridated toothpaste and who have control over swallowing.
- Estimates of intakes from food (and beverages) are really just educated guesses because of variability in diets and in the magnitude of the halo effect.

Despite the limitations on the validity of the estimates of exposure, the data in the tables can be evaluated in light of recommendations made by relevant organizations of health professionals. There have been a number of recommendations through the years, and the situation is complicated by the fact that some recommendations are in terms of mg per individual per day and others in terms of mg per kg per day. In the opinion of the task force, the key recommendations are:

- Adequate daily intake (Institute of Medicine, 1997):
  - 0.0014 mg/kg/day for infants 0–6 months
  - 0.06 mg/kg/day for infants 7–12 months
  - 0.05 mg/kg/day for other children and all adults
- Upper limits:
  - Agency for Toxic Substances and Disease Registry (ATSDR): 0.05 mg/kg/day
  - Environmental Protection Agency (EPA, 2010): 0.06 mg/kg/day
  - Institute of Medicine tolerable upper intake (Institute of Medicine, 1997):
    - 0.1 mg/kg/day for newborns through age 8
    - 0.15 mg/kg/day for ages 9 through adult

The ATSDR limit (minimal risk level) is an estimate of the daily human exposure to fluoride that is likely to be without appreciable risk of adverse noncancer health effects (set, in the case of fluoride, by the lowest level of fluoride judged to be correlated with increased bone fracture rates and then divided by a “safety factor” of ten). The EPA limit (“reference dose”) is based on a “no observed adverse effect level” for mottling of the teeth. The Institute of Medicine limits (tolerable upper intake limits, or ULs), which were also endorsed by the American Dental Association in 1994 and the American Dietetic Association in 2000, are set to minimize the risk of dental fluorosis but are at or near those that have been associated with mild (Institute of Medicine, 1997) or even crippling (National Research Council, 1993) skeletal fluorosis. While these upper limit recommendations have been used in formulation of a number of public health programs, the opponents of fluoridation have often critiqued and questioned the propriety of the recommendations and have called for lower limits for exposure to fluoride (see, for example, Connett et al., 2010). The problems associated with using these guidelines to develop public policy is perhaps best illustrated by the observation that the adequate daily intakes recommended by the Institute of Medicine for individuals greater than six months of age are equal to or greater than upper limits recommended by the ATSDR and the EPA.

The relationships between estimated fluoride exposures of several subpopulations of Fairbanks residents consuming drinking water with 0.7 or 0.3 ppm fluoride can be analyzed with the aid of Figs. 5.2 and 5.3 (derived from Tables 5.7 and 5.8, respectively). In analyzing these data, it is important to keep in mind that the numbers represent “average” individuals and that the consumption of drinking water varies widely among individuals (Fig. 5.1). In the existing scenario (0.7 ppm fluoride in drinking water, Fig. 5.2), it is apparent that nursing infants (NI) and those over twenty years of age (20+ YR) are estimated to be exposed to daily fluoride doses well below those established by ATSDR, EPA, and IOM. However, non-nursing infants (NNI) and 1 to 2 year-olds (1–2 YR) receive daily doses slightly above the upper limits recommended by ATSDR but below those recommended by EPA and IOM. Three to five year olds, while apparently below the EPA upper limit, are at risk of overexposure as well. In contrast, drinking water with 0.3 ppm fluoride does not lead to estimates of clear overexposure to fluoride for any of the subpopulations (Fig. 5.3). However, any child below the age of six who consumes approximately twice the “average” volume of drinking water containing 0.3 ppm fluoride on a daily basis is also at risk for overexposure to fluoride.

In addition to the officially defined upper and lower limits for exposure to fluoride, there has been a widely accepted “optimal intake” of fluoride of 0.05 to 0.07 mg/kg/day. The optimal intake was thought to be a narrow range of doses that provide protection from caries but do not cause dental fluorosis. However, recently the concept of an “optimal” intake has been called into question because of (1) the overlap in fluoride intakes of groups of children who are caries-free and groups of children diagnosed with fluorosis and (2) the high variability in individual fluoride intakes (Warren et al., 2009).

Because the Fairbanks Fluoride Task Force had concerns about exposure of infants to fluoride and about the uncertainties associated with estimates of drinking water consumption, we performed some independent calculations. The results of the calculations for infants are displayed in Table 5.9. While the values in Table 5.9 are not identical with corresponding entries in Tables 5.3 through 5.5, the task force judges that they are sufficiently consistent, given the uncertainties and assumptions involved.

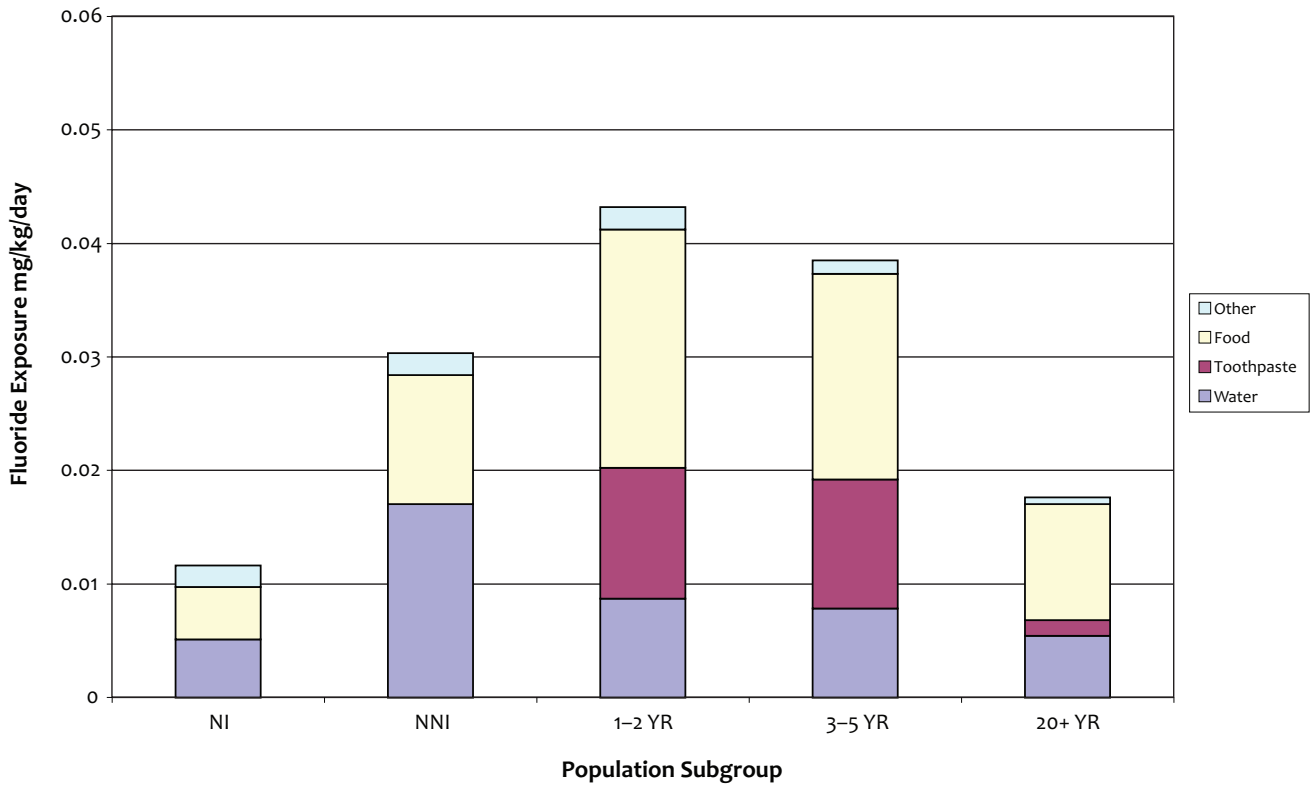


Figure 5.3. Estimates of fluoride exposure of individuals with 0.3 ppm fluoride in drinking water (data from Table 5.8). NI = nursing infant, NNI = non-nursing infant

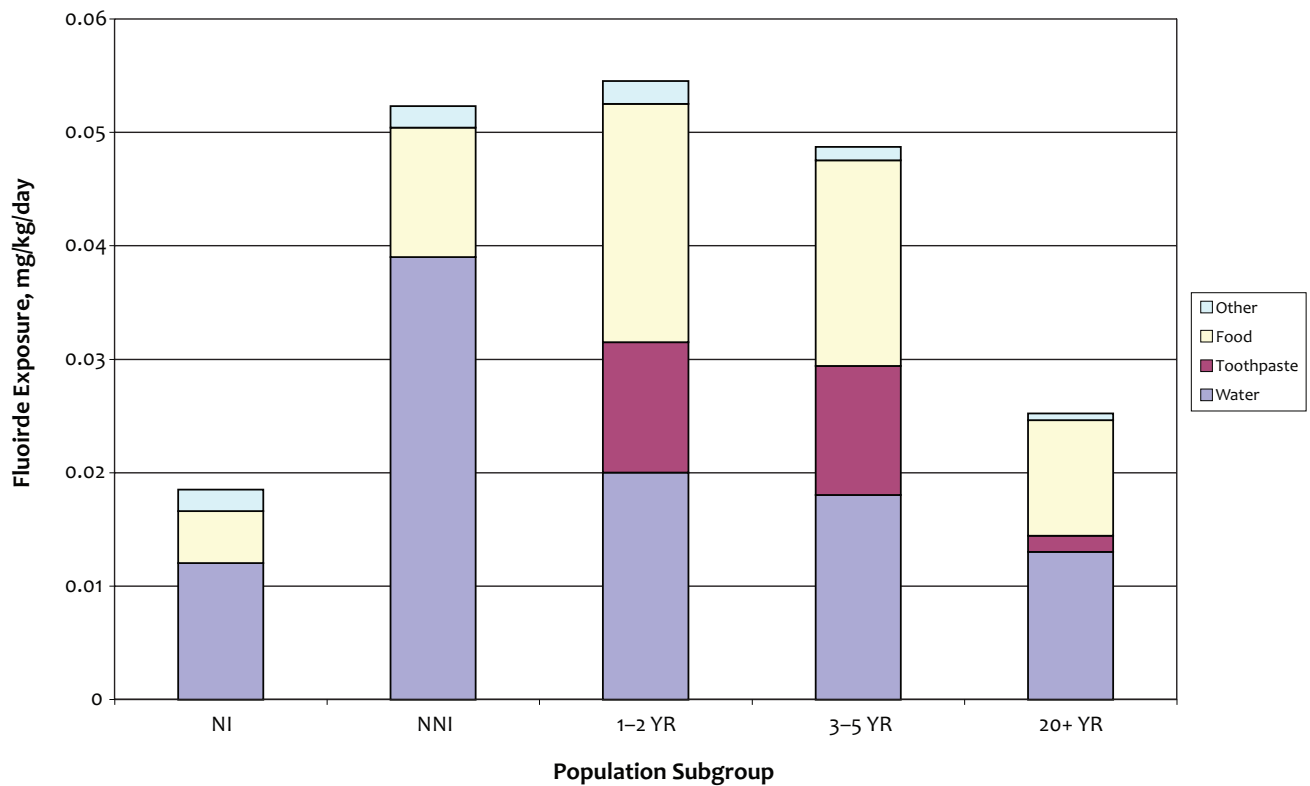


Figure 5.2. Estimates of fluoride exposure of individuals with 0.7 ppm fluoride in drinking water (data from Table 5.7)

Table 5.9. Average fluoride intake per day by non-nursing infants (mg/kg/day)

Age	1 ppm F in water	0.7 ppm F in water	0.3 ppm F in water	target dose
Birth	0.164	0.115	0.049	0.05, <sup>a</sup> 0.10 <sup>b</sup>
1 mo.	0.161	0.113	0.048	0.05, <sup>a</sup> 0.10 <sup>b</sup>
2 mo.	0.179	0.125	0.054	0.05, <sup>a</sup> 0.10 <sup>b</sup>
4 mo.	0.130	0.091	0.039	0.05, <sup>a</sup> 0.10 <sup>b</sup>
8 mo.	0.089	0.064	0.027	0.05, <sup>a</sup> 0.10 <sup>b</sup>
10 mo.	0.070	0.049	0.021	0.05, <sup>a</sup> 0.10 <sup>b</sup>
12 mo.	0.065	0.045	0.019	0.05, <sup>a</sup> 0.10 <sup>b</sup>

a. ATSDR

b. IOM (1997)

## Findings

1. The problematic relationship between fluoride concentration in drinking water and “fluoride dose,” due to varying amounts of water consumed by individuals and to other sources of ingested fluoride, severely complicates attempts to determine both health risks and benefits associated with 0.7 ppm fluoride in drinking water. In particular, commonly available foods and beverages contain from high (greater than 2 ppm) to negligible levels of fluoride, and fluoridated toothpaste is variably used and swallowed. We believe that these factors grossly complicate interpretation of drinking water studies and explain why the numerous studies conducted have come to a variety of conclusions that, in some cases, are quite different.
2. The concentration of fluoride in raw Fairbanks city water averages 0.3 ppm and is adjusted to 0.7 ppm in the treatment process. Because removing the fluoride from the raw water is impractical, the City of Fairbanks does not seem to have a realistic option for “fluoride free” city water (for a discussion of fluoride-removal processes see Fawell et al., 2006). Whatever benefits and detriments are caused by fluoride in drinking water will continue to a smaller degree if Fairbanks city water is no longer fluoridated.
3. Fluoride concentrations in Fairbanks area well water vary from 0.1 to greater than 1.0 ppm. Thus, some well water in the Fairbanks area contains more fluoride than fluoridated city water.
4. Fluoridation of Fairbanks city water has ramifications throughout the surrounding area because of the distribution of GHU water by College Utilities and several suppliers of trucked water.
5. The practice of fluoridation as carried out in Fairbanks has sufficient safeguards to protect public health beyond whatever health effects are associated with 0.7 ppm fluoride. The chemical employed is of sufficient purity and the manner in which it is added and monitored meets or exceeds standard practices.
6. An analysis of the estimates in Tables 5.3 through 5.8 and Figures 5.2 and 5.3 indicates that two segments of the Fairbanks area population must be considered separately with respect to professional recommendations on upper limits of fluoride exposure: (1) the average consumer of GHU water (fluoride concentration of 0.7 ppm) who is greater than five years of age is projected

to consume less than any of the daily upper limits set by the ATSDR, EPA, and IOM, and (2) children less than six years of age (with the exception of nursing infants) are projected to have total fluoride exposures that remain below the upper limit set by IOM but range from near to above those set by EPA and ATSDR. It appears that drinking water with a fluoride concentration of 0.3 ppm would bring total fluoride exposure for “average” drinking water consumers of all age classes to below the lowest of the recommendations of upper limits (ATSDR). However, due to the tremendous variability in amount of drinking water consumed by individuals, the fluoride exposures of significant portions of the population are not adequately represented by the average values.

7. Nevertheless, the estimates of Table 5.9 highlight additional concerns about fluoride exposure of non-nursing infants in their first year. The use of fluoridated water to make up infant formula leads to levels of fluoride consumption that exceed recommended upper limits. While the magnitude of the problem obviously declines with a decline in fluoride concentration in the water used to make up formula, the most conservative of the upper limits of fluoride exposure would be approached or exceeded even when using GHU well water (fluoride concentration averaging 0.3 ppm) to which no fluoride has been added. The American Dental Association has addressed these concerns by recommending that infant formula be made up with “water that is fluoride free or contains low levels of fluoride” ([www.ada.org/1767.aspx](http://www.ada.org/1767.aspx)). While bottled water would seem to be the water of choice, the data of Table 5.2 indicate that not all bottled waters available in the United States meet the ADA criteria. The use of bottled water for this purpose is further complicated by the absence of information about fluoride content on the labels of most bottled water. The only certainty for consumers seems to be that the distilled water sold in supermarkets has an undetectable concentration of fluoride.

## Chapter 6

# Efficacy of Community Water Fluoridation

### Evaluation of Efficacy Before 2000

The addition of fluoride was effective in reducing caries in those municipalities that were the subject of reports in the primary dental literature during the mid-twentieth century. The Ft. Collins report gives the historical background that led to widespread fluoridation of public water systems:

In 1901, a Colorado Springs dentist recognized that his patients with teeth with a brown stain or mottled dental enamel also had a very low prevalence of cavities (also called caries) (Centers for Disease Control and Prevention [CDC], 1999b). At this time in history, extensive dental caries were common, so this observation and its subsequent correlation with high amounts of fluoride ion in the water supply (2.0–12.0 milligrams per liter, mg/L) proved to be significant. Another dentist, H. T. Dean, DDS, took this information and conducted a survey of dental caries in relation to natural concentrations of fluoride in drinking water of 21 U.S. cities (Committee to Coordinate Environmental Health and Related Programs, USPHS [USPHS], 1991, pp. 18–19; CDC, 1999a, p. 934). Dean observed that at a concentration of 1 mg/L, fluoride would significantly reduce caries while causing a low incidence of mottled enamel, now called fluorosis, of the mostly very mild type. Beginning in 1945 and 1946, community trials were conducted over 13–15 years in four pairs of cities in the U.S. and Canada. These studies found a 50–70% reduction of caries in children following addition of fluoride (in the form of sodium fluoride) to community water supplies at 1 mg/L. The incidence of mild fluorosis remained low (CDC, 1999a, p. 936). Some of the early studies were criticized for lacking appropriate controls, not applying randomization, and not controlling for potential examiner bias (Sutton, 1960). However, the large effect sizes in these trials, along with replication of these findings in subsequent studies, led to the acceptance of community water fluoridation as a public health approach to caries prevention. (Fluoride Technical Study Group, 2003)

Many reviews and meta-analyses, which combine the results of several studies that address a set of related research hypotheses, support the hypothesis that water fluoridation reduces the incidence of caries. The York report (McDonagh et al., 2000) is a systematic review made to assess the evidence of the positive and negative effects of population-wide drinking water fluoridation strategies to prevent caries. It is a summary of 254 studies published from the mid-1960s to mid-1999, which were chosen for relevance from over 3,000 studies identified in the literature. The authors of the York report identified five objectives to make their assessment.

Their first objective was to answer the question: “What are the effects of fluoridation of drinking water supplies on the incidence of caries?” Of the 254 studies, twenty-six were relevant to this question. They are optimistic about the caries reductions caused by water fluoridation, yet cautious.

The best available evidence suggests that fluoridation of drinking water supplies does reduce caries prevalence, both as measured by the proportion of children who are caries free and by

the mean change in dmft/DMFT score. The studies were of moderate quality (level B), but of limited quantity. The degree to which caries is reduced, however, is not clear from the data available. The range of the mean difference in the proportion (%) of caries-free children is -5.0 to 64%, with a median of 14.6%. . . . The range of mean change in dmft/DMFT score was from 0.5 to 4.4, with a median of 2.25 teeth. . . . It is estimated that a median of six people need to receive fluoridated water for one extra person to be caries-free. . . . The best available evidence from studies following withdrawal of water fluoridation indicates that caries prevalence increases, approaching the level of the low fluoride group. Again, however, the studies were of moderate quality (level B), and limited quantity. The estimates of effect could be biased due to poor adjustment for the effects of potential confounding factors. (McDonagh et al., 2000, p. xii)

Their second objective was to answer the question: “If water fluoridation is shown to have beneficial effects, what is the effect over and above that offered by the use of alternative interventions and strategies?” Of the 254 studies, nine conducted after 1974 were relevant to this question. Again, their summary statement is positive toward the extra benefits of water fluoridation in the presence of other sources of fluoride:

In those studies completed after 1974, a beneficial effect of water fluoridation was still evident in spite of the assumed exposure to non-water fluoride in the populations studied. The meta-regression conducted for Objective 1 confirmed this finding. (McDonagh et al., 2000, p. xii).

A summary of observed effects of fluoridation on caries in children is presented in Figs. 6.1 and 6.2 (McDonagh et al., 2000, pp. 12–13).

An examination of twenty-one studies, half of which were published between 1990 and 2000, came to a similar conclusion, although without as many caveats: “According to *Community Guide* rules of evidence, strong evidence shows that CWF (community water fluoridation) is effective in reducing the cumulative experience of dental caries within communities” (Truman et al., 2002, p. 28; see <http://www.thecommunityguide.org/index.html> for more about Community Guide).

A meta-analysis of twenty studies concluded that fluoride prevents caries among adults of all ages (Griffin et al., 2007). Some details are worth noting. Water fluoridation was responsible for preventing 27% of the caries. Self- and professionally applied topical fluoride was responsible for the remaining 73% reduction. For studies published after 1980, fluoride from all sources annually averted 0.29 carious coronal and 0.22 carious root surfaces per person. The authors point out the value of all types of fluoride for low-income adults and the elderly, who may not be receiving routine dental care. Note that the York report (McDonagh et al., 2000) does not support this conclusion.

An epidemiological study in the United Kingdom addressed the question of differences in effect of water fluoridation over a range of socioeconomic groups (Riley et al., 1999). They conclude that water fluoridation reduced dental caries more in materially deprived wards than in affluent wards. In addition, the introduction of community water fluoridation substantially reduced inequalities in dental health. This conclusion is supported to an extent in the York report (McDonagh et al., 2000, p. xii), although with considerable caution due to the low quality of the evidence and the general lack of variance

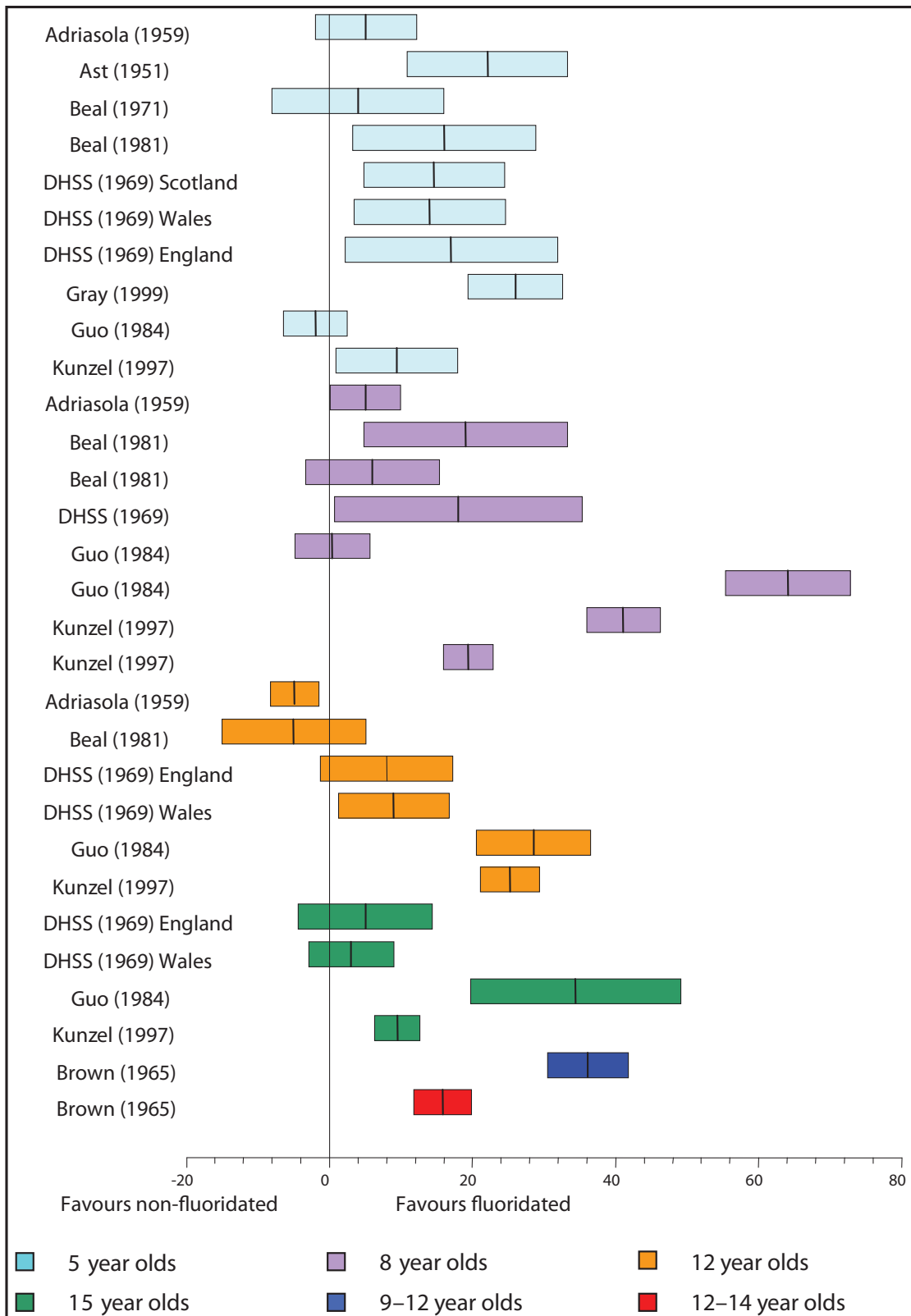


Figure 6.1. The mean difference of the change in the proportion (%) of caries-free children in the exposed (fluoride) group compared with the control group (low fluoride), for all ages extracted (color coded by age), for studies in which fluoridation was initiated after the baseline survey (McDonagh et al., 2000, p. 12)

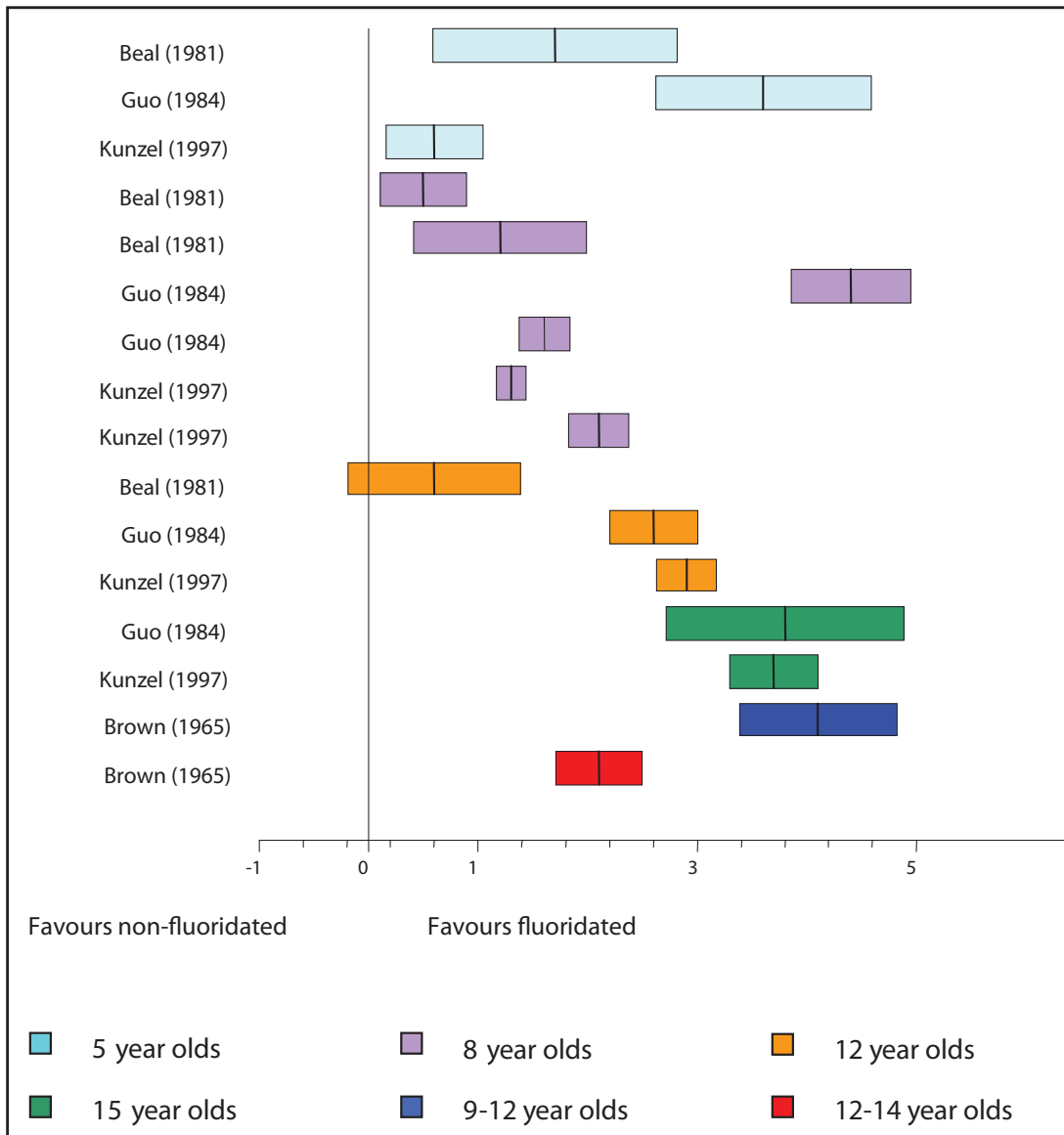


Figure 6.2. Change in dmft/DMFT Score (mean difference and 95% CI) (McDonagh et al., 2000, p. 13)

estimates in the fifteen studies. To objective 3, “Does water fluoridation result in a reduction of caries across social groups and between geographical locations, bringing equity?”, their response was

There appears to be some evidence that water fluoridation reduces the inequalities in dental health across social classes in 5 and 12 year-olds, using the dmft/DMFT measure. This effect was not seen in the proportion of caries-free children among 5 year-olds. The data for the effects in children of other ages did not show an effect. The small quantity of studies, differences between these studies, and their low quality rating, suggest caution in interpreting these results. (McDonagh et al., 2000, p. xii)

It is apparently difficult to design and execute good studies to test the hypothesis that fluoridation of public water systems decreases the incidence of caries. Questions have been raised on a regular basis about the design and analysis of studies investigating the efficacy of municipal water fluoridation for the reduction of caries incidence. Concerns about experimental design and examiner bias were raised long ago (Sutton, 1960). The York report (McDonagh et al., 2000), a meta-analysis of 214 studies published before 2000, presented relatively positive results for efficacy, with many caveats. In particular, they note the general lack of analysis, lack of control for potentially confounding factors, and the lack of any measure of variance for the estimates of decay. The difficulties of an accurate analysis and interpretation of data from a large and carefully designed longitudinal trial have been pointed out, with the observation made that “our analysis shows no convincing effect of fluoride-intake on caries development” in the permanent first molars in children between 7 and 12 years of age (Komárek et al., 2005, p. 145).

Equally important to the critical evaluation of the efficacy of water fluoridation to prevention of caries is “The Mystery of Declining Tooth Decay,” which was reported in the journal *Nature* (Diesendorf, 1986). He notes in summary that “large temporal reductions in tooth decay, which cannot be attributed to fluoridation, have been observed in both unfluoridated and fluoridated areas of at least eight developed countries over the past thirty years” (p. 125). The magnitude of the reductions observed in unfluoridated areas were generally comparable with those observed in fluoridated areas over similar periods. In his discussion of the why’s of the reductions, the author emphasized the literature that suggests changes in diet, immunity, and perhaps topical fluoride exposure with time are more likely candidates than fluoridated municipal water. The magnitude of the decrease in tooth decay is demonstrated in World Health Organization data, which was put into graphical form (Fig. 6.3) for the antifuoridation Fluoride Action Network (FAN) (Osmunson, 2010b).

The European experience has been one of generally decreasing DMFT scores. This is reported for fluoridated regions, nonfluoridated regions, and regions where fluoridation has been discontinued. In East Germany, the introduction of water fluoridation in Spremberg and Zittau brought about caries reduction averaging 48%. Surprisingly, caries levels for the twelve-year-olds of both towns significantly decreased following the cessation of water fluoridation (Kunzel et al., 2000). In Spremberg, DMFT fell from 2.4 to 1.4 (~40 %) and in Zittau from 2.5 to 2.0 (~20%). In Tiel (The Netherlands), where water fluoridation was discontinued in 1973, DMFS scores varied somewhat less consistently. The mean DMFS score increased between 1968/1969 and 1979/1980 from 10.8 to 12.7 (+18%) and then decreased to 9.6 (-26%) in 1987/1988. Overall the mean DMFS score decreased by 11% from 1968/1969, when water was fluoridated, to 1987/1988, when the town water had been

unfluoridated for fourteen years. In Culemborg, where the water was never fluoridated, the mean DMFS score decreased from 27.7 in 1968/1969 to 7.7 in 1987/1988. This decrease of 72% occurred with no fluoridation of the public water supply (Kalsbeek et al., 1993). Presuming the application of existing preventive measures, the question as to whether water fluoridation would have had an additional effect if it had been continued cannot be answered, because no communities in The Netherlands now fluoridate water.

## Evaluation of Efficacy After 2000

A recent review of community water fluoridation and caries prevention considers only recent data (Pizzo et al., 2007). Using MEDLINE as the primary database, the authors reviewed articles published from January 2001 to June 2006. They conclude that community water fluoridation is not necessary for caries prevention in modern, industrialized societies. Because the primary cariostatic action of fluoride occurs after tooth eruption, the use of topical fluoride is a more effective approach in communities where caries levels have become low. This line of thought is noted in a recent analysis published in the *British Medical Journal* (Cheng et al., 2007). The average number of decayed, missing, and filled teeth in twelve-year-old children in a number of European countries is near 1.5, and half of children have no cavities. There is no correlation in the downward trends with degree of water fluoridation. Pizzo and coworkers are cautious, however, and these cautions may be germane in Fairbanks. They state that “water fluoridation may still be a relevant public health measure in populations where oral hygiene conditions are poor, lifestyle results in high caries incidence, and access to a well-functioning oral health care system is limited” (p. 192).

An evaluation of three reviews culled from fifty-nine publications published between 2000 and 2008 resulted in positive support for the effectiveness of water fluoridation in prevention of dental caries (Parnell et al., 2009). Two of the reviews have been discussed previously and they include mostly older literature (McDonagh et al., 2000; Griffin et al., 2007). The third review (National Health and Medical Research Council, 2007) identified one systematic review (Truman et al., 2002) and one cessation study (Seppa et al., 2000) published since the York review (McDonagh et al., 2000). As noted above, the Truman study was strongly positive toward water fluoridation. In contrast, the Seppa study showed no evidence of increased caries when a previously fluoridated town reverted to nonfluoridated water. Parnell et al. concluded that the two new studies do not change the findings of the York review that “the existing body of evidence strongly suggests that water fluoridation is beneficial at reducing dental caries” (p. 143).

A recent, somewhat indirect, study makes an association between lack of water fluoridation and inclusion of Nevada youth in the high caries prevalence group (Ditmyer et al., 2010). For adolescents in the study group (the 30% highest DMFT scores, DMFT > 4.0), 27.3% lived in a water-fluoridated community. For the control group (caries free, DMFT score = 0), 64.7% lived in a water-fluoridated community. Thus, participants living in nonfluoridated communities were almost twice as likely to be in the highest DMFT group as those living in fluoridated communities.

Publications and a federal proposal made even in the past year show that the jury is very much ‘out’ with respect to questions about the efficacy of community water fluoridation at 1 ppm fluoride and about the benefit-to-risk assessment.

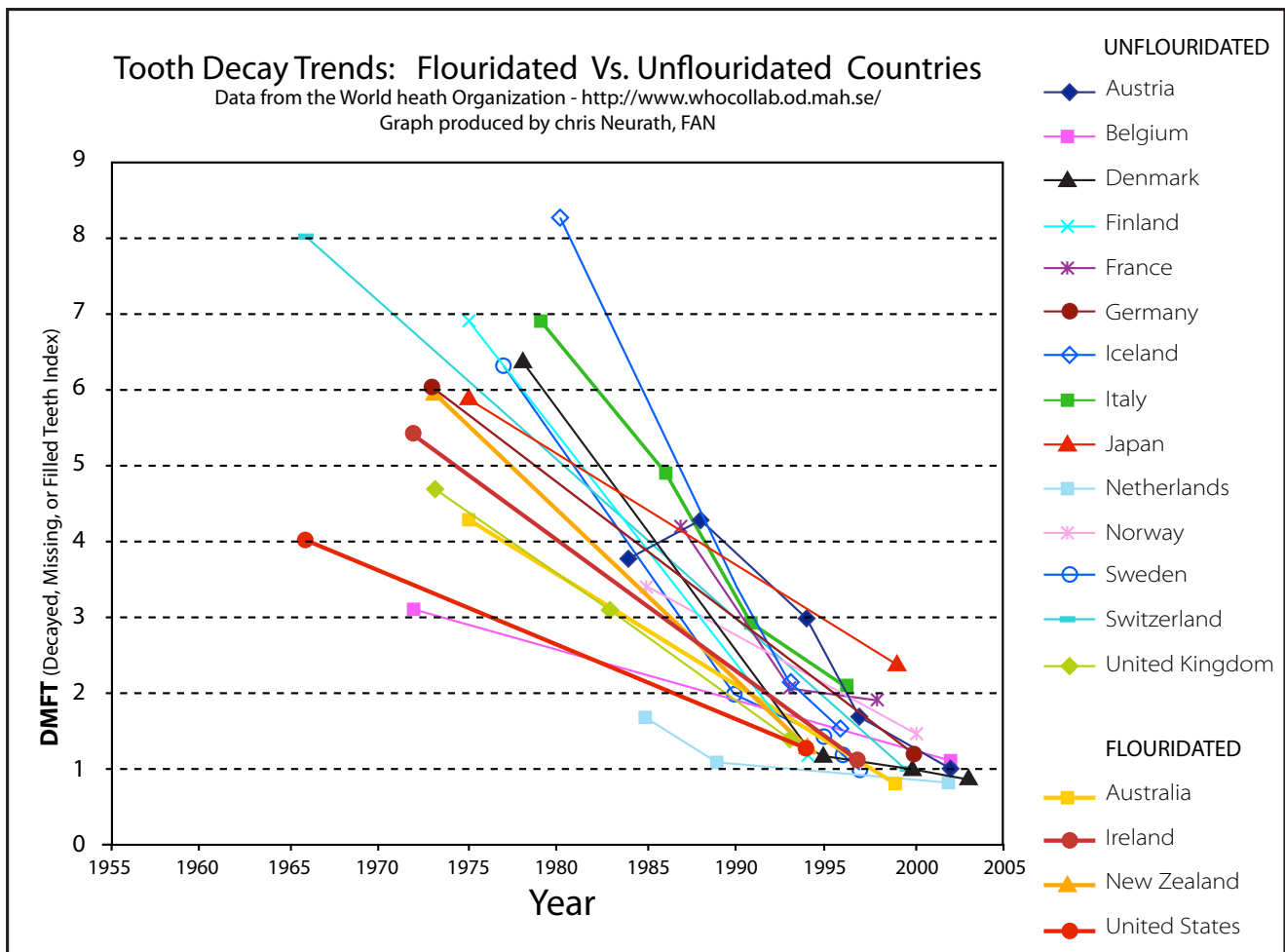


Figure 6.3. Tooth decay trends internationally in countries with fluoridated vs. unfluoridated water

- A proponent of community water fluoridation has recently written of the existing uncertainties associated with the efficacy of community water fluoridation (Newbrun, 2010). These include the effect of reducing the concentration of fluoride below 1 ppm, the expected result of discontinuing community water fluoridation in a community, and the role of socioeconomic factors in the importance of continuing water fluoridation.
- On January 7, 2011, the U.S. Department of Health and Human Services (HHS) announced a proposal recommending that water systems practicing fluoridation adjust their fluoride content to 0.7 ppm, as opposed to the previous temperature-dependent optimal levels ranging from 0.7 ppm to 1.2 ppm (<http://www.hhs.gov/news/press/2011pres/01/20110107a.html>, accessed January 27, 2011).
- An opponent of community water fluoridation has noted the 15% difference in the proportion of caries-free children reported in the York report and the 20% to 40% reduction in tooth decay reported by the American Dental Association (Thiessen, 2009a). She has no apparent objection to the numerical accuracy. However, she does put these values in context: “which would translate to < 1 decayed, missing, or filled permanent tooth (DMFT) in older children and adolescents (based on U.S. data from CDC 2005). Is this adequate justification for imposing inadequately characterized risks?” (Thiessen, 2009a, p. 3).

## Findings

1. There has never been a double blind, randomized, long-term study of the effectiveness of community water fluoridation on decreasing the incidence of caries. Nor has there been a comparable study on the effect of discontinuing water fluoridation on the incidence of caries.
2. The degree of caries reduction due to community water fluoridation was large and significant in the first decades that it was done. In recent decades, the degree of caries reduction attributed to community water fluoridation has decreased as other sources of fluoride have come into common use and as effective dental health measures have become more prevalent. The relative importance of water fluoridation is currently much smaller, more variable among populations, and perhaps unknowable.
3. The problematic relationship between fluoride concentration in drinking water and “fluoride dose” (due to varying amounts of water consumed by individuals and to other sources of ingested fluoride) severely complicates attempts to determine both health risks and benefits associated with 1 ppm fluoride in drinking water. In particular, at this time commonly available foods and beverages range from high (greater than 2 ppm) to negligible fluoride content, and fluoridated toothpaste is variably swallowed. We believe that these factors grossly complicate interpretation of drinking water studies and explain why the numerous studies conducted have come to a variety of different conclusions.
4. Studies of the relative effectiveness of community water fluoridation among socioeconomic groups give contradictory results. Dietary habits, dental hygiene, and intervention by health/dental providers are independent factors that confound the investigation of the efficacy of fluoridation of water on caries prevalence.

## Chapter 7

# Adverse Effects

### Introduction

Fluoride can clearly lead to adverse health effects in humans. However, as for most chemicals, the dose that one is exposed to is a critical factor in determining the effect(s). For example, many drugs with therapeutic benefit are toxic at higher-than-recommended doses. Further, some drugs may have a very narrow window of therapeutic benefit. That is, the dose at which the drug provides benefit may be only slightly lower than the dose leading to ill effects. We focused primarily on studies that examined the effects on humans of drinking water with fluoride concentrations of less than 2 ppm (or 2 mg/L).

In Fairbanks (Golden Heart Utilities), the water is fluoridated to a concentration of 0.7 ppm. One challenge in understanding possible adverse effects is that, depending on water consumption and other possible sources of fluoride exposure (such as toothpaste or heavy tea consumption), individuals may be exposed to widely different doses of fluoride. Another challenge is that the average expected dose may also vary by age (an infant receiving most nutrition from formula reconstituted with fluoridated water vs. an infant who is breast fed), health (for example, patients with kidney problems vs. people with normal kidney function), or other confounding factors.

In this section we rely heavily on several comprehensive review studies. Notably, we frequently cite the 2006 National Research Council (NRC) report by the Committee on Fluoride in Drinking Water, *Fluoride in Drinking Water: A Scientific Review of EPA's Standards*. Although the purpose of this well-researched report was to determine if the Environmental Protection Agency's drinking water standard of 4 ppm maximum allowable concentration for fluoride protects the public from harmful effects of fluoride, the report also provides valuable information about possible effects of drinking water containing lower concentrations of fluoride, such as those found in Golden Heart Utilities water. We supplemented information from this report with other comprehensive reviews and with refereed literature, particularly those papers published since the NRC report came out in 2006.

### Dental Fluorosis

Dental fluorosis, a mottling and/or pitting of the tooth surface due to fluoride exposure, develops in children during tooth formation when exposure to excess fluoride leads to disruption of the crystalline-enamel structure. Fluoride has a strong affinity for developing pre-eruptive enamel, leading to integration of fluoride into the crystal lattice. Teeth appear to be most susceptible to fluorosis at early maturation stages, which vary for different tooth types. For example, central incisors of the upper jaw are most susceptible at age 15 to 24 months for boys and age 21 to 30 months for girls (Fluoride Recommendations Work Group, 2001).

While some fluoride exposure during infancy is likely healthy for developing teeth, infants primarily ingesting formula reconstituted with fluoridated water, even at concentrations recommended for municipal systems, may receive doses of fluoride that could lead to more than mild fluorosis or

possibly other adverse health effects from fluoride. For example, a recent study (Levy et al., 2010) found that participants with fluorosis of permanent incisors (generally rated as mild) had significantly greater intake of fluoride from reconstituted powdered infant formula or other beverages with added water than those without fluorosis. The clinical implication suggested by the authors is that avoiding ingestion of formula or other drinks mixed with fluoridated water can reduce the likelihood of fluorosis. Because of the increased risk for fluorosis for non-nursing infants, the American Dental Association (ADA) made an interim recommendation that infant formula be reconstituted with water that is fluoride-free or containing low levels of fluoride (ADA, <http://www.ada.org/1767.aspx>). In January 2011, the ADA's Council on Scientific Affairs revised the recommendation to now say that when dentists "advise parents and caregivers of infants who consume powdered or liquid concentrate infant formula as the main source of nutrition, they can suggest the continued use of powdered or liquid concentrate infant formulas reconstituted with optimally fluoridated drinking water while being cognizant of the potential risks of enamel fluorosis development" (Berg et al., 2011). For slightly older children (16 to 36 months), fluorosis risk was increased with higher fluoridated toothpaste ingestion. To avoid fluorosis, ingestion of toothpaste should be reduced through parental supervision and using only a small smear of toothpaste when brushing.

The results of fluoride exposure on developing teeth range from mild discoloration to highly stained and pitted teeth, depending on the concentration of fluoride and to a certain degree the susceptibility of the individual (NRC, 2006; Fagin, 2008). Severe enamel fluorosis characterized by pitting results in teeth that are very susceptible to dental caries. Severe fluorosis is estimated to occur at a rate of about 10% among children drinking water at the current EPA maximum allowable fluoride concentration (4 ppm) (NRC, 2006). The incidence of severe dental fluorosis is near zero where fluoride in water is below 2 ppm (NRC, 2006). But fluoride ingestion at levels commonly used to fluoridate water (1 ppm) can lead to mild to moderate levels of fluorosis. In its mildest form, fluorosis leads to opaque areas on the teeth. Estimates in the literature on the incidence of fluorosis vary, but it can be expected that at least 30% of school-aged children who consume water with between 0.7 and 1.2 ppm fluoride will have very mild or more severe dental fluorosis (Heller et al., 1997). A more recent study reported that the incidence of fluorosis has increased since the 1980s, and an analysis of data from 1999 to 2004 found that the prevalence of dental fluorosis in adolescents aged 12 to 15 is 41% (Centers for Disease Control and Prevention, 2010b). This condition has not been linked to other adverse health effects (Fagin, 2008). However, even mild fluorosis is considered by some to be of cosmetic concern. Since fluorosis cannot be reversed, treatment requires costly cosmetic dentistry where teeth are coated to hide the effects.

There are challenges to determining the relationship between fluorosis and dental caries. One challenge is consistent diagnosis of mild dental fluorosis, which is subjectively rated using various rating scales. Another challenge is that there is some evidence that fluoride delays the eruption of permanent teeth, thus affecting studies comparing caries rates in children of different age groups exposed to varying fluoride concentrations (NRC, 2006). A final challenge that affects all studies linking water fluoridation to both positive and negative health effects is that the concentration in water can lead to widely different individual doses, depending on water consumption and exposure to other sources of fluoride.

## Bone Effects and Skeletal Fluorosis

Since about 50% of ingested fluoride not excreted is deposited in bone, and 99% of the fluoride in a human body is contained in the skeleton (cited in Bassin et al., 2006), a number of studies have examined the effects of fluoride on bone. Ingestion of fluoride at very high concentrations results in thickened bone and can lead to bone deformities (skeletal fluorosis). Debilitating skeletal fluorosis is rare in the U.S. (NRC, 2006), and there is no evidence that ingestion of fluoride at levels used to treat drinking water leads to significant skeletal fluorosis. However, exposure to fluoride at relatively high concentrations has been linked to an increased risk of bone fractures because fluoride incorporation, while increasing bone density, also leads to a decrease in bone strength. The Committee on Fluoride in Drinking Water (NRC, 2006) found that people consuming drinking water containing 4 ppm or greater fluoride over their lifetime had an increased risk of bone fractures. However, they could not reach a conclusion about the relationship between consumption of water containing lower concentrations of fluoride and risk of bone fractures.

There are a number of studies on the relationship between fluoride consumption and bone fractures. Interestingly, since fluoride is known to increase bone density, treating patients at risk of osteoporosis with fluoride was once a clinically accepted strategy. However, studies suggesting, at best, no protection against fractures and a high level of side effects have led to a decline in fluoride treatment (Vestergaard et al., 2008). Studies are confounded by factors that include the possibility that fluoride may affect different bones differently (NRC, 2006). Two comprehensive reviews of the literature have concluded that there is no clear association between hip fractures (either positive or negative) or osteoporosis and water fluoridation (McDonagh et al., 2000; Yeung, 2008). Overall, the data suggesting an increased risk of bone fractures in populations drinking fluoridated water in the concentration range recommended for drinking water are not conclusive.

## Cancer

The potential link between fluoride and cancer, most specifically osteosarcoma, is an area of recent controversy. Since fluoride incorporates readily into developing bone and increases the proliferation of osteoblasts, it has been hypothesized that there could be a link between fluoride and osteosarcoma. Published studies have drawn different conclusions about whether or not there is a relationship, in part complicated by the relative rarity of this type of cancer. But several studies have indicated a potential link, including a 1990 study conducted by the U.S. National Toxicology Program (Bucher et al., 1991). In this study, where rats were exposed to high levels of fluoride, there appeared to be a relationship between osteosarcoma frequency in male rats and the level of exposure to fluoride.

A more recent paper by Bassin et al. (2006) on humans used a case-control approach to assess the patient history of 103 patients with osteosarcoma matched with 215 controls. The authors concluded “our exploratory analysis found an association between fluoride exposure in drinking water during childhood and the incidence of osteosarcoma among males but not consistently among females.” Interestingly, Dr. Bassin’s PhD supervisor, Chester Douglass, challenged the data in a rebuttal published in the same issue of the journal that the Bassin et al. paper appeared (Douglass and Joshipura, 2006). In that rebuttal he suggested that a paper was forthcoming with more extensive data that would show no link. To date, no such paper has been published. Our task force committee chair

contacted Dr. Douglass by e-mail to try to get more information. Dr. Douglass was not forthcoming with information, only stating that: “A paper has been submitted to a scientific journal for publication. Thank you for your interest.” A literature search in late November 2010 did not find a publication on this topic by Dr. Douglass.

While the Bassin paper is intriguing, the authors admit that the results are in contrast to several other case control studies (see Bassin et al., 2006) that found no link between fluoride consumption and osteosarcoma. They were careful to outline limitations to their preliminary study, including lack of data on actual consumption of fluoride by their subjects, lack of data on other potential unidentified factors, and selection bias. The authors cautiously referred to their study as “exploratory” and urged that “further research is required to confirm or refute this observation.” Unfortunately, as of 2010 it appears that no more comprehensive studies have been published that might shed light on a possible link between fluoride consumption and osteosarcoma. We find that although there may be such a link, the data published to date suggesting a link are limited and published studies are conflicting in their conclusions. This conclusion is supported by comprehensive reviews of the literature (Yeung, 2008; McDonagh et al., 2000), which both concluded that there is no clear association between water fluoridation and overall cancer incidence and mortality.

## Other Effects

**Endocrine Effects:** Fluoride exposure has been shown to affect some endocrine glands and may function as an endocrine disruptor. Although fluoride is generally not thought to accumulate in soft tissues, there is evidence that it may accumulate in the thyroid where exposure can lead to decreased thyroid function. According to the NRC’s *Fluoride in Drinking Water* report (2006), many effects of low-dose fluoride exposure may be “subclinical effects, meaning there are no adverse health effects.” However, they also point out that “borderline hormonal imbalances” might lead to an increased risk of adverse health effects. Their report concluded that studies to date on the effects of fluoride on endocrine function have limitations and that further research is needed to explore the possible connections between fluoride, particularly at low doses, and endocrine function. Additional research is important since there is some indication that concentrations of fluoride in drinking water of 4 ppm or less may affect endocrine function in “young children” or in “individuals with high water intake.”

**Neurotoxicity and Neurobehavioral Effects:** A number of studies have reported changes to the nervous system following fluoride exposure that could lead to functional effects. Of the neurobehavioral studies, epidemiological studies suggesting a link between fluoride exposure and cognitive abilities are of particular interest. For example, several Chinese studies have consistently reported lower IQs in children drinking water containing 2.5 to 4 ppm fluoride (e.g., see NRC, 2006). The mechanism of the action of fluoride on IQ is not clear (Tang et al., 2008) but could be related to changes in membrane lipids in brain cells or to effects of fluoride on thyroid activity. It is unclear how the Chinese studies relate to U.S. populations, since U.S. populations are generally exposed to drinking water with less than 2.5 ppm and there may be other confounding factors affecting the Chinese communities studied. Although the NRC’s Fluoride in Drinking Water committee (2006) did not include neurological effects on their list of adverse effects not protected by the current EPA maximum allowable concentration for fluoride in drinking water, they did strongly advise that because of the “consistency of the results” in studies, such as those conducted

on Chinese populations, additional research on the effects of fluoride on intelligence and on other neurological processes is warranted. A literature search conducted in December 2010 did not find published results that provide new information. It appears that there is reasonably good evidence that fluoride in drinking water at concentrations above 4 ppm may have neurological effects, including an effect on cognitive abilities. But the effects, if any, at lower concentrations of fluoride are not clear.

**Effects on Other Organ Systems:** Other systems that may be affected by fluoride exposure include the gastrointestinal system, kidneys, liver, and immune system. The NRC committee (2006) found a lack of well-documented studies on humans exposed to drinking water at 4 ppm or less for all of these systems. They concluded that the risk of adverse effects was likely to be low for most individuals drinking water with fluoride at 4 ppm but that there is a possibility of adverse effects in particular subpopulations such as those with renal impairment. In an apparent response to the possibility of an increased risk of adverse health effects for renal-impaired patients, the National Kidney Foundation recently changed its position on fluoridated water from “safe” to “takes no position” and “further research is needed” ([www.kidney.org/atoz/pdf/Fluoride\\_Intake\\_in\\_CKD.pdf](http://www.kidney.org/atoz/pdf/Fluoride_Intake_in_CKD.pdf)).

## Findings

1. The problematic relationship between fluoride concentration in drinking water and “fluoride dose” (due to varying amounts of water consumed by individuals and to other sources of ingested fluoride) severely complicates attempts to determine both health risks and benefits associated with 1 ppm fluoride in drinking water. In particular, at this time commonly available foods and beverages range from high (greater than 2 ppm) to negligible fluoride content, and fluoridated toothpaste is variably swallowed. We believe that these factors grossly complicate interpretation of drinking water studies and explain why the numerous studies conducted have come to a variety of different conclusions.
2. The only commonly agreed-upon adverse effect related to drinking water with 1 ppm fluoride is mild dental fluorosis. Although debate continues concerning the quality of the studies, there are a large number that report deleterious effects from elevated fluoride in drinking water. On the other hand, numerous communities around the world use drinking water with natural fluoride concentrations of 1 ppm with no obvious ill effects, aside from mild dental fluorosis.
3. A fluoride concentration in water of 4 ppm is not protective for several adverse effects, including bone effects. That means that at best there is only a safety factor of about six for persons drinking Fairbanks water fluoridated to 0.7 ppm.
4. Although there may be a link between fluoride and osteosarcoma, the data published to date suggesting a link are limited and published studies are conflicting in their conclusions.
5. Fluoridated water is not recommended for all consumers. Recently several organizations have recommended using fluoride-free water to reconstitute infant formula, and the American Dental Association has recognized that infants primarily consuming formula reconstituted with optimally fluoridated water may be at risk for development of enamel fluorosis. Despite those recommendations and cautions, pediatricians in the Fairbanks area (polled by committee member Dr. Medford) were not aware of these recommendations. The National Kidney Foundation has also changed its position on fluoridated water from “safe” to “takes no position” and “further research is needed.”

6. Research on possible adverse effects of drinking fluoridated water (at concentrations less than 2 ppm) on the endocrine glands, nervous system, or other organ systems has showed mixed results, with many studies showing no effects. However, studies involving extensive review of the literature (e.g., McDonagh et al., 2000; NRC, 2006) recommend that more high-quality research is warranted.

## Chapter 8

# Socioeconomic Issues

One of the public policy arguments put forward for fluoridation of public water supplies has been that it reduces disparities in dental health among populations. The argument goes that, if fluoridated water reduces the incidence of caries, it seems reasonable that the availability of fluoridated water for an entire community should provide particular benefit to those with the greatest risk of developing caries. This argument has been strongly put forward by professional organizations and government officials, including former U.S. Surgeon General David Satcher who “noted that water fluoridation is a powerful strategy in efforts to eliminate health disparities among populations” (ADA, 2005, p. 46).

For decades it has been noted that members of lower socioeconomic categories have significantly higher rates of caries than those who are more fortunate (Kozol, 1992; CDC, 2010a), so fluoridation should provide particularly valuable benefits to these groups. The refereed literature contains numerous reports that support (for example, Riley et al., 1999; Jones and Worthington, 2000) and refute this proposal (for example, Bradnock et al., 1984; Carmichael et al., 1989). McDonough et al. (2000) could reach no clear consensus on whether this public policy argument is valid, and shortly thereafter Cohen and Locker (2001) concluded that there is “little evidence that water fluoridation has reduced social inequalities in dental health” (p. 579). However, the most recent reviews of the matter tend to be guardedly positive (Cheng et al., 2007; Pizzo et al., 2007; Parnell et al., 2009; Newbrun, 2010). Newbrun’s review provides a good example of the dilemma. It cites evidence in support of the proposition but concludes by stating, “whether fluoridation reduces disparities in caries is a continuing research question.”

Arguments that members of lower socioeconomic groups disproportionately benefit from fluoridation of public water supplies raise questions about the existence of evidence that these groups also bear elevated risk of adverse effects from consuming fluoridated water. While the task force could find no good evidence on this topic, it does note that there is documentation that breast-feeding rates among mothers from lower socioeconomic groups are lower than those of their more affluent counterparts (Scanlon et al., 2010). Thus the task force’s concerns about the exposure of formula-fed infants to fluoride (see Chapter 5) are particularly directed toward those from lower socioeconomic groups.

### **Finding**

Although claims are made both that the detriments and the benefits of fluoridated water are greater for those in lower socioeconomic status, documentation of this is not conclusive.

## Chapter 9

# Cost

The proponents of water fluoridation continue to tout its cost effectiveness. For example, both the Centers for Disease Control and Prevention (CDC, 2010a) and the American Dental Association (ADA, 2005) claim that the fluoridation of public water supplies in the United States costs between approximately \$0.50 and \$3.00 per person per year and provides something on the order of \$40 per person in annual benefits (decreased costs of dental care) for every dollar invested. However, both costs and benefits are very difficult to identify and quantify in any generally agreed upon and reliable way, so there is widespread disagreement about the legitimacy of any of these estimates.

In Fairbanks, the only clearly quantifiable cost of the water fluoridation program is the annual GHU expenditure for sodium fluorosilicate, which is \$10,000 to \$12,000 per year. The additional indirect costs to GHU for handling the material, adding it to the water, and monitoring the concentration of fluoride in the distributed water are difficult to estimate but are probably negligible in that these duties are incorporated into the work schedules of employees who dedicate the majority of their time and effort to other responsibilities. Similarly, while there are real costs associated with the purchase, operation, and maintenance of equipment used in the fluoridation process, those costs have never been documented but are probably modest.

No attempts have been made to quantify indirect medical and dental costs or benefits resulting from the fluoridation of Fairbanks water.

### **Finding**

There is little in the way of reliable data that can be used to estimate the cost of fluoridating Fairbanks' water. In some sense the cost of fluoridation is not an issue at all because the city does not directly pay for the process; rather it pays GHU to provide city water. The relevant question of how the terms of the contract between the city and GHU would change if fluoridation were discontinued can probably only be answered by the results of an after the fact negotiation.

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## Appendix A Resolution

Introduced By: Council Member Cleworth  
Introduced: February 8, 2010

### RESOLUTION NO. 4398

#### A RESOLUTION ESTABLISHING A TASK FORCE TO RESEARCH CURRENT POLICY REGARDING FLUORIDATION OF THE MUNICIPAL WATER SUPPLY.

**WHEREAS**, the health and security of Fairbanks citizens are a primary concern of the City Council; and

**WHEREAS**, the use of fluoride in the City's water supply was established in 1960 (FGC Sec. 82-1) as a way to enhance dental care; and

**WHEREAS**, this practice has raised questions regarding potential long-term effects caused by the use of fluoride; and

**WHEREAS**, it is advisable to periodically reanalyze this policy to make sure the potential benefits outweigh any potential side effects associated with fluoridation; and

**WHEREAS**, the amount of research available on this subject is voluminous and often extremely technical.

**NOW, THEREFORE, BE IT RESOLVED**, that a committee is formed consisting of the six individuals listed below to research documentation provided by both proponents and opponents of fluoridation through public hearings and to supplement this information with any other sources deemed appropriate. A final report along with analysis and recommendations will be presented to the City Council no later than early July. Legal notifications and assistance will be given by the City Clerk's office. The committee consists of individuals having extensive backgrounds in chemistry, biology, dentistry, and medicine, who have expressed a strong interest in objectively analyzing research regarding fluoridation.

Committee Chair: Dr. Paul Reichardt, former Provost, Dean, and Professor at UAF, with a Ph.D. in Organic Chemistry;

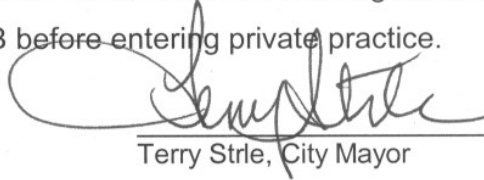
Dr. Dick Stolzberg: Professor Emeritus of Chemistry at UAF, with a Ph.D. in Chemistry, who has done extensive research in the field of analytical chemistry;

Dr. Rainer Newberry: Professor in Geochemistry, Mineralogy, and Economic Geology, with a Ph.D. in Economic Geology;

Dr. Bryce Taylor: Doctorate of Dental Surgery, formerly serving in public health with the TCC, now in private practice;

Dr. Joan Braddock: Most recently Dean of the College of Natural Science and Mathematics, with a Master's Degree in Microbiology and a Ph.D. in Oceanography;

Dr. Beth Medford: Board Certified Pediatrician with a background in biochemistry; formerly at Eielson AFB before entering private practice.




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Terry Strle, City Mayor

AYES: Roberts, Eberhart, Gatewood, Bratcher, Cleworth, Stiver  
NAYS: None  
ABSTAIN:  
ABSENT:  
ADOPTED: February 08, 2010


ATTEST:



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Janey Hovenden, CMC, City Clerk

APPROVED AS TO FORM:



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Paul J. Ewers, City Attorney