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# Water Fluoridation Principles & Practices

Sixth Edition



American Water Works  
Association

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# Water Fluoridation

## INTRODUCTION

The goal of this manual is to assist with the planning and operation of fluoridation systems by decision makers, design engineers, and water utility personnel. This chapter discusses fluoride occurrence, growth of community water fluoridation, and legal issues surrounding fluoridation. The regulatory requirements of community water fluoridation are also addressed, including both federal regulations and the varying approaches states have used to implement fluoridation programs. Additionally, fluoridation outside of the United States is discussed.

Fluoridation in this manual refers to the addition of fluoride to drinking water to maintain a recommended level to improve oral health. Fluoridation was named as one of the Ten Great Public Health Achievements in the 20th Century by the Centers for Disease Control and Prevention (CDC) along with the use of chlorine for disinfection of public water supplies (CDC Morbidity and Mortality Weekly Report, April 2, 1999). Control of infectious diseases has resulted from clean water and improved sanitation. Infections such as typhoid and cholera transmitted by contaminated water, a major cause of illness and death early in the 20th century, have been reduced dramatically by improved sanitation. Water fluoridation was first implemented in 1945, and in 1951, the National Research Council (NRC) of the National Academy of Sciences (NAS), the US Surgeon General, and professional organizations including the American Water Works Association (AWWA) and the American Dental Association (ADA) recommended that communities implement water fluoridation. The US Public Health Service (USPHS) recommended a range of 0.7 to 1.2 mg/L (based on annual average ambient temperature) as part of the 1962 Drinking Water Standards. In 2011, the US Department of Health and Human Services (USHHS) proposed changing the recommended fluoride level in drinking water to a single value of 0.7 mg/L. According to national health surveillance statistics reported by the USPHS and the CDC, the number of people with access to fluoridated water continues to increase and in 2012, 210.6 million people in the United States had access to fluoridated water.\*

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\* 2012 Water Fluoridation Statistics from the US Centers for Disease Control (CDC).

## OCCURRENCE

Fluorine, a gaseous halogen, is the 13th most abundant element in the earth's crust. Fluorine is also the most electronegative element, so it is not found in its free elemental form in nature. Instead, it exists as a mineral such as fluorosilicates in granites, calcium fluorides in some ores, along with other mineral forms, or as a dissolved reduced ionic form in solution. Fluoride ion solubility varies, but the sodium and potassium salts of fluoride are highly water soluble.

There are both natural and anthropogenic sources of fluoride. Natural sources of fluoride include volcanic and geothermal activity emissions, weathering of certain types of rocks, wind-blown erosion of soils, and marine origin. Commercial ore deposits of fluorospar, fluorapatite, and cryolite are the source for most fluoride products. Anthropogenic releases of fluoride occur predominantly because of the burning of coal for power production and are also caused by manufacturing, steel and aluminum production, and oil refining.

Fluoride is ubiquitous in the environment and therefore likely to be present to some extent in all water sources. Seawater contains approximately 1.2 to 1.5 mg/L of fluoride. The concentration present in source water is often equal to the fluoride in rainfall, which is typically 0.1 to 0.2 mg/L. However, natural levels in proximity to volcanic sources can be significantly higher because volcanic emissions are recognized as a significant environmental source. The naturally occurring concentrations in surface waters are generally lower than those needed to promote good dental health. Fluoride concentrations in groundwater can be more variable than in surface water, with the concentration dependent on the geological setting. In the United States, groundwater levels typically range from nondetectable levels to greater than 4 mg/L. However, elevated levels of naturally occurring fluoride are not common. Based on reported natural fluoride levels in community public water systems, the CDC estimates that less than 0.5% of the US population served by public water systems has natural fluoride levels exceeding 2 mg/L, and less than 0.1% of the population served by public water supplies has naturally occurring fluoride in excess of 4 mg/L. The US Geological Survey (USGS), in a survey of private groundwater wells, estimated that up to 4% of private wells exceed 2 mg/L and up to 1.2% exceed 4 mg/L (Quality of Water from Domestic Wells in the United States, Leslie DeSimone et al. November 2009). Private wells can have a higher incidence of elevated fluoride as many homeowners do not test their wells for contaminants, while public water supplies are required to report on contaminants levels and have worked to identify alternate sources when possible.

## HISTORY OF USE (GROWTH OF COMMUNITY WATER FLUORIDATION)

The importance of fluoride as a nutrient for good oral health resulted from environmental observations of communities with naturally occurring fluoride. In the 1920s and 1930s, fluoride was identified as a factor in tooth development. Investigations showed that in communities having naturally fluoridated water, fluorosis (mottled or discolored teeth) occurred when the fluoride content of the water was abnormally high. However, these teeth also showed decreased incidence of tooth decay or dental caries, which was unusual considering the large prevalence of tooth decay in that era. During the 1930s, studies concluded that the beneficial range of fluoride to prohibit dental caries while still minimizing risk of dental fluorosis was 1.0 mg/L to 1.5 mg/L, with an optimum concentration of 1.0 mg/L to achieve the beneficial level while remaining below the higher levels that could stain teeth.

Starting in 1945, initial community trials were held to test the theories that fluoride reduced tooth decay formulated over the preceding decades. In each of these trials, one

city implemented community water fluoridation, while at least one other city acted as the control. The cities had parallel characteristics except for the fluoride content of the water supply. Several of these studies, implemented between 1945 and 1947, are listed here (naturally occurring fluoride levels are given in parentheses):

1. Grand Rapids, Mich. (0.15 mg/L): Adjusted to 1.0 mg/L as part of this study. This city was compared with the control cities of Muskegon, Mich. (0.15 mg/L) and Aurora, Ill. (naturally 1.2 mg/L).
2. Newburgh, N.Y. (0.1 mg/L): Adjusted to 1.1 mg/L as part of this study. The control city for this trial was Kingston, N.Y. (0.1 mg/L).
3. Evanston, Ill.: Adjusted to approximately 1 mg/L as part of this study. This city was compared with the control city of Oak Park, Ill. (negligible amounts of natural fluoride).
4. Brantford, Ont. (0.1 mg/L): Adjusted to 1.0 mg/L as part of the study. This city was compared with the control cities of Sarnia, Ont. (0.1 mg/L), and Stratford, Ont. (naturally 1.2 mg/L).

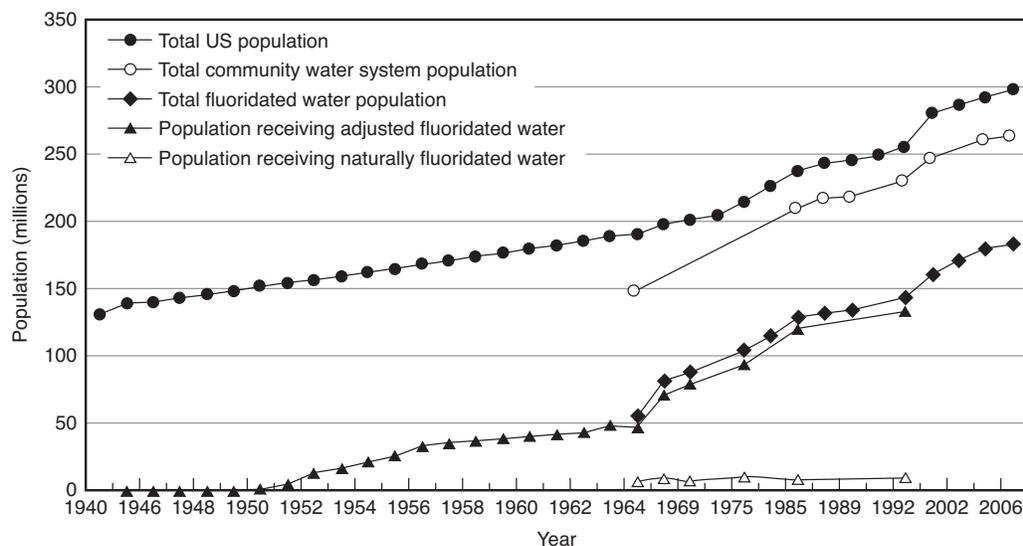
On Jan. 25, 1945, Grand Rapids, Mich., became the first city to add fluoride to its water supply. In this study, the oral health in Grand Rapids was compared with that of Muskegon, a nearby community consuming water from the same source without fluoride addition. Six years after the study began, surveys indicated that tooth decay levels in six-year-old children (i.e., those born since fluoridation commenced) in Grand Rapids was approximately half that of Muskegon.

At the time of these early community trials, poor oral health and widespread dental decay was common, so favorable results were met with great interest. The analysis of the first results from these community trials was published by the National Research Council (NRC) of the National Academy of Sciences (NAS) in November 1951 and summarized in the January 1952 issue of *Journal AWWA* (Vol. 44, no. 1, 1–8) with the recommendation that all cities with a child population of sufficient size should fluoridate the water supply. Preliminary reports from the NRC in 1951 prompted the US Surgeon General to recommend that cities should fluoridate their water supplies. In July 1951, city officials in Muskegon decided to withdraw from the study and fluoridate the city's water supply. Similar results were observed in the other trials referenced, i.e., significant reduction in dental decay rates was observed in the cities that were fluoridating, with little or no change in the controls. Since that time, the US population receiving optimally fluoridated drinking water has continued to increase (Figure 1-1).

In 1951, major organizations such as the USPHS, NRC, US Surgeon General, and AWWA all endorsed community water fluoridation. In 1962, the USPHS recommended that fluoride in drinking water should be 0.7 to 1.2 mg/L based on ambient annual temperature to reflect the different consumption of water between warmer climates and cooler climates. In 2011, the Department of Health and Human Services proposed changing this range to a single recommended value of 0.7 mg/L to reflect modern exposures and water consumption; this is discussed in further detail in chapter 2.

The AWWA policy statement on fluoridation was adopted by the organization's board of directors on Jan. 25, 1976, reaffirmed on Jan. 31, 1982, and revised on Jan. 20, 2002, Jan. 21, 2007, and Jan. 22, 2012. The official text is as follows:

The American Water Works Association (AWWA) supports the recommendations of the World Health Organization (WHO), American Medical Association (AMA), Canadian Medical Association (CMA), Centers for Disease Control (CDC), American Dental Association (ADA), Canadian Dental Association (CDA), and other professional organizations in the medical community, for the



**Figure 1-1 Growth of community water fluoridation around the world**

Source: CDC - *Fluoridation Growth*. 2012.

fluoridation of public water supplies as a public health benefit. AWWA supports the application of fluoride in a responsible, effective, and reliable manner that includes monitoring and control of fluoride levels mandated by provincial, state, and/or federal laws and that is subject to community acceptance through applicable local decision-making processes. AWWA is committed to regular reviews of the most current research on fluoride and the positions of the medical and dental communities.

In 1945, Brantford, Ont., became the first Canadian city to add fluoride to its water as part of the community trials referenced previously. Approximately 45 percent of the Canadian population using public water supplies receives fluoridated water.

As the use of drinking water fluoridation increased in the United States and Canada, countries in Europe, South America, Africa, and Asia also began implementing water fluoridation. By the year 2004, water fluoridation was being practiced in more than 60 countries for almost 405 million people. In addition, another 50 million people have water supplies that are considered naturally fluoridated at levels sufficient for good oral health. Fluoridation is practiced extensively in Australia, Brazil, Canada, Chile, Columbia, Ireland, Israel, Malaysia, New Zealand, People's Republic of China, Hong Kong, Singapore, and the United Kingdom. In addition to US organizations such as the American Medical Association (AMA), American Dental Association (ADA), and the CDC, international organizations such as the World Health Organization (WHO) support water fluoridation.

More detailed information about fluoridation in the international community can be found in the American Dental Association's *Fluoridation Facts* document.

*Benefits of community water fluoridation.* Fluoridation is a cost-effective and practical form of preventing tooth decay. The benefits of community water fluoridation include prevention of dental caries, the ability to provide a consistent and optimized level of fluoride, and an inexpensive mechanism to provide health benefits to all, regardless of age, income, education, or socioeconomic status. Fluoridation has traditionally been justified based on the economics of a 40 to 65 percent reduction in dental caries. The CDC estimates that every \$1 invested

in water fluoridation yields an approximate \$38 in savings from dental treatment costs in most cities (Griffin et al. 2001).

## Legal Issues

Fluoridation of public water supplies has not been without controversy. Opponents of community water fluoridation have challenged its safety and effectiveness. The legality of fluoridation has been tested in the courts numerous times. Beginning in 1952, injunctions were sought in some communities to prevent the initiation or continuance of fluoridation. These cases were generally based on the following types of arguments:

- Violation of religious freedom
- Abuse of police power (the ability of the state to make laws concerning the health, safety, and welfare of its citizens)
- Infringement of personal choice through mass medication, class legislation (i.e., only children benefit)
- Violation of pure food acts
- An unreasonable or unnecessary measure, wasteful or illegal use of public funds
- An unsafe measure or nuisance
- Availability of alternative
- Breach of contract
- Deprivation of fundamental liberties

In more than 65 years of litigation, fluoridation has withstood challenges based on constitutional objections (related to the First, Ninth, Tenth, Fourteenth, and Fifteenth Amendments). It has withstood legal challenges in more than 25 states and has been upheld in the highest courts in more than a dozen states. The US Supreme Court has denied review several times, generally on the grounds that no substantial federal or constitutional questions were involved. Courts have viewed fluoridation as a proper means of furthering public health and welfare, rejecting the legal argument that fluoridation ordinances are a deprivation of freedoms guaranteed under the Constitution.

More information can be found at [www.fluidlaw.org](http://www.fluidlaw.org), which is a database maintained by American University's Washington College of Law and the Children's Dental Health Project. FLUID (the Fluoride Legislative User Information Database) is a collection of legal documents related to the fluoridation of water supplies.

## REGULATORY

### Federal

Fluoridation of public water supplies is not mandated by the US Environmental Protection Agency (USEPA) or any other federal agency in the United States. The 1974 Safe Drinking Water Act (SDWA) specified that no national primary drinking water regulation can require the addition of any substance for preventive health benefits not related to drinking water contamination. This prohibition inherently established fluoridation as a decision to be made by each individual state or local municipality.

The SDWA further required that the USEPA determine the level of contaminants in drinking water at which no adverse health effects are likely to occur, and to apply limits based on possible health risks assuming a lifetime of exposure. These limits (which are nonenforceable) are maximum contaminant levels goals (MCLGs). The enforceable limits

are maximum contaminant levels (MCLs). Though MCLs are set as close as possible to MCLGs, the enforceable MCLs must also consider cost, the ability to provide a meaningful impact on human health, and the ability of utilities to detect and remove contaminants. MCLs are never lower than MCLGs, but may be higher.

The Interim Regulation for Fluoride was promulgated in 1975 as a National Interim criteria with the MCL varying from 1.4 to 2.4 mg/L based on annual ambient temperature that was double the level recommended by the USPHS. This Interim Standard was challenged in 1981 by South Carolina with a request to delete the MCL but instead implement a Secondary Maximum Contaminant Level (SMCL) for dental fluorosis. In 1986, the USEPA established the current regulatory basis for fluoride in drinking water with a MCL of 4 mg/L and a SMCL of 2 mg/L. The MCLG and MCL for fluoride are both 4 mg/L. This concentration is the level below which a lifetime of exposure is not expected to cause health problems associated with skeletal fluorosis, a crippling disease, and is an enforceable maximum allowable concentration under the SDWA. As of the publication of this manual, USEPA was in the process of reviewing its criteria for fluoride.

The USEPA has established the secondary drinking water regulations with associated SMCLs, which are nonenforceable guidelines. The secondary contaminant list is based on aesthetic (taste, odor, staining of clothes or materials) or cosmetic effects (skin or tooth discoloration). Fluoride is the only contaminant other than copper that has both a primary and secondary standard. The SMCL for fluoride is 2 mg/L and is meant to prevent discoloration or pitting of teeth in children exposed during their formative years to water with high naturally occurring levels of fluoride. The SMCL seeks to balance the beneficial effects of fluoridation (protection against dental caries) with the undesirable cosmetic effects caused by excessive exposure. A state may choose to adopt a secondary standard (or any level lower than the federal MCL) as its enforceable standard.

The SDWA requires that water utilities notify customers in their annual Consumer Confidence Report when any regulated contaminant exceeds the regulatory limit in its treated water, regardless of whether the contaminant is naturally occurring or added as part of the treatment process. Any public water system that exceeds the primary or secondary MCL for fluoride should consult with its primary drinking water administrator to clarify the specific requirements for public notification. In general, an exceedance of the 4 mg/L MCL must meet the Tier 2 public notification requirements. An exceedance of the 2 mg/L SMCL must meet the Tier 3 public notification requirements. Because some states use the SMCL as the enforceable standard, the public notification requirements may differ from state to state. Any water utility serving a community considering fluoridation should have a firm understanding of the notification requirements in its state prior to initiating fluoridation.

## State and Local

States have used different strategies to implement community water fluoridation programs, including legislation, administrative regulation, and public referenda at the state or local level. Thirteen states require fluoridation of public water systems that do not naturally contain optimal levels (Table 1-1). The specific requirements of these laws vary from state to state. Some have population thresholds, such that only systems serving a minimum number of customers are required to add fluoride, while others allow individual communities to opt out.

Ohio and Kentucky provide a good example of the variation between states. Ohio's state fluoridation statute requires all community water systems serving more than 10,000 customers to adjust fluoride to optimal levels. In contrast, Kentucky's regulation is an administrative code that imposes different requirements based on the population size of the community served.

**Table 1-1 States requiring fluoridation of public water supplies**

State	Year of mandate
Connecticut	1965
Kentucky	1966
Illinois	1967
Minnesota	1967
Ohio	1969
South Dakota	1969
Georgia	1973
Nebraska	1973, 2008
California	1995
Delaware	1998
Nevada	1999
Louisiana	2008
Arkansas	2011

Source: CDC, [www.fluidlaw.org](http://www.fluidlaw.org)

In addition to the states listed in Table 1-1, Washington, D.C., and Puerto Rico have fluoridation mandates. The US Army Corps of Engineers Washington Aqueduct (the wholesale water supplier to the District of Columbia Water and Sewer Authority; Arlington County, Va.; and the City of Falls Church, Va.) has been adding fluoride since 1952.

Puerto Rico enacted legislation in 1998 requiring water fluoridation as needed to bring the fluoride concentration to an optimal level. The standards are governed by the Department of Health and operational compliance is overseen by the Aqueduct and Sewer Authority. Although Puerto Rico requires community water fluoridation, it is not widely practiced primarily due to infrastructure issues.

Although only 13 states have a fluoridation mandate, no state prohibits fluoridation. In most states, the decision is made at a local (regional or municipal) level. The decision at a local level can arise and be implemented in several ways. As an example, a local municipal health agency may make the recommendation to a city's governing body (i.e., mayor, city council, etc.). The local legislature may put the recommendation to referendum as a ballot question during a future election. Some municipalities have local ordinances requiring fluoridation. A local ordinance may be instituted if the legislature grants the recommending health agency the authority to require fluoridation without a referendum. The issue can become more complex when a public water supplier serves more than one municipality, such as in consecutive systems.

In most cases, the water supplier is not the entity that authorizes fluoridation, although it is tasked with implementation. The mandate to fluoridate can be the result of a legislative act or a directive from a state or local health agency. Regardless of the mechanism by which fluoridation was instituted, the water supplier is responsible for working with its primary regulatory drinking water administrator to ensure compliance with relevant permit requirements, such as design and maintenance of the fluoride chemical feed system, monitoring of fluoride levels in water samples, reporting data, and public notification.

The obligation a utility may have under fluoridation requirements is likely to be different in different communities. It is imperative that the water utility in any community considering fluoridation consult with its state drinking water administrator throughout the process of consideration and implementation of fluoridation.

## Regulations in Other Countries

Similar to the SDWA in the US, the European Water Quality Directive (1980) provides maximum allowable concentrations of substances in water, and European countries use this directive as the framework for establishing their own water quality regulations. Currently, the WHO's guideline for fluoride is 1.5 mg/L. The directive neither mandates nor prohibits fluoridation. In the UK, the decision to fluoridate is made at a local level. The fluoridating utility works to a Code of Practice for fluoridation, which provides standards for the water industry. Compliance with the standards is monitored by the Drinking Water Inspectorate (the regulator for drinking water quality). Most recently, the European Parliament on May 16, 2006, voted 526 in favor and 126 against to maintain fluorides on the approved list of additives.

As in the United States, the fluoridation of public water supplies in Canada is not mandated nationally. Health Canada is the agency that oversees drinking water quality and works with the provincial and territorial governments to review, maintain, and periodically revise the Guidelines for Canadian Drinking Water Quality. Canada's maximum acceptable concentration (MAC) of fluoride in drinking water is 1.5 mg/L. As with organizations in the United States, Health Canada has recently revised its recommendation that the optimal level of fluoride in drinking water (for protection against dental caries) be decreased from a range (0.8 to 1.0 mg/L) to the single value of 0.7 mg/L. The decision to fluoridate is made by municipalities in collaboration with their provincial or territorial authority, and may include input from residents. Health Canada, the Canadian Public Health Association, the Canadian Dental Association, and the Canadian Medical Association all endorse the use of fluoride for the prevention of dental cavities. More information on water fluoridation in Canada can be found in *Fluoride and Human Health*, Health Canada, October 2010.

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