Fluoridation Facts

- Effectiveness and Benefits
- Safety
- Fluoridation Practice
- Public Policy

ADA American Dental Association®

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Dedication

This 2025 edition of *Fluoridation Facts* is dedicated to Myron Allukian Jr., DDS, MPH, and Howard Pollick, BDS, MPH, for their unending support for community water fluoridation resulting in improved oral health for millions of people in the United States.

About *Fluoridation Facts*

Fluoridation Facts contains answers to 69 frequently asked questions regarding community water fluoridation. A number of these questions are responses to myths and misconceptions advanced by a small faction opposed to water fluoridation. The answers to the questions that appear in *Fluoridation Facts* are based on generally accepted, peer-reviewed scientific evidence. They are offered to assist policymakers and the general public in making informed decisions. The answers are supported by more than 400 credible scientific articles, as referenced within the document. It is hoped that decision makers will make sound choices based on this body of generally accepted, peer-reviewed science.

Acknowledgments

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Disclaimer

This publication is designed to answer frequently asked questions about community water fluoridation, based on a summary of relevant published articles. It is not intended to be a comprehensive review of the extensive literature on fluoridation and fluorides or to provide professional advice. Readers also must rely on their own review of the literature, including the sources cited herein and any subsequently published ones, for a complete understanding of these issues.

American Dental Association Executive Summary

Fluoridation Facts, 2025

As of the writing and publication of this document, the political and regulatory environment of community water fluoridation is experiencing significant disruption.

There will be periodic electronic updates to this document as governmental regulations change and reviews of sound science- and evidence-based studies are offered through peer-reviewed journals and periodicals.

- Fluoridation of community water supplies is the single most effective public health measure to prevent tooth decay.
- Throughout more than 80 years of research and practical experience, the overwhelming weight of credible scientific evidence has consistently indicated that fluoridation of community water supplies is safe.
- Studies prove water fluoridation continues to be effective in reducing tooth decay by more than 25% in children and adults, even in an era with widespread availability of fluoride from other sources, such as fluoride toothpaste.
- Because of the important role community water fluoridation has played in the reduction of tooth decay, the US Centers for Disease Control and Prevention (CDC) has proclaimed it one of 10 great public health achievements of the 20th century (along with vaccinations and infectious disease control).
- Community water fluoridation is the controlled adjustment of fluoride that occurs naturally in all water to optimal levels to prevent tooth decay (0.7 milligrams per liter).
- Community water fluoridation benefits everyone, especially those without access to regular dental care. Fluoridation is a powerful tool in the fight for social justice and health equity.
- Simply by drinking water, people can benefit from fluoridation's cavity protection whether they are at home, work, or school.
- Water that has been fortified with fluoride is similar to fortifying salt with iodine, milk with vitamin D, and orange juice with vitamin C—all of which are supplements, not medications.
- When compared to the cost of other prevention programs, water fluoridation is the most cost-effective means of preventing tooth decay for both children and adults in the United States. The cost of a lifetime of water fluoridation for one person is less than the cost of one filling.
- For community water systems that serve more than 1,000 people, the economic benefit of fluoridation exceeds the cost. The benefit-cost ratio increases as the size of the population served increases (largely due to economies of scale). Fluoridation is a cost-saving method to prevent tooth decay.
- According to data from 2022, 72.3% of the US population is served by public water systems that are optimally fluoridated.

- Fluoridation has been thoroughly tested in the US court system and has been found to be a proper means of furthering public health and welfare.*
- The American Dental Association (ADA) supports community water fluoridation as a safe, effective, cost-saving, and socially equitable way to prevent tooth decay.
- The ADA is one of the most widely respected sources for information regarding fluoridation and fluorides. It maintains Fluoride and Fluoridation web pages at *http://www.ADA.org/fluoride*.

* In September 2024, the United States District Court for the Northern District of California ruled in "Food & Water Watch, Inc. v. United States Environmental Protection Agency" (EPA) (*https://www.cand.uscourts.gov/food-and-water-watch-v-us-epa/*) that the current levels of fluoride used in community water fluoridation in the United States present an unreasonable risk of reduced IQ in children under the Toxic Substances Control Act. However, the Court's ruling has been widely criticized by major health and scientific authorities for drawing conclusions that are not supported by the best available evidence. At the time of this publication, the EPA has filed an appeal to that ruling.

Introduction

Fluoridation Facts has been published by the American Dental Association (ADA) since 1952. Revised periodically, *Fluoridation Facts* answers frequently asked questions about community water fluoridation. In this 2025 edition, the ADA Council on Advocacy for Access and Prevention provides updated information for individuals and groups interested in the facts about fluoridation. The United States now has more than 80 years of extensive experience with community water fluoridation. Its remarkable longevity and success are testimony to fluoridation's significance as a public health measure. In recognition of the impact that water fluoridation has had on the oral and general health of the public, in 1999, the Centers for Disease Control and Prevention (CDC) named fluoridation of drinking water as one of 10 great public health achievements of the 20th century.[1,2]

Many organizations in the United States and around the world recognize the benefits of community water fluoridation.

Support for Water Fluoridation

Since 1950, the ADA has continuously and unreservedly endorsed the optimal fluoridation of community water supplies as a safe and effective public health measure for the prevention of tooth decay. The ADA's policy is based on the best available scientific evidence on the safety and effectiveness of fluoridation. Since the ADA first adopted a policy recommending community water fluoridation in 1950, the Association has continued to reaffirm its position of support for water fluoridation and has strongly urged that its benefits be extended to communities served by public water systems.[3]

Over the years, additional support has come from numerous US Surgeons General, who are the leading spokespeople on matters of public health in the federal government. In 2016, Surgeon General Dr. Vivek H. Murthy, in his "Statement on Community Water Fluoridation,"[4] noted:

> Water fluoridation is the best method for delivering fluoride to all members of the community, regardless of age, education, income level, or access to routine dental care. Fluoride's effectiveness in preventing tooth decay extends throughout one's life, resulting in fewer—and less severe—cavities. In fact, each generation born over the past 70 years has enjoyed better dental health than the one before it. That's the very essence of the American promise.[4]

In addition to the ADA, the American Medical Association (AMA),[5] the American Academy of Pediatrics (AAP),[6] the World Health Organization (WHO),[7] and many other organizations in the United States and around the world support community water fluoridation.

Scientific Support for Fluoridation

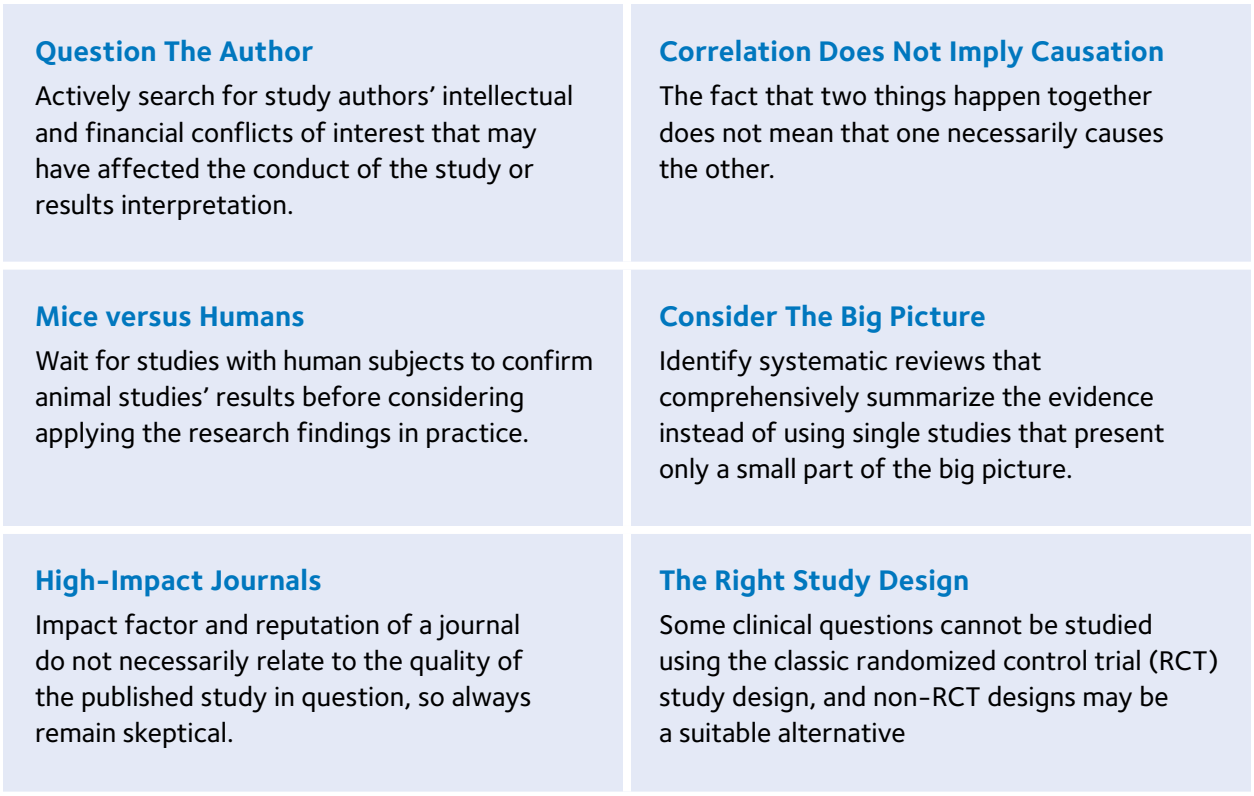
The ADA's policies regarding community water fluoridation are based on the best available scientific knowledge. This body of knowledge results from the efforts of nationally recognized scientists who have conducted research using the scientific method, drawn appropriate balanced conclusions based on their research findings, and published their results in refereed (peer-reviewed) professional journals that are highly regarded or circulated. Studies showing the safety and effectiveness of water fluoridation have been confirmed by independent scientific studies conducted by a number of nationally and internationally recognized scientific investigators. While opponents of fluoridation have questioned its safety and effectiveness, none of their charges has been substantiated by scientific evidence.

With the advent of the Information Age, a new type of "pseudo-scientific literature" has developed. The public often sees scientific and technical information quoted in the press or on television or radio, printed in a letter to the editor, or distributed via an Internet web page. Often the public accepts such information as true simply because it is "in print." Yet the information is not always based on research conducted according to the scientific method, and the conclusions drawn from research are not always scientifically justifiable.

In the case of community water fluoridation, an abundance of misinformation has been circulated. Therefore, scientific information from all print and electronic sources must be critically reviewed before conclusions can be drawn (See Figure 1). Pseudo-scientific literature can pique a reader's interest, but when read as science, it can be misleading. The scientific validity and relevance of claims made by opponents of fluoridation might be best viewed when measured against criteria set forth by the US Supreme Court.[8]

Additional information about this topic can be found in the Public Policy Section, Question 61.

Figure 1. A Guide to Identifying and Using Trustworthy Information



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History of Water Fluoridation

Research into the effects of fluoride began in the early 1900s. Dr. Frederick McKay, a young dentist, opened a dental practice in Colorado Springs, Colorado, and was surprised to discover that many local residents exhibited brown stains on their permanent teeth. Dr. McKay could find no documentation of the condition in the dental literature and eventually convinced Dr. G.V. Black, dean of the Northwestern University Dental School in Chicago, to join him in studying the condition. Through their research, Drs. Black and McKay determined that mottled enamel, as Dr. Black termed the condition, resulted from developmental imperfections in teeth. Drs. Black and McKay wrote detailed descriptions of mottled enamel.[9,10] ("Mottled enamel" is a historical term. Today, this condition is called dental or enamel fluorosis).

In the 1920s, Dr. McKay, along with others, suspected that something either in or missing from the drinking water was causing the mottled enamel. Dr. McKay wrote to the Surgeon General in 1926 indicating that he had identified regions in Colorado, New Mexico, Arizona, California, Idaho, South Dakota, Texas, and Virginia where cases of mottled enamel existed. Also in the late 1920s, Dr. McKay made another significant discovery—these stained teeth were surprisingly resistant to decay.[10]

Following additional studies completed in the early 1930s in St. David, Arizona,[11] and Bauxite, Arkansas,[12] it was determined that high levels of naturally occurring fluoride in the drinking water were causing the mottled enamel. In Arizona, researchers studied in great detail 250 residents in 39 local families and were able to rule out hereditary factors and environmental factors, except for one—fluoride in the water that occurred naturally at levels of 3.80 mg/L to 7.15 mg/L.[11] In Bauxite, Arkansas, H.V. Churchill, chief chemist with the Aluminum Company of America (name later changed to ALCOA), was using a new method of spectrographic analysis in his laboratory to look at the possibility that the water from an abandoned deep well in the area might have high levels of aluminum-containing bauxite that were causing mottled teeth. What he found was that the water contained a high level of naturally occurring fluoride (13.7 mg/L). When McKay learned of this new form of analysis and Churchill's findings, he forwarded to Churchill samples of water from areas where mottled enamel was commonplace. All the samples were found to have high levels of fluoride when compared to waters tested from areas with no mottled enamel.[10]

Dr. Henry Klein, a dentist and epidemiologist in the US Public Health Service (USPHS), led a study of more than 8,200 American Indian schoolchildren in 16 states in 1929 through 1932 and suggested that the low caries (tooth decay) prevalence among children in the Southwest may be related to the endemic fluorosis in that area.[13] That study formed the basis for subsequent epidemiologic studies on the association between naturally occurring fluoride levels in drinking water and children's dental caries experience.[14]

During the 1930s, Dr. H. Trendley Dean, a dental officer with USPHS, and his associates conducted classic epidemiological studies in the United States on the geographic distribution and severity of mottled enamel.[15] These early studies quantified the severity of tooth decay and dental fluorosis according to fluoride levels in the water. In so doing, it was observed that "at Aurora, Illinois where the domestic water contained 1.2 ppm of fluoride (F) and where a relatively low tooth decay prevalence was recorded, mottled enamel as an esthetic problem was not encountered."[16] Dean and his staff had made a critical discovery. Namely, fluoride levels of up to 1.0 ppm in drinking water did not cause dental fluorosis in most people and caused only mild dental fluorosis in a small percentage of people.[16–18]

In 1939, Dr. Gerald J. Cox and his associates at the Mellon Institute evaluated the epidemiological evidence and conducted independent laboratory studies. While the issue was being discussed in the dental research community at the time, they were the first to publish a paper that proposed adding fluoride to drinking water to prevent tooth decay.[19] In the 1940s, four pioneering community trials were carried out to evaluate the effects of the controlled addition of sodium fluoride to fluoride-deficient water supplies. The first

community water fluoridation program, under the direction of Dr. Dean, began in Grand Rapids, Michigan, in January 1945 with Muskegon, Michigan, as the non-fluoridated control community. The other three studies were conducted in the following three pairs of cities with the fluoridated city listed first: Newburgh and Kingston, New York (May 1945); Brantford and Sarnia, Ontario, Canada (June 1945); and Evanston and Oak Park, Illinois (February 1947).[20–22]

In the 1940s, four pioneering community trials, were carried out to evaluate the effects of the controlled addition of sodium fluoride to fluoride-deficient water supplies.

The astounding success of these comparison studies firmly established the practice of water fluoridation as a practical, safe, and effective public health measure to prevent tooth decay, and it was embraced quickly by other communities. After 10 years of fluoridation, the decay rate in Grand Rapids, Michigan had significantly decreased by 54% in deciduous teeth and 60% in permanent teeth.[23]

The history of water fluoridation is a classic example of a curious professional making exacting clinical observations that led to epidemiologic investigations and eventually to a safe and effective community-based public health intervention, which even today remains the cornerstone of communities' efforts to prevent tooth decay.

In addition to these studies noted, reviews on fluoride in drinking water have continued to be issued over the years. Beginning in 1951, the National Research Council (NRC) of the National Academies issued its first report stating fluoridation was safe and effective. The NRC has continued to issue reports on fluoride in drinking water (1977[24] and 1993[25]), with the most recent review published in 2006.[26] Additional reviews completed over the 17-year period from 2007 to 2024 include:

2024 Iheozor-Ejiofor Z, Walsh T, Lewis SR, Riley P, Boyers D, Clarkson JE, Worthington HV, Glenny A-M, O'Malley L. Water fluoridation for the prevention of dental caries. *Cochrane Database Syst Rev.* 2024, Issue 10. Art. No.: CD010856. DOI: 10.1002/14651858.CD010856.pub3.[27]

2023 Fiore G, Veneri F, Di Lorenzo R, Generali L, Vinceti M, Filippini T. Fluoride exposure and ADHD: A systematic review of epidemiologic studies. *Medicina.* 2023; 59(4), 797.[28]

2023 Kumar JV, Moss ME, Liu H, Fisher-Owens S. Association between low fluoride exposure and children's intelligence: a meta-analysis relevant to community water fluoridation. *Public Health.* 2023, 219: 73-84. DOI:10.1016/j.puhe.2023.03.011.[29]

2022 Belotti L, Frazão P. Effectiveness of water fluoridation in an upper-middle-income country: a systematic review and meta-analysis. *Int J Paediatr Dent.* 2022, 32(4), 503-13.[30]

2019 Cury J, Ricomini-Filho AP, Perecin Berti FL, Tabchoury CPM. Systemic Effects (Risks) of Water Fluoridation. *Brazilian Dent J.* 2019, 30(5), 421-428.[31]

2018 Ajiboye AS, Dawson DR, Fox CH. American Association for Dental Research Policy Statement on Community Water Fluoridation. *J Dent Res.* 2018, 97(12),1293-1296.[32]

2018 Chaitanya NC, Karunakar P, Allam NSJ, Priya MH, Alekhya B, Nauseen S. A systematic analysis on possibility of water fluoridation causing hypothyroidism. *Indian J Dent Res.* 2018,29(3), 358-363.[33]

2017 Australian Government. National Health and Medical Research Council (NHMRC). *Information Paper — Water Fluoridation: Dental and Other Human Health Outcomes.*[34]

2016 O'Mullane DM, Baez RJ, Jones S, Lennon MA, Petersen PE, Rugg-Gunn AJ, Whelton H, Whitford GM. *Fluoride and Oral Health.*[35]

2016 American Water Works Association. *Water Fluoridation Principles and Practices*. AWWA Manual M4. Sixth edition.[36]

2015 Water Research Foundation. *State of the Science: Community Water Fluoridation.*[37]

2015 Ireland Health Research Board. *Health Effects of Water Fluoridation: An Evidence Review.*[38]

2015 US Department of Health and Human Services Federal Panel on Community Water Fluoridation. *US Public Health Service Recommendation for Fluoride Concentration in Drinking Water for the Prevention of Dental Caries.*[39]

2014 Public Health England. *Water Fluoridation: Health Monitoring Report for England.*[40]

2014 Royal Society of New Zealand and the Office of the Prime Minister's Chief Science Advisor. *Health Effects of Water Fluoridation: A Review of the Scientific Evidence.*[41]

2013 US Community Preventive Services Task Force. The Guide to Community Preventive Services. *Preventing Dental Caries: Community Water Fluoridation.*[42]

2011 European Commission of the European Union Scientific Committee on Health and Environmental Risks (SCHER). *Fluoridation.*[43]

2008 Health Canada. *Findings and Recommendations of the Fluoride Expert Panel.*[44]

2007 Australian Government. National Health and Medical Research Council *A Systematic Review of the Efficacy and Safety of Fluoridation; Part A: Review Methodology and Results.*[45]

Water Fluoridation as a Public Health Measure

Throughout decades of research and more than 80 years of practical experience, the fluoridation of public water supplies has dramatically improved public oral health. In 1994, the US Department of Health and Human Services (HHS) issued a report that reviewed public health achievements.[46] Along with other successful public health measures, such as the virtual eradication of polio and reductions in childhood blood lead levels, fluoridation was lauded as one of the most economical preventive interventions in the nation.[46]

In 2000, US Surgeon General Dr. David Satcher issued the first Surgeon General report on oral health, *Oral Health in America: A Report of the Surgeon General*.[47] In the report, Dr. Satcher stated that community water fluoridation continues to be the most cost-effective, practical, and safe means for reducing and controlling the occurrence of tooth decay in a community. Additionally, Dr. Satcher noted that water fluoridation is a powerful strategy in efforts to eliminate health disparities across populations. Studies have shown that water fluoridation is the most significant strategy employed to reduce disparities in tooth decay.[48–51]

Additional information about this topic can be found in the Public Policy Section, Question 59.

Because of the important role fluoridation has played in the reduction of tooth decay, the CDC proclaimed community water fluoridation as one of 10 great public health achievements of the 20th century.[1,2]

In the 2003 *National Call to Action to Promote Oral Health,*[52] Surgeon General Dr. Richard Carmona called on policymakers, community leaders, private industry, health professionals, the media, and the public to affirm that oral health is essential to general health and well-being. Additionally, Dr. Carmona urged these groups to apply strategies to enhance the adoption and maintenance of proven community-based interventions such as community water fluoridation.

Writing in *Public Health Reports* in 2010, Surgeon General Dr. Rebecca Benjamin noted that, "Community water fluoridation continues to be a vital, cost-effective method of preventing dental caries."[53]

In a 2015 Surgeon General's Perspective[54] issued to coincide with the release of the updated USPHS recommendation on fluoride levels in drinking water to prevent tooth decay, Surgeon General Dr. Vivek H. Murthy stated, "As Surgeon General, I encourage all Americans to make choices that enable them to prevent illness and promote well-being. Community water fluoridation is one of the most practical, cost-effective, equitable, and safe measures communities can take to prevent tooth decay and improve oral health."[54]

HHS announced in 2015 that, after more than four years of additional research and review following the initial notice of intent, the USPHS had made a final recommendation on the fluoride level in drinking water[39] that updated and replaced the 1962 Drinking Water Standards related to community water fluoridation. In this guidance, the single optimal concentration of fluoride in drinking water of 0.7 mg/L (milligrams per liter) for all the United States was defined as "the concentration that provides the best balance of protection from dental caries while limiting the risk of dental fluorosis."[39]

Additional information about this topic can be found in the Safety Section, Question 19.

Established by the HHS, Healthy People 2030[55] provided an evidence-based, comprehensive set of ambitious, achievable, national objectives for improving public health and reducing health disparities over 10 years, from 2020 to 2030. Healthy People 2030 recognizes the importance of water fluoridation in promoting oral health and reducing disparities. Healthy People 2030 aims to increase the proportion of people whose water systems have the recommended amount of fluoride.[55] The target is to have 77.1% of people served by community water systems with optimally fluoridated water to reduce oral health disparities.[56] In 2022, the CDC indicated that 72.3% of the US population on public water systems, or a total of 209.1 million people, had access to fluoridated water.[57]

Fluoridation of community water supplies is the single most effective public health measure to prevent tooth decay. Fluoridation helps prevent and, in some cases, reverse tooth decay across the lifespan. Increasing numbers of adults are retaining their teeth throughout their lifetimes due in part to the benefits they receive from water fluoridation. Dental costs for these individuals have been reduced and many hours of needless pain and suffering due to untreated tooth decay have been avoided. By preventing tooth decay, community water fluoridation has been shown to save money, both for families and the health care system. The return on investment for community water fluoridation varies with the size of the community, and in general, increases as the community size increases. Community water fluoridation is cost saving, even for small communities.

Additional information about this topic can be found in the Cost Section, Question 68.

Fluoridation of community water supplies is the single most effective public health measure to prevent tooth decay. Studies show that community water fluoridation prevents about 25% of tooth decay in children and adults, even in an era with widespread availability of fluoride from other sources, such as fluoride toothpaste.

Community water fluoridation is an extremely valuable public health measure because:

- Optimally fluoridated water is accessible to the entire community regardless of socioeconomic status, educational attainment, or other social variables.[58]
- Individuals do not need to change their behavior to obtain the benefits of fluoridation.
- Frequent exposure to small amounts of fluoride over time makes fluoridation effective through the lifespan in helping to prevent tooth decay.[59]
- Community water fluoridation is more cost effective and cost saving than other forms of fluoride treatments or applications.[60,61]

Water Fluoridation's Role in Reducing Tooth Decay

Water fluoridation has played a significant role in improving oral health. Numerous studies and reviews on fluoridation have been published, making it one of the most widely studied public health measures in history. Studies show that community water fluoridation prevents about 25% of tooth decay in children[62] and adults,[63] even in an era with widespread availability of fluoride from other sources, such as fluoride toothpaste.

Tooth decay is caused by sugars in food and beverages being converted into acid by the bacteria in *dental plaque,* a thin, sticky, colorless deposit on teeth. The acid attacks the tooth enamel (the hard surface of the tooth) or root surface. After repeated attacks, the enamel or root surface loses minerals (a process called *demineralization*), and the acids and bacteria penetrate the dentin (an inner softer layer of tooth). Without intervention, the decay process can reach the innermost part of the tooth called pulp. The soft tissue of the pulp contains nerves and blood vessels. Once the decay enters the pulp, the pulp becomes infected, and without treatment, the infection progresses and travels into the surrounding tissues. It can enter the bloodstream and potentially spread the infection to other parts of the body like the brain or the throat closing off the airway, which can be life-threatening.[64]

Additional information about this topic can be found in the Benefits Section, Question 2.

There are a number of factors that increase an individual's risk for tooth decay:[65–69]

- Recent history of tooth decay
- Elevated oral bacteria count
- Inadequate exposure to fluoride
- Exposed roots
- Frequent intake of sugar or sugary foods and sugar-sweetened beverages
- Poor or inadequate oral hygiene
- Decreased flow of saliva
- Deep pits and fissures on the chewing surfaces of teeth

Exposure to fluoride is a key component in any recommended decay prevention strategy; however, the use of fluoride alone will not prevent all tooth decay. In formulating a decay prevention program, in addition to consuming fluoridated tap water, a number of intervention strategies should be considered. These can include improved daily home care, including brushing with fluoride toothpaste, reducing sugar in the diet, placement of dental sealants, home use of prescription-strength fluoride toothpaste, and professionally applied topical treatments.

Ongoing Need for Water Fluoridation

Because of the risk factors for tooth decay noted previously, many indi0viduals and communities still experience high levels of tooth decay. Although water fluoridation demonstrates an impressive record of effectiveness and safety, only 72.3% of the US population on public water supplies in 2022 received fluoridated water containing protective levels of fluoride[57] Unfortunately, some people continue to be confused or misinformed about this effective public health measure. If the number of individuals drinking fluoridated water is to increase, the public must be accurately informed about its benefits and safety.

Section 1

Effectiveness and Benefits

1. What is fluoride?

Answer

Fluoride is a naturally occurring mineral that can help prevent tooth decay.

Fact

The element fluorine is abundant in the Earth's crust as a naturally occurring fluoride compound found in rocks and soil.[70,71] As groundwater moves through the Earth, it passes over rock formations and dissolves the fluoride minerals that are present, releasing fluoride ions from the naturally occurring fluorine in the rocks. This increases the fluoride content of the water. The concentration of fluoride in groundwater (e.g., wells, springs) varies according to such factors as the depth at which the water is found and the quantity of fluoride-bearing minerals in the area.

Fluoride is present at varied concentrations in all water sources, including rainwater and oceans. For example, ocean fluoride levels range from 1.2 to 1.4 mg/L.[72] In the United States, the natural level of fluoride in groundwater varies from very low levels to more than 4 mg/L.[26] In comparison, the fluoride concentrations in surface water sources, such as lakes and rivers, are very low. For example, a water analysis completed by the city of Chicago for 2023 lists the range for Lake Michigan's natural fluoride level as 0.06 to 0.11 mg/L.[73]

2. How does fluoride help prevent tooth decay?

Answer

Tooth decay begins when the outer layer of a tooth loses some of its minerals due to acid produced by bacteria in dental plaque that breaks down the sugars and other refined carbohydrates that we eat. This process is called *demineralization*. Fluoride protects teeth by helping to prevent the loss of these minerals and by restoring them with a fluoride-containing mineral that is more resistant to acid attacks. In other words, fluoride protects teeth by reducing demineralization and enhancing remineralization. Fluoride also works to hinder bacterial activity necessary for the formation of tooth decay.

Fact

One of fluoride's main mechanisms of action is its ability to prevent or delay the loss of minerals in teeth.[35,59] Cavities start to form when minerals from the tooth surface are lost due to acid attacks from bacteria in dental plaque, the soft, sticky film that is constantly forming on teeth. Acid-producing bacteria thrive on the sugars and refined carbohydrates that we consume.

Fluoride's second mechanism of action is called *remineralization,* which is the reversal of this demineralization process.[59,74] Teeth gain back the minerals lost during acid attacks through remineralization, but with an important difference. Some of the hydroxyapatite crystal lost is replaced with *fluorapatite*. This fluoride-rich replacement mineral is even more resistant to acid attacks than the original tooth surface.[59]

Fluoride has a third mechanism of action that involves disruption of the ability of bacteria to metabolize carbohydrates and produce acids.[35] It can also hinder the ability of the bacteria to stick to the tooth surface.[75]

Fluoride and other minerals, including calcium and phosphate, are present in saliva[59,75] and are stored in dental plaque. To hinder the formation of tooth decay or rebuild tooth surfaces, fluoride must be constantly present in low concentrations in saliva and plaque.[59] Frequent exposure to small amounts of fluoride, such as that which occurs when drinking fluoridated water, helps maintain the reservoir of available fluoride in saliva and plaque to resist demineralization and enhance remineralization.[59,76] In other words, drinking fluoridated water provides the right amount of fluoride at the right place at the right time. Fluoride in water and water-based beverages is consumed many times during the day, providing frequent contact with tooth structures and making fluoride available to fluoride reservoirs in the mouth. This explains why fluoride at the low levels found in fluoridated water helps prevent tooth decay.[59]

Additionally, fluoride ingested during tooth formation becomes incorporated into the tooth structure, making the teeth more resistant to acid attacks and demineralization.[77–81] In particular, this pre-eruptive exposure to fluoride, before the teeth come into the mouth during childhood, can play a significant role in preventing tooth decay in the pits and fissures of the chewing surfaces, particularly of molars.[59,82,83] Sources of fluorides in the United States that provide this pre-eruptive effect include fluoridated water, dietary fluoride supplements, and fluoride present in foods and beverages.

Pre-eruptive effects are sometimes called *systemic,* while post-eruptive effects are called *topical.* However, these terms really refer to different things. *Pre-* and *post-eruptive* refer to the timing of fluoride benefits, while *systemic* and *topical* refer to the mode of administration or source of fluoride. Defining the preventive effects of fluoride from a specific source as solely systemic or topical is not entirely accurate. For example, water fluoridation prevents tooth decay due to both a systemic effect during tooth development and a topical effect at the time of ingestion as well as from being present in saliva.

Today, it is understood that the maximum reduction in tooth decay occurs when systemic and topical effects are combined, that is, when fluoride has been incorporated into the tooth during formation and when it is available at the tooth surface during demineralization and remineralization. Water fluoridation works in both ways to prevent tooth decay.[75,78,80,82,83]

The maximum reduction in tooth decay occurs when fluoride has been incorporated into the tooth during formation and when it is available at the tooth surface during demineralization and remineralization. Water fluoridation works in both ways to prevent tooth decay.

3. What is water fluoridation?

Answer

Water fluoridation is the controlled adjustment of the natural fluoride concentration in community water supplies to the concentration recommended for optimal dental health. Fluoridation helps prevent tooth decay in children and adults.

Fact

In 2015, the HHS, using the best available science, established the recommended concentration for fluoride in the water in the United States at 0.7 mg/L.[39] This level effectively reduces tooth decay while minimizing dental fluorosis.

The level of fluoride in water is measured in milligrams per liter (mg/L) or parts per million (ppm). When referring to water, a concentration in mg/L is the same as ppm and the notations can be used interchangeably. Thus, 0.7 mg/L of fluoride in water is identical to 0.7 ppm. The preferred notation is mg/L.

At 0.7 mg/L, there are seven-tenths of one part of fluoride mixed with 999,999.3 parts of water. While not exact, the following comparisons can be of assistance in comprehending 0.7 mg/L:

- 1 inch in approximately 23 miles
- 1 minute in approximately 1,000 days
- 1 cent in approximately $14,000
- 1 seat in more than 34 Wrigley Field baseball stadiums (seating capacity 41,268)

The following terms and definitions are used in this publication:

- **Community water fluoridation** is the controlled adjustment of the natural fluoride concentration in water up to 0.7 mg/L, the level recommended for optimal dental health. Other terms used interchangeably are water fluoridation, fluoridation, and optimally fluoridated water. Optimal levels of fluoride can be present in the water naturally or by adjusted means.
- **Sub-optimally fluoridated water** is water that naturally contains less than the optimal level (below 0.7 mg/L) of fluoride. Other terms used are non-fluoridated water and fluoride-deficient water.

Additional information on this topic can be found in this Section, Question 6.

The level of fluoride in water is measured in milligrams per liter (mg/L) or parts per million (ppm). When referring to water, a concentration in mg/L is identical to ppm and the notations can be used interchangeably. Thus, 0.7 mg/L of fluoride in water is identical to 0.7 ppm. The preferred notation is mg/L.

4. How much fluoride is in your water?

Answer

If your water comes from a public or community water supply, options to learn the fluoride level of the water include contacting the local water supplier or the local, county, or state health department; reviewing the Consumer Confidence Report (CCR) issued by your local water supplier; and using the CDC's Internet-based "My Water's Fluoride." If your water source is a private well, it will need to be tested, with the results obtained from a certified laboratory.

Fact

The fluoride content of the local public or community water system can be obtained by contacting the local water supplier or the local, county, or state health department. The name of your water system might not be the same as the name of your community.

In 1999, the EPA began requiring water suppliers to make annual drinking water quality reports accessible to their customers. Available prior to July 1 each year for the preceding calendar year, these CCRs, or Water Quality Reports (WQR),[84] can be mailed to customers, placed in the local newspaper, or made available through the Internet. To obtain a copy of the report, contact the local water supplier. If the name of the community water system is unknown, contact the local health department.

Two sites on the Internet supply national information on the water quality of community water systems. The online source for WQRs or CCRs is the EPA website[85] and the CDC's fluoridation website, "My Water's Fluoride."[86] The latter website allows consumers in currently participating states to learn the fluoridation status of their water system. It also provides information on the number of people served by the water system, the water source, and whether the water system is naturally fluoridated or the fluoride level in the water supply is adjusted.[86]

The EPA does not have the authority to regulate private drinking water wells. However, the EPA recommends that private well water be tested once a year.[87] For the most accurate results, a state-certified laboratory that conducts drinking water tests should be used for fluoride testing. For a list of state-certified laboratories, contact the local, county, or state water or health department.

The EPA does not specifically recommend testing private wells for the level of fluoride. However, if a household with a private well has children under 16 years of age, their health care providers will need to know the fluoride level of the well water prior to considering a prescription of dietary fluoride supplements[75] or to counseling patients about alternative water sources to reduce the risk of fluorosis if the natural fluoride level is above 2 mg/L.

Dietary fluoride supplements (tablets, drops, or lozenges) are available only by prescription in the United States and are intended for use by children ages 6 months to 16 years living in non-fluoridated areas and at high risk of developing tooth decay. A dentist or physician can prescribe the correct dosage.[75]

Additional information on this topic can be found in this Section, Question 12 and in the Safety Section, Questions 21, 27, 28, and 29.

5. What additives are used to fluoridate water supplies in the United States?

Answer

Sodium fluoride, sodium fluorosilicate, and fluorosilicic acid are the three additives approved for use in community water fluoridation in the United States. Sodium fluorosilicate and fluorosilicic acid are sometimes referred to as silicofluoride additives.

Fact

The three primary additives used to fluoridate water in the United States are: (1) *sodium fluoride,* which is a white, odorless material available either as a powder or crystals; (2) *sodium fluorosilicate,* which is a white or yellow-white, odorless crystalline material; and (3) *fluorosilicic acid,* which is a white or straw-colored liquid.[36]

Water fluoridation began in the United States in 1945 with the use of sodium fluoride. The use of silicofluorides began in 1946, and by 1951, they were the most commonly used additives.[88] First used in the late 1940s, fluorosilicic acid is currently the most commonly used additive to fluoridate communities in the United States.[89]

To ensure the public's safety, additives should meet safety standards for water treatment in the United States, regardless of where the additives are manufactured.[36] Specifically, additives used in water fluoridation should meet standards of the American Water Works Association (AWWA). Fluoride additives, like any other water additive, should also meet standards set by NSF (formerly the National Sanitation Foundation) and the American National Standards Institute (ANSI).[90] In the United States, the authority to regulate products for use in drinking water, including additives used to fluoridate community water systems, rests with individual states. In 2020, NSF reported that 49 states had adopted the NSF/ANSI Standard 60, which specifies the product quality, with validation supplied by independent certification entities.[90]

To ensure the public's safety, additives should meet safety standards for water treatment in the United States, regardless of where they are manufactured.

Additional information on the topic of fluoride additives can be found in the Fluoridation Practice section of this publication and at the CDC's website, "Fluoridation Engineering and Operations."[91]

6. Is there a difference in effectiveness between naturally occurring fluoridated water (at optimal fluoride levels) and water that has fluoride added to reach the optimal level?

Answer

No. The dental benefits of optimally fluoridated water occur regardless of the fluoride's source.

Fact

Fluoride is present in water as "ions" or electrically charged atoms.[92] These ions are the same whether acquired by water as it seeps through rocks and sand or added to the water supply under carefully controlled conditions.

The major features of the human fluoride metabolism are not affected by which of the three fluoride additives is used in community water fluoridation, nor are they affected by whether the fluoride is present naturally or added to drinking water.[93] In simpler terms, there is no difference chemically between natural and adjusted fluoridation.

When fluoride is added under controlled conditions to fluoride-deficient water, the dental benefits are the same as those obtained from naturally fluoridated water. Fluoridation is merely an increase of the level of the naturally occurring fluoride present in all drinking water sources to the level recommended for optimal dental health.

> Fluoridation is merely an adjustment of the level of the naturally occurring fluoride present in all drinking water sources to the level recommended for optimal dental health.

For example, a fluoridation study[22] conducted in the Ontario, Canada, communities of Brantford (optimally fluoridated by adjustment), Stratford (optimally fluoridated naturally), and Sarnia (fluoride-deficient) revealed much lower decay rates in both Brantford and Stratford as compared with non-fluoridated Sarnia. There was no observable difference in the decay-reducing effect between the naturally occurring fluoride and adjusted fluoride concentration water supplies.[22]

Some individuals use the term "artificial fluoridation" to imply that the process of water fluoridation is unnatural and that it delivers a foreign substance into a water supply when, in fact, all water sources contain some fluoride. The fluoride ion released in water is the same regardless of the source[92] and is metabolized (processed) by the body in the same way no matter what the source is.[93] Community water fluoridation is a natural way to improve oral health.

7. Is water fluoridation effective in helping to prevent tooth decay?

Answer

Yes. According to the best available scientific evidence, community water fluoridation is an effective public health measure for preventing tooth decay in children, adolescents, and adults. With hundreds of studies published in peer-reviewed scientific journals, fluoridation is one of the most studied public health measures in history, and it continues to be studied today.

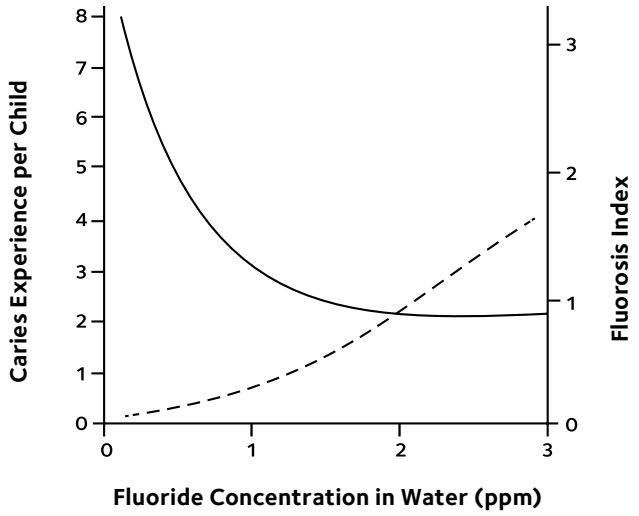
Fact

The effectiveness of fluoride in drinking water to prevent tooth decay has been documented in the scientific literature for more than 80 years. Before the first community fluoridation program began in 1945, epidemiologic data from the 1930s and 1940s were collected and analyzed.[17,18,94] What began as research to learn what caused "Colorado Brown Stain" (dental fluorosis) led to the discovery of strikingly low tooth decay rates associated with fluoride in drinking water at approximately 1 ppm (mg/L). Figure 2 shows the results of early research by Dr. H. Trendley Dean noting the association among children's experience with tooth decay (solid line), dental fluorosis (dotted line), and the fluoride concentration in drinking water.[18,94]

Additional information on this topic can be found in the Introduction.

Figure 2. Dean's Graph

Relationships of tooth decay experience (solid line), dental fluorosis index (dashed line) and the fluoride concentration of drinking water.[28,29]



Systematic Reviews and Meta-Analyses

Since that time, hundreds of studies have continued to show fluoride's effectiveness in helping to prevent tooth decay. Those individual studies have been included in a number of systematic reviews. A *systematic review* is an analysis of studies that identifies and evaluates all the evidence with which to answer a specific, narrowly focused question. It entails a methodical and unbiased review process that locates, assesses, and combines high-quality evidence from a collection of scientific studies to obtain a comprehensive, valid, and reliable review on a specific topic. Systematic reviews provide the highest level of scientific evidence about a specific research question. The following is a summary of significant reviews of community water fluoridation demonstrating that water fluoridation effectively reduces tooth decay.

Cochrane Review (Iheozor-Ejiofor et al., 2024)

A Cochrane Review[95] is a systematic review that attempts to identify, appraise, and synthesize all the empirical evidence that meets pre-specified eligibility criteria to answer a specific research question. The 2024 Cochrane Review[27] on the effectiveness of community water fluoridation found that adding fluoride to water supplies may lead to slightly less tooth decay in children's baby teeth. and more children being free of tooth decay. This review added just one new study to its 2015 report because its stringent inclusion criteria limited it to prospective cohort studies that were started before the initiation of a new fluoridation program. That one recent U.K. study found a reduction in the incidence rate of caries (tooth decay) in children that was consistent with other recent studies.[27]

Systematic Review and Meta-Analysis—Brazil (Belotti and Frazão, 2021)

This 2021 systematic review[30] examined the impact of community water fluoridation on tooth decay among children in Brazil, a country where fluoride toothpaste is widely used. The review focused on studies conducted in Brazil and published after 1995, analyzing data from 16 studies that assessed tooth decay in children under 13 years old. The comparison between children living in fluoridated and non-fluoridated communities revealed that water fluoridation significantly reduced the prevalence and severity of tooth decay in both primary and permanent teeth. Children in fluoridated communities had approximately 46% lower odds of experiencing decay. Additionally, among children aged 5–8 years, those in fluoridated areas had, on average, 2.28 fewer decayed teeth compared to those in non-fluoridated areas. These findings underscore the effectiveness of water fluoridation in preventing tooth decay in children, even in settings where other fluoride sources are commonly available.[30]

National Health and Medical Research Council Review—Australia (2017)

In 2017, the Australian government's National Health and Medical Research Council (NHMRC) released the *NHMRC Public Statement 2017–Water Fluoridation and Human Health in Australia,*[96] recommending community water fluoridation as a safe, effective, and ethical way to help reduce tooth decay. Based on a comprehensive review of the evidence, published in 2016, and the translation of that evidence into the *NHMRC Information Paper–Water Fluoridation: Dental and Other Human Health Outcomes,*[34] published in 2017, the Public Statement noted that the NHMRC found that water fluoridation reduces tooth decay by 26–44% in children and adolescents and by 27% in adults. Additionally, it noted that recent Australian research found that access to fluoridated water from an early age is associated with less tooth decay in adults. The Statement notes that NHMRC supports Australian states and territories fluoridating their drinking water supplies within the range of 0.6 to 1.1 mg/L.[96]

The Guide to Community Preventive Services (2013)

Established by the HHS in 1996, the Community Preventive Services Task Force (CPSTF) develops and disseminates guidance on which community-based health promotion and disease prevention intervention approaches work and which do not work, based on available scientific evidence. The Task Force issues findings based on systematic reviews of effectiveness and economic evidence. The Guide to Community Preventive Services ("The Community Guide") is a collection of evidence-based findings of the CPSTF and is designed to assist decision makers in selecting interventions to improve health and prevent disease.[97]

In a 2013 update of the evidence, the CPSTF continued to recommend community water fluoridation to reduce tooth decay, noting that cavities decreased when fluoridation was implemented and that cavities increased when fluoridation was stopped, as compared to communities that continued fluoridation.[42]

Summary of Systematic Reviews (Parnell et al., 2009)

A summary of systematic reviews by the Oral Health Services Research Centre at the University Dental School in Cork, Ireland, published in 2009,[98] reviewed results from three systematic reviews, all of which were published between 2000 and 2007. The summary of results concluded that the best available scientific evidence demonstrated that water fluoridation was an effective community-based method to prevent tooth decay, especially for the disadvantaged who bear the greatest burden of disease.[98]

Systematic Review and Meta-Analysis (Griffin et al., 2007)

A meta-analysis (a type of systematic review that seeks to determine a statistical estimate of an overall benefit based on the results of the collection of studies included in the review) published in 2007 in the *Journal of Dental Research* demonstrated the effectiveness of water fluoridation for preventing tooth decay in adults.[63] Twenty studies representing more than 13,500 participants were included in the analysis. Of the 20 studies, nine examined the effectiveness of water fluoridation. A review of these studies found that fluoridation prevents approximately 27% of tooth decay in adults.[63]

First Fifty Years Review—International (Murray, 1993)

In 1993, the results of 113 studies in 23 countries (more than half the studies were from the United States) were compiled and analyzed.[99] That review provided effectiveness data for 66 studies of primary teeth and 86 studies of permanent teeth. The analysis of the studies demonstrated a 40–49% overall decay reduction for primary teeth and a 50–59% overall decay reduction for permanent teeth for those living in fluoridated communities.[99]

First 50 Years Review—United States (Ripa, 1993)

A comprehensive analysis of the first 50 years of community water fluoridation in the United States concluded that "Community water fluoridation is one of the most successful public health disease prevention programs ever initiated."[100] While noting that the difference in tooth decay between optimally fluoridated communities and fluoride-deficient communities was smaller than in the early days of fluoridation, largely due to additional sources of fluoride, the difference was still significant and the benefits for adults should be emphasized. The report ended by noting that water fluoridation is a near-ideal public health measure whose benefits can transcend racial, ethnic, socioeconomic, and regional differences.[100]

The systematic reviews noted here provide scientific evidence that, for more than 80 years, fluoridation has been effective in helping to prevent tooth decay.

8. With other sources of fluoride now available, is water fluoridation still an effective method for preventing tooth decay?

Answer

Yes. Even in an era with widespread availability of fluoride from other sources, studies show that community water fluoridation prevents about 25% of tooth decay in children and adults throughout the lifespan.

Fact

During the 1940s, studies demonstrated that children in communities with optimally fluoridated drinking water had reductions in tooth decay rates of approximately 40–60% compared to those living in non-fluoridated communities.[101,102] At that time, drinking water was the only source of fluoride other than fluoride that occurred naturally in foods.

Increase in the Number of Sources of Fluoride

Fluoride is available today from a number of sources, including water, beverages, food, and dental products (toothpaste; rinses; professionally applied fluoride foams, gels, and varnish; and dietary supplements).[39] As a result of the widespread availability of these various sources of fluoride, the difference between decay rates in fluoridated areas and non-fluoridated areas is less than it was several decades ago, yet it is still significant.[39] Contemporary studies show that community water fluoridation prevents about 25% of tooth decay in children and adults throughout the lifespan.[62,63] The benefits of fluoridation are extended to everyone in a community where they live, work, attend school or daycare, or play, and it does not require a change of behavior or access to dental care.

The benefits of fluoridation are extended to everyone in a community where they live, work, attend school or daycare, or play, and it does not require a change of behavior or access to dental care.

The Diffusion or Halo Effect

The diffusion or "halo" effect occurs because foods and beverages processed in optimally fluoridated communities, which generally contain higher levels of fluoride than those processed in non-fluoridated communities, are also distributed to non-fluoridated areas. This exposure to fluoride in non-fluoridated areas through the diffusion effect lessens the differences in the amount of tooth decay among communities.[100,103,104] The best available national data demonstrate that the failure to account for the diffusion effect results in an underestimation of the total benefit of water fluoridation, especially in areas where large quantities of beverage and food products produced with optimally fluoridated water are brought into non-fluoridated communities.[105]

Exposure to Fluoridation over the Lifespan

Another factor in the difference between decay rates in fluoridated areas and non-fluoridated areas is the high geographic mobility of our society. On a day-to-day basis, many individuals reside in a non-fluoridated community but spend a significant part of their day in a fluoridated community at work, school, or daycare. Additionally, over their lifetime, people tend to move and reside in a number of

communities, some with optimally fluoridated water and some without. This mobility makes it increasingly difficult to study large numbers of people who have spent their entire lives in one (fluoridated or non-fluoridated) community.[103] It also means that many individuals benefit from fluoridation for at least some part of their lives. For children who have resided in fluoridated communities their entire lives, studies have demonstrated they had less tooth decay than children who never lived in fluoridated communities.[106]

Brazilian Systematic Review

To assess the impact of water fluoridation on dental caries during the era of widespread use of fluoride toothpaste, a 2022 systematic review[30] of 16 fluoridation studies conducted in Brazil limited its scope to studies published after 1995. This review compared the tooth decay experience of children younger than 13 years living in fluoridated communities with that of those in non-fluoridated communities. It found that children in fluoridated communities had about 46% lower odds of experiencing decay. Among children aged 5–8 years, those in fluoridated communities had a mean of 2.28 fewer teeth affected by decay than did those in non-fluoridated communities.[30]

Despite fluoride from a number of other sources, the "halo effect," and the mobility of today's society, studies show that community water fluoridation prevents about 25% of tooth decay in children and adults throughout the lifespan.[62,63]

Additional information on this topic can be found in this Section, Question 11.

9. What happens if water fluoridation is discontinued?

Answer

Tooth decay can be expected to increase if water fluoridation in a community is discontinued, even if topical products such as fluoride toothpaste and fluoride mouthrinses are used widely.

Fact

In 2013, using an updated systematic review, the CPSTF continued to recommend community water fluoridation to reduce tooth decay, noting that cavities decreased when fluoridation was implemented and that cavities increased when fluoridation was stopped, as compared to communities that continued fluoridation.[42] This confirmed the CPSTF's earlier systematic review published in 2002,[62] which also noted an increase in tooth decay when fluoridation was halted (a median 17.9% increase in tooth decay during 6–10 years of follow-up).

Historical Studies Noting an Increase in Tooth Decay after Discontinuation of Fluoridation:

United States: Antigo, Wisconsin (Lemke et al., 1970)

Antigo, Wisconsin, began water fluoridation in June 1949 and ceased adding fluoride to its water in November 1960. After 5.5 years without optimal levels of fluoride, children in second grade had a 200% increase in tooth decay experience, fourth graders a 70% increase, and sixth graders a 91% increase in decay experience compared with the levels of those children of the same ages in 1960. Residents of Antigo re-instituted water fluoridation in October 1965 on the basis of the severe deterioration of their children's oral health.[107]

United States: Galesburg, Illinois (Way, 1964)

A study[108] that reported the association between fluoridated water and tooth decay prevalence focused on the city of Galesburg, Illinois, a community whose public water supply contained naturally occurring fluoride at 2.2 mg/L. In 1959, Galesburg switched its community water source to the Mississippi River. This alternative water source provided the citizens of Galesburg a sub-optimal level of fluoride at approximately 0.1 mg/L. In the period of time between a baseline survey conducted in 1958 and a new survey conducted in 1961, data revealed a 10% decrease in the percentage of decay-free 14-year-olds (oldest group observed), and a 38% increase in mean tooth decay experience. Two years later, in 1961, the water was fluoridated at the then-recommended level of 1.0 mg/L.[108]

Scotland: Wick (Stephen et al., 1987)

In 1979, fluoridation in the northern Scotland town of Wick was discontinued after 8 years. The water was returned to its sub-optimal, naturally occurring fluoride level of 0.02 mg/L. Data collected to monitor the oral health of Wick children clearly demonstrated a negative health effect from the discontinuation of water fluoridation. Five years after the cessation of water fluoridation, the prevalence of decay in primary teeth had increased by 27%. That increase in decay occurred during a period when there had been a reported overall reduction in decay nationally and when fluoride toothpaste had been widely adopted. Those data suggest that decay levels in children can be expected to rise where water fluoridation is interrupted or terminated, even when topical fluoride products are widely used.[109]

Scotland: Stranraer (Atwood and Blinkhorn, 1991)

In a similar evaluation, the prevalence of tooth decay in 5- and 10-year-old children in Stranraer, Scotland, increased after the discontinuation of water fluoridation. That increase in tooth decay was estimated to result in a 115% increase in the mean cost of restorative dental treatment for decay. Those data support the important role water fluoridation plays in the reduction of tooth decay.[110]

United States: Juneau, Alaska (Meyer et al., 2018)

A 2018 study[111] used Medicaid dental claims records to assess the consequences of community water fluoridation cessation in Juneau, Alaska. Dental caries procedures and restoration costs were measured in 2003, when water was optimally fluoridated, and compared to all claims for the same age group in 2012, 5 years after the cessation of fluoridation. Patients ages 0–18 years in the suboptimal fluoride group were found to have a higher mean number of caries-related procedures. The study also reported that patients born after fluoridation cessation underwent the most dental caries procedures on average.[111]

Israel (Tobias et al., 2022)

Israel began implementing water fluoridation in 1981 as a public health measure to prevent dental caries. However, in 2014, the country discontinued mandatory fluoridation following a policy change, citing environmental and ethical concerns. The cessation has since prompted studies examining its impact on oral health outcomes, particularly among children. A 2022 retrospective study[112] assessed the impact of discontinuing water fluoridation in Israel. It focused on children aged 3–12 years in areas where fluoridation had ceased, using populations from regions that never had optimal fluoridation as a control. No significant age-related changes in dental treatments were observed from 2014–2015. However, following fluoride cessation, dental treatment nearly doubled between 2016 and 2019, with the number of treatments increasing with age. Compared to areas with partial or no fluoridation, regions with optimal fluoride levels were found to consistently have fewer dental treatments.[112]

United States: Juneau and Anchorage, Alaska (Meyer et al., 2022)

A retrospective study published in 2022[113] revisited the impact of Juneau after the cessation of community water fluoridation in 2007 by comparing it to comparable data from Anchorage, where fluoridation continued. Using Medicaid dental claims from 2003 to 2012, the study compared caries-related procedures and costs for children aged 0–18 years. In Anchorage, caries-related procedures and inflation-adjusted treatment costs showed no significant changes, while Juneau experienced a substantial increase in both.[113]

Canada: Calgary and Edmonton (McLaren et al., 2022)

A 2022 study[114] examined the effect of fluoridation cessation in the Canadian cities of Calgary, which started fluoridation in 1991 and stopped it in 2011, and Edmonton, which has remained fluoridated since 1967. The cities had no significant difference in the prevalence of decay in primary teeth from 2004—2005 through 2013–2014, but by 2018–2019 the prevalence of tooth decay was significantly higher in Calgary, which stopped fluoridation, than in fluoridated Edmonton. The authors concluded that the cessation of community water fluoridation had an adverse impact on children's dental health in Calgary.[114] This study aligns with the findings of a 2016 systematic review pointing to an increase in dental caries following fluoridation cessation.[115]

Canada: Calgary and Edmonton (Yazdanbakhsh et al., 2024)

A 2024 study[116] evaluated the effect of fluoridation cessation in Calgary on pediatric dental treatments performed under general anesthesia. Health administrative databases provided records of children under 12 years of age who underwent caries-related procedures under general anesthesia at publicly funded facilities in Alberta between 2010 and 2019. Children from Calgary, where fluoridation was discontinued, were compared to those from Edmonton, where fluoridation remained in place. An increase in general anesthesia procedures was reported in Calgary, particularly among children aged 0–5 years. This increase was found to be more pronounced over time, with the non-fluoridated areas experiencing higher rates of treatments compared to fluoridated areas.[116]

Israel (Nezihovski et al., 2024)

Community water fluoridation began in Israel in 1981, became a mandatory policy in 2002, and was discontinued by the Ministry of Health in 2014. To assess the impact of this policy change, a 2024 study[117] assessed the dental health treatment among children aged 3–5 years who were treated under general anesthesia or sedation. Treatment records, including restorative procedures and stainless-steel crowns, were examined and analyzed from 2014–2019. A statistically significant increase in dental treatments post-fluoridation cessation was observed, with the number of procedures nearly doubling across all age groups.[117] These findings align with a previous study conducted in Israel using 2014–2019 data.[112]

Historical Studies and Factors Noting No Increase in Tooth Decay after Discontinuation of Fluoridation

There have been several studies from outside the United States that have not reported an increase in tooth decay following the discontinuation of fluoridation. In all these, the discontinuation of fluoridation coincided with the implementation of other measures to prevent tooth decay.

Cuba: La Salud (Kunzel and Fischer, 2000)

In La Salud, Cuba, a study on tooth decay in children indicated that the rate of tooth decay did not increase after fluoridation was stopped in 1990. However, at the time fluoridation was discontinued, a new preventive fluoride program was initiated in which all children received fluoride mouthrinses on a regular basis and children 2–5 years of age received fluoride varnish once or twice per year.[118]

Finland: Kuopio and Jyväskylä (Seppa et al., 2002)

In Finland, a longitudinal study in Kuopio (fluoridated from 1959–1992) and Jyväskylä (with low levels of natural fluoride) showed little difference in decay rates between the two communities, which were extremely similar in terms of ethnic background and social structure.[119] That finding was attributed to a number of factors. First, the dental programs provided intensive topical fluoride regimens and dental sealant programs for Finnish children. In addition, nearly all children and adolescents in those cities used the government-sponsored, comprehensive, free dental care. As a result, the net benefit of water fluoridation appeared minimal. Because of this unique set of factors, the authors concluded that those results would not be replicated in countries with less-intensive preventive dental care programs.[119]

(Former) East Germany: Chemniz and Plauen (Kunzel et al., 2000)

No significant decrease in tooth decay was seen after fluoridation was discontinued in 1990 in Chemniz and Plauen, located in what was formerly East Germany.[120] The intervening factors in those communities included improvements in attitudes toward oral health behaviors, and broader availability and increased use of other preventive measures, including fluoridated salt, fluoride toothpaste, and dental sealants.[120]

Netherlands: Tiel and Culemborg (Kalsbeek et al., 1993)

A similar situation was reported from the Netherlands. A study conducted among 15-year-old children in Tiel (fluoridated 1953–1973) and Culemborg (non-fluoridated) compared tooth decay rates in the two cities from 1968 to 1988. The lower tooth decay rate in Tiel after the cessation of fluoridation was attributed in part to the initiation of a dental health education program, free dietary fluoride supplements, and a greater use of professionally applied topical fluorides.[121]

In the preceding examples, many communities that discontinued fluoridation found higher tooth decay rates in their children. The absence of caries increases in some communities that discontinued fluoridation likely was due to the availability and use of free dental services for all children or the implementation of widespread decay prevention programs that require significant professional and administrative support and are less cost-effective than fluoridation.

10. Is tooth decay still a serious problem in the United States?

Answer

Yes. Tooth decay, or a cavity in the tooth, is a disease that continues to be a significant oral health problem for children and adults, with 46% of children ages 2–19 having one or more untreated or restored cavities. Among adults aged 20 and older, nearly 90% have had at least one cavity.[122]

Fact

Good oral health is often taken for granted by many people in the United States. However, while largely preventable, tooth decay, cavities, or dental caries (a term used by health professionals) remain a common, debilitating, chronic condition for many children and adults.

Tooth decay begins with a weakening and/or breakdown (loss of minerals) of the enamel (the hard outer layer of teeth) caused by acids produced by bacteria that live in plaque. Dental *plaque* is a soft, sticky film that is constantly forming on teeth. Eating foods or drinking beverages that contain sugars or other refined carbohydrates allows the bacteria in the plaque to produce acids that attack the enamel. The plaque helps to keep these acids in contact with the tooth surface and *demineralization* (loss of mineral) occurs. After repeated acid attacks, the enamel can break down, creating a cavity.

Left unchecked, bacteria and acid can penetrate the *dentin* (the next, inner layer of teeth) and then finally the *pulp*, which contains nerves and blood vessels. Once the bacteria enter the pulp, the tooth becomes infected (abscessed) and, without treatment, the infection can progress and travel into the surrounding tissues. The infection can enter the bloodstream and potentially spread the infection to other parts of the body which, in rare cases, becomes life-threatening.

Additional information on this topic can be found in this Section, Question 2.

Tooth decay can negatively affect an individual's quality of life and ability to succeed. Tooth decay can cause pain that can affect how we eat, speak, smile, learn at school, or succeed at work. Children with cavities often miss more school and receive lower grades than children who are cavity-free.[123] More than $6 billion of productivity is lost each year in the United States because people miss work to get dental care.[124]

While cavities are often thought of as a problem for children, adults in the United States are keeping their teeth longer (partly due to exposure to fluoridation), and this increased retention of teeth means more adults are at risk for cavities—as people age, the gumline recedes and leaves exposed root surfaces.[125,126] Tooth root surfaces are covered with cementum (a softer surface than the enamel) and so are susceptible to decay. As the baby boomer generation ages, root decay experience is expected to increase in future years, possibly to the point where older adults experience similar or higher levels of new cavities than do school children.[125]

Additional information on this topic can be found in this Section, Question 11

Preventing cavities and remineralizing teeth at the earliest stages of decay are very important, not only in saving tooth structure but also in reducing the cost for dental care. Community water fluoridation is an effective public health measure that is a cost-saving and cost-effective approach to preventing tooth decay.

Additional information on this topic can be found in the Cost Section, Question 68.

Oral health disparities exist in the United States and have been documented through extensive studies and reviews.[48,127,128] Despite the fact that millions of people in the United States enjoy good dental health, disparities exist for many racial and ethnic groups, as well as by socioeconomic status, sex, age, and geographic location.[129] Water fluoridation helps to reduce the disparities in oral health at the community level as it benefits all residents served by community water supplies.

In a 2015 Surgeon General's Perspective,[54] Surgeon General Dr. Vivek Murthy noted, "...it is one of the most cost-effective, equitable, and safe measures communities can take to prevent tooth decay and improve oral health."

Additional information on this topic can be found in the Public Policy Section, Question 59.

Dental cavities are largely preventable with good oral hygiene (brushing and flossing) and preventive care such as routine dental exams, cleanings, topical fluoride applications, dental sealants, and community water fluoridation. Established by HHS, Healthy People 2030[55] provides a science-based, comprehensive set of ambitious yet achievable 10-year national objectives for improving the health of the public. The current Healthy People 2030 objectives[55] include an oral health objective to expand the fluoridation of public water supplies. Objective OH-11 states that at least 77.1% of the US population served by community water systems should be receiving the benefits of water fluoridated at recommended levels by the year 2030.[56] Data from the CDC indicate that, in 2022, 72.3% of the US population on public water systems, or a total of 209.1 million people, had access to fluoridated water.[57] Conversely, approximately 27% or more than 78 million people on public water systems do not receive the decay-preventing benefits of fluoridation.

11. Do adults benefit from fluoridation?

Answer

Yes. Fluoridation plays a protective role against tooth decay throughout life, benefiting both children and adults.

Fact

While the early fluoridation trials were not designed to study the possible benefits fluoridation might have for adults, by the mid-1950s, it became evident from the results of the first fluoridation trial in Grand Rapids, Michigan, that the beneficial effects of fluoridation were not confined to children drinking the fluoridated water from birth. The fact that a reduction in tooth decay was observed for teeth that had already been calcified or were erupted when fluoridation was started indicated that a beneficial effect could be gained by older age groups.[23,130] Today, it is understood that the maximum reduction in tooth decay occurs when fluoride has been incorporated into the tooth during formation and when it also is available at the tooth surface during demineralization and remineralization. Fluoride enhances the remineralization of teeth and inhibits bacterial growth and acid production by the bacteria in the plaque. Fluoridation works topically after teeth have erupted and systemically while teeth are forming to prevent tooth decay.[39,76,79,81,83]

Fluoride and minerals, including calcium and phosphate, are present in saliva[74,76] and are stored in dental *plaque* (a soft, sticky biofilm that is constantly forming on teeth). To halt the formation of tooth decay or rebuild tooth surfaces, fluoride must be constantly present in low concentrations in saliva and the plaque biofilm.[74] Frequent exposure to small amounts of fluoride, such as that which occurs when drinking fluoridated water, helps maintain the reservoir of available fluoride in saliva and plaque to resist

demineralization and enhance remineralization.[74,77,131] In other words, drinking fluoridated water provides the right amount of fluoride at the right place at the right time. Fluoride in water and water-based beverages is consumed many times during the day, providing frequent contact with tooth structures and making fluoride available to fluoride reservoirs in the mouth. This helps explain why fluoride at the low levels found in fluoridated water helps prevent tooth decay in teeth after they have erupted.[74]

Additional information on this topic can be found in this Section, Question 2.

Benefit of Community Water Fluoridation for Adults

All adults receive the benefit of decay protection while teeth are already present in the mouth when exposure to water fluoridation begins. However, studies have indicated that adults who have consumed fluoridated water continuously from birth receive the maximum protection against tooth decay.[77–81]

Journal of Dental Research Meta-Analysis

A meta-analysis published in 2007 in the *Journal of Dental Research* showed that fluoridation prevents approximately 27% of tooth decay in adults. The studies for this meta-analysis were limited to participants who were lifelong residents of communities with fluoridated water and control groups of lifelong residents of communities without fluoridated water.[63]

Additional studies summarized in this section provide evidence for the benefit of community water fluoridation on adults.

Study of Adults in Washington State

A study published in 1992[132] in the Journal of the American Dental Association examined adults aged 20–34 years in the state of Washington and found that those who had a continuous lifetime exposure to optimally fluoridated water had 31% less tooth decay experience compared to similar aged adults with no exposure to fluoridated water. It also concluded that exposure to fluoridation only during childhood has lifetime benefits because adults exposed to fluoridated water only during childhood had decay experiences similar to those adults exposed to fluoridated water only after age 14.[132]

Decay among Australian Defense Force Personnel

A noteworthy Australian study[133] published in 2008 examined decay experience among Australian Defense Force personnel and showed that a longer period of exposure to water fluoridation was associated with lower decay rates in adults between the ages of 17–44. Adults who lived at least 90% of their lifetime in communities with fluoridated water had 24% less decay than adults who lived in fluoridated areas for less than 10% of their lifetimes.[133]

Data from the Australian National Survey of Adult Oral Health

A 2013 study using data from the Australian National Survey of Adult Oral Health showed that adults with greater lifetime exposure to fluoridated water had lower caries experience.[134]

Another study emphasized that benefits from lifetime access to fluoridated water could be observed clearly up to age 45 but seemed to flatten out in older age groups. The authors suggested that a cumulative measure such as the number of tooth surfaces classified as decayed, missing, or filled could become "saturated" in a chronic disease such as dental caries, making it hard to show differences by exposure level.[135]

Data from National Lithuanian Oral Health Survey

Similar findings supporting the benefits of community water fluoridation for adults include a 2021 study of adults ages 34–74 in Lithuania where greater exposure to optimal fluoride in water corresponds with lower caries experience.[136]

Data from US National Health and Nutrition Examination Surveys

A window into the positive impact of community water fluoridation in the United States can be seen from research done in nationally representative samples of US adults. Differences in tooth decay patterns between two cohorts of young adults highlight this: the first cohort grew up before fluoridation was widely available and the second after fluoridation became more widespread. Comparing data from two different US National Health and Nutrition Examination Surveys (NHANES), NHANES I (1971–1974), and NHANES III (1988–1984), the results indicated that total tooth decay declined among people aged 45 years and younger at the time of the survey. No decline was observed in people then aged 46–65, the cohort that grew up during the late 1940s and early 1950s before fluoridation was widely available. Lack of exposure to community water fluoridation was cited as the major reason this older cohort did not show a decline in tooth decay.[137]

Root Surface Decay

An important issue for adults is the prevention of root surface decay.[125,126] People in the United States are living longer and retaining more of their natural teeth than ever before, in part due to water fluoridation. Adults with gum recession are at risk for root surface decay because the root surface, a much softer tooth surface than enamel, becomes exposed to decay-causing bacteria in the mouth as gums recede.

While most studies related to the prevention of root surface decay focus on professional fluoride treatments, such as fluoride varnish, there is evidence that demonstrates fluoridation has an impact on root surface decay.[138–140] For example, in Ontario, Canada, lifelong residents of the non-fluoridated community of Woodstock had a 21% higher root surface decay experience than those living in the naturally fluoridated (1.6 ppm) matched community of Stratford.[139] Similarly, Iowa residents more than 40 years of age living long-term in fluoridated communities had significantly less root decay than lifelong residents of non-fluoridated communities (0.56 versus 1.11 surfaces).[140]

Fluoridation is unique in that it remains the one dental public health measure that reaches all members of a community, including young, middle-aged, and older adults. It is a cost-effective approach for achieving life-long caries prevention in a manner that addresses health equity.[141]

12. Are dietary fluoride supplements effective in helping to prevent tooth decay?

Answer

Yes. Dietary fluoride supplements can be effective in preventing tooth decay.

Fact

Dietary fluoride supplements are available only by prescription in the United States and are recommended by the ADA75 and the US Preventive Services Task Force.[142,143] They are recommended by the ADA for use by children who are at high risk for developing tooth decay and living in areas where the primary source(s) of water are deficient in fluoride.[75] Similar to the benefits of community water fluoridation, fluoride in dietary supplements is incorporated into developing teeth to strengthen them and reduce the risk of decay.[142]

Dietary fluoride supplements can be effective in helping to prevent tooth decay for those at high risk for tooth decay. To receive the optimal benefit from fluoride supplements, the use of supplements should begin at 6 months of age and continue daily until the child is 16 years old.[75]

Recommendations for health professionals seeking to prescribe dietary fluoride supplements are found in *The Evidence-Based Clinical Recommendations on the Prescription of Dietary Fluoride: A Report of the American Dental Association Council on Scientific Affairs* published in 2010.[75] *The Chairside Guide: Dietary Fluoride Supplements: Evidence-Based Clinical Recommendations* can be accessed from the ADA's website, *ADA.org*.[144]

The current dietary fluoride supplement schedule appears in Table 1.

Table 1. Dietary Fluoride Supplement Schedule for Children at High Caries Risk[75]

Age	Fluoride ion level in drinking water (ppm)*		
	<0.3 ppm	**0.3-0.6 ppm**	**>0.6 ppm**
Birth–6 months	None	None	None
6 months–3 years	0.25 mg/day**	None	None
3–6 years	0.50 mg/day	0.25 mg/day	None
6–16 years	1.0 mg/day	0.50 mg/day	None

*1.0 part per million (ppm) = 1 milligram/liter (mgL) | **2.2 mg sodium fluoride contains 1 mg fluoride ion.

Additional information on this topic can be found in this Section, Question 13.

The expert panel convened by the ADA Council on Scientific Affairs developed the recommendations and emphasized that they must be balanced with the practitioner's professional judgment and the individual patient's needs and preferences. They also emphasized that children are exposed to multiple sources of fluoride. The panel encouraged health care providers to evaluate all potential fluoride sources and to conduct a caries risk assessment before prescribing systemic fluoride supplements.

Specific to prescribing dietary fluoride supplements, the recommendations included conducting an accurate assessment of the fluoride content of the patient's primary drinking water source(s).[75] The identification of the "primary" sources is sometimes difficult because some patients have multiple sources of drinking water during a typical day. For example, while a patient may have access to drinking water in the home, they often also spend a large part of their day accessing drinking water at day care, school, or a place of work, which could be a different water system. To determine fluoride levels, it might be necessary to contact the local, county, or state health departments or municipalities or private water companies for information on the fluoride content of multiple public water sources or to contact a certified laboratory that can provide a fluoride test for private wells.

Additional information on this topic can be found in this Section, Question 4.

The ADA offers information on caries risk assessment[145] on its website. Caries risk assessments should be completed for patients on a regular basis to determine their risk for tooth decay, which can change over time.

While dietary fluoride supplements can be an effective means of caries prevention, they must be used daily, and individual patterns of adherence to the schedule (compliance) vary greatly. Therefore, the recommendations suggest that providers carefully monitor compliance to maximize the therapeutic benefit of dietary fluoride supplements in caries prevention. If the health care provider has concerns regarding compliance, it might be best to consider other sources of fluoride exposure for the patient, such as ensuring regular twice daily use of fluoride toothpaste.[75]

While dietary fluoride supplements can be effective in reducing tooth decay, there are several factors that can impede their use and resulting therapeutic value:

- Patients/parents/caregivers must have access to a professional health care provider who can conduct the necessary assessments and provide prescriptions for dietary fluoride supplements repeatedly over time, with these often needing adjustment based on age and changes in water sources.
- The dietary fluoride supplements must be obtained through a pharmacy/pharmaceutical service and refilled as necessary.
- The cost of the dietary fluoride supplements can be a financial hardship for some individuals.
- The compliance required (a child should take the supplement every day until 16 years of age) to obtain the optimal therapeutic effect often is difficult to achieve.
- Tablets and lozenges are manufactured with 1.0, 0.5, or 0.25 mg fluoride. To maximize the topical effect of fluoride, tablets and lozenges are intended to be chewed or sucked for 1–2 mins before being swallowed; for infants, supplements are available as a liquid and used with a dropper.

Noting the potential obstacles listed above, where feasible, community water fluoridation is preferred because it offers proven decay prevention benefits without the need for access to a health care professional or a change in behavior on the part of the individual. Simply by drinking water at home, school, work, or play, everyone in the community benefits regardless of socioeconomic status, educational attainment, or other social variables.[58]

While dietary fluoride supplements can reduce a child's risk of tooth decay, community water fluoridation extends that benefit to adults in the community. Additionally, the cost of dietary fluoride supplements over an extended period of time can be a financial concern to a family. In looking at overall costs, consideration should be given to the cost per person and the number of people who can benefit from a dietary fluoride supplement or community fluoridation program.[60]

13. The ADA Dietary Fluoride Supplement Schedule from 2010 contains the word "none" in specific boxes. Does this mean the ADA does not recommend fluoride for children?

Answer

No, that would be a misinterpretation of the purpose of the schedule. The schedule reflects the recommended dosage of dietary fluoride supplements based on age and the fluoride level of the child's primary source of drinking water, in addition to what would be consumed from other sources.

Fact

The dietary fluoride supplement schedule[75] (Table 1) is just that–a supplement dosage schedule. Children residing in areas where the drinking water is not fluoridated will receive some fluoride from other sources, such as foods and beverages. Dietary fluoride supplements are designed for children over 6 months of age who do not receive a sufficient amount of fluoride from those sources. The dosage amounts in Table 1 reflect the additional amount of supplemental fluoride intake necessary to achieve an optimal anti-cavity effect. To reduce the risk of dental fluorosis, children under 6 months of age should not take dietary fluoride supplements.

Additional information on this topic can be found in the Safety Section, Question 29.

The dietary fluoride supplement schedule should not be viewed as a recommendation of the absolute upper limits of the amount of fluoride that should be ingested each day. In 2011, the Food and Nutrition Board of the Institute of Medicine (now National Academies of Sciences, Engineering, and Medicine) developed Dietary Reference Intakes, a comprehensive set of reference values for dietary nutrient values. The values present nutrient requirements to optimize health and, for the first time, set maximum-level guidelines to reduce the risk of adverse effects from excessive consumption of nutrients. In the case of fluoride, levels were established to reduce tooth decay without causing moderate dental fluorosis.[146]

For example, the dietary fluoride supplement schedule recommends that a 2-year-old child at high risk for tooth decay living in a non-fluoridated area (where the primary water source contains less than 0.3 ppm fluoride) should receive 0.25 mg of supplemental fluoride per day. This does not mean that this child should ingest exactly 0.25 mg of fluoride per day total. Instead, a two-year-old child could receive important anti-cavity benefits by taking 0.25 mg of supplemental fluoride a day without causing any adverse effects on health. This child would most probably be receiving fluoride from other sources (other beverages and foods), even in a non-fluoridated area, and the recommendation of 0.25 mg of fluoride per day takes this into account. In the unlikely event that the child did not receive any additional fluoride from food and beverages, the 0.25 mg per day could be inadequate fluoride supplementation to achieve an optimal anti-cavity effect.

Additional information on this topic can be found in the Safety Section, Question 23.

It is important to note that the dietary fluoride supplement dosage schedules have been lowered in the past as exposure to fluoride from other sources has increased. Rather than being a problem, as those opposed to the use of fluoride might imply, this is evidence that ADA policy is based on the best available science. Specifically, the ADA periodically reviews the dosage schedule and, working with other national groups, issues updated recommendations based on the best available science.

In 1994, a Dietary Fluoride Supplement Workshop, co-sponsored by the ADA, the American Academy of Pediatric Dentistry (AAPD), and the American Academy of Pediatrics (AAP), was held in Chicago. Based on a review of scientific evidence, a consensus was reached on a new dosage schedule acknowledging that numerous sources of topical and systemic fluoride were available that were not available many years previously.[147]

Subsequently, the dietary fluoride supplement schedule was reviewed and reissued in December 2010. At that time, the ADA Council on Scientific Affairs (CSA) published evidence-based clinical recommendations for the dosage schedule for dietary fluoride supplements.[75] The evidence-based review recommended that the age stratification established in the ADA's 1994 supplement schedule remain unchanged. The review also recommended that, prior to prescribing dietary fluoride supplements, the prescribing provider should assess the patient's risk for cavities and only those at high risk should receive supplements.[75] If at high risk, the fluoride level(s) of the patient's primary drinking water source(s) should be assessed.[75] It should be noted that an accurate assessment of the patient's primary drinking water source(s) often includes more than one source. For example, the patient might not have access to fluoridated water at home but may drink fluoridated water while at day care or school, so both should be considered. The current dietary fluoride supplement schedule appears in Table 1[75] under Question 12.

Additional information on this topic can be found in this Section, Question 12.

14. What are salt and milk fluoridation and where are they used?

Answer

Salt and milk fluoridation are methods used to provide community-based fluoridation in countries other than the United States where various political, geographical, financial, or technical reasons prevent the use of water fluoridation.

Fact

The practice of salt fluoridation began in the 1950s, approximately 10 years after water fluoridation was initiated in the Unites States.[148] Based on the success several decades earlier of the use of iodized salt for the prevention of goiter, fluoridated salt was first introduced in Switzerland in 1956.[149]

Salt Fluoridation in Europe

According to a review published in 2013, salt fluoridation is available in a number of countries in Europe, but its coverage varies greatly.[148,150] Germany and Switzerland have attained a coverage exceeding two-thirds of their populations (67% and 85%, respectively). In other European countries, including Austria, the Czech Republic, France, Slovakia, and Spain, salt fluoridation is reportedly used on a very limited scale.[148] Additional countries, such as Hungary, Romania, Slovenia, Croatia, and Poland, have considered salt fluoridation but have failed to take action.[150]

European regulations (as of 2024) permit the addition of fluoride to salt and water.[151] On a historical note, prior to the political changes that occurred in the late 1980s and early 1990s in Europe, water fluoridation was widely available in the German Democratic Republic and the Czechoslovak Republic and to a lesser extent in Poland. With the end of the Communist regimes, efforts related to public health dentistry were largely discontinued. While fluoridation continued in several small towns until 1993, in general, it was abandoned.[150] In 2013, it was estimated that approximately 60 million people in Europe and 160 million in the Americas had access to fluoridated salt.[148]

Salt Fluoridation in the Americas

In North, South, and Central America, salt fluoridation is available in Belize, Bolivia, Colombia, Costa Rica, the Dominican Republic, Ecuador, Mexico, Peru, Uruguay, and Venezuela. Like in Europe, the extent of salt fluoridation varies among countries. Columbia, Costa Rica, Jamaica, Mexico, and Uruguay provide fluoridated salt to nearly their entire populations, while there is less coverage in other countries.[148]

The Pan American Health Organization (PAHO), a regional division of the WHO with responsibilities for health matters in North, South, and Central America and the Caribbean, has been active in developing strategies to implement decay-prevention programs in the regions of the Americas using water and salt fluoridation.[152] To achieve the greatest reduction in tooth decay while minimizing the risk of dental fluorosis, it is advisable that a country implement only one of these two public health measures–either community water fluoridation or salt fluoridation. The United States has implemented water fluoridation. The US Food and Drug Administration (FDA) has not approved fluoridated salt for use in the United States.

Early studies evaluating the effectiveness of salt fluoridation conducted in Columbia, Hungary, and Switzerland indicated that fluoride delivered via salt might produce a reduction in tooth decay similar to that seen with optimally fluoridated water.[153,154] When all salt destined for human consumption (both domestic salt and bulk salt used by commercial bakeries, restaurants, institutions, and industrial food production) is fluoridated, the decay-reducing effect could be comparable to that of water fluoridation over an extended period of time.[153,154] When only domestic salt is fluoridated, the decay-reducing effect is diminished.[150] Studies conducted in Costa Rica, Jamaica, and Mexico in the 1980s and 1990s also showed significant reductions in tooth decay. However, it was noted that these studies did not assess other variables that could have contributed to the reductions.[153]

The fact that salt fluoridation does not require a centralized piped water system is of particular value in countries that do not have such water systems. Fluoridated salt is also a very cost-effective public health measure. For example, in Jamaica, where all salt destined for human consumption is fluoridated, the use of fluoridated salt was reported to reduce tooth decay by as much as 84%, at a cost of 6 cents per person per year.[152] In some cases, the cost to produce fluoridated salt is so low that, for consumers, the cost of fluoridated salt is the same as for non-fluoridated salt.[155]

Implementing Salt Fluoridation

The implementation of salt fluoridation has unique challenges not incurred with water fluoridation. Sources of salt, the willingness of local manufacturers to produce fluoridated salt, or the need to import fluoridated salt would need to be studied. Because fluoridated salt should only be consumed by the public in areas with a naturally low level of fluoride, it would be necessary to completely map the naturally occurring levels of fluoride and devise a plan to keep fluoridated salt out of the areas with moderate to high naturally occurring fluoride (to aid in reducing the risk of dental fluorosis). Additionally, a plan would need to be developed to monitor the fluoride level in urine of those consuming fluoridated salt, starting with a baseline before implementation and including follow-up testing on a regular basis. While salt fluoridation typically is not implemented through a public vote, it would be necessary to gain the cooperation of salt manufacturers and institutions of all kinds that would use salt in their food preparation.[154] Additionally, educational efforts would need to be directed at health professionals and health authorities to avoid referendum approaches and identify enabling regulations.[149]

In a number of European countries, consumers have a choice of purchasing either fluoridated or non-fluoridated salt for use in the home. While it has been argued that, unlike water fluoridation, this option to purchase fluoridated or non-fluoridated salt allows for personal choice, studies indicate that

fluoridated salt is not as effective a public health measure when only a small portion of the population opts to purchase and use the product.[153] For example, in France, fluoridated salt for home use became available to the consumer by decree in 1986, while non-fluoridated salt remained available for purchase. By 1991, with an aggressive public health campaign, the market share of fluoridated salt was 50%, and it reached a high of 60% in 1993. Then the public health campaign ended. By 2003, the market share had decreased to 27%.[148,156] It has been suggested that to be a successful public health measure that effectively reaches those who are disadvantaged, approximately 70% of the population needs to use fluoridated salt.[150] Conversely, usage rates less than 50% should be considered as having minimal effect on public health.[150]

Occurrence of Dental Fluorosis with Salt Fluoridation

Numerous studies have shown an increase in the occurrence of dental fluorosis in areas where salt fluoridation programs have been implemented. For example, a 2006 cohort study[157] examined the prevalence and severity of dental fluorosis in children before and after the implementation of salt fluoridation in Campeche, Mexico, in 1991. The study showed that while 85% of the dental fluorosis identified was categorized as very mild, children born in 1990–1992 were more likely to have dental fluorosis than those born in 1986–1989.[157]

A study published in 2009[158] of children in Jamaica showed similar results. Jamaica began a fluoridated salt program in 1987. In 1999, an area around St. Elizabeth was found to have high prevalence of dental fluorosis. Examiners returned in 2006 to re-evaluate students in the area. While their results indicated a slightly reduced tooth decay experience for 6-year-olds in 2006 compared to 6-year-olds in 1999, they also found that 6-year-olds had a higher prevalence of dental fluorosis in 2006 than the 6-year-olds examined in 1999. In addition to the implementation of salt fluoridation, other factors including the increased use of fluoridated toothpaste and mouthrinses could have played a role.[158] However, both studies point out the need to carefully monitor fluorides from multiple sources, especially when implementing fluoridated salt programs.

Fluoridated Milk

Fluoridated milk has been suggested as another alternative to community water fluoridation in countries outside the Unites States. Studies on the effectiveness of milk fluoridation have been carried out in numerous countries, including Brazil, Bulgaria, China, Israel, Japan, Russia, and the United Kingdom.[159] Many of these studies have found milk fluoridation programs to be an efficient and cost-effective method to prevent cavities.[159] For example, a 2001 study[160] of Chilean preschoolers using fluoridated powdered milk and milk derivatives reported a 41% reduction in the number of primary tooth decayed missing and filled surfaces as compared to the control group that did not receive fluoridated milk.[160] Additionally, in the same study, the proportion of decay-free children increased from 22% to 48% in the study group after 4 years of implementing the program.[160]

In 2004, the dental health of schoolchildren from the northwest of England, who were enrolled in the school milk fluoridation program, was compared to that of children with similar characteristics who were not consuming fluoridated milk.[161] The average age of the children in the study was 11 years. To partake in the study, participants chosen for the test group were required to have been receiving fluoridated milk for a minimum of 6 years. First, permanent molars were examined for tooth decay experience. Results from the study indicated that children consuming fluoridated milk had less tooth decay experience (1.01 DMFT) than the children who did not receive fluoridated milk (1.46 DMFT).[161]

A study of community milk programs in Bulgaria examined children at age 3 and again at age 8.[162] The study found that tooth decay experience was substantially lower in the cohort of children who had received fluoridated milk in school for five years (5.61 dmfs and 0.48 DMFS versus 9.41 dmfs and 1.24 DMFS, respectively).[162]

In these two examples, "dmfs" is the mean number of decayed, missing, or filled tooth surfaces on primary (or baby) teeth while "DMFS" is the mean number of decayed, missing, or filled tooth surfaces on permanent teeth.

It was estimated that as of 2013, more than one million children worldwide were receiving fluoridated milk.[159] The majority of studies conducted have indicated that fluoridated milk is effective in preventing tooth decay under certain conditions. It is most effective if the consumption of fluoridated milk starts before 4 years of age and continues until the permanent teeth are present in the mouth. Most successful programs are conducted through schools where the natural fluoride levels in water are low and children are able to consume fluoridated milk for a minimum of 200 days a year.[159] While these conditions may prevent fluoridated milk from being recommended as a public health measure for an entire community, fluoridated milk might be the most appropriate and effective means of fluoride exposure for children in some circumstances.

15. Can the consistent use of bottled water result in individuals missing the benefits of optimally fluoridated water?

Answer

Yes. The large majority of bottled waters on the market do not contain optimal levels (0.7 mg/L) of fluoride.

Fact

There is not a large body of research regarding the risk for tooth decay associated with the consumption of bottled water. However, a lack of exposure to fluoride in drinking water could increase an individual's risk for tooth decay. The vast majority of bottled waters do not contain significant amounts of fluoride.[163] Individuals who drink bottled water as their primary source of water could be missing the decay-preventive effects of optimally fluoridated water available from their community water supplies. These consumers should seek advice from their dentists about their risk for tooth decay and specific fluoride needs. A study is under way to evaluate the preventive effects of fluoridated bottled water on dental caries compared to non-fluoridated bottled water in 4-year-old children.[164]

While drinking water from the tap is regulated by the EPA, bottled water is regulated by the FDA.[165] The FDA has established maximum allowable levels for physical, chemical, microbiological, and radiological contaminants in bottled water.[166]

Individuals who drink bottled water as their primary source of water could be missing the decay-preventive effects of optimally fluoridated water available from their community water supplies.

FDA Bottled Water Standards

Noting that fluoride can occur naturally in source waters used for bottled water or can be added by a bottled water manufacturer, the FDA has approved standards for the fluoride content of bottled water.[166] However, the FDA regulations require the fluoride content of bottled water to be listed on the label only if fluoride is added during processing.[167] If the fluoride level is not shown on the label of the bottled water, the company can be contacted, or the water can be tested to obtain this information. Most consumers are unaware that the vast majority of bottled waters, including all products treated by distillation or reverse osmosis, are largely fluoride-free. Unknowingly, individuals who drink bottled water as their primary source of water could be missing the decay-preventive effects of optimally fluoridated water available from their community water supplies. The ADA supports the labeling of the fluoride content of bottled water to aid consumers in making informed decisions about choices of drinking water.[168]

Recognizing the benefit of fluoride in drinking water, in 2006 the FDA issued the "FDA Health Claim Notification for Fluoridated Water and Reduced Risk of Dental Caries,"[169] which states that bottled water meeting the specific standards of identity and quality set forth by the FDA, and containing between 0.6–1.0 mg/L total fluoride, can be labeled with the following health claim: "Drinking fluoridated water may reduce the risk of [dental caries or tooth decay]." This health claim is not intended for use on bottled water products specifically marketed for use by infants.[169]

Additional information on this topic can be found in the Safety Section, Question 28.

Prevalence of Bottled Water in the United States

According to a 2017 press release from the Beverage Marketing Corporation,[170] bottled water surpassed carbonated soft drinks in 2016 to become the largest beverage category by volume in the United States. Per capita consumption of bottled water was approximately 39.3 gallons in 2016, while the average consumption of carbonated soft drinks was approximately 38.5 gallons per person per year. The per capita consumption of bottled water continues to grow, reaching roughly 46.5 gallons in 2022.[171] Single-serve bottled water accounted for the majority (71%) of US bottled water volume sales.[171]

Individuals choose to drink bottled water for various reasons. Some find it a calorie-free substitute for carbonated soft drinks or other sugary beverages. Others dislike the taste of their tap water or have concerns about the possible contaminants in their local water supply.

A small study[172] of a convenience sample of caretakers and adolescents at an urban clinic published in 2012 found that 17% drank tap water exclusively, 38% drank bottled water exclusively, and 42% drank both. Bottled water was ranked significantly higher in taste, clarity, purity, and safety than tap water. Only 24% of caretakers of children and adolescents knew if fluoride was in their drinking water. The authors concluded that perceptions of the qualities of water were most responsible for choices of drinking water.[172] Similar findings have been found in earlier studies.[173–175] Additionally, cultural influences can affect drinking water preferences. In some Latino communities, parents were less likely to give tap water to their children because they believed tap water would make them sick. This often is based largely on the fact that many have come to the United States from places with poor water quality where water-borne illness was common.[175] Besides missing the decay-preventive effects of fluoridated tap water, families spend hundreds of dollars more each year on purchasing water than if they were to consume tap water.[173,175]

16. Do home water treatment systems such as water filters, reverse osmosis, and water softeners remove fluoride from drinking water?

Answer

Some types of home water treatment systems can reduce the fluoride levels in water supplies. Individuals who drink water processed by home water treatment systems as their primary source of water could be losing the decay-preventive effects of optimally fluoridated water available from their community water supply.

Fact

There are many kinds of home water treatment systems, including reverse osmosis systems, distillation units, water softeners, and water filters such as carafe filters, faucet filters, under-the-sink filters, and whole-house filters. There has not been a large body of research regarding the extent to which these treatment systems affect the fluoride content of optimally fluoridated water.[176]

However, it has been documented consistently that when working properly, almost all reverse osmosis systems and distillation units remove most of the fluoride from the water supply.[176-178] Studies regarding water softeners show clearly that the water-softening process does not significantly change fluoride levels.[179,180]

With other types of water filters, the fluoride concentration remaining in the water depends on the type and quality of the filter being used, the status of the filter, and the filter's age. Most carbon filters do not remove fluoride. However, some filters containing activated alumina can remove significant amounts of fluoride. Additionally, some filters containing bone char also can remove significant amounts of fluoride.[178,181] Accordingly, each type of filter should be assessed individually.

Individuals who drink water processed by home water treatment systems as their primary source of water could be losing the decay-preventive effects of optimally fluoridated water available from their community water supply. Therefore, it might be necessary to contact the installer, distributor, or manufacturer of the water treatment system or water filter in question to determine whether the item removes fluoride. Information regarding the existing level of fluoride in a community's public water system can be obtained by asking a local dentist or contacting the local or state health department or the local water supplier. If the consumer is using a private well, it is suggested that it be tested yearly to determine the fluoride level.

Additional information on this topic can be found in this Section, Question 4.

Section 2

Safety

17. Does fluoride in the water supply, at the levels recommended for the prevention of tooth decay, adversely affect human health?

Answer

No. The overwhelming weight of scientific evidence supports the safety of community water fluoridation.

Fact

Assuring the safety of community water fluoridation has been at the forefront of public health practice since the earliest studies were conducted on fluoride more than 80 years ago. The evidence for safety is compelling. For generations, millions of people in North America have lived in areas where fluoride is found naturally in drinking water in concentrations as high or higher than the optimal level recommended to prevent tooth decay. To date, research conducted among these populations confirms the safety of fluoride in the water supply.[182-190]

As with other nutrients, fluoride is safe and effective when used and consumed as recommended. No charge against the benefits and safety of fluoridation has ever been substantiated by generally accepted scientific knowledge. Reviews on fluoride in drinking water have been issued periodically over the years. Beginning in 1951 the NRC issued its first report[191] stating that fluoridation was safe and effective. Additional reviews by the NRC followed in 1977,[24] 1993,[25] and 2006.[26] Additional reviews completed over the 17-year period from 2007 to 2024 include:

2024 Iheozor-Ejiofor Z, Walsh T, Lewis SR, Riley P, Boyers D, Clarkson JE, Worthington HV, Glenny A-M, O'Malley L. Water fluoridation for the prevention of dental caries. *Cochrane Database Syst Rev.* 2024, Issue 10. Art. No.: CD010856. DOI: 10.1002/14651858.CD010856.pub3. Accessed December 9, 2024.[27]

2023 Fiore G, Veneri F, Di Lorenzo R, Generali L, Vinceti M, Filippini T. Fluoride exposure and ADHD: A systematic review of epidemiologic studies. *Medicina.* 2023, 59(4), 797; *https://pmc.ncbi.nlm.nih.gov/articles/PMC10143272/pdf/medicina-59-00797.pdf.*[28]

2023 Kumar JV, Moss ME, Liu H, Fisher-Owens S. Association between low fluoride exposure and children's intelligence: a meta-analysis relevant to community water fluoridation. *Public Health.* 2023, 219, 73-84. DOI:10.1016/j.puhe.2023.03.011.[29]

2022 Belotti L, Frazão P. Effectiveness of water fluoridation in an upper-middle-income country: a systematic review and meta-analysis. *Int J Paediatr Dent.* 2022, 32(4), 503-513.[30]

2019 Cury J, Ricomini-Filho AP, Perecin Berti FL, Tabchoury CPM. Systemic effects (risks) of water fluoridation. *Brazilian Dent J.* 2019, 30(5), 421-428.[31]

2018 Ajiboye AS, Dawson DR, Fox CH. American association for dental research policy statement on community water fluoridation. *J Dent Res.* 2018, 97(12), 1293-1296.[32]

2018 Chaitanya NC, Karunakar P, Allam NSJ, Priya MH, Alekhya B, Nauseen S. A systematic analysis on possibility of water fluoridation causing hypothyroidism. *Indian J Dent Res.* 2018, 29(3), 358-363.[33]

2017 Australian Government. National Health and Medical Research Council (NHMRC). Information Paper—Water Fluoridation: Dental and Other Human Health Outcomes.[34]

2016 O'Mullane DM, Baez RJ, Jones S, Lennon MA, Petersen PE, Rugg-Gunn AJ, Whelton H, Whitford GM. Fluoride and Oral Health.[35]

2016 American Water Works Association. Water Fluoridation Principles and Practices. AWWA Manual M4. Sixth edition.[36]

2015 Water Research Foundation. State of the Science: Community Water Fluoridation.[37]

2015 Ireland Health Research Board. Health Effects of Water Fluoridation: An Evidence Review.[38]

2015 US Department of Health and Human Services Federal Panel on Community Water Fluoridation. US Public Health Service Recommendation for Fluoride Concentration in Drinking Water for the Prevention of Dental Caries.[39]

2014 Public Health England. Water Fluoridation: Health Monitoring Report for England.[40]

2014 Royal Society of New Zealand and the Office of the Prime Minister's Chief Science Advisor. Health Effects of Water Fluoridation: A Review of the Scientific Evidence.[41]

2013 US Community Preventive Services Task Force. The Guide to Community Preventive Services. Preventing Dental Caries: Community Water Fluoridation.[42]

2011 European Commission of the European Union Scientific Committee on Health and Environmental Risks (SCHER). Fluoridation.[43]

2008 Health Canada. Findings and Recommendations of the Fluoride Expert Panel.[44]

2007 Australian Government National Health and Medical Research Council: A Systematic Review of the Efficacy and Safety of Fluoridation; Part A: Review Methodology and Results.[45]

The overwhelming weight of scientific evidence supports the safety of community water fluoridation. There is a clear commitment on the part of the public health community to continue to monitor the safety of community water fluoridation.

18. Are additional studies being conducted to determine the effects of fluorides on humans?

Answer

Yes. Since its inception, fluoridation has undergone a nearly continuous process of re-evaluation. As with other areas of science, additional studies on the effects of fluorides on humans can provide insight as to how to make effective choices for the use of fluoride. The ADA and the USPHS support this ongoing research.

Fact

For more than 80 years, detailed reports have been published on multiple aspects of fluoridation. The accumulated dental, medical, and public health evidence concerning fluoridation has been reviewed and evaluated numerous times by academicians, committees of experts, special councils of governments, and most of the world's major national and international health organizations. The consensus of the scientific community is that water fluoridation, at the level recommended to prevent tooth decay, safely provides oral health benefits, which in turn support improved general health. The question of

possible secondary health effects caused by fluorides consumed at optimal concentrations throughout life has been the object of thorough medical investigations that have failed to show any impairment of general health throughout life.[27–45]

According to the British Fluoridation Society, as of 2020, approximately 380 million people in 25 countries worldwide were supplied with water fluoridated by adjustment.[465]

In scientific research, there is no such thing as "final knowledge." New information is continuously emerging and being disseminated. Government agencies, such as the US National Institute of Dental and Craniofacial Research (NIDCR), along with other institutes of the National Institutes of Health (NIH), and others continue to fund fluoride research. Two examples are highlighted here:

Fluoride and Neurodevelopmental Effects

One example is the National Toxicology Program's (NTP) systematic review of the literature concerning the association between fluoride exposure and neurodevelopmental and cognitive effects and its efforts to determine the level of confidence in that evidence.[192] A National Academies of Science, Engineering, and Medicine (NASEM) committee reviewed two earlier drafts of a NTP monograph and concluded that the evidence did not support their conclusion about neurodevelopmental effects. Therefore, the NTP monograph removed the neurodevelopmental hazard statement. The monograph found an association between high fluoride concentrations and lower IQ in children; however, these findings were based on exposures exceeding WHO guidelines (1.5 mg/L) and are not relevant to US fluoridation practices. **"The monograph and addendum do not address whether the sole exposure to fluoride added to drinking water in some countries (i.e., fluoridation, at 0.7 mg/L in the United States and Canada) is associated with a measurable effect on IQ."** The NTP report found no evidence that fluoride exposure negatively impacts adult cognition. The review also highlighted limited mechanistic insight because animal studies were of poor quality and human studies lacked clarity on biological pathways.[192]

Fluoride and Osteosarcoma

A comprehensive US study led by Harvard University researchers investigated the relationship between fluoride exposure and malignant bone tumors, analyzing data from nine hospitals over 8 years (1992–2000) with NIH support. An exploratory 2006 analysis[193] suggested a possible increased risk of osteosarcoma in boys aged 7, but the findings were likely influenced by methodological limitations, such as fluoride exposure estimation based on climate. A follow-up 2020 analysis[194] of the larger dataset found no association between osteosarcoma and fluoride exposure through community water or other sources. Similarly, a 2011 study[195] measuring actual fluoride levels in bone samples from osteosarcoma patients and controls found no significant differences, disproving a link between fluoride and bone cancer.

19. Why did the USPHS issue a report in 2015 recommending 0.7 mg/L as the optimal level for fluoride in drinking water for all temperature zones in the United States?

Answer

The USPHS updated and replaced its 1962 Drinking Water Standards related to community water fluoridation to set a single value of 0.7 mg/L as the optimal concentration of fluoride in drinking water for the whole country. This concentration provides the best balance of protection from tooth decay while limiting the risk of dental fluorosis.[196]

Fact

The previous USPHS recommendations for optimal fluoride concentrations were based on average ambient air temperatures of geographic areas and ranged from 0.7–1.2 mg/L. In 2011, the HHS issued a notice of intent in the *Federal Register*[196] proposing that all US community water systems adjust the amount of fluoride to 0.7 mg/L to achieve an optimal fluoride level.

The new guidance was based on several considerations:

- Scientific evidence related to the effectiveness of water fluoridation on caries prevention and control across all age groups.
- Fluoride in drinking water as one of several available fluoride sources.
- Trends in the prevalence and severity of dental fluorosis.
- Recent evidence on fluid intake in children across various ambient air temperatures.

As part of the process leading to the notice of intent, the HHS convened a federal interdepartmental, interagency panel of scientists to review the scientific evidence relevant to the 1962 USPHS Drinking Water Standards for fluoride concentrations in drinking water in the country and to update these recommendations based on current science. Panelists included representatives from the NIH, EPA, CDC, FDA, the Agency for Healthcare Research and Quality (AHRQ), the Office of the Assistant Secretary for Health (OASH), and the US Department of Agriculture (USDA).[196]

A public comment period followed the publication of the notice of intent, during which time more than 19,000 comments were received. The vast majority (more than 18,000) were variations on a letter submitted by an organization opposing community water fluoridation. Comments received were summarized and reported to the full federal panel. The panel then spent several years reviewing each comment in light of the best available science. After completing its extensive review, the panel did not alter the recommendation based on the following:

- Community water fluoridation remains an effective public health approach for delivering fluoride to prevent tooth decay and is the most feasible and cost-effective strategy for reaching entire communities.
- In addition to drinking water, other sources of fluoride exposure have contributed to the prevention of dental caries and an increase in dental fluorosis prevalence.
- Caries preventive benefits can be achieved and the risk of dental fluorosis reduced at 0.7 mg/L.
- Recent data did not show a convincing relationship between water intake and outdoor air temperature. Thus, recommendations for water fluoride concentrations that differ based on outdoor temperature are no longer necessary.[196]

In 2015, the USPHS published a final report establishing guidance for water systems that are actively fluoridating or those that may initiate fluoridation in the future.[39] For community water systems that add fluoride to their water, the USPHS recommends a uniform fluoride concentration of 0.7 mg/L (ppm) for the entire United States to maintain caries (tooth decay) prevention benefits and reduce the risk of dental fluorosis.

The USPHS further noted that surveillance of dental caries (tooth decay), dental fluorosis, and fluoride intake through the National Health and Nutrition Examination Survey (NHANES) will be done to monitor changes that might occur following implementation of the recommendation.[39]

20. What is the recommendation for the maximum level of naturally occurring fluoride in drinking water contained in the 2016 EPA 6-Year Review 3?

Answer

As established by the EPA, the maximum allowable level of naturally occurring fluoride in drinking water is 4 mg/L (or ppm). Under the Maximum Contaminant Level (MCL) standard, if the naturally occurring level of fluoride in a public w0ater supply exceeds the MCL, the water supplier is required to lower the level of fluoride below the MCL—a process called defluoridation. The MCL is a federally enforceable standard.[197] (Additional details regarding the EPA maximum contaminant standards can be found in Figure 3.)

Fact

Under the Safe Drinking Water Act (SDWA),[197] the EPA is required to periodically review the existing National Primary Drinking Water Regulations (NPDWRs) "not less often than every 6 years." This review is a routine part of the EPA's operations as dictated by the SDWA.

In April 2002, the EPA announced the results of its preliminary "revise/not revise" decisions for 68 chemical NPDWRs as part of its first 6-Year Review of drinking water standards.[198] Fluoride was one of the 68 items reviewed. While the EPA determined that it fell under the "Not Appropriate for Revision at this Time" category, the agency asked the National Academies to update the risk assessment for fluoride. The NRC previously had completed a review of fluoride for the EPA, which was published as *Health Effects of Ingested Fluoride* in 1993.[25]

The NRC's Committee on Toxicology created the Subcommittee on Fluoride in Drinking Water,[26] which reviewed toxicologic, epidemiologic, and clinical findings published since 1993 and exposure data on orally ingested fluoride from drinking water and other sources (e.g., foods and beverages, toothpaste, dental rinses). Based on these reviews, the subcommittee evaluated independently the scientific and technical basis of the EPA's maximum contaminant level goal (MCLG) of 4 mg/L and the secondary maximum contaminant level (SMCL) of 2 mg/L in drinking water (see Figure 3).

On March 22, 2006, almost 3 years after work began, the NRC issued a 500-page report titled *Fluoride in Drinking Water—A Scientific Review of the EPA's Standards*[26] to advise the EPA on the adequacy of its fluoride MCLG and SMCL to protect children and others from adverse effects. (For additional information on the EPA maximum contaminant standards, refer to Figure 3.) The report contained two major recommendations related to the MCLG:

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Figure 3: USEPA Standards and USPHS Recommendations for Fluoride in Drinking Water[203]

US Environmental Protection Agency (EPA) Standards for Fluoride in Drinking Water

The EPA standards for fluoride in drinking water apply to the ***naturally occurring*** fluoride in water. They are the:

- Maximum Contaminant Level Goal (**MCLG**) – 4 mg/L
- Maximum Contaminant Level (**MCL**) – 4 mg/L
- Secondary Maximum Contaminant Level (**SMCL**) – 2 mg/L

MCLG — The MCLG is the levela of contaminants in drinking water at which no adverse health effects are likely to occur. This health goal is based solely on possible health risks and exposure over a lifetime with an adequate margin of safety. The current MCLG for fluoride is 4 mg/L and is set at this level to provide protection against the increased risk of crippling skeletal fluorosis.

MCL — The MCL is an enforceable standard which is set as close to the health goal as possible, considering the benefit to the public, the ability of public water systems to detect and remove contaminants using suitable treatment technologies and cost. In the case of fluoride, the MCL is set at the MCLG.

Under the MCL standard, if the naturally occurring level of fluoride in a public water supply exceeds 4 mg/L, the water supplier is required to lower the level of fluoride or defluoridate. Community water systems that exceed the fluoride MCL of 4 mg/L must notify persons served by that system as soon as practical, but no later than 30 days after the system learns of the violation.

SMCL — Secondary standards are non-enforceable guidelines regulating contaminants that may cause cosmetic effects (such tooth discoloration). The EPA recommends secondary standards to water systems but does not require systems to comply. However, states may choose to adopt them as enforceable standards. Tooth discoloration and/or pitting is caused by excess fluoride exposures during the formative period prior to eruption of the teeth in children. The level of the SMCL was set based upon a balancing of the beneficial effects of protection from tooth decay and the undesirable effects of excessive exposures leading to discoloration.

Under the SMCL, if water exceeds 2 mg/L, the water system is to notify consumers that regular consumption of water with fluoride above 2 mg/L, may increase the risk for fluorosis in young (under 9 years of age) children. Community water systems that exceed the fluoride secondary standard of 2 mg/L must notify persons served by that system as soon as practical but no later than 12 months from the day the water system learns of the exceedance.

US Public Health Service (USPHS) Recommendation for Fluoride in Drinking Water

In 2015, the USPHS published a final report establishing guidance for water systems that are actively fluoridating or those that may initiate fluoridation in the future. For community water systems that add fluoride to their water, the USPHS recommends a uniform fluoride concentration of 0.7 mg/L for the entire United States to maintain caries (tooth decay) prevention benefits and reduce the risk of dental fluorosis.

Why is the EPA MCL of 4 mg/L different from the USPHS recommendation of 0.7 mg/L?

The two benchmarks have different purposes and are set under different authorities. The EPA MCL of 4 mg/L is set to protect against risks from exposure to too much fluoride. The USPHS recommended level of fluoride on 0.7 mg/L is set to promote the benefit of fluoride in preventing tooth decay while minimizing the chance for dental fluorosis.

Information Source: EPA Fact Sheet: Questions and Answers on Fluoride. 2011.
Available at *https://www.epa.gov/dwsixyearreview/fact-sheet-questions-and-answers-fluoride*

> In light of the collective evidence on various health end points and total exposure to fluoride, the committee concludes that the EPA's MCLG of 4 mg/L should be lowered. Lowering the MCLG will prevent children from developing severe enamel fluorosis and will reduce the lifetime accumulation of fluoride into bone that the majority of the committee concludes is likely to put individuals at increased risk of bone fracture and possibly skeletal fluorosis, which are particular concerns for subpopulations that are prone to accumulating fluoride in their bones.[26]
>
> To develop an MCLG that is protective against severe enamel fluorosis, clinical stage II skeletal fluorosis, and bone fractures, the EPA should update the risk assessment of fluoride to include new data on health risks and better estimates of total exposure (relative source contribution) for individuals. The EPA should use current approaches for quantifying risk, considering susceptible subpopulations, and characterizing uncertainties and variability.[26]

The 2006 NRC report[26] contained one major recommendation related to the SMCL:

> The prevalence of severe enamel fluorosis is very low (near zero) at fluoride concentrations below 2 mg/L. From a cosmetic standpoint, the SMCL does not completely prevent the occurrence of moderate enamel fluorosis. The EPA has indicated that the SMCL was intended to reduce the severity and occurrence of the condition to 15% or less of the exposed population. The available data indicate that fewer than 15% of children will experience moderate enamel fluorosis of aesthetic concern (discoloration of the front teeth) at that concentration. However, the degree to which moderate enamel fluorosis might go beyond a cosmetic effect to create an adverse psychological effect or an adverse effect on social functioning is not known.[26]

Additionally, the subcommittee identified data gaps and made recommendations for future research relevant to future revisions of the MCLG and SMCL for fluoride.[26]

It should be emphasized that the 2006 NRC report was not a review of fluoride as used in community water fluoridation. In fact, the 2006 NRC Report in Brief[26] states: "The committee did not evaluate the risks or benefits of the lower fluoride concentrations (0.7–1.2 mg/L) used in water fluoridation. Therefore, the committee's conclusions regarding the potential for adverse effects from fluoride at 2–4 mg/L in drinking water do not apply at the lower water fluoride levels commonly experienced by most US citizens."[26]

In response to the recommendations noted above from the NRC report, in 2011, the EPA completed and peer-reviewed a quantitative dose-response assessment based on the available data for severe dental fluorosis as recommended by the NRC.[199] Additionally, the EPA completed and peer-reviewed a document on the environmental exposure of children and adults to fluoride and the relative source contribution for water that is needed to derive the MCLG from the dose-response assessment.[199] These efforts were being undertaken during 6-Year Review 2, and therefore no action on fluoride MCLG and SMCL levels was taken during the 6-Year Review 2.

In December 2016, the EPA announced the review results for its third 6-Year Review (called 6-Year Review 3),[200] in which the EPA completed a detailed review of 76 national primary drinking water regulations. The regulation for naturally occurring fluoride in water was examined as part of this review and is included among the list of regulated contaminants considered to be "Low priority and/or no meaningful opportunity" under "Not Appropriate for Revision at this Time."[200]

The announcement of the results of the 6-Year Review 3 in the *Federal Register*[201] indicated that, with the reviews of fluoride conducted since the first 6-Year Review (including but not limited to the 2006 NRC report and the EPA Fluoride Risk Assessment and Relative Source Contribution) and noting that other contaminants are of much greater concern, the EPA recommended that no further action

be taken at that time to change the current MCL/MCLG of 4 mg/L (the maximum level of naturally occurring fluoride allowed in drinking water).[201]

The EPA decided in July 2024 that the fluoride National Primary Drinking Water Regulations are not a candidate for revision.[202] In addition, the NTP has not made a final decision about the report's developmental neurotoxicity systematic review conclusions and has not formally released a final report. Following publication of the final NTP report, the EPA will consider the systematic review and meta-analysis conclusions regarding developmental neurotoxicity to inform the agency's future development of a health effects assessment for fluoride. The EPA has not as yet changed this decision (as of January 25, 2025).

21. What is the Secondary Maximum Contaminant Level (SMCL) for naturally occurring fluoride in drinking water established by the EPA?

Answer

The SMCL for naturally occurring fluoride in water is 2 mg/L (or ppm). This is a non-enforceable federal standard.

Fact

In addition to the MCL, the EPA has established an SMCL of 2.0 mg/L and requires consumer notification by the water supplier if the naturally occurring fluoride level exceeds 2.0 mg/L. The SMCL, while not federally enforceable, is intended to alert families that regular consumption of water with natural levels of fluoride greater than 2.0 mg/L by young children could cause moderate to severe dental fluorosis in the developing permanent teeth.[204] The notice to be used by water systems that exceed the SMCL must contain the following points:

- The notice is intended to alert families that children under 9 years of age who are exposed to levels of fluoride greater than 2.0 mg/L may develop dental fluorosis.
- Adults are not affected because dental fluorosis occurs only when developing teeth are exposed to elevated fluoride levels.
- The water supplier can be contacted for information on alternative water sources or treatments that will ensure the drinking water would meet all standards (including the SMCL).[204]

22. Does the total intake of fluoride from air, water, food, and beverages in the community in the United States with drinking water fluoridated at the recommended level pose significant health risks?

Answer

No. The total intake of fluoride from air, water, food, and beverages in the community in the United States with drinking water fluoridated at the recommended level does not pose significant health risks.

Fact

In the United States, the Safe Drinking Water Standards in place account for all sources of fluoride and provide assurance of safety with respect to fluoride exposure. From time to time, concerns have been raised about fluoride exposures adversely affecting different aspects of health; however, with further study, none of these concerns has been demonstrated to pose significant health risks.

Fluoride from the Air

The atmosphere contains negligible concentrations of airborne fluorides. Studies reporting the levels of fluoride in air in the United States show that ambient fluoride contributes very little to a person's overall fluoride intake.[26,199]

Fluoride from Water

Water and water-based beverages are the chief source of dietary fluoride intake. Previous studies, when the recommended water fluoride level was 1.0 mg/L, estimated that most individuals received approximately 75% of dietary fluoride from water and water-based beverages.[205,206] The recommended level for fluoride in drinking water in the United States since 2015 has been established at 0.7 mg/L by the USPHS to reduce tooth decay substantially while balancing the occurrence of dental fluorosis.[39] Thus, the proportion of dietary fluoride from water has decreased for those drinking optimally fluoridated water, although water remains the chief source.

In the United States, the natural level of fluoride in groundwater varies from very low levels (less than 0.2 mg/L) to more than 4 mg/L. Public water systems in the country are monitored by the EPA, which requires that public water systems not exceed a naturally occurring fluoride level of 4 mg/L.[201]

When considering water fluoridation, an individual consuming 1 L of water fluoridated at 0.7 mg/L receives 0.7 milligrams of fluoride, while those consuming 1 L of water at 4.0 mg/L receive 4.0 milligrams of fluoride. Thus, while there can be considerable variation in fluoride intake from water across all water fluoride levels, for people drinking optimally fluoridated water, the amount of fluoride intake from water is relatively low. Individuals living in a community with water fluoridation get a portion of their daily fluoride intake from fluoridated water and a portion from dietary sources, which include foods and other beverages.

For generations, millions of people have lived in areas where fluoride is found naturally in drinking water in concentrations as high as or higher than those recommended to prevent tooth decay, and sometimes higher than 4.0 mg/L. Research conducted among these populations confirms the safety of fluoride in the water supply.[182-186] For example, a 10-year comparison study[186] of long-time residents of Bartlett and Cameron, Texas, where the water supplies contained 8.0 and 0.4 mg/L of fluoride, respectively, included examinations of organs, bones, and tissues. Other than a higher prevalence of dental fluorosis in the Bartlett residents (8.0 mg/L fluoride), the study indicated that long-term consumption of fluoride from water and food sources (resident average length of fluoride exposure

was 36.7 years), even at these levels more than 10 times higher than recommended for tooth decay prevention, resulted in no clinically significant physiological or functional effects.[186]

Fluoride in Food and Beverages

In looking at the fluoride content of food and beverages over time, it appears that fluoride intake from dietary sources has remained relatively constant.[207] Except for products prepared (commercially or by the individual) or cooked with fluoridated water, the fluoride content of most food and beverages is not significantly different between fluoridated and non-fluoridated communities. When fluoridated water is used to prepare or cook the samples, the fluoride content of food and beverages is higher.[205,207]

While information on the fluoride content of food and beverages, including the USDA's National Fluoride Database,[206] is limited and may not reflect current levels, in general, the fluoride content of fresh solid food in the United States is relatively low and ranges from 0.01 to 1.0 ppm.[207] The foods highest in fluoride are fish and shellfish, reflective of the fluoride found in ocean water and the presence or absence of bone fragments, such as those in sardines.[207] (Fluoride has an affinity for calcified tissues such as bones.) Cereals, baked goods, breads, and other grain products generally have fluoride concentrations between 0.06 and 0.72 ppm.[207] The majority of vegetables (leafy, root, legumes, green, or yellow) have a relatively low fluoride concentration (ranging from 0.01 to 0.5 ppm), with fruits generally having lower concentrations (ranging from 0.01 to 0.2 ppm) than vegetables.[207] Raisins are one exception in the fruit category, with a higher fluoride concentration due to the use of certain pesticides and concentrations of fluoride through drying.[207] Brewed teas generally contain fluoride concentrations of 1–6 ppm, depending on the amount of dry tea used, the water fluoride concentration, and the brewing time.[208] Note that the fluoride concentration of unsweetened instant tea powder appears very high when reported as a dry powder because this product is extremely concentrated. However, when one teaspoon of the unsweetened tea powder is added to an 8-ounce cup of water, the concentration for prepared instant tea is similar to that reported for regular brewed tea.[206]

Alcoholic beverages also contain fluoride and the amount varies, with distilled spirits showing the lowest average levels at 0.08 ppm, beer at 0.45 ppm, red wine at about 1 ppm, and white wine at about 2 ppm.[206]

Food and beverages that are processed commercially in cities fluoridated to the recommended level generally contain higher levels of fluoride than those processed in non-fluoridated communities. These foods and beverages are consumed not only in the city where they are processed, but also often are distributed to and consumed in non-fluoridated areas.[58] This "halo" or "diffusion" effect results in increased fluoride intake by people in non-fluoridated communities, providing them increased protection against tooth decay.[105,209]

Also, most people in both water-fluoridated and non-fluoridated communities use fluoride toothpaste. As a result of the widespread availability of these various sources of fluoride, the differences between tooth decay rates in fluoridated areas and non-fluoridated areas are somewhat less than they were many decades ago, but these differences are still substantial. Failure to account for the diffusion effect results in an underestimation of the total benefit of water fluoridation.[105]

The average daily dietary intake of fluoride (expressed on a body weight basis) by children residing in communities with water fluoridated at 1.0 mg/L has been found to be about 0.05 milligrams per kilogram of body weight per day (mg/kg/day).[146] In communities without optimally fluoridated water, average intakes for children were about 50% lower.[146] Dietary fluoride intake by adults in communities where water was fluoridated at 1.0 mg/L averaged 1.4–3.4 mg/day, and in non-fluoridated areas it averaged 0.3–1.0 mg/day.[146] With the current recommendation that drinking water be fluoridated at 0.7 mg/L, average intakes would be about 30% lower in fluoridated communities than when they were fluoridated at 1.0 mg/L.

23. How much fluoride is recommended to maximize the tooth decay prevention benefits of fluoride?

Answer

As with all nutrients, the appropriate amount of daily fluoride intake varies with age and body weight. Fluoride is safe and effective when used and consumed properly.

Fact

The Food and Nutrition Board of the National Academies of Sciences, Engineering, and Medicine (formerly the Institute of Medicine) has developed a comprehensive set of reference values for dietary nutrient intakes.[146] These reference values, the Dietary Reference Intakes (DRI), represent nutrient requirements to optimize health and set maximum-level guidelines to reduce the risk of adverse effects from excessive consumption of a nutrient. Along with calcium, phosphorous, magnesium, and vitamin D, DRIs for fluoride were established because of fluoride's proven preventive effects on tooth decay.

The Adequate Intake (AI) establishes a goal for intake to sustain a desired indicator of health without causing side effects. With fluoride, the AI is the daily intake level required to reduce tooth decay without causing moderate dental fluorosis. The AI for fluoride intake from all sources (fluoridated water, food, beverages, fluoride dental products, and dietary fluoride supplements) is 0.05 mg/kg/day. Using the established AI of 0.05 mg/kg, the amounts of fluoride for optimal health to be consumed each day have been calculated stratified by sex and age group based on average weight; they are presented in Table 2 in mg/day.[146]

Table 2. Reference Intakes for Fluoride

Food and Nutrition Board of the Institute of Medicine 1997[40]

Age Group	Reference Weights kg (lbs)*	Adequate Intake (mg/day)	Tolerable Upper Intake (mg/day)
Infants 0-6 months	7 (16)	0.01	0.7
Infants 7-12 months	9 (20)	0.5	0.9
Children 1-3 years	13 (29)	0.7	1.3
Children 4-8 years	22 (48)	1.0	2.2
Children 9-13 years	40 (88)	2.0	10.0
Boys 14-18 years	64 (142)	3.0	10.0
Girls 14-18 years	57 (125)	3.0	10.0
Males 19 years and over	76 (166)	4.0	10.0
Females 19 years and over	61 (133)	3.0	10.0

* Value based on data collected during 1988-94 as part of the Third National Health and Nutrition Examination Survey (NHANES III) in the United States.[40]

 |

The Tolerable Upper Intake Level (UL) establishes a maximum guideline, but it is not the recommended level of intake. The UL is the estimated maximum intake level that should not produce unwanted effects on health. The UL for fluoride intake from all sources (fluoridated water, food, beverages, fluoride dental products, and dietary fluoride supplements) is 0.10 mg/kg/day (milligram per kilogram of body weight per day) for infants, toddlers, and children through 8 years of age. For older children and adults, who are no longer at risk for dental fluorosis, the UL for fluoride is 10 mg/day regardless of weight. Using the established ULs for fluoride, the amount of fluoride that can be consumed each day to protect against the risk of moderate enamel fluorosis for children through age 8 has been calculated by sex and age group (based on average weight).[146]

As a practical example, daily intake of 2 mg of fluoride is adequate for a 9- to 13-year-old child weighing 88 pounds (40 kg). This was calculated by multiplying 0.05 mg/kg/day (AI) times 40 kg (weight) to equal 2 mg. At the same time, that 88-pound (40 kg) child could consume 10 mg of fluoride a day as a tolerable upper intake level.

Children living in a community with water fluoridation get a portion of their daily fluoride intake from fluoridated water and a portion from dietary sources, including various types of foods and other beverages. When considering water fluoridation, an individual must consume one liter of water fluoridated at 0.7 mg/L to receive 0.7 mg of fluoride. Children under 6 years of age, on average, consume less than one-half liter of drinking water a day.[207] Therefore, children under 6 years of age would consume, on average, less than 0.35 mg of fluoride a day from drinking optimally fluoridated water (at 0.7 mg/L).

If a child lives in a non-fluoridated area and is determined to be at high risk for tooth decay, the dentist or physician may prescribe dietary fluoride supplements.[75] As shown earlier in Table 1 for the Dietary Fluoride Supplement Schedule (see Benefits Section, Question 12), the current dosage schedule recommends supplemental fluoride amounts that are below the AI for each age group.[75] The dosage schedule was designed to offer the benefit of decay reduction with a margin of safety to prevent mild to moderate enamel fluorosis. For example, the AI for a child 3 years of age is 0.7 mg/day. The recommended dietary fluoride supplement dosage for a child 3 years of age in a non-fluoridated community is 0.5 mg/day. This provides leeway for some fluoride intake from processed foods and beverages, as well as toothpaste and other sources.

Tooth decay rates have declined substantially in many population groups because children today are being exposed to fluoride from a wider variety of sources than many decades ago.[39] Many of these sources are intended for topical use only; however, some fluoride is ingested inadvertently by children.[210,211] By reducing the inappropriate ingestion of fluoride from toothpaste, the risk of dental fluorosis can be reduced without jeopardizing the benefits to oral health through caries prevention.

For example, it has been reported in a number of studies that young children inadvertently swallow about 30–60% of the fluoride toothpaste applied, or an average of about 0.30 mg of fluoride from fluoride toothpaste at each brushing.[212-217] If a child brushes twice a day, 0.60 mg of fluoride could be ingested inappropriately. This could slightly exceed the AI values from Table 2. The 0.60 mg consumption is 0.10 mg higher than the AI value for children 6–12 months and is 0.10 mg lower than the AI for children from 1 to 3 years of age.[146] Although toothpaste is not meant to be swallowed, children could consume the daily recommended AI amount of fluoride from toothpaste alone. In order to decrease the risk of dental fluorosis, the ADA recommends:[218]

- "For children younger than 3 years, caregivers should begin brushing children's teeth as soon as they begin to come into the mouth using fluoride toothpaste in an amount no more than a smear or the size of a grain of rice (Figure 4). Brush teeth thoroughly twice per day (morning and night) or as directed by a dentist or physician. Supervise children's brushing to ensure they use the appropriate amount of toothpaste.

- For children 3 to 6 years of age, caregivers should dispense no more than a pea-sized amount (Figure 4) of fluoride toothpaste. Brush teeth thoroughly twice per day (morning and night) or as directed by a dentist or physician. Supervise children's brushing to minimize swallowing of toothpaste."

Additional information on this topic can be found in this Section, Question 29.

Figure 4. Examples of Toothpaste Amounts for Children[49]

For children under three years old, use no more than a smear or grain-of-rice-sized amount of fluoride toothpaste.

For children three to six years old, use only a pea-sized amount of fluoride toothpaste.

It should be noted that the amounts of fluoride discussed here are intake, or ingested, amounts. When fluoride is ingested, a portion is retained in the body and a portion is excreted.

Additional information on this topic can be found in this Section, Question 25.

24. Is there a need for prenatal dietary fluoride supplementation?

Answer

No. There is no scientific basis to suggest the need to increase a person's daily fluoride intake during pregnancy or breastfeeding to protect their health. Scientific evidence is insufficient to support the recommendation for prenatal fluoride supplementation for decay prevention for infants.

Fact

The National Academy of Medicine (NAM) determined that, "No data from human studies document the metabolism of fluoride during lactation. Because fluoride concentrations in human milk are very low (0.007–0.011 ppm) and relatively insensitive to differences in the fluoride concentrations of the mother's drinking water, fluoride supplementation during lactation would not be expected to significantly affect fluoride intake by the nursing infant or the fluoride requirement of the mother."[146]

A 2005 randomized, double-blind study[219] compared the amount of fluoride incorporated into primary teeth exposed to prenatal and postnatal fluoride supplements to the incorporation of fluoride in primary teeth that were exposed to only postnatal fluoride. The study concluded that teeth exposed to prenatal and postnatal fluoride supplements had no additional measurable fluoride other than that attributable to postnatal fluoride alone.[219] This study confirmed the findings of a 1997 randomized, double-blind study that evaluated the effectiveness of prenatal dietary supplementation, which concluded that the data did not support the hypothesis that prenatal fluoride had a strong decay preventive effect on primary teeth.[220]

25. When fluoride is ingested, where does it go?

Answer

Much of the ingested fluoride is excreted. Of the fluoride retained, almost all is found in calcified (hard) tissues, such as bones and teeth.

Fact

After ingestion of fluoride, such as drinking a glass of fluoridated water, the majority of the fluoride is absorbed from the stomach and small intestine into the bloodstream. This causes a short-term increase in fluoride levels in the blood. Fluoride is distributed through the body by plasma (a component of blood) to hard and soft tissues. Following ingestion, the fluoride plasma levels increase quickly and reach a peak concentration within 20–60 minutes. The concentration declines rapidly, usually approximating the baseline levels within three to 6 hours, due to the uptake of fluoride by calcified tissues and excretion in urine. In adults, approximately 50% of the fluoride absorbed each day becomes associated with calcified tissues within 24 hours, while the remainder is excreted in the urine. Approximately 99% of the fluoride present in the body is in calcified tissues (mainly bone).[221]

Ingested or systemic fluoride becomes incorporated into developing tooth structures. Fluoride ingested regularly during the time when teeth are developing is deposited throughout the tooth structure and contributes to long-lasting protection against tooth decay.[78,79,82,83,222]

Additional information on this topic can be found in the Benefits Section, Question 2.

An individual's age and stage of skeletal development will affect the rate of fluoride retention. The amount of fluoride taken up by bone and retained in the body is negatively associated with age. A greater percentage of fluoride is absorbed in young bones than in the bones of older adults.[221] However, once fluoride is absorbed into bones, some of it can be released back into plasma when fluoride levels in plasma fall to maintain a near steady state. This absorption and release cycle continues throughout the life span.[221]

26. Will drinking water that is fluoridated at the recommended level adversely affect bone health?

Answer

No. According to the best available science, drinking water that has been fluoridated at the recommended level does not have an adverse effect on bone health.

Fact

Several systematic reviews have concluded that fluoride at the level used in community water fluoridation has no adverse effect on bone health. A systematic review published in 2000 concluded that there was no clear association between water fluoridation and hip fracture.[223] Twenty-nine studies that looked at the association between bone fracture/bone development and water fluoridation were included in the review. The evidence regarding other types of bone fractures was similar.[223] A systematic review published in 2017[34] concurred with the earlier review, concluding that fluoridated water at recommended levels is not associated with bone fracture.[34]

The following studies, listed in reverse chronological order, add to the body of evidence indicating that there is no association between consumption of optimally fluoridated water and bone fracture.

Iowa Fluoride Study/Iowa Bone Development Study

The Iowa Fluoride Study/Iowa Bone Development Study followed a cohort in Iowa from birth to age 23, with frequent assessment of fluoride exposures with parents completing detailed fluoride questionnaires linked to water fluoride assay results and multiple bone densitometry assessments during bone development. The combined fluoride intakes were estimated from a number of sources, including water, other beverages, selected foods, dietary fluoride supplements, and fluoride toothpaste. Six publications looked at the associations of fluoride intakes over defined periods and cumulatively from birth with bone densitometry outcomes at ages 11–23, including dual-energy x-ray absorptiometry (DXA), peripheral quantitative computed tomography (pQCT), and multi-detector computed tomography (MDCT).[224-229] The studies consistently found weak and almost all non-significant relationships between the fluoride intakes and bone densitometry outcomes in adjusted regression analyses. This includes DXA bone mineral content and density outcomes of the hip, lumbar spine, and whole body at age 15,[226] multiple pQCT radial and distal tibial measures at ages 11[225] and 17,[227] and MDCT distal tibial measures at ages 19[228] and 23.[229] The authors concluded that fluoride exposures at typical levels for most US adolescents in fluoridated areas do not have significant effects on bone mineral measures.[224,225,227] Additional analyses found that fluoride intakes were not associated with estimated strength measures from finite element analyses (FEA) at age 23.[230]

Swedish Study

In one of the largest studies of its kind with nearly half a million subjects, Swedish researchers looked at residents' chronic consumption of various levels of fluoride and the risk of hip fracture.[231] All individuals born in Sweden between January 1, 1900, and December 31, 1919, alive and living in their municipality of birth at the time of the start of follow-up, were eligible for the study. Information on the study population was linked to the Swedish health registers. Estimated individual drinking water fluoride exposure was stratified into four categories: very low, < 0.3 mg/L; low, 0.3 to 0.69 mg/L; medium, 0.7 to 1.49 mg/L; and high, ≥ 1.5 mg/L. The 2013 published study found no association between chronic fluoride exposure and the occurrence of hip fracture. The authors concluded that, "The risk estimates did not change in analyses restricted to only low-trauma osteoporotic hip fractures. Chronic fluoride exposure from drinking water does not seem to have any important effects on the risk of hip fracture, in the investigated exposure range."[231]

Bone Mineral Density Study

A study published in 2005 evaluated the bone mineral density levels and rates of bone fracture of 1,300 ambulatory women aged 20–92 years living in three separate communities with diverse mineral content.[232] The sizes and demographics of the three communities were similar. One part of the study looked at whether fluoride was associated with adverse bone-related outcomes. The study measured fluoride serum levels, fluoride exposure, and bone metabolism as related to fluoride exposure and fluoride's interaction with other important bone factors, including age, menopause status, and medications. The high-fluoride community was found to have significantly higher serum fluoride levels (2.11 µmol/L) compared to the control and high-calcium communities. Serum fluoride was not significantly associated with bone mineral density, except for higher distal radius bone mineral density in the high-fluoride community. No relationship was found between serum fluoride levels and the risk of osteoporotic fractures over 4 years. The study concluded that long-term exposure to fluoride was not associated with adverse effects on bone health.[232]

Bone Fractures Risk Study

A study published in 2001[233] examined the risk of bone fractures, including hip fractures, associated with long-term exposure to fluoridated water in six Chinese samples. The water fluoride concentrations ranged from 0.25 to 7.97 mg/L. A total of 8,266 male and female subjects, all of whom were 50 years old or older, participated in the study. The results showed an interesting and potentially important finding regarding overall bone fractures. The lowest overall fracture rates were observed at fluoride concentrations of 1–1.06 ppm, forming a U-shaped pattern where both lower and higher fluoride levels increased fracture risk. High fluoride levels (above 4.32 ppm) were associated with a significant increase in hip fractures. The study emphasized that fluoride exposure at optimal levels for dental health may also reduce overall fracture risk, but excessive levels lead to adverse effects. These findings highlight the importance of maintaining balanced fluoride levels to protect bone health.[233] **(Note that 4.32 mg/L is more than six times the fluoride level currently recommended for community water fluoridation in the Unites States.)**

Hillier and Phipps Studies

While a number of studies reported findings at a population level, both the Hillier[234] and Phipps[235] studies published in 2000 examined risk on an individual basis, rather than a community basis.

Using this more rigorous study design, these two studies reported no effect on the risk of hip fracture[234] and no increase in the risk of hip fracture in those drinking fluoridated water,[235] respectively.

Hillier et al. (2000)[234] conducted a case-control study in the United Kingdom that examined the potential link between fluoride in drinking water and hip fracture risk among adults aged 50 years and older. The study included 914 cases of hip fracture and 1,196 controls. The estimated lifetime fluoride exposure ranged from 0.15 to 1.79 ppm, with Hartlepool residents having the highest exposure. After adjusting for confounders such as body mass index (BMI) and physical activity, no increased risk of hip fractures was found for fluoride levels at or above 0.9 ppm.[234]

Phipps et al. (2000)[235] investigated whether long-term exposure to fluoridated drinking water affects bone mineral density (BMD) and fracture risk in older women. Among 7,129 participants, women with 20 years of continuous fluoride exposure had a slightly higher BMD at the femoral neck (2.6%) and lumbar spine (2.5%), but a slightly lower BMD at the distal radius (1.9%). Continuous fluoride exposure was associated with a reduced risk of hip fractures (risk ratio 0.69) and vertebral fractures (0.73), though there was a non-significant trend toward an increased risk of wrist fractures (1.32). No difference in humerus fracture risk was observed. Overall, the findings indicate that long-term fluoridation does not increase fracture risk and may provide some protective effects for certain bones.[235]

In summary, according to the best available science, drinking water that has been fluoridated at the recommended level does not have an adverse effect on bone health.

27. What is dental fluorosis or enamel fluorosis?

Answer

Dental fluorosis, also called *enamel fluorosis,* is a change in the appearance of the tooth enamel that only occurs when younger children consume too much fluoride, from all sources combined, over extended periods when teeth are developing under the gums. It can cause opaque or white blemishes on teeth. The permanent teeth (except the "wisdom teeth" or third molars) finish their development when children are 8 to 10 years old, so dental fluorosis only occurs when too much fluoride is consumed during the period of birth to 8 to 10 years of age (with the first 4 years of life being most important for the front teeth that are visible when smiling). After that age, there is no longer any risk of developing fluorosis.[236]

Fact

Dental fluorosis is associated with total fluoride intake during the ages when teeth are forming, so fluoride intake not only from water but also from other beverages, foods, and fluoride products, such as toothpaste, mouthrinses, and dietary fluoride supplements, is important. The best available evidence indicates that the majority of fluorosis in the United States is caused by the inappropriate ingestion of fluoride products.[237]

It should be noted that there are many other developmental changes that affect the appearance of tooth enamel that are not related to fluoride intake, including enamel hypoplasia, demarcated opacities, and others. In other words, not all opaque or white blemishes on teeth are caused by fluoride. Furthermore, dental fluorosis occurs among some people in all communities, even in communities that do not have community water fluoridation or have low natural concentrations of fluoride in their drinking water.[238–240]

In the United State, the vast majority of dental fluorosis cases are mild or very mild. These mild or very mild changes to the enamel are only seen when the teeth are dry and clean, such as when a dentist examines them. For this reason, it is often difficult to detect dental fluorosis in its milder forms, and even trained specialists can sometimes disagree over the presence of fluorosis or its severity. Mild or very mild fluorosis has no effect on tooth function and is associated with the teeth being more resistant to decay. More information on mild dental fluorosis can be found on the ADA's website.[241]

Measurement and Classification of Dental Fluorosis

Dental fluorosis usually is assessed by direct visual inspection of the teeth, with or without drying of the teeth with compressed air or gauze squares. There are several different classification schemes that vary in the codes used and the degree to which the teeth are dried. Because of how drying the teeth can affect the detection and assessment of dental fluorosis, some researchers have proposed using standardized photographs for evaluating dental fluorosis.[242,243]

In the United States, the most widely used classification is the Dean's Fluorosis Index, which was developed by Dr. Trendley Dean in 1942 as part of his pioneering research on water fluoride concentrations, dental caries, and dental fluorosis.[94] For Dean's Fluorosis Index, each tooth in an individual's mouth is rated according to the fluorosis index in Table 3. The individual's person-level dental fluorosis score is based on the two most affected teeth in the mouth recorded as the second most affected tooth. Dean's Fluorosis Index remains popular for prevalence studies, in large part due to its simplicity and the ability to make comparisons with findings from a number of earlier studies.[244]

Table 3. Dean's Fluorosis Index[245]

Table 3. Dental Fluorosis Classification by H.T. Dean – 1942	
Classification	**Criteria-Description of Enamel**
Normal	Smooth, gloss, pale creamy-white translucent surface
Questionable	A few white flecks or white spots
Very Mild	Small opaque, paper-white areas covering less than 25% of the tooth surface
Mild	Opaque white areas covering less than 50% of the tooth surface
Moderate	Large areas of the tooth are affected and biting surfaces have marked wear; brown stain may be present
Severe	Affected tooth surfaces have discrete or confluent pitting; brown stain present

The CDC through its National Center for Health Statistics (NCHS) regularly conducts surveys and examinations on a representative sample of Americans to assess the health and nutritional status of adults and children in the United States. This program, called the National Health and Nutrition Examination Survey (NHANES), includes an oral health component that periodically assesses dental fluorosis by using Dean's Index. Thus, NHANES periodically reports on the prevalence of dental fluorosis and, in this way, trends in prevalence and severity can be tracked over time. Specifically, data from the periods 1999–2004 and 2011–2016 are available to characterize dental fluorosis prevalence and severity.[246] A separate but similar nationally representative study conducted by the National Institute of Dental Research (NIDR) in 1986–1987 provides additional historical information to assess long-term trends in dental fluorosis.[247]

As described previously, dental fluorosis is inherently difficult to assess, and its prevalence (total percentage of population affected), as reported in the NHANES surveys, has varied considerably from year to year. In fact, despite the examinations being conducted by highly trained dental examiners, the NCHS suggested that examiners may have evaluated fluorosis differently during the 2012–2016 NHANES reporting period than in previous surveys, and that these data should not be compared directly to previous data on fluorosis prevalence and trends.[246] Nonetheless, these data, combined with the 1986–1987 NIDR data, suggest an overall increase in fluorosis prevalence over the past four decades among children and adolescents. The 2011–2016 fluorosis prevalence was 71.5% among children and adolescents aged 6–19 years, with most of this fluorosis (~80%) being in the mild or very mild categories. There was marked variation in prevalence and severity in the year-to-year data during this period, with a prevalence of 57.0% in 2011–2012, 88.3% in 2013–2014, and 68.9% in 2015–2016. This compares to a prevalence of 36.6% in 1999–2004 for the same age group, with 90% of fluorosis being mild or very mild during this period.[246]

There is also evidence that the appearance of dental fluorosis may change over time, becoming less evident in the years after tooth eruption. A large longitudinal US study that followed children from birth into their early 20s reported that the tooth- and person-level appearance of mild to moderate fluorosis declined substantially during adolescence and young adulthood.[248,249] These findings are consistent with results from other longitudinal studies conducted in Hong Kong[250] and Australia[251] as well as an earlier US study.[252]

Despite limitations with the quality and consistency of the fluorosis data from the 2011–2016 NHANES survey and findings of changes in fluorosis over time, it is important to emphasize that the vast majority of fluorosis is mild or very mild and not readily apparent to the casual observer. Moreover, the NHANES surveys have consistently found that severe fluorosis is quite rare, affecting no more than 2% of children and adolescents in any year of the survey, with prevalence generally well below 1%.[246] Whether severe fluorosis has anything more than a cosmetic effect on affected teeth has been called into question, but a consensus reached during the early 2000s was that severe dental fluorosis was an adverse health effect. Specifically, members of a committee convened by the NRC for the EPA concluded that severe dental fluorosis involves damage to the tooth structure, and that the EPA's drinking water standard should aim to prevent the occurrence of this unwanted condition.[26]

As described in Questions 28 and 29, the USPHS recommended in 2015 that the optimal water fluoride concentration be reduced to 0.7 mg/L throughout the United States.[39] This was done to provide the best balance of protection from tooth decay while reducing the risk of dental fluorosis. It is important to note that it will take several more years for the change in recommended water fluoride concentrations to be reflected fully in any studies of dental fluorosis, including NHANES data, because fluorosis occurs during tooth development and doesn't become apparent until those teeth erupt some 6–8 years later. Thus, it is not possible for the 2011–2016 NHANES data to reflect any changes resulting from the new water fluoride recommendations.

The Effects of Dental Fluorosis

In contrast to severe fluorosis, very mild, mild, and moderate dental fluorosis have no effects on tooth function but are associated with tooth enamel being more resistant to decay. A study published in 2009 investigated the relationship between dental fluorosis and tooth decay in US schoolchildren.[253] The study clearly demonstrated that teeth with dental fluorosis were more resistant to tooth decay than were teeth without dental fluorosis. Not only should the cavity-preventive benefits of fluoridation be considered when evaluating policy to introduce or retain water fluoridation, but the cavity-preventive benefits associated with having mild dental fluorosis should also be considered.

Limited research on the psychological effects of dental fluorosis on children and adults has been conducted. However, a 2010 literature review that assessed the relationships between perceptions of dental appearance/oral health-related quality of life (OHRQoL) and dental fluorosis concluded that very mild to mild dental fluorosis has little impact, and some evidence suggested that mild dental fluorosis is associated with enhanced quality of life.[254] When evaluating the OHRQoL of children by tooth decay (cavities) and dental fluorosis experience, a 2007 study concluded that cavities and malocclusion were associated with negative impacts, while mild dental fluorosis had a positive impact on children's and parents' quality of life.[255]

As discussed later in Question 29, dental fluorosis is a result of the over-ingestion of fluoride **from all sources** during tooth development, and not just fluoride from fluoridated water. Other sources of fluoride that have been linked to the development of dental fluorosis include ingestion of fluoride toothpaste (using and swallowing too much toothpaste when brushing), use of dietary fluoride supplements, and fluoride intake from other beverages and foods. Additionally, studies have suggested that other factors, including living at higher altitudes and with higher average temperatures, can increase fluorosis prevalence[256] and that diagnoses of dental fluorosis sometimes do not seem to match known fluoride exposures.[257]

28. Is it safe to use fluoridated water to reconstitute infant formula?

Answer

Yes, it is safe to use fluoridated water to reconstitute infant formula.

Fact

Fluoridated water can be used to prepare infant formula. However, if the child is exclusively consuming infant formula reconstituted with fluoridated water, there could be an increased chance of mild dental fluorosis.[196] To lessen this chance, parents can use low-fluoride bottled water some of the time to mix infant formula. These bottled waters are labeled as deionized, purified, demineralized, or distilled. However, parents should be aware that using these types of waters exclusively means an infant does not receive the amount of fluoride the NAM indicated is required to prevent tooth decay.[146]

On the other hand, the exclusive use of non-fluoridated water to reconstitute infant formula will not guarantee that an infant will not develop dental fluorosis. The chance of development of dental fluorosis exists through approximately 8–10 years of age when the later-erupting permanent teeth are still forming under the gums. Fluoride intake during this time from other sources, such as from toothpaste, mouthrinse, dietary fluoride supplements, and from other beverages and foods also contributes to the chance of dental fluorosis for children living in both non-fluoridated and fluoridated communities.[258]

The ADA's 2011 report, *Evidence-Based Clinical Recommendations Regarding Fluoride Intake From Reconstituted Infant Formula and Enamel Fluorosis: A Report of the American Dental Association Council on Scientific Affairs,*[258] encourages clinicians to follow the AAP guidelines for infant nutrition, which now recommend exclusive breastfeeding until the child is about 6 months, with the introduction of complementary solids at about 6 months.[259]

Additionally, the ADA report,[258] designed for use by clinical practitioners, offers the following suggestions in advising parents and caregivers of infants who consume powdered or liquid concentrate infant formula as the main source of nutrition:

> *Suggest the continued use of powdered or liquid concentrate infant formulas reconstituted with optimally fluoridated drinking water while being cognizant of the potential risk of enamel fluorosis development.*[260]
>
> *When the potential risk of enamel fluorosis development is a concern, suggest ready-to-feed formula or powdered or liquid concentrate formula reconstituted with water that either is fluoride-free or has low concentrations of fluoride.*[258]

It should be noted that the CDC,[261] as well as other agencies and organizations such as HHS,[196] the American Public Health Association (APHA),[262] and health departments such as the New York State Health Department,[263] provide similar information regarding the use of fluoridated water to reconstitute infant formula.

29. What can be done to reduce the occurrence of dental fluorosis in the United States?

Answer

The vast majority of dental fluorosis in the country can be prevented by limiting the ingestion of topical fluoride products such as toothpaste and recommending the appropriate use of dietary fluoride supplements—without denying young children the decay-prevention benefits of community water fluoridation, the recommended optimal concentration of which has been reduced to better balance caries and fluorosis prevention.

Fact

Tooth decay has decreased substantially in the country because more children today than decades ago are benefitting from access to fluoride that is available from a wide variety of sources. Many of these sources are intended for topical use only; however, when they are used, some fluoride is inadvertently swallowed by children.[210,211,260] Inappropriate ingestion of topical fluoride can be minimized, thus reducing the risk for dental fluorosis without reducing decay prevention benefits.

Fluoride Toothpaste

Fluoride toothpastes are effective in helping to prevent tooth decay, but the ingestion of fluoride from toothpaste is a major risk factor for enamel fluorosis.[210,211,260] Data from NHANES found that more than 38% of children aged 3 to 6 years used more than the recommended amount of toothpaste for their age group.[264]

> To decrease the risk of dental fluorosis, the ADA recommends:[218]
>
> *"For children younger than 3 years, caregivers should begin brushing children's teeth as soon as they begin to come into the mouth by using fluoride toothpaste in an amount no more than a smear or the size of a grain of rice. (See Figure 4 in Question 23.) Brush teeth thoroughly twice per day (morning and night) or as directed by a dentist or physician. Supervise children's brushing to ensure that they use the appropriate amount of toothpaste.*
>
> *For children 3–6 years of age, caregivers should dispense no more than a pea-sized amount (Figure 4) of fluoride toothpaste. Brush teeth thoroughly twice per day (morning and night) or as directed by a dentist or physician. Supervise children's brushing to minimize swallowing of toothpaste."*

The reason for including age information on directions for use of fluoride toothpaste is that it takes into account the ages during which teeth are most susceptible to dental fluorosis (during the time when the teeth are forming under the gums). Additionally, until approximately 6 years of age, children have not developed the full ability to spit and not swallow toothpaste. Inadvertently swallowing toothpaste during brushing can increase the risk of dental fluorosis. After age 8, the enamel formation of permanent teeth (with the exception of the third molars) is basically complete;[236] therefore, the risk of developing dental fluorosis is minimal. Because dental fluorosis occurs while teeth are forming under the gums, teeth that have erupted are not at risk for enamel fluorosis.

Additional information on this topic can be found in this Section, Question 27.

Several studies have established a direct association between young children brushing with more than a pea-sized amount of fluoride toothpaste and the risk for very mild or mild dental fluorosis in fluoridated or non-fluoridated communities.[210,211,216,239,260] It was noted that 34% of the dental fluorosis cases in a

non-fluoridated community were attributed to children having brushed with fluoride toothpaste more than once per day during the first 2 years of life.[265] Fluoride toothpaste use had an even greater impact on fluorosis in the optimally fluoridated community, with 68% of fluorosis due to children using more than a pea-sized amount of toothpaste during the first year of life. However, recognizing that the risk for tooth decay can start before a child's first birthday with initial tooth eruption, it is considered important to begin using a fluoride toothpaste when the child's first tooth appears in the mouth.[218]

Dietary Fluoride Supplements

Dietary fluoride supplements should only be prescribed for children at high risk for tooth decay who live in non-fluoridated areas.[75] Furthermore, dietary fluoride supplements should be prescribed according to the dosage schedule found in the *Evidence-Based Clinical Recommendations on the Prescription of Dietary Fluoride Supplements for Caries Prevention: A Report of the American Dental Association Council on Scientific Affairs* published in 2010.[75] There is strong evidence that the use of dietary fluoride supplements during the first 3 years of life is associated with significantly increased risk for dental fluorosis,[266] so they should only be used for children at high risk for caries where the risk of tooth decay is of great concern.

It is important to determine the risk for tooth decay through a professional caries risk assessment, which assists the healthcare provider to identify and modify factors that could contribute to the development of cavities.[145] A child's risk for dental caries should be routinely evaluated because risk status can be affected by changes in the child's development, home conditions, dietary regimen, and oral hygiene practices. Additional information on caries risk assessments can be found on the ADA's website.[145]

Because of the many sources of fluoride in the diet, proper prescribing of dietary fluoride supplements can be complex. It is suggested that all sources of fluoride be evaluated with a thorough fluoride history before dietary fluoride supplements are prescribed for a child.[75] This evaluation should include testing of the home water supply and other important water sources (e.g., childcare/preschool/school) if the fluoride concentrations are unknown. Families on community water systems should contact their water supplier to ask about its fluoride level. Consumers with private wells should have the water tested annually to accurately determine the fluoride content.

Over-the-Counter Fluoride-Containing Dental Products

Parents, caregivers, and health care professionals should judiciously monitor the use of all fluoride-containing dental products by children younger than age 6. As is the case with any therapeutic product, more is not always better. The same is true for most products found in the medicine cabinet; care should be taken to adhere to label directions on fluoride prescriptions and over-the-counter (OTC) products (e.g., fluoride toothpastes and mouthrinses).

The ADA recommends the use of fluoride mouthrinses, but not for children less than 6 years of age because they often swallow the rinse, thus increasing the risk for fluorosis. This is particularly true if used by the youngest children. For this reason, such products should be stored out of the reach of children. Additional information regarding the use of mouthrinses can be found on the ADA's website.[267]

While professionally applied fluoride products, such as fluoride varnish, gels, foams, and silver diamine fluoride (SDF), have high fluoride concentrations,[241] they are used so infrequently (compared to fluoride toothpaste, mouthrinses, or water containing higher amounts of fluoride), that their use has not been shown to affect dental fluorosis prevalence.[268]

Drinking Water

As stated in Question 27, in 2015 the USPHS established a nation-wide recommended level of fluoride for water fluoridation (at 0.7 mg/L) to provide the best balance of protection from tooth decay while reducing the risk for dental fluorosis.[39] While it is too early to determine the impact of this change on the prevalence and severity of dental fluorosis, studies in other countries where optimal water fluoride levels were reduced showed lower fluorosis prevalence.[269]

In areas where naturally occurring fluoride levels in ground water are high (e.g., 2 mg/L or higher), the EPA recommends consumers consider alternative sources for drinking water for young children.[204] Families with young children on community water systems should check their Consumer Confidence Reports on water quality or contact their water suppliers to ask about the fluoride level in their drinking water. Consumers with private wells should have the water tested yearly to accurately determine the fluoride content. Consumers should consult with their dentist regarding water-testing results and discuss appropriate dental health preventive measures.[204]

Infant Formula

As detailed in Question 28, promoting breastfeeding is consistent with guidelines for infant nutrition, and breastfeeding of more than 6 months has been shown to reduce the prevalence of dental fluorosis compared with not breastfeeding.[270] Another study demonstrated that fluoride ingestion is significantly lower when reconstituting infant formula concentrate with bottled water than it is when using tap water.[271]

30. Why is there a warning label on a tube of fluoride toothpaste?

Answer

The FDA has established regulations for warning labels for a number of OTC items it considers safe and effective, including fluoride toothpaste.

Fact

The FDA has published regulations regarding warning labels for OTC drugs in the Code of Federal Regulations (CFR).[272] All non-prescription drugs covered by these regulations must display the general warning "Keep out of the reach of children" in bold type. The regulations outline three additional warning statements (based on the most likely route of exposure) to be listed on the label in the event the drug is misused. While they vary slightly, they all include the following language: "...get medical help or contact a Poison Control Center right away."[272]

In the CFR, the FDA has outlined the drug categories to be covered by these warning labels.[273] Some of the 26 categories include antacids, allergy treatment products, antiperspirants, cold remedies, ophthalmic products, dentifrices (toothpastes), and dental products such as analgesics and antiseptics.[273] A specific FDA regulation[274] applies to "Anticaries Drug Products for Over-The-Counter Human Use," which provides the exact language for the warning label to be used on "fluoride dentifrice (gel, paste, and powder) products." The regulation requires that the following language appear on these products under the heading "Warning":

> "Keep out of reach of children under 6 years of age. **If more than used for brushing is accidentally swallowed, get medical help or contact a Poison Control Center right away."**[274]

The OTC drugs listed in these regulations are generally recognized as safe and effective by the FDA.[272] Fluoride toothpaste is just one in a long list of OTC products that carries a warning label.

The OTC drugs listed in these regulations are generally recognized as safe and effective by the FDA. Fluoride toothpaste is just one in a long list of OTC products that carries a warning label.

31. Is fluoride, as provided by community water fluoridation, a toxic substance?

Answer

No. Fluoride in water at the recommended level is not toxic according to the best available scientific evidence.

Fact

Like many common substances essential to life and good health–salt, iron, vitamins A and D, chlorine, oxygen, and even water itself–fluoride can be toxic in massive quantities. Toxicity is generally related to dose. While large doses of fluoride could be toxic, it is important to recognize the difference between the effect of a massive dose of an extremely high level of fluoride versus the fluoride level currently recommended for public water systems. Fluoride at the much lower recommended concentrations (0.7 mg/L) used in community water fluoridation is not harmful or toxic.[39]

Fluoride at the much lower recommended concentrations (0.7 mg/L) used in community water fluoridation is not harmful or toxic.

The single dose (consumed all at one time) of fluoride that could cause acute fluoride toxicity is 5 mg/kg of body weight (11 mg/kg of body weight of sodium fluoride).[275] This dose is sometimes called the probable toxic dose (PTD), which is defined "as the minimum dose that could cause serious or life-threatening systemic signs and symptoms and that should trigger immediate therapeutic intervention and hospitalization."[275] Acute fluoride toxicity occurring from the ingestion of optimally fluoridated water is impossible.[275] With water fluoridated at 1 mg/L, an individual would need to drink five (5 L) liters of water for every kilogram of body weight. For example, for an adult male (155 pound/70.3 kg man), it would require that he consume more than 350 L (nearly 93 gallons) of water at one time to reach an acute fluoride dose. With optimally fluoridated water now set at 0.7 mg/L fluoride, it would take almost 30% more, or nearly 120 gallons (more than 1,900 8-ounce glasses) of water, at one time to reach the acute dose. To address potential concerns from parents regarding young children, let's consider a 4-year-old child weighing approximately 36 pounds (16 kg). At 0.7 mg/L, this child would need to drink 114 L (about 30 gallons or 475 8-ounce glasses) of water at one time to reach an acute toxic dose. For comparison, a 3-year-old weighing around 30 pounds (13.6 kg) would need to consume 95 L (about 25 gallons or 400 8-ounce glasses) at one time. These hypothetical figures are intended to highlight how unrealistic it is for anyone–child or adult–to consume the volume of water required for acute fluoride toxicity from optimally fluoridated water.

Chronic fluoride toxicity can develop after 10 or more years of exposure to very high levels of fluoride, levels much higher than what is associated with drinking water fluoridated at recommended levels. The primary functional adverse effect associated with long-term excess fluoride intake is skeletal fluorosis.[146,207] The development of skeletal fluorosis and its severity are directly related to the level and duration of fluoride intake. For example, the ingestion of water naturally fluoridated at approximately 5 mg/L or greater for 10 years or more is needed to produce clinical signs of osteosclerosis (a mild form of skeletal fluorosis that can be seen as a change in bone density on x-rays) in the general population. In areas naturally fluoridated at 5 mg/L, daily fluoride intake of 10 mg/day would not be uncommon.[146]

A survey of x-rays from 170,000 people in Texas and Oklahoma whose drinking water had naturally occurring fluoride levels of 4–8 ppm revealed only 23 cases of osteosclerosis and no cases of crippling skeletal fluorosis.[276] Evidence of advanced skeletal fluorosis, or crippling skeletal fluorosis, was not seen in US communities where water supplies contained up to 20 mg/L of naturally occurring fluoride.[146,277] In these communities, "daily fluoride intake of 20 mg/day would not have been uncommon."[146] Crippling skeletal fluorosis is extremely rare in the United States and is not associated with water fluoridated at the recommended level.[146,207]

Additional information on this topic can be found in this Section, Question 26.

While large doses of fluoride could be toxic, it is important to recognize the difference in the effect of a massive dose of an extremely high level of fluoride versus the recommended amount of fluoride found in optimally fluoridated water. The implication that fluoride in large doses and fluoride in trace amounts have the same effect is completely unfounded. Many substances in widespread use are very beneficial in small amounts while toxic in large quantities.

The possibility of adverse health effects from continuous low-level consumption of fluoride over long periods has been studied extensively. As with other nutrients, fluoride is safe and effective when used and consumed properly. No charge against the safety of fluoridation has ever been substantiated by generally accepted scientific knowledge. After more than 80 years of research and practical experience, the best available scientific evidence indicates that fluoridation of community water supplies is safe.

After more than 80 years of research and practical experience, the best available scientific evidence indicates that fluoridation of community water supplies is safe.

32. Does drinking water fluoridated at the recommended levels cause or accelerate the growth of cancer?

Answer

No. According to the best available scientific evidence, there is no association between cancer rates in humans and drinking water that is fluoridated at the recommended levels.

Fact

Since community water fluoridation was introduced in 1945, more than 50 epidemiologic studies in different populations and at different times have failed to demonstrate an association between fluoridation and the risk of cancer.[182] Studies have been conducted in the United States,[278-283] Japan,[284] the United Kingdom,[285-287] Canada,[288] and Australia.[289] In addition, over the years, a number of independent bodies from around the world have conducted extensive reviews of the scientific literature and concluded that there is no relationship between fluoridation and cancer.[182,183,185,223,290] At the beginning of the Safety Section in Question 17, a number of recent reviews are listed that have also concluded there is no relationship between fluoridation and cancer.[34,35,37-41] The best available science clearly indicates there is no association between fluoridation and cancer.

> The best available science clearly indicates there is no association between fluoridation and cancer.

Many of the questions about a possible association between fluoride and cancer center around a form of bone cancer called osteosarcoma. This topic is covered in Question 33.

California Office of Environmental Health Hazard Assessment

In October 2011, the California Office of Environmental Health Hazard Assessment (OEHHA) through its Carcinogen Identification Committee (CIC) determined that fluoride does not cause cancer. The review was part of California's Proposition 65 listing process.[291] Proposition 65 was enacted in 1986 with the intent to protect California citizens and the state's drinking water sources from chemicals known to cause cancer, birth defects, or other reproductive harm and to inform citizens about exposure to such chemicals. It requires the governor to publish, at least annually, a list of chemicals known to the state to cause cancer or reproductive toxicity. The OEHHA administers meetings of the CIC and the list of items to be reviewed through the Proposition 65 process.

On May 29, 2009, fluoride was selected by OEHHA for review by the CIC. Due to its widespread nature, fluoride was identified as one of five high-priority chemicals to be evaluated. A public comment period followed. On July 8, 2011, as the next step in the Proposition 65 process, the CIC released a hazard identification document, *Evidence on the Carcinogenicity of Fluoride and its Salts*. It was used by the CIC in its deliberations on whether fluoride should be listed as a carcinogen under Proposition 65. A second public comment period followed. At a public meeting on October 12, 2011, the CIC heard additional testimony and then voted on the question, "Do you believe that it has been clearly shown, through scientifically valid testing according to generally accepted principles, that fluoride causes cancer?" The CIC's vote was unanimous (6-0) that fluoride had not been clearly shown to cause cancer.[292]

American Cancer Society

In addition, the American Cancer Society's (ACS) website provides basic information regarding water fluoridation, as well as information on a number of studies that examined the possible association between fluoridation and cancer. Many of these are referenced by the ACS, which states:

> "The general consensus among the reviews done to date is that there is no strong evidence of a link between water fluoridation and cancer. However, several of the reviews noted that further studies are needed to clarify the possible link."[293]

ACS also notes more recent research on this potential link, reporting that these studies have not found an increased risk of osteosarcoma in areas of water fluoridation.[194,293]

33. Does fluoridated water cause osteosarcoma?

Answer

No. The best available scientific evidence shows that fluoridated water does not cause osteosarcoma.

Fact

The National Cancer Institute estimates that a total of 1,000 people, including 440 children and teens, would be diagnosed with osteosarcoma (a form of bone cancer) in the United States each year.[294] About 2% of all childhood cancers are osteosarcoma, which most often affects those between the ages of 10 and 30. Osteosarcoma is about 50% more common in boys than girls. The 5-year survival rate for children and teens with osteosarcoma that is only in one place at the time of diagnosis is 70%.[294]

In 2014, researchers from England published the largest study ever conducted examining the possible association between fluoride in drinking water and the risk of osteosarcoma or Ewing sarcoma.[295] Analyzing 2,566 osteosarcoma cases and 1,650 Ewing's sarcoma cases from 1980 to 2005, the study found that higher levels of natural or adjusted fluoride in drinking water in Great Britain (England, Scotland, and Wales) had no impact on the incidence of either osteosarcoma or Ewing's sarcoma in people aged 0–49. Water fluoride levels ranged from near zero to a maximum of approximately 1.26 ppm.[295]

In the United States, the most extensive study to date on the issue was led by Harvard researchers. They collected information about newly diagnosed malignant bone tumors from nine US hospitals over an 8-year period between 1993 and 2000. Funding and expert input for this case control study came from three agencies of the NIH: the National Cancer Institute, the National Institute of Environmental Health Sciences, and the National Institute of Dental and Craniofacial Research. To date, three analyses have been published.

An exploratory analysis was published in 2006[193] in which fluoride exposure was determined by CDC data on fluoride levels in the community water supplies and residence study participants' communities. The analysis considered only cases under 20 years of age. At the time this study was conducted, it was assumed that water consumption varied by climate and the optimal fluoride levels for community water fluoridation were 0.7–1.2 ppm. The authors adjusted the fluoride exposure estimates based on the climate where participants lived. A subsequent study found that water ingestion did not vary by climate in the United States and supported a change in the recommended optimal fluoride levels from a temperature-related range of 0.7–1.2 ppm to a single concentration, later to be determined to be 0.7 ppm.[296]

The exploratory analysis[193] found that for boys at age 7, there was an increased risk for osteosarcoma. However, no statistically significant increased risks were found at other ages for boys or girls. Logically,

it is difficult to accept that there's a risk for just a single age group and not for others. Further, as this was an exploratory analysis excluding cases over age 20 and adjusting fluoride levels based on climate, it is likely that fluoride exposure estimates were inaccurate, and it is possible that these findings were impacted by these methodological decisions. Later, in 2020, a similar analysis was completed on the larger case control study, which found no association between osteosarcoma and residence in a fluoridated community or ingestion of topical or supplemental fluoride.[194]

A completely different type of analysis was published in 2011, finding no significant association between the fluoride levels in bone and osteosarcoma risk.[195] The study analyzed fluoride levels in bone samples from 137 patients with primary osteosarcoma and bone samples from 51 patients with other newly diagnosed malignant bone tumors who served as a control group. The vast majority of fluoride in the body is located in calcified tissue such as bone. The study hypothesized that if chronic exposure to fluoride was a risk factor for osteosarcoma, those cases would have a significantly higher level of fluoride in bone than the controls. This was not the case. The major advantage of this study was the ability to use actual bone fluoride levels as a measure of fluoride intake rather than estimating fluoride exposure. Both the 2011 and 2020 papers had data analysis independently verified by independent researchers and biostatisticians at the University of North Carolina at Chapel Hill.

The best available scientific evidence shows that fluoridated water does not cause osteosarcoma.

34. Does fluoride, as provided by community water fluoridation, inhibit the activity of enzymes in humans?

Answer

No. The best available scientific evidence demonstrates that the recommended levels of fluoride in drinking water have no effect on human enzyme activity.

Fact

Enzymes are organic compounds that promote chemical change in the body. The best available scientific evidence has not indicated that water fluoridated at the recommended levels has any influence on human enzyme activity. There are no available data to indicate that in humans drinking water fluoridated at the recommended levels, the fluoride affects enzyme activities with toxic consequences.[297] The WHO report *Fluorides and Human Health* states, "No evidence has yet been provided that fluoride ingested at 1 ppm in the drinking water affects intermediary metabolism of food stuffs, vitamin utilization, or either hormonal or enzymatic activity."[298]

In 2006, the NRC report stated that the available data were not sufficient to draw any conclusions about potential effects or risks to liver enzymes from low-level, long-term fluoride exposures such as those seen with community water fluoridation.[26]

The concentrations of fluoride used in laboratory studies to produce significant inhibition of enzymes are hundreds of times greater than the concentration present in body fluids or tissues.[299] While fluoride could affect enzymes in an artificial environment outside a living organism in the laboratory, it is unlikely that adequate cellular levels of fluoride to adversely alter enzyme activities would be attainable in a living organism. The two primary physiological mechanisms that maintain a low concentration of fluoride ion in body fluids are the rapid excretion of fluoride by the kidneys and the uptake of fluoride by calcified tissues.[211]

35. Does the ingestion of fluoridated water at recommended levels adversely affect the thyroid gland or its function?

Answer

No. The best available scientific evidence indicates optimally fluoridated water does not have an adverse effect on the thyroid gland or its function.

Fact

Several systematic reviews and individual studies completed in the last 15 years have looked at a possible association between exposure to fluoride and thyroid function. Much of the literature that reports an association between fluoride and a risk of thyroid disease discusses the risks of excessive fluoride exposure[33,189,300] at levels well above those currently recommended by the ADA and most public health institutions, and thus should not be used as evidence against optimal water fluoridation.

The following reviews support the safety of community water fluoridation at *recommended* levels:

National Toxicology Program Monograph (2024)

The NTP Monograph[301] systematically reviewed human, animal, and mechanistic studies on the thyroid gland and hormones on the extent and quality of the evidence linking fluoride exposure to neurodevelopmental and cognitive effects in humans (Question 41). Changes in thyroid hormones have been proposed as a potential mechanism for neurodevelopmental effects,[39,302] which is why thyroid effects were also evaluated in the final report. The NTP report evaluated eight low risk-of-bias studies and 16 high risk-of-bias studies. The studies examined thyroid hormones—the thyroid-stimulating hormone (TSH), triiodothyronine (T3), and thyroxine (T4)—as markers of thyroid gland function. The evidence includes a mix of findings, with some variability across studies based on factors such as fluoride concentration, age, and study design. When examining associations between fluoride exposure and thyroid hormones (TSH, T3, and T4), studies that analyzed changes across all three hormones reported varied results, including increases, decreases, or no changes in hormone levels. These studies also highlighted age-related differences in the associations between fluoride exposure and thyroid hormones. The findings indicate that while high levels of fluoride exposure may influence thyroid hormones, the evidence does not conclusively demonstrate that consuming fluoridated water at recommended levels adversely affects the thyroid gland or its function. The variability in study results and the complex interplay between the thyroid and other physiological systems suggest that any potential effects are not straightforward. Therefore, based on current evidence, fluoridated water at recommended concentrations is not clearly linked to negative impacts on thyroid health.[301]

Iamandii et al. (2023)

A 2023 systematic review[300] of fluoride exposure and thyroid function evaluated data from studies conducted in Asia, Europe, Africa, and Canada. The authors examined low and high levels of naturally fluoridated water reported in the original papers. Thyroid function, as measured by TSH and T4, showed little or no impact related to water fluoride. It is important to note that community water fluoridation was not evaluated, and no US studies were included. Furthermore, results showed that levels of natural fluoride at the same level as that recommended in the United States (0.7 ppm) showed no negative impact on thyroid function or thyroid disease.[300]

Australian National Health and Medical Research Council Systematic Review (2017)

In 2017, the Australian National Health and Medical Research Council's systematic review *Information Paper—Water Fluoridation: Dental and Other Human Health Outcomes*[34] concluded, "There is no reliable evidence of an association between water fluoridation and current Australian levels and thyroid function including goiter (enlargement of the thyroid gland) and hypothyroidism (underactive thyroid)." (Current recommendations for fluoride levels in drinking water in Australia are a range of 0.6–1.1 mg/L depending on climate.)[34]

USPHS Recommendation (2015)

In 2015, the *USPHS Recommendation for Fluoride Concentration in Drinking Water for the Prevention of Dental Caries*[39] was released. It referred to the 2006 NRC's report, *Fluoride in Drinking Water—A Scientific Review of the EPA's Standards,*[26] stating:

> "The 2006 NRC review considered a potential association between fluoride exposure (2–4 mg/L) and changes in the thyroid, parathyroid, and pineal glands in experimental animals and humans." The report noted that available studies of the effects of fluoride exposure on endocrine function have limitations. For example, many studies did not measure actual hormone concentrations, and several studies did not report nutritional status or other factors likely to confound findings. The NRC called for better measurement of exposure to fluoride in epidemiological studies and for additional research "to characterize the direct and indirect mechanisms of fluoride's action on the endocrine system and factors that determine the response, if any, in a given individual."[26]

Scientific Committee on Health and Environmental Risks Report (2011)

A scientific evaluation of agents used in fluoridating drinking water was done by the Scientific Committee on Health and Environmental Risks (SCHER) as requested by the European Commission (EC).[43] The EC is the European Union's (EU) executive body with responsibility to manage EU policy. The final report, *Critical review of any new evidence on the hazard profile, health effects, and human exposure to fluoride and the fluoridating agents of drinking water,* was released in 2011. It stated that "A systematic evaluation of the human studies does not suggest a potential thyroid effect at realistic exposures to fluoride."[43]

Highlighted Studies

The following studies provide additional evidence that consumption of optimally fluoridated water at levels recommended in the United States (0.7 mg/L) does not affect thyroid function:

- **Griebel-Thompson et al. (2023):** In 2023, a scoping review of maternal thyroid function and effects on offspring in relation to iodine and fluoride exposure during pregnancy was published.[303] In this review, the authors stated that there were only two published studies[304,305] on the effects of fluoride exposure in relation to iodide status that appropriately corrected for urinary concentration when measuring urinary iodine and fluoride concentrations. However, only the study on non-pregnant adults measured thyroid hormones.[304] The authors concluded that more studies are needed to inform our understanding of iodine intake and fluoride exposure in pregnant women.[303]
- Two studies have explored the association between fluoridated water and cancer of the thyroid gland.[281,285] Both studies found no association between optimal levels of fluoride in drinking water and thyroid cancer.

36. Does fluoride affect the function of the pineal gland?

Answer

No. There is no known effect of fluoride on the functions of the pineal gland.

Fact

The pineal gland is an endocrine gland located in the brain that produces melatonin.[306] Endocrine glands secrete their products into the bloodstream and body tissues and help regulate many kinds of body functions. The hormone melatonin plays a role in sleep, aging, and reproduction.[307]

A single researcher has published one study[308] in a peer-reviewed scientific journal regarding fluoride accumulation in the pineal gland. The purpose of the study was to discover whether fluoride accumulates in the pineal gland of older adults. This limited study, conducted on only 11 cadavers whose average age at death was 82 years, indicated that fluoride deposited in the pineal gland was significantly linked to the amount of calcium in the pineal gland.[308] It would not be unexpected to see higher levels of calcium in the pineal gland of older individuals, as this would be considered part of a normal aging process. As discussed in Question 25, approximately 99% of the fluoride present in the body is associated with hard or calcified tissues.[221] The study concluded that fluoride levels in the pineal gland were not indicators of long-term fluoride exposure.[308]

The same researcher had theorized in her 1997 dissertation,[309] portions of which are posted on numerous Internet sites opposed to fluoridation, that the accumulation of fluoride in children's pineal glands leads to an earlier onset of puberty. However, the researcher notes in the dissertation that there is no verification that fluoride accumulates in children's pineal glands. Moreover, a study conducted in Newburgh (fluoridated) and Kingston (non-fluoridated), New York, found no statistically significant difference between the onset of menstruation for girls living in a fluoridated versus non-fluoridated area.[310]

The NRC's 2006 report, *Fluoride in Drinking Water: A Scientific Review of EPA's Standards*, stated "Fluoride has not been measured in the pineal glands of children or young adults, nor has there been any investigation of the relationship between pineal fluoride concentrations and either recent or cumulative fluoride intakes."[26]

37. Does fluoride, at the levels found in drinking water that is fluoridated to the recommended levels, alter immune function or produce an allergic reaction (hypersensitivity)?

Answer

No. There is no scientific evidence of any adverse effect from fluoridation on any specific immunity, nor have there been any medically confirmed reports of allergic reaction from drinking or being in contact with optimally fluoridated water.

Fact

There is no scientific evidence linking health conditions related to immune function, such as human immunodeficiency virus (HIV) or acquired immune deficiency syndrome (AIDS), with community water fluoridation.[311]

There are no confirmed cases of allergy to fluoride or of any positive skin testing in human or animal models.[312] A committee of the National Academy of Sciences evaluated clinical reports of possible allergic responses to fluoride in 1977 and stated, "The reservation in accepting (claims of allergic reaction) at face value is the lack of similar reports in much larger numbers of people who have been exposed to considerably more fluoride than was involved in the original observations."[24] The WHO also judged these cases to represent "a variety of unrelated conditions" and found no evidence of allergic reactions to fluoride.[313, 314]

38. Is fluoride, as provided by community water fluoridation, a genetic hazard?

Answer

No. The best available scientific evidence indicates that drinking water fluoridated at the recommended levels is not a genetic hazard.

Fact

Chromosomes are structures that carry our genetic information. The genetic information on our chromosomes is organized into genes, which are made up of specific DNA sequences. Individual genes give our body information on how to grow, develop, and function. Many studies have examined the possible effects of fluoride on chromosome damage, which is also referred to as genotoxicity.

In 1993, the NRC issued a report[25] that supported the conclusion that drinking optimally fluoridated water is not a genetic hazard. In a statement summarizing its research,[25] the NRC stated:

> "*In vitro* data indicate that:
>
> 1. The genotoxicity of fluoride is limited primarily to doses much higher than those to which humans are exposed.
> 2. Even at high doses, genotoxic effects are not always observed.
> 3. The preponderance of the genotoxic effects reported are of types that probably are of no or negligible genetic significance."[25]

The lowest dose of fluoride reported to cause chromosomal changes in mammalian cells was approximately 170 times that normally found in human cells in areas where drinking water was fluoridated at 1.0 mg/L, which indicates a large margin of safety.[25] (Note that this would be 242 times the current fluoridation level of 0.7 mg/L.)

In its subsequent 2006 report,[26] the NRC stated that, after reviewing the evidence available since its 1993 report, the weight of evidence from studies on rodents indicated a very low probability that fluoride presents a risk of genetic mutation for humans.[26]

In addition, the 2006 NRC report[26] indicated that the results of human studies related to fluoride and its effect on genotoxicity since its 1993 report are inconsistent and do not strongly indicate the presence or absence of genotoxic potential for fluoride.

A systematic review published in 2024[315] concluded "...that fluoride is not a genotoxic agent since the majority of studies demonstrated negative findings."

39. Does fluoride at the levels found in water fluoridation affect human reproduction, fertility, or birth rates?

Answer

No. According to the best available scientific evidence, water fluoridation does not have an adverse effect on human reproduction, fertility, or birth rates.

Fact

European Scientific Committee on Health and Environmental Risks Critical Review

In 2011, the European Commission requested that SCHER perform a critical review of fluoridating agents of drinking water. A portion of that report looked at reproductive issues. The report concluded that there was no new evidence from human studies indicating that fluoride in drinking water influences male or female reproductive capacity.[43]

NRC Report

In its 2006 report,[26] the NRC indicated that since 1990, the quality and number of reproductive and developmental studies using laboratory animals had improved significantly. These high-quality studies indicated that adverse reproductive and developmental effects occurred only at levels of fluoride much higher than 4 mg/L.[26] The NRC also indicated that a few studies conducted with human populations have suggested that fluoride might be associated with alterations in reproductive hormones and fertility. However, the report continued on to explain that limitations in study design, such as the lack of control of reproductive variables, make these studies of little value for risk evaluation.[26]

Journal of Epidemiology and Community Health Study

A study examining the relative risk of stillbirths and congenital abnormalities (facial clefts, Down syndrome, and neural tube defects) found no evidence that fluoridation had any influence on the rates of congenital abnormalities or stillbirths.[316] The study, conducted in 2003 and published in the *Journal of Epidemiology and Community Health,* analyzed data from two population-based registries to identify all stillbirths and congenital abnormalities occurring in northeastern England between 1989 and 1998. It then compared the rates of stillbirths and specific congenital abnormalities in fluoridated and non-fluoridated communities. The study found no significant association between the occurrence of stillbirths or specific congenital abnormalities and fluoride levels in drinking water.[316]

A study examining the relative risk of stillbirths and congenital abnormalities (facial clefts, Down syndrome, and neural tube defects) found no evidence that fluoridation had any influence on the rates of congenital abnormalities or stillbirths.[316]

40. For women, does drinking water fluoridated at the recommended level create a risk for their children to be born with Down syndrome?

Answer

No. There is no known association between the consumption of drinking water fluoridated at the recommended levels and Down syndrome.

Fact

All people with Down syndrome have an extra, critical portion of chromosome 21 present in all or some of their cells. This additional genetic material alters the course of development and causes the characteristics associated with Down syndrome. The cause of the extra full or partial chromosome is still unknown. Maternal age is the major factor that has been linked to an increased chance of having a baby with Down syndrome. There is no definitive scientific research that indicates that Down syndrome is caused by environmental factors or the parents' activities before or during pregnancy.[317] A number of studies have looked at this issue and several are summarized here.

US Studies

A detailed study[318] of approximately 2,500 children born with Down syndrome was conducted in Massachusetts. A rate of 1.5 cases per 1,000 births was found in both fluoridated and non-fluoridated communities, providing strong evidence that fluoridation does not increase the risk of Down syndrome.[318]

A comprehensive study of Down syndrome births was conducted in 44 US cities over a two-year period. Rates of Down syndrome were comparable in fluoridated and non-fluoridated cities.[319]

United Kingdom (UK) Studies

In 2014, a systematic review published by *Public Health England* reviewed the literature and concluded there was no evidence of a difference in the rate of Down syndrome in fluoridated and non-fluoridated areas.[40]

Another large population-based study examined trends in births before and after fluoridation in the Birmingham. The study showed no association between water fluoridation and the incidence of congenital malformations, including Down syndrome.[320]

Rates of Down syndrome were comparable in fluoridated and non-fluoridated cities.[319]

41. Does ingestion of water fluoridated at recommended levels have an adverse effect on neurodevelopment or intelligence (IQ) or behavioral disorders in children?

Answer

No. The best available scientific evidence does not establish a causal relationship between consumption of water fluoridated at recommended levels and lowered intelligence (IQ) or behavioral disorders in children.

Fact

Several systematic reviews, meta-analyses, and individual studies provide evidence that the consumption of optimally fluoridated water at levels recommended in the United States (0.7 mg/L) does not lower IQ or cause behavior problems in children.

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NTP Monograph

The NTP monograph systematically reviewed human, animal, and mechanistic studies to evaluate potential associations between fluoride exposure and neurodevelopmental effects such as IQ deficits.[301] A National Academies of Science, Engineering, and Medicine (NASEM) committee reviewed two earlier drafts of an NTP monograph and concluded that the evidence did not support their conclusion about neurodevelopmental effects.[192] Therefore, the NTP monograph removed the neurodevelopmental hazard statement.[301] The monograph found an association between high fluoride concentrations and lower IQ in children; however, these findings were based on exposures exceeding WHO guidelines (1.5 mg/L) and are not relevant to US fluoridation practices. **"The monograph and addendum do not address whether the sole exposure to fluoride added to drinking water in some countries (i.e., fluoridation, at 0.7 mg/L in the United States and Canada) is associated with a measurable effect on IQ."** The NTP report found no evidence that fluoride exposure negatively impacts adult cognition. The review also highlighted limited mechanistic insight because animal studies were of poor quality and human studies lacked clarity on biological pathways. Significant methodological limitations, such as biases and the use of cross-sectional study designs, further weakened causal conclusions. The monograph did not assess the benefits of the use of fluorides in oral health or provide a risk/benefit analysis.[301]

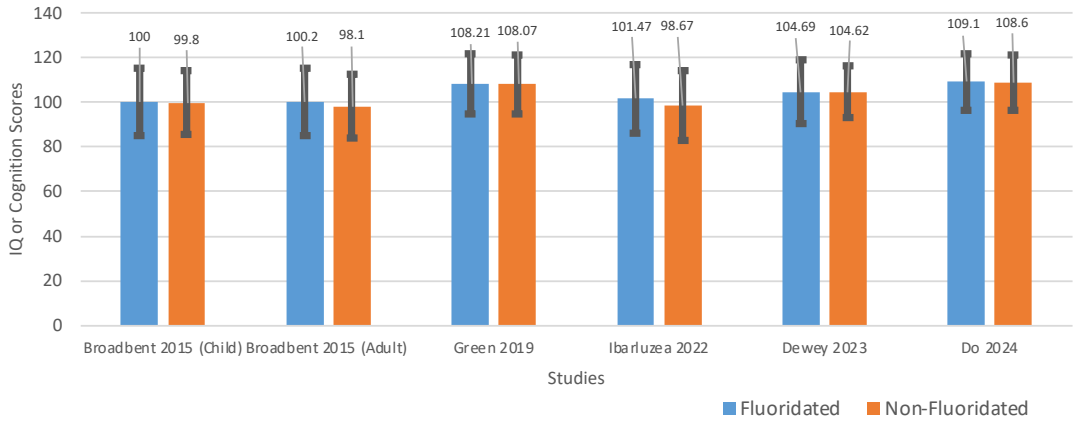
Systematic Reviews and Meta-Analyses

Most studies of fluoride-IQ association were conducted in high-fluoride areas of China, Iran, and India, which exceeded the WHO guideline value of 1.5 mg/L.[321] Many of these studies found associations between high fluoride exposure and IQ deficits, but these are mostly cross-sectional studies in impoverished communities where access to clean water is a significant problem. Cross-sectional studies cannot be used to establish cause and effect relationships and can help in generating hypotheses. According to Kumar et al.,[29] the authors need to analyze and present much more data to judge that the socioeconomic status and education of parents in the high-fluoride areas are

comparable to those in the low-fluoride areas used as controls in these studies. The following reviews support the safety of community water fluoridation at recommended levels:

- **Kumar et al. (2023):** A meta-analysis of eight studies conducted in areas relevant to community water fluoridation (less than 1.5 mg/L in drinking water or urine) found no association between fluoride exposure and IQ.[29] As of 2024, five studies comparing mean IQ scores between fluoridated and non-fluoridated areas are available and show no difference in IQ scores (Figure 5: Mean IQ or cognition scores (unadjusted) by fluoridation status.[29])
- **Broadbent et al. (2015):** This population-based birth cohort study in New Zealand found no association between early-life exposure to fluorides and IQ during childhood or in adulthood.[322]
- **Green et al. (2019):** This prospective birth cohort study in Canada examined the association between maternal fluoride exposures and children's IQ at ages 3–4 years. The study's analysis used the biobank of specimens from the Maternal-Infant Research on Environmental Chemicals (MIREC) study. The study found that maternal urinary fluoride adjusted for specific gravity (MUFSG) was not associated with full-scale IQ (FSIQ). However, when the data were analyzed by sex, MUF_{SG} was associated with FSIQ in boys, but not girls. The authors cited the lack of data on fluoride exposures or consumption during infancy and childhood as a limitation.[323]
- **Ibarluzea et al. (2022):** This study examined mother-child dyads from the Infancia y Medio Ambiente (Childhood and Environmen) birth cohort project in Spain. Researchers replicated the Canadian mother-child dyad studies but reported completely opposite results. The study found that maternal urinary fluoride across the pregnancy was associated with significantly increased McCarthy scores in boys for the verbal, performance, numeric, and memory domains and General Cognitive Index, but was not significantly associated for girls.[324]
- **Dewey et al. 2023:** This prospective ecological cohort study found no association between fluoride exposure and FSIQ in preschool children in Alberta, Canada. However, exposure to fluoridated drinking water throughout pregnancy was associated with poorer performance on the Gift Delay test.[325]
- **Do et al. 2023:** This study of schoolchildren in Australia found that exposure to fluoridated water during the first 5 years of life was not associated with altered measures of children's emotional or behavioral development or executive functioning.[326]

Figure 5: Mean IQ Scores (Fluoridated versus Non-fluoridated) (unadjusted) by Fluoridation Status



- **Veneri et al. (2023):** This systematic review and dose-response meta-analysis observed that although the negative association between fluoride exposure and IQ was particularly strong in the studies at high risk of bias, no association was found in the only study judged at low risk of bias.[327]
- **Gopu et al. (2022):** This systematic review investigated the association between fluoride exposure and cognitive outcomes from gestation to adulthood. Evidence from this review indicated that fluoride exposure at levels exceeding 2 mg/L in drinking water may be associated with impaired cognitive outcomes in children. However, the reliance on numerous low-quality studies and the absence of accurate estimates of fluoride exposure from all sources limited the ability to draw definitive conclusions.[328]
- **Miranda et al. (2021):** This systematic review and meta-analysis assessed the association between fluoride exposure and neurological disorders. According to the authors, "The methodological quality analyses of the studies detected serious problems related to the quality of sample, measurements, and outcomes. There were also problems related to the absence of randomization, sample size calculation, and blinding, which increase the risk of bias and limit the inference capacity of studies on the neurotoxic effects of fluoride."[329]
- **Guth et al. (2020):** This was a critical evaluation of evidence on the toxicity of fluoride. Based on the available evidence, the review did not support the presumption that fluoride should be assessed as a human developmental neurotoxicant at the current exposure levels in Europe.[187]
- **Canadian Agency for Drugs and Technologies in Health (2019):** This systematic review reported that there was not conclusive evidence for an association between water fluoridation at recommended Canadian levels (optimum at 0.7 mg/L) and IQ, cognitive function, or neurological development in children and adolescents.[330]

Additional Studies

The following studies provide further evidence that the consumption of fluoridated water at levels recommended in the United States (0.7 mg/L) does not lower IQ or cause behavior problems in children:

- **Aggeborn and Ohman (2021):** This ecological study used Swedish registry data of 80,000 individuals to study the causal effects of fluoride in drinking water. Results of this study found "zero effect" of fluoride on cognitive ability.[331]
- **Lin et al. (2023):** This cross-sectional study from Taiwan found that dental fluorosis and urinary fluoride levels were not significantly associated with the IQ of schoolchildren living in low-fluoride areas.[332]
- **Till et al. (2020):** This Canadian study examined mother-child dyads in the MIREC cohort who reported drinking tap water. Researchers found that infant fluoride intake was not consistently associated with IQ deficits in multiple analyses of fluoride and FSIQ scores. Prenatal exposure was not associated with FSIQ in boys or girls. However, exposure to higher fluoride levels in tap water was associated with diminished performance IQ (PIQ), that is, nonverbal intellectual abilities. That association was more pronounced among formula-fed children such that a 0.5 mg/L increase in water fluoride level was associated with a decrement in PIQ of 9.3 points in the formula-fed and 6.2 points in the breastfed group. In these analyses, the authors did not account for the correlation between exposures during pregnancy and infancy and did not adjust the statistical significance level for multiple comparison hypothesis testing. Such analytic flaws often result in false positive findings.[333]

- **Farmus et al. (2021):** This Canadian study used repeated exposures from mother–child pairs in the MIREC pregnancy and birth cohort to assess the association between fluoride and IQ scores across prenatal and postnatal exposure windows. Researchers analyzed the data by using generalized estimating equations for repeated exposure variables and adjusted for multiple hypothesis testing. This study found that the associations between fluoride exposure and PIQ differed based on the timing of exposure, and therefore concluded that the prenatal window may be critical for boys. In contrast, infancy may be a critical window for girls.[334] However, samples were taken from six cities and each city had a different IQ assessor, and this study did not account for a possible lack of measurement reliability among those assessors. When this was considered by including the variable city and corrected for multiple comparisons, fluoride exposures during pregnancy, infancy, or childhood were not associated with IQ outcomes.[335]
- **Farmus et al. (2022):** In an addendum to their previous study,[334] this study found that exposures during the trimesters of pregnancy, infancy, and childhood were not significantly associated with IQ outcomes once the variable city was controlled and the false discovery rate was applied.[335]

Fluoride and Attention Deficit Hyperactivity Disorder

Some reports have linked fluoride to attention deficit hyperactivity disorder (ADHD), a neurodevelopmental disorder. Fiore et al.[28] conducted a systematic review of studies conducted before March 31, 2023, to assess whether fluoride increased the risk of ADHD development in children and adolescents. The authors concluded that the current evidence did not allow them to conclusively confirm that fluoride exposure was specifically linked to ADHD development.

Ibarluzea and colleagues subsequently published the results of a prospective birth cohort study conducted in Spain.[336] They did not find any significant association between fluoride exposure during pregnancy and ADHD symptoms. Interestingly, higher levels of maternal urinary fluoride adjusted for creatinine in pregnant women were associated with a lower risk of inattention problems at 11 years of age.

Limitations to Fluoride Studies

Those opposed to water fluoridation have promoted studies that reportedly show fluoride causes a lower IQ in children. The cited studies are primarily from China, Mexico, India, or Iran, where social, nutritional, and environmental conditions are significantly different from those in the United States.[29] The vast majority of these studies have not been published in peer-reviewed English language journals. The consensus of those who have reviewed these studies is that their quality does not stand up to scientific scrutiny.[28,192] The studies are of low quality, have a high risk of bias, and use a study design unsuited to prove or disprove theories. They generally do not adequately account for other factors that are known to cause a lowering of IQ such as nutritional status, socioeconomic status, iodine deficiency, and consumption of other harmful elements in ground water such as arsenic or lead.

42. Does drinking fluoridated water increase the level of lead in the blood or cause lead poisoning in children?

Answer

No. The best available scientific evidence has not shown any association between water fluoridation and blood lead levels.

Fact

A number of reviews and data analyses indicate no association between water fluoridation and blood lead levels.

European Scientific Committee on Health and Environmental Risks Critical Review

In 2011, the European Commission requested that SCHER perform a critical review of fluoridating agents of drinking water. The committee concluded that "it is highly unlikely that there would be an increased release of lead from pipes due to hexafluorosilicic acid."[43] Hexafluorosilicic acid is another name for fluorosilicic acid, which is one of the additives used to fluoridate water in the United States.

Additional information on this topic can be found in the Fluoridation Practice Section, Question 49.

National Health and Nutrition Examination Survey Study and Fluoridation Census

A 2006 study[337] analyzed data from the third NHANES (1988–1994) and the 1992 Fluoridation Census to evaluate the relationship between water fluoridation and lead concentrations in children. The study concluded that the results did not support that the silicofluorides used in community water systems caused higher lead concentrations in children.[337]

Findings from the NHANES from 1976–1980 to 2003–2008 showed that the percentage of children aged 1–5 years having high lead blood levels (≥10 µg/dL) declined dramatically from 88.2% to 0.9%.[338] During that same time (1976–2008), the percentage of the US population receiving fluoridated water rose from approximately 48.8% to 64.3%.[339] Moreover, in the 1991–1994 NHANES, the overall (all age groups) prevalence of high lead blood levels (≥10 µg/dL) was 2.2%, and it decreased to 0.7% by the 1999–2002 survey.[338]

CDC Data

According to the CDC, the average blood lead levels of young children in the United States have continued to decline since the 1970s, primarily due to lead poisoning prevention laws, such as the phase-out of leaded paint and leaded gasoline.[338] The primary remaining sources of childhood lead exposure are deteriorated leaded paint, house dust contaminated by leaded paint, soil contaminated by leaded paint, and decades of industrial and motor vehicle emissions. Besides exposure to lead paint in older homes, lead water pipes and fixtures also can be found in homes built before 1978. In some areas of the country, folk remedies and pottery also add to lead exposure.[338] The CDC updated the blood lead reference value (BLRV) to 3.5 µg/dL, which provides an opportunity for additional progress in addressing longstanding disparities in lead exposure and blood lead levels (BLL) in children.[340]

While opponents of fluoride claim that fluoridated water increases BLLs in children, the fact is that since 1976, while the use of water fluoridation has increased, the percentage of US children with high BLLs has continued to decrease substantially.[341] This demonstrates that the claim made by those opposed to water fluoridation that fluoride in water increases lead concentrations in children is unfounded.

It should be noted that approximately 95% of the primary sources of adult lead exposure are occupational.[342] In general, adult BLLs have continued to decline over recent decades due largely to improved prevention measures in the workplace and changes in employment patterns.[342]

Acidity of Drinking Water and EPA Research

Those opposed to water fluoridation sometimes claim that there is an increase in acidity when fluoride is added to water and that the acidic water in the local water system leaches lead from pipes and fixtures. The process of adding fluoride to water has minimal impact on the acidity or pH of drinking water. Under some water quality conditions, a small increase in the acidity of drinking water that is already slightly acidic can be observed after treatment with alum, chlorine, fluorosilicic acid, or sodium fluorosilicate. In such cases, additional water treatment to adjust the pH to neutralize the acid in water distribution systems is standard practice in water plants.[343] Water facilities typically maintain a pH of between 7.0 and 8.0 as standard practice so the water leaving the plant is slightly alkaline and non-acidic.[344]

Despite this information, opponents continue to exploit unfounded claims that fluoridation can lead to an increased uptake of lead by children. A 1999 study[345] charged that fluorosilicic acid and sodium silicofluoride did not disassociate completely when added to water systems and could be responsible for lower pH (more acidic) levels of drinking water, leaching lead from plumbing systems and increasing lead uptake by children. In response to the study, scientists from the EPA reviewed the basic science that was the foundation for the claim that silicofluorides leach lead from water pipes and found that many of the chemical assumptions made in the original ecological study were scientifically unjustified.[346] Fluoride additives do disassociate very quickly and completely release fluoride ions into the water. The research from the 1999 study was inconsistent with accepted scientific knowledge, and the authors of that study failed to identify or account for those inconsistencies. The EPA scientists discounted the 1999 study and said there were no credible data to suggest any link between fluoridation and lead. Overall, the EPA scientists concluded that "...no credible evidence exists to show that water fluoridation has any quantifiable effects on the solubility, bioavailability, bioaccumulation, or reactivity of lead compounds."[346]

In 2006, researchers at the University of Michigan used sophisticated laboratory techniques to confirm the EPA's theoretical predictions that hexafluorosilicate completely hydrolyzed (broke down) when added to water, separating into free fluoride ions and silica ions.[347]

43. Does drinking water fluoridated at recommended levels cause Alzheimer's disease?

Answer

No. The best available scientific evidence shows that optimally fluoridated water does not cause and has not been shown to have an association with Alzheimer's disease.

Fact

Scientists believe the causes of late-onset Alzheimer's disease, the most common form of the disease, include a combination of age-related brain changes and genetic, lifestyle, and environmental factors. The importance of these factors in increasing or decreasing the risk of developing Alzheimer's disease differs from person to person. Early onset Alzheimer's disease is less common (fewer than 10% of Alzheimer's disease cases), with the first signs of the disease typically appearing between an individual's 30s and mid-60s. It is believed to be caused primarily by gene changes passed down from parent to child.[348]

A study published in 1998[349] raised concerns about the potential relationships among fluoride, aluminum, and Alzheimer's disease. However, several flaws in the study's experimental design precluded drawing any definitive conclusions.[350] Concerns were noted about a number of aspects of the protocol, including the high percentage of the test rodents dying during the study and the failure of the researchers to account for the high levels of aluminum and fluoride in the food fed to all test rodents.[350] For decades, a small number of researchers have implicated aluminum in the development of late-onset Alzheimer's disease. However, the "Aluminum Hypothesis" has been abandoned by the majority of mainstream Alzheimer's disease scientists.[351]

In 2000, a study[352] investigated the relationships between trace elements in drinking water and the thought processes of 1,016 subjects over the age of 65 living in two rural areas of China. In today's US society, people are very mobile and tend to live in multiple places during their lifetimes. In contrast, the rural residents of China rarely move, so in this study the researchers were able to assume that this elderly population had used the same water and food sources throughout their lifetimes. The researchers evaluated the effects on thought processes of seven elements (cadmium, calcium, fluoride, iron, lead, selenium, and zinc) found in the water sources at the two study sites. The study assessed thought processes in three areas (memory, language, and attention) using a Chinese translation of the Community Screening Interview for Dementia. Considering the effects of the seven trace elements, the authors concluded that fluoride was not significantly related to impairment of thought processes such as was seen in Alzheimer's disease.[352]

In a 2021 systematic review and meta-analysis of 27 studies on the association between fluoride exposure and neurological diseases, there was no evidence to support an association between optimally fluoridated water and any neurological disease.[329]

44. Does drinking water fluoridated at recommended levels cause or contribute to heart disease?

Answer

No. Drinking water fluoridated at recommended levels is not a risk factor for heart disease.

Fact

The American Heart Association (AHA) identifies aging, male gender, heredity, cigarette and tobacco smoke, high blood cholesterol levels, high blood pressure, physical inactivity, obesity, and diabetes mellitus as major risk factors for cardiovascular disease.[353]

A number of historical studies have evaluated urban mortality in relation to fluoridation status.

National Heart, Lung, and Blood Institute of the National Institutes of Health Study

Researchers from the National Heart, Lung, and Blood Institute of the NIH examined a wide range of data from communities that had naturally high levels, optimal levels, and low levels of fluoride in water. The results of their analysis published in 1972[354] concluded, "Thus, the evidence from comparison of the health of fluoridating and non-fluoridating cities, from medical and pathological examination of persons exposed to a lifetime of naturally occurring fluorides or persons with high industrial exposures, and from broad national experience with fluoridation all consistently indicate no adverse effect on cardiovascular health."[354]

Mortality Rate Trends

Two additional studies were published in 1978.[279,280] In the first study,[279] the mortality trends from 1950 to 1970 were studied for 473 US cities with populations of 25,000 or more. Findings showed no relationship between fluoridation and heart disease death rates over the 20-year period.[279] In the second study,[280] the mortality rates for approximately 30 million people in 24 fluoridated cities were compared with those of 22 non-fluoridated cities for two years. No evidence was found of any harmful health effects, including heart disease, attributable to fluoridation.[280]

Nuclear Medicine Communications Study

A study published in *Nuclear Medicine Communications* in January 2012[355] examined the possible benefits of using a sodium fluoride isotope marker in testing to determine the presence of atherosclerosis and risk for coronary disease. In this case, fluoride's affinity for calcified tissue aided in the location of calcium deposited in arterial walls, which could be associated with an increased risk of coronary artery disease. These results were misinterpreted by those opposed to fluoridation,[356] claiming that "research highlights the fact that mass fluoride exposure may be to blame for the cardiovascular disease epidemic that takes more lives each year than cancer."[356] The study made no reference to any relationship between exposure to fluoride or the consumption of fluoridated water and heart disease.[355]

45. Is the consumption of water fluoridated at recommended levels harmful to the kidneys?

Answer

No. Consuming water fluoridated at recommended levels has not been shown to cause or worsen kidney disease.

Fact

Approximately 60% of the fluoride absorbed daily by adults (45% for children) is removed from the body by the kidneys.[221] Several large community-based studies of people with long-term exposure to drinking water with fluoride concentrations up to 8 ppm have failed to show an increase in kidney disease.[186,310,357]

National Research Council (NRC) Report

In a report issued in 1993 by the NRC,[25] the Subcommittee on Health Effects of Ingested Fluoride stated that the threshold dose of fluoride in drinking water that causes kidney effects in animals is approximately 50 ppm–more than 12 times the maximum level allowed in drinking water by the EPA. Therefore, they concluded that "ingestion of fluoride at currently recommended concentrations is not likely to produce kidney toxicity in humans."[25]

Furthermore, the NRC report on fluoride in drinking water issued in 2006[26] concluded that there were no published studies that demonstrated that drinking water fluoridated at recommended levels damages kidneys. The report concluded that fluoride concentrations need to be higher than 4 ppm to affect kidney tissues and function.[26]

Kidney Health Australia Review

A review of scientific studies completed in 2007 for Kidney Health Australia (KHA)[358] summarized findings from the then-recent literature related to the health effects of fluoridated water for people with chronic kidney disease (CKD). The purpose of the review was to provide an updated summary of studies on the topic so that KHA, the leading organization in Australia that promotes kidney and urinary tract health, could develop a fluoride position paper. The review concluded that while studies on the topic are limited, "there is no evidence that consumption of optimally fluoridated drinking water increases the risk of developing CKD." For those people who already had CKD, the report stated that "there is no evidence that consumption of optimally fluoridated drinking water poses any health risks for people with CKD, although only limited studies addressing this issue are available." There is limited evidence that people with advanced CKD (stages 4 or 5) "who ingest substances with a high concentration of fluoride may be at risk of fluorosis." Accordingly, the report recommended that it would be "prudent" for patients with advanced CKD to monitor fluoride intake and avoid fluoride-rich substances. These conclusions are the basis for KHA's position statement on fluoride, which was released in 2007[358] and updated in 2011[359] and 2018.[360] The 2018 review concluded that "On the basis of the KHA 2011 Review and the NHMRC 2016 Evidence Evaluation, KHA concludes that there is no new published evidence to retract the 2007 KHA Position Statement."[360]

National Kidney Foundation

The National Kidney Foundation (NKF) is a US organization dedicated to the awareness, prevention, and treatment of kidney disease. A 2008 NFK report titled *Fluoride Intake in Chronic Kidney Disease*[361] included the following analysis and recommendations:

- Dietary advice for patients with CKD should focus primarily on established recommendations for sodium, potassium, calcium, phosphorus, energy/calorie, protein, fat, and carbohydrate intake. Fluoride intake is a secondary concern.[361]
- Because plasma fluoride levels tend to increase with the severity of CKD, individuals with CKD, especially those at stage 4 and 5, should be notified of the potential risk of fluoride exposure by providing information on the NKF website including a link to the Report in Brief of the NRC and the KHA position paper. The risk is likely greatest in areas with high naturally occurring water fluoride levels.[361]
- The NKF has no position on the optimal fluoridation of water. The oral health of people with CKD is certainly of interest to the NKF, but balancing the overall benefits and risks of fluoride exposure is their primary concern.[361]

Hemodialysis

Many people with kidney failure depend on hemodialysis (treatment with an artificial kidney machine) for their survival. During hemodialysis, the patient's blood is exposed to large amounts of water each week (280–560 quarts). Therefore, procedures have been designed to ensure that the water utilized in the process contains a minimum of dissolved substances that could diffuse indiscriminately into the patient's bloodstream.[362] Both KHA and the NKF recommend careful monitoring of hemodialysis systems to ensure proper mechanical function.[358,361] Because the composition of water varies in different geographic locations in the United States, the PHS recommends that dialysis units use techniques such as reverse osmosis and de-ionization to remove excess iron, magnesium, aluminum, calcium, and other minerals as well as fluoride from tap water before the water is used for dialysis.[362]

46. What are some of the erroneous health claims made against water fluoridation?

Answer

From sources such as social media, the Internet, newsletters, and personal anecdotes in emails, it is frequently and falsely claimed that community water fluoridation causes one or more of the following adverse health conditions:

- Acquired immunodeficiency syndrome (AIDS)
- Allergic reactions (e.g., loss of hair, skin that burns and peels after contact with fluoridated water)
- Accelerated aging
- Alzheimer's disease
- Arthritis
- Asthma
- Autism
- Behavioral problems (e.g., attention deficit disorders)
- Bone disease (e.g., osteoporosis, increased bone/hip fractures)
- Cancer (all types including osteosarcoma or bone cancer)
- Chronic bronchitis
- Colic (acute abdominal pain)
- Cystic fibrosis
- Down syndrome
- Emphysema
- Enzyme effects (gene alterations)
- Flatulence (gas)
- Gastrointestinal problems (irritable bowel syndrome)
- Harmful interactions with medications
- Heart disease
- Increased infant mortality
- Low birth weight for infants
- Kidney disease
- Lead poisonings
- Lethargy (lack of energy)
- Lower IQ scores
- Malpositioned teeth
- Parkinson's disease
- Calcification of the pineal gland (causing early puberty, chronic insomnia)
- Reproductive issues (damaged sperm, reduced fertility)
- Skin conditions (redness, rash/welts, itching)
- Sudden infant death syndrome (SIDS)

Thyroid problems (goiter and obesity due to hypothyroidism)

Tooth decay

Fact

As discussed throughout this monograph, the best available scientific evidence consistently has indicated that fluoridation of community water supplies is safe and effective. The possibility of any adverse health effects from continuous low-level consumption of fluoride has been and continues to be studied extensively. Of the thousands of credible scientific studies on fluoridation, none has shown health problems associated with the consumption of optimally fluoridated water.

Of the thousands of credible scientific studies on fluoridation, none has shown health problems associated with the consumption of optimally fluoridated water.

Section 3

Fluoridation Practice

47. Who regulates drinking water additives in United States?

Answer

The EPA regulates drinking water additives.

Fact

In 1974, Congress passed the Safe Drinking Water Act (SDWA), which protects the public's health by regulating the nation's public drinking water supply.[197] The SDWA, as amended in 1986 and 1996, requires the EPA to ensure that the public is provided with safe drinking water.[197] On June 22, 1979, the FDA and the EPA entered into a Memorandum of Understanding (MOU) to clarify their roles and responsibilities in water quality assurance.[363] The stated purpose of the MOU is to "avoid the possibility of overlapping jurisdiction between the EPA and FDA with respect to control of drinking water additives." The two agencies agreed that SDWA passage in 1974 implicitly repealed FDA's jurisdiction over drinking water as a "food" under the Federal Food, Drug, and Cosmetic Act (FFDCA). Under the MOU, the EPA has exclusive regulatory authority over drinking water provided by public water systems, including any additives in such water.[363]

While drinking water from the tap is regulated by the EPA, the FDA retains jurisdiction over bottled drinking water under Section 410 of the FFDCA and "water (and substances in water) used in food or food processing once it enters the food processing establishment."[363] The FDA has established standards for bottled water quality.[363] The FDA has noted that fluoride can occur naturally in source waters used for bottled water or can be added by a bottled water manufacturer. Recognizing the benefits of fluoride in water, the FDA has stated that bottled water that meets specific standards of identity (regulations that define different types of bottled water) and quality set forth by FDA, and the provisions of the authorized health claim related to fluoride, can be labeled with the following health claim: "Drinking fluoridated water may reduce the risk of [dental caries or tooth decay]."[169]

> While drinking water from the tap is regulated by the EPA, bottled water is regulated by the FDA, which has established standards for its quality.

From time to time, states and communities have had to deal with legislation or ballot initiatives aimed at requiring FDA approval before any agent can be added to community water systems. Often referred to as the Fluoride Product Quality Control Act, Water Product Quality Ordinance, or Pure Water Ordinance, the legislation is specifically used by those opposed to water fluoridation as a tool to prevent water systems from providing community water fluoridation. Often this legislation does not specifically mention fluoride or fluoridation. Those supporting this type of legislation may claim that they are not against water fluoridation but are proponents of pure water, and do not want anything added to water that has not been approved by the FDA. On the surface, this appears to be a "common sense" approach. However, its only real purpose is to defeat efforts to provide water fluoridation. That is because this proposed legislation would require the FDA—which does *not* regulate public water systems—to approve any water additive. By mistakenly (and perhaps craftily) naming the wrong federal agency, the desired outcome is to stop or prevent water fluoridation.

48. What standards have been established to ensure the safety of fluoride additives used in community water fluoridation in the United States?

Answer

The three fluoride additives used in the United States to fluoridate community water systems (sodium fluoride, sodium fluorosilicate, and fluorosilicic acid) meet safety standards established by the American Water Works Association and NSF International.[36]

Fact

Additives used in water treatment meet safety standards prepared in response to a request by the EPA to establish minimum requirements to ensure the safety of products added to water for its treatment, thereby ensuring the public's health.[36] Specifically, fluoride additives used in water fluoridation meet standards established by the American Water Works Association (AWWA) and NSF International.[36] Additionally, the American National Standards Institute (ANSI) endorses both AWWA and NSF standards for fluoridation additives and includes its name on these standards.[36]

The AWWA[364] is an international nonprofit scientific and educational society dedicated to providing total water solutions to assure the effective management of water. Founded in 1881, the AWWA is the largest organization of water supply professionals in the world. The membership represents the full spectrum of the water community: public water and wastewater system professionals, environmental advocates, scientists, academicians, and others who hold a genuine interest in water. AWWA unites the diverse water community to advance public health, safety, the economy, and the environment.[364]

NSF International,[365] an independent accredited organization, is dedicated to being the leading global provider of public health and safety-based risk management solutions. Manufacturers, regulators, and consumers look to NSF to develop public health standards and certifications that help protect food, water, consumer products, and the environment. Its professional staff includes microbiologists, toxicologists, chemists, engineers, and environmental and public health professionals. Founded in 1944 as the National Sanitation Foundation, NSF's mission is to protect and improve global human health.[365]

ANSI[366] is a private non-profit organization that administers and coordinates the US voluntary standardization and conformity assessment system. ANSI's mission is to enhance both the global competitiveness of US business and the US quality of life by promoting and facilitating voluntary consensus standards and conformity assessment systems as well as safeguarding their integrity.[366]

The AWWA documents provide manufacturers, suppliers, and purchasers with standards for the manufacturing, quality, and verification for each of the three fluoride additives listed below. The AWWA standards set the physical, chemical, and impurities standards, including information on verification of the standard requirements and requirements for delivery.[364]

- ANSI/AWWA B701 Sodium Fluoride
- ANSI/AWWA B702 Sodium Fluorosilicate
- ANSI/AWWA B703 Fluorosilicic Acid[36]

NSF/ANSI Standard 60[367] provides for the purity of drinking water additives by limiting additives' contributions of harmful contaminants to drinking water. The Standard also provides for safety assurances from production through distribution to ensure product quality is maintained. Additionally, the Standard requires documentation of the purity of the additives, including specific criteria for products imported from other countries. NSF/ANSI Standard 61[368] is a related standard that provides guidance for equipment and products used in water treatment plants that come in contact with drinking water. Both NSF/ANSI standards were developed by a consortium of associations, including NSF, AWWA, the Association of State Drinking Water Administrators (ASDWA), and the Conference of State Health and Environmental Managers, with support from the EPA.[36]

Fluoride additives, like all of the more than 40 additives typically used in water treatment, are classified as "water-grade" additives meeting NSF Standard 60 requirements. Examples of other water-grade additives that are commonly used in water plant operations are chlorine (gas), ferrous sulfate, hydrochloric acid, sulfur dioxide, and sulfuric acid.[92]

Sometimes those who raise concerns about community water fluoridation express the view that they are not really opposed to fluoridation but are opposed to the use of "industrial-grade" fluoride additives. There is no industrial grade for fluoride additives, but industrial users (or large-scale consumers) establish their own product requirements. Some opponents of water fluoridation may even go so far as to state that they would support fluoridation if the process was implemented with pharmaceutical-grade fluoride additives that were approved by the FDA. On the surface, this may appear to be a "common sense" approach. In fact, this is usually a ploy whose only real purpose is to stop fluoridation. First, the EPA, not the FDA, has regulatory authority for additives used in public water systems. Second, and perhaps most importantly, the US Pharmacopeia (USP) monograph on sodium fluoride does not provide for certification of quality by an independent credentialing body.[36,91] Third, the USP and the National Formulary (USP-NF) standards used to formulate prescription drugs are not appropriate for water fluoridation additives, as they could actually allow higher levels of contaminants to be introduced into drinking water than is allowed by current EPA standards.[36,91] According to the CDC:[91]

> The USP does not provide specific protection levels for individual contaminants, but establishes a relative maximum exposure level for a group of related contaminants. Some potential impurities have no restrictions by the USP, including arsenic, some heavy metals regulated by the EPA, and radionuclides. Given the volumes of chemicals used in water fluoridation, a pharmaceutical grade of sodium fluoride for fluoridation could potentially contain much higher levels of arsenic, radionuclides, and regulated heavy metals than an NSF/ANSI Standard 60-certified product.

Additional information about this topic can be found in this Section, Question 49.

Lastly, the use of a USP-grade sodium fluoride product is more likely to result in water plant personnel being exposed to fluoride dust, as it is more powder-like than the preferred AWWA-grade sodium fluoride, which is crystalline and thus minimizes dusting during handling.[36]

Additional information about this topic can be found in this Section, Question 52.

49. Does fluoridating the community water supply raise concerns about lead, arsenic, and other toxic contaminants to the water supply?

Answer

No. The concentrations of contaminants in drinking water as a result of fluoridation do not exceed and are in fact well below regulatory standards set to ensure the public's safety.

Fact

Fluorosilicic acid is used to fluoridate the majority of community water systems in the United States.[89] Because the additive is derived from ore mined from the Earth, fluorosilicic acid can contain minute amounts of contaminants, such as lead and arsenic. However, existing regulations and standards require that these contaminants, and others, be at levels considered acceptable by the EPA when fluorosilicic acid or other fluoridation additives are diluted to produce optimally fluoridated water.[365] NSF/ANSI Standard 60, as well as AWWA standards, are applicable to all fluoride additives.[36,365]

Testing of fluoride additives provides evidence that the levels of these contaminants do not exceed and are in fact well below regulatory standards set to ensure the public's safety. NSF has prepared a detailed fact sheet, NSF Fact Sheet on Fluoridation Products,[90] that provides the documented quality of fluoride additives based on product samples analyzed. The NSF reports that the majority of fluoridation products as a class, based on NSF test results, do not add measurable amounts of arsenic, lead, or other heavy metals or radionuclides to drinking water.[90,91]

50. Have fluoride additives been tested for safety?

Answer

The claim is sometimes made that no studies on safety exist on the additives used in water fluoridation. This statement is misleading because the scientific community does not study the health effects of the concentrated additives; studies are done on the health effects of the treated water.

Fact

A 1999 study[345] charged that fluorosilicic acid and sodium silicofluoride did not disassociate (break down) completely when added to water systems and could be responsible for lower pH (acid) levels of drinking water, leaching lead from plumbing systems and increasing lead uptake by children. Scientists from the EPA evaluated the disassociation of fluoride additives[346] and concluded that at the typical pH level of drinking water (which is normally slightly alkaline) and the fluoride levels used in drinking water, the fluoride additives quickly and completely broke down to fluoride ions and silica.

University of Michigan Study

In 2006,[347] researchers at the University of Michigan verified for the EPA that theoretical predictions that hexafluorosilicate completely hydrolyzed (broke down) when added to water, separating into free fluoride ions and silica ions, were confirmed. The research demonstrated that there was no hexafluorosilicate that could be measured in the finished water.[347]

Silicofluoride

While sodium fluoride was the first additive used in water fluoridation, the use of silicofluoride additives (sodium fluorosilicate and fluorosilicic acid) began in the late 1940s. By 1951, silicofluorides had become the most commonly used fluoride additives in water fluoridation.[88] Many of the early studies

on the health effects of fluoridation were completed in communities that were using the silicofluoride additives, generally fluorosilicic acid.[369–374]

However, at that time, the additives used to fluoridate were not always identified in research reports. As the body of research on fluoridation grew, it became evident that there were no adverse health effects associated with water fluoridation regardless of which fluoride additive was used. Additionally, over time, a number of comprehensive reviews of the health effects of fluoridation were published. These reviews, which support the safety of water fluoridation, include many studies conducted in large, fluoridated communities that used the silicofluoride additives.[10,25,182,183,185,375–377]

There is now more than 80 years of practical experience that supports the statement that the best available science demonstrates that fluoridation is safe.

51. What is the source of the additives used to fluoridate water supplies in the United States?

Answer

The majority of fluoridation additives used in the United States are derived from the mineral apatite (a component of calcium phosphate).

Fact

About 95% of the fluoridation additives used in water fluoridation are byproducts that come from the processing of calcium phosphate into phosphate fertilizer. About 4% are derived from the processing of calcium fluoride, and the remaining 1% are from the production of high-purity silica.[89]

In the production of phosphate fertilizer, calcium phosphate ore (which contains apatite) is mixed with sulfuric acid, resulting in a calcium sulfate (gypsum) slurry. The gaseous phosphoric acid released from this process is collected by vacuum extraction, condensed, and then desiccated and formed into phosphate fertilizer pellets. Fluoride is a trace constituent (3–7%) of the mineral apatite found in calcium phosphate ore. Silica tetrafluoride is also released as a gas in the creation of the calcium sulfate slurry and is collected by vacuum extraction along with the gaseous phosphoric acid. In about half of US phosphate fertilizer plants, the silica tetrafluoride gas is condensed and processed along with the phosphoric acid and becomes a trace component of the phosphate fertilizer. In the other plants, the silica tetrafluoride gas is separated from the phosphoric acid. Roughly 60% of the fluoride recovered from processing calcium phosphate ore is sold for use as a fluoridation additive. The fluoridation additive produced by this process is fluorosilicic acid. While most of the product is sold as fluorosilicic acid, some of the product is partially neutralized to sodium fluorosilicate salt and some is fully neutralized to sodium fluoride salt. In the United States, about 77% of the fluoridation additives used are fluorosilicic acid, 15% are sodium fluorosilicate, and 8% are sodium fluoride.[89]

About 4% of the fluoridation additives used are derived from the processing of calcium fluoride into hydrogen fluoride using a gas separation technique to recover the fluorosilicic acid from the hydrogen fluoride.[89]

About 1% of the fluoridation additives used are derived from the production of high-purity silica. Fluorosilicic acid is produced as part of the purification of silica.[89]

From time to time, opponents of fluoridation allege that fluoridation additives are byproducts of the phosphate fertilizer industry in an effort to suggest the additives are not safe. By definition, byproducts are materials produced as a result of producing something else. In the chemical industry, a byproduct (secondary product) is anything other than the principal product produced. The fact that a product is a secondary product of a manufacturing process should not suggest the item is bad, harmful, or a waste product. On the contrary, byproducts may have certain characteristics that make them valuable resources. In the production of phosphate fertilizer, the fluoridation additive fluorosilicic acid is a byproduct along with gypsum.[378] Gypsum is commonly used in manufacturing wall board used in construction. The production of orange juice provides another example of valuable byproducts. In addition to orange juice, various byproducts are obtained from oranges during juice production that are used in cleaners, fragrances, and flavorings.[379]

Fluoridation additives are valuable byproducts that come from producing phosphate fertilizer. To ensure the public's safety, additives used in water fluoridation meet standards of the AWWA and NSF.[36]

52. Does the process of water fluoridation present unusual safety concerns for water systems and water facility operators?

Answer

No. With proper monitoring, maintenance, water facility operator training, and systems planning, water fluoridation is a safe and reliable process.

Fact

Water facilities and water facility operators perform a valuable public service by carefully adjusting the level of fluoride in water to improve the oral health of the community. Facilities and personnel are subject to a number of regulations designed to ensure safety.

Employers must conform to federal Occupational Safety and Health Administration (OSHA) requirements.[380] OSHA's mission is to assure safe and healthful workplaces by setting and enforcing standards, and by providing training, outreach, education, and assistance. Under the Occupational Safety and Health Act, employers are responsible for providing a safe and healthful workplace. Employers must comply with all applicable OSHA standards.[380]

Additionally, to assist in protecting the professionals who produce sustainable supplies of high-quality drinking water, the AWWA publishes detailed guidance on safety and safe working conditions for water plant personnel.[381]

Furthermore, OSHA requires that Safety Data Sheets (SDSs), previously known as Material Safety Data Sheets (MSDSs), be readily available to all employees for potentially harmful substances handled in the workplace under the Hazard Communication regulation.[382] SDSs often include instructions for the safe use and potential hazards associated with a particular material and typically are made available in the area where the material is stored or used. Information contained in an SDS focuses on the potential hazards of working with the material in an occupational setting. Adherence to SDS guidelines for handling fluoride additives helps to ensure that the recommended level of fluoride in drinking water flows through the water system while maintaining water operator safety. With fluoride, the potential hazards faced by a water facility employee in dealing with concentrated fluoride additives before they enter the water system are not related to the level of fluoride in water as used by consumers. The information found in the SDS is for the concentrated fluoride additives and is not applicable to water with fluoride at the recommended level. Therefore, SDS sheets should not be used by consumers to gauge potential hazards of community water fluoridation.

As part of safety procedures, water facility personnel receive training on the management of the additives in water plants. With proper use of personal protective equipment (PPE), an operator will not have hazardous exposure to fluoride additive products. Fluoride additives present risks comparable to other water additives in common use at water facilities, such as hypochlorite, quicklime, aluminum sulfate, sodium hydroxide, and ferrous sulfate. In some cases, the fluoride additives are much less dangerous than many other additives, including chlorine gas commonly used in many water facilities.[381]

Today's equipment generally allows water facility personnel to easily monitor and maintain the desired fluoride concentration. Automatic monitoring technology is also available that can help to ensure that the fluoride concentration of the water remains within the recommended range.[36]

It is important that the water facility personnel responsible for monitoring the addition of fluoride to the water supply are appropriately trained and that the equipment used for this process is adequately maintained.[36] With more than 80 years of experience and thousands of water systems adding fluoride every day, water facility personnel have not only an excellent safety record related to their personal safety, but also an excellent record in providing safe drinking water to their customers.

53. Does fluoridation present difficult engineering problems?

Answer

No. Adding fluoride products to water is no different than adding other commonly used water treatment additive products using the same equipment and techniques.

Fact

Fluoride additives used to adjust the fluoride level in drinking water are compatible with other water treatment processes, often using the same type of equipment and other standard materials designed for the safe handling of other water treatment additive products in drinking water treatment facilities. Fluoride additives are introduced to the water supply as liquids. There are many control devices, some in use for decades and some newer equipment, that allow water facility personnel to easily monitor and maintain the desired fluoride level, as well as levels of other water treatment additives and naturally occurring substances that can be in the water. Automatic monitoring technology is available that can help to ensure that the fluoride concentration of the water remains within the recommended range.[36]

When added to community water supplies, the concentrated fluoride additives become greatly diluted.[89] For example, fluorosilicic acid is typically diluted approximately 315,000 times to reach the recommended target concentration of 0.7 mg/L. The exact dilution factor depends on the concentration of the fluoride additive and the amount of additive being used to reach the concentration of 0.7 mg/L. At 0.7mg/L (or 0.7 ppm), seven-tenths of one part of fluoride is diluted in 999,999.3 parts of water.

With more than 80 years of experience with water fluoridation, there is considerable guidance on sound engineering practices to design, construct, operate, and maintain water fluoridation systems. By design and with proper maintenance and testing, water systems can provide the recommended level of fluoride within a narrow control range of the target of 0.7 mg/L.[383,384] Additional design features such as the use of a day tank (that holds only one day's supply of fluoride) can limit the amount of fluoride that can be added to a water system in a 24-hour period and is the most reliable method to ensure overfeed protection.[36] The state Office of Drinking Water, or a similar state agency, will normally establish engineering requirements for safety. Additional standards and references on best engineering practice are available from the AWWA and the CDC.[36,385]

54. Does fluoride at levels used in fluoridation corrode water pipes?

Answer

No. Allegations that fluoridation causes corrosion of water pipes are not supported by the best available scientific evidence.

Fact

The process of adding fluoride to water has minimal impact on the acidity or pH of drinking water, and therefore will not corrode water pipes. Corrosion of drinking water pipes is related primarily to induced electrical current between dissimilar metals. Other contributing factors include the dissolved oxygen concentration, water temperature, acidity/alkalinity (pH), hardness, salt concentration, hydrogen sulfide content, and the presence of certain bacteria. Under some water quality conditions, a small increase in the acidity of drinking water that is already slightly acidic may be observed after treatment with alum, chlorine, fluorosilicic acid, or sodium fluorosilicate. In such cases, further water treatment to adjust the pH to neutralize the acidity for corrosion control in water distribution systems is standard procedure in water plants.[343]

The process of adding fluoride to water has minimal impact on the acidity or pH of drinking water, and therefore will not corrode water pipes.

Note that the Water Quality Report or Consumer Confidence Report that all water systems must make available to customers on a yearly basis may list the pH of the system's finished water.[386] Control of neutral pH (7.0) is essential as part of corrosion control requirements. Water facilities typically maintain a pH of between 7.0 and 8.0 as good practice so that the water leaving the plant is slightly alkaline and non-acidic.[344]

Use of corrosion control measures by water utilities is a standard practice to ensure the system meets the EPA requirements under the lead/copper rule.[343,344,386] Those actions would ensure that any potential corrosion by water additives is identified and neutralized to remain in compliance with regulatory requirements.

55. Does fluoride at levels used in water fluoridation corrode glass, concrete, or other surfaces in water plants?

Answer

No. A correctly engineered and maintained system will not result in damage to the water plant.

Fact

Fluorosilicic acid in a concentrated form can be corrosive if not correctly handled. The concentrated fluorosilicic acid is 75% water and 25% fluorosilicic acid. Up to 1% of the fluorosilicic acid can be other acids, including hydrogen fluoride. Hydrogen fluoride is volatile near room temperature, so it will evaporate from the solution if the system is not properly engineered and maintained. The evaporation process occurs at an extremely slow rate. Less than 1% of fluorosilicic acid will be lost over a month from the evaporation of hydrogen fluoride. However, only a small release of hydrogen fluoride can be very corrosive to concrete, glass, and electrical components.[89]

If a water system is reporting problems with corrosion from evaporating hydrogen fluoride in the storage room or fluoride handling room (i.e., the glass in the facility has become "frosted"), there is a leak in the conveyance piping. The storage tank and other locations in the fluorosilicic acid feed system may not be sealed or correctly vented and hydrogen fluoride gas can be released (leaked) at those points. The storage, handling, and feed systems of all fluoride products should be vented to the outside of the building and the system and piping should be pressure tested (low pressure is sufficient) to identify possible locations of leaks. Leaks should be promptly corrected.[89]

With no system leaks and proper venting to outside the building, there will be no corrosion problems.[89]

56. Does fluoridated water harm the environment?

Answer

No. Scientific evidence supports the fluoridation of public water supplies as safe for the environment and beneficial for people.

Fact

Fluoride occurs naturally in the environment and is the 13th most abundant element in the Earth's crust. It is found naturally in all water sources, with typical concentrations as noted here.[72,387]

Rain—0.01 to 0.08 mg/L
Streams and lakes—generally 0.03 to 0.3 mg/L; can be >200 mg/L in high-fluoride regions
Groundwaters—0.1 to 10 mg/L
Oceans and seawater—1.2 to 1.4 mg/L

Comprehensive reviews published in 2004 revealed no negative environmental impacts as a result of water fluoridation.[388,389] A 1990 study[390] concluded that fluoridation has little or no impact on the surrounding aquatic environment or soil. Historically, issues surrounding problems with fluoride and the environment have involved incidents related to serious industrial pollution or accidents.[390]

There is no evidence that the recommended level of fluoride in drinking water has any adverse effect on gardens or lawns.

Additional information regarding water fluoridation additives and engineering issues can be found on the CDC's fluoridation website, "Fluoridation Engineering and Operations."[91]

Section 4

Public Policy

57. What is public health?

Answer

Public health is the science of promoting and protecting the health of people and the communities where they live, learn, work, and play. Public health measures improve the health and quality of life for members of the community.

Fact

Public health has numerous definitions and dimensions. It can encompass research, education, regulation, policy, and more. It focuses on the health of entire populations that can vary in size from as small as a local neighborhood to a small community and a large city. It also can focus on populations with a state, national, or even global perspective. But how does public health affect our everyday lives? Individuals are touched by public health measures every day without giving them a second thought. For example, garbage pickup and disposal prevent the spread of disease. The stoplight at a busy intersection protects motorists and pedestrians from injury. Building sidewalks in communities promotes walking and outdoor physical activity to reduce dependence on motor vehicles and help prevent chronic disease. Smoke-free laws help prevent lung cancer and other smoking-related diseases. All of these are public health in action.

During the 20th century, the health and life expectancy of US residents improved dramatically. Since 1900, the average lifespan of persons in the United States increased by more than 30 years. Twenty-five years of that gain are attributable to advances in public health. Many notable public health achievements occurred during the 1900s. In a series of reports during 1999, the CDC's *Morbidity and Mortality Weekly Report (MMWR)* profiled 10 public health achievements chosen to highlight the contributions of public health and to describe the impact of these contributions on the health and well-being of persons in the United States.[1]

In discussing the contribution of fluoridation, the October 22, 1999, MMWR[2] noted that the fluoridation of community drinking water was a major factor responsible for the decline in tooth decay during the second half of the 20th century.

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58. Is water fluoridation a valuable public health measure?

Answer

Yes. Community water fluoridation is a public health measure that benefits people of all ages and saves money for families and the health care system. Because fluoridation reaches large numbers of people where they live, learn, work, and play, it is more efficient than other forms of fluoride delivery. Water fluoridation reaches everyone in the community regardless of age, race, education, income level, or access to routine dental care. Because of the important role community water fluoridation has played in the reduction of tooth decay, the CDC has proclaimed it one of 10 great public health achievements of the 20th century.[1,2]

Fact

Throughout decades of research and more than 80 years of practical experience, the fluoridation of public water supplies has been responsible for dramatically improving the public's oral health.

Oral Health in the 1930s and 1940s

It has been said that those who cannot remember the past are condemned to repeat it. As generations pass, details from life in the 1930s and 1940s fade. The oral health of Americans suffered greatly during the Great Depression and into World War II. There were no public health programs in place that addressed tooth decay, and the loss of teeth was viewed as an eventuality. In fact, as World War II approached, those joining the US Army were required to have six back teeth (three on the top and three on the bottom) that opposed each other to serve the function of chewing food as well as six front teeth (three on the top and three on the bottom) that opposed each other for the purpose of biting into food. The number of men disqualified for dental reasons far exceeded all expectations, as "dental disease" became the most common reason for military deferment. One out of 11 registrants examined was disqualified for military service due to dental issues.[391] After Pearl Harbor, it was apparent that the manpower needed to fight a global war could be obtained only if dental standards for induction were drastically relaxed. By March 1942, the standards had been revised so that a man who was "well nourished, of good musculature, and free from gross dental infections" but who was completely edentulous (without any teeth) could be inducted if his condition was corrected or could be corrected with dentures.[391]

Because fluoridation reaches large numbers of people where they live, learn, work, and play, it is more efficient than other forms of fluoride delivery.

In January 1945, the first US city to include community water fluoridation was Grand Rapids, Michigan, followed within months by Newburgh, New York (May 1945), Brantford, Ontario (June 1945), and Evanston, Illinois (February 1947). The comparison of decay rates in the fluoridated cities versus cities without community water fluoridation showed dramatically lower rates of tooth decay in fluoridated cities.[16] A classic study, the Newburgh-Kingston study of two cities in New York, one fluoridated (Newburgh) and one non-fluoridated (Kingston), also showed substantially lower decay rates in Newburgh.[21] The optimal level for caries reduction without risk of fluorosis was found to be 1.0 ppm,[17] leading to the rapid adoption of fluoridation in cities across the United States. As a result, tooth decay declined sharply during the second half of the 20th century.[18,392] Tooth loss was no longer considered inevitable.[18,392]

Community Water Fluoridation Endorsements by US Surgeons General

Former US Surgeon General Dr. Luther Terry called fluoridation as vital a public health measure as immunization against disease, pasteurization of milk, and purification of water.[10]

Another former US Surgeon General, Dr. C. Everett Koop, wrote:

> ...this preventive measure (fluoridation) is the single most important commitment that a community can make to the oral health of its children and to future generations. I urge all health officials and concerned citizens to join me in supporting this commitment and in the task of achieving water fluoridation for all community drinking water supplies which lack the fluoride content needed for the prevention of dental caries.[393]

In May 2000, US Surgeon General Dr. David Satcher issued the first ever Surgeon General's report on oral health, *Oral Health in America: A Report of the Surgeon General.*[47] He noted "Community water fluoridation is safe and effective in preventing dental caries in both children and adults." In 2001, Dr. Satcher issued a statement on fluoridation in which he noted:

> ...community water fluoridation continues to be the most cost-effective, practical, and safe means for reducing and controlling the occurrence of dental decay in a community...water fluoridation is a powerful strategy in efforts to eliminate health disparities among populations.[394]

In the 2003 *National Call to Action to Promote Oral Health,*[52] US Surgeon General Dr. Richard Carmona called on individuals and groups who are most concerned and in a position to act to apply strategies to enhance the adoption and maintenance of proven community-based interventions such as community water fluoridation.[52] In his 2004 *Statement on Community Water Fluoridation,*[395] Dr. Carmona wrote:

> While we can be pleased with what has already been accomplished, it is clear that there is much yet to be done. Policymakers, community leaders, private industry, health professionals, the media, and the public should affirm that oral health is essential to general health and well-being and take action to make ourselves, our families, and our communities healthier. I join previous Surgeons General in acknowledging the continuing public health role for community water fluoridation in enhancing the oral health of all Americans.[395]

In 2013, US Surgeon General Dr. Regina M. Benjamin wrote:[396]

> ...As Surgeon General I have been working hard to encourage individuals and communities to make healthy choices because I believe it is better to prevent illness and disease rather than treat it after it occurs. Community water fluoridation is one of the most effective choices communities can make to prevent health problems while actually improving the oral health of their citizens... Fluoridation's effectiveness in preventing tooth decay is not limited to children, but extends throughout life, resulting in fewer and less-severe cavities. In fact, each generation born since the implementation of water fluoridation has enjoyed better dental health than the generation that preceded it...[396]

US Surgeon General Dr. Vivek Murthy issued a statement supporting community water fluoridation in December 2015.[4] In the statement on fluoridation issued in 2016,[4] Surgeon General Murthy emphasized:

> Our progress on this issue over the past 70 years has been undeniable. But we still have work to do. Because we know that so much of our health is determined by Zip code rather than genetic code. That's why creating a culture of disease prevention through community efforts—and ensuring health equity for all—is one of my highest priorities. Community water fluoridation helps us meet these goals, as it is one of the most cost-effective, equitable, and safe measures communities can take to prevent tooth decay and improve oral health.[4]

Healthy People 2030

Today, the focus in achieving and maintaining health is on prevention. Established by the HHS, Healthy People 2030 provides an evidence-based, comprehensive set of ambitious, achievable, 10-year national objectives for improving public health and reducing health disparities. Healthy People 2030 recognizes the importance of water fluoridation in promoting oral health and reducing disparities.[55]

Healthy People 2030 recognizes the importance of water fluoridation in promoting oral health and reducing disparities.[55]

Healthy People 2030 aims to increase the proportion of people whose water systems have the recommended amount of fluoride.[55] The target is to have 77.1% of people served by community water systems with optimally fluoridated water to reduce oral health disparities.[56] The CDC reported that in 2022, 72.3% of the US population on public water systems, or a total of 209.1 million people, had access to fluoridated water.[57]

The Guide to Community Preventive Services

Established by the HHS in 1996, the CPSTF develops and disseminates guidance on which community-based health promotion and disease prevention intervention approaches work and which do not, based on available scientific evidence. The CPSTF issues findings based on systematic reviews of effectiveness and economic evidence. The Guide to Community Preventive Services ("The Community Guide") is a collection of evidence-based findings of the CPSTF that is designed to assist decision-makers in selecting interventions to improve health and prevent disease.[97]

The Community Guide reviews are designed to answer three questions:

1. What has worked for others and how well?
2. What might this intervention approach cost, and what am I likely to achieve through my investment?
3. What are the evidence gaps?[97]

The CPSTF recommends community water fluoridation to reduce tooth decay.[42]

Institute of Medicine Reports

Reports have been released by the HHS that encourage the use of preventive interventions to improve the overall and oral health of the nation.[397,398] Specific to oral health, two reports issued in 2011 by the Institute of Medicine acknowledge that water fluoridation is an effective intervention for the prevention of tooth decay.[399,400] *Advancing Oral Health in America*[399] referred to water fluoridation as an effective prevention intervention, while *Improving Access to Oral Health Care for Vulnerable and Underserved Populations*[400] acknowledged that evidence regarding community water fluoridation programs continues to validate its effectiveness, safety, and cost-saving benefits.

59. Does water fluoridation reduce disparities and improve health equity in dental health?

Answer

Yes. Water fluoridation helps to reduce the disparities in oral health at the community level. Populations with low socioeconomic status who live in fluoridated communities have less tooth decay than their peers in non-fluoridated communities.

Fact

Health equity is defined by the CDC as "the state in which everyone has a fair and just opportunity to attain their highest level of health."[401] It is achieved by addressing historical and ongoing injustices; overcoming economic, social, and other obstacles to health and healthcare; and eliminating preventable health disparities.[401]

Health equity arises from access to the social determinants of health, specifically from wealth, power, and prestige.[402] Achieving health equity requires valuing everyone equally with focused and ongoing societal efforts to address avoidable inequalities and historical and contemporary injustices while eliminating health and healthcare disparities.[403] Health and health equity are determined by the conditions in which people are born, grow, live, work, play, and age as well as biological determinants.[404] Structural determinants, such as political, legal, and economic factors, shape the distribution of power and resources that affect health outcomes.[404] Discriminatory practices are often embedded in institutional and systems processes, leading to groups being underrepresented in decision-making or being underserved.[404]

Health disparities are defined by the CDC as "preventable differences in the burden of disease, injury, violence, or opportunities to achieve optimal health that are experienced by socially disadvantaged populations."[401] These disparities are linked with social, economic, and/or environmental disadvantage and adversely affect groups of people who have systematically experienced more obstacles to health based on factors such as race or ethnicity, gender, education, income, disability, geographic location, or sexual orientation.[405] Health disparities result from multiple factors, including poverty, environmental threats, inadequate access to health care, individual and behavioral factors, and educational inequalities.[406]

In the first ever Surgeon General's Report on Oral Health issued in May 2000, US Surgeon General David Satcher noted that community water fluoridation is safe and effective in preventing dental caries in both children and adults.[47] Fluoridation benefits all residents served by community water supplies regardless of their social or economic status.[47] In 2001, Dr. Satcher issued a statement on fluoridation in which he noted:

> ...community water fluoridation continues to be the most cost-effective, practical and safe means for reducing and controlling the occurrence of dental decay in a community...water fluoridation is a powerful strategy in efforts to eliminate health disparities among populations.[394]

The association between social class and disparities in dental health has been established through extensive studies and reviews.[48,127,128] The 2021 NIH) report called *Oral Health in America: Advances and Challenges*[407] and the CDC have emphasized the impact of social determinants of health on oral health disparities, particularly among racial/ethnic and socioeconomic groups.

The Oral Health Foundation[408] highlighted the higher prevalence of tooth decay among people of lower socioeconomic status than among those with higher socioeconomic status due to a lack of prevention and treatment services and a diet high in sugar, further underscoring the impact of socioeconomic

inequalities on oral health. Research has consistently shown that social and economic factors significantly impact oral health outcomes, leading to disparities among socioeconomic groups.[49,51,409–413]

Research highlights the significant positive impact of water fluoridation in reducing disparities in tooth decay, particularly benefiting low-income communities compared to their more affluent counterparts.[414,415]

Furthermore, the CDC emphasizes the remarkable benefits of drinking fluoridated water, reporting a 25% reduction in cavities for children and adults.[416] Water fluoridation is the most efficient and cost-effective method to deliver fluoride to all community members, regardless of age, income, or education level.[114,417,418]

Established by the HHS, Healthy People 2030 provides an evidence-based, comprehensive set of ambitious, achievable, 10-year national objectives for improving public health and reducing health disparities.[55] Healthy People 2030 recognizes the importance of water fluoridation in promoting oral health and reducing disparities. Healthy People 2030 aims to increase the proportion of people whose water systems have the recommended amount of fluoride. The target is to have 77.1% of people served by community water systems with optimally fluoridated water to reduce oral health disparities.[56]

60. Along with the ADA, who supports community water fluoridation?

Answer

Many organizations, such as the National Dental Association (NDA), American Academy of Pediatrics (AAP), American Medical Association (AMA), American Public Health Association, and the World Health Organization (WHO) also have policies that support community water fluoridation.

Fact

The ADA adopted its original resolution in support of fluoridation in 1950 and has repeatedly reaffirmed its position publicly and in its House of Delegates based on its continuing evaluation of the safety and effectiveness of fluoridation.[3]

NDA

The NDA is the largest and oldest organization of minority oral health professionals in the world.[419] Representing more than 7,000 minority dentists nationally and abroad,[419] the NDA seeks to provide continued advancement of the highest quality of oral health care and safety for the public.[420] In 2012, the NDA adopted the following position:[420]

It is therefore the position of the NDA that community water fluoridation is safe, beneficial, and cost-effective and should be encouraged and supported under the following conditions:

- Community water supplies should contain the optimal fluoride levels as recommended by the PHS.
- Local communities and dental societies should be in agreement with and support the fluoridation project in their communities.
- Appropriate resource-monitoring capabilities should be available to ensure that the appropriate water fluoride monitoring infrastructures are in place at all times in the impacted communities.[420]

AAP

As part of its core values,[421] the AAP is committed to promoting optimal health and well-being for every child. The AAP states, "Tooth decay, which is almost completely preventable, is the most common chronic condition experienced by children, disproportionately affecting families with low incomes and those in historically underserved communities…Water fluoridation is an equitable and inexpensive way to ensure that prevention of dental disease reaches everyone in a community."[422]

The AAP actively promotes community water fluoridation through its policies, advocacy initiatives, and educational programs.[422] As a trusted resource for healthcare providers and families, the AAP supports informed decision-making and encourages community engagement with water fluoridation efforts.[6] Their comprehensive, evidence-based materials are tailored to educate both professionals and the general public, encompassing scientific research, clinical guidelines, caregiver-oriented tools, and advocacy materials, all aimed at advancing equitable access to oral health care.[422]

AMA

The AMA's mission is to promote the art and science of medicine and the betterment of public health.[423] Its House of Delegates first endorsed fluoridation in 1951[424] and the AMA reaffirmed its support for water fluoridation in 2011.[5]

APHA

The APHA champions the health of all people and communities and speaks out for public health issues and policies backed by science.[425] It has supported community water fluoridation as a safe and effective public health measure for the prevention of tooth decay since 1950.[426] The APHA reaffirmed its support in 2008 by stating that it strongly endorses and recommends "the fluoridation of all community water systems as a safe and effective public health measure for the prevention of tooth decay."[262]

WHO

The goal at the WHO is to build a better, healthier future for people all over the world.[427] The WHO, which initially adopted policy recommending the practice of water fluoridation in 1969,[428] reaffirmed its support for fluoridation in 1994,[429] stating:

> Providing that a community has a piped water supply, water fluoridation is the most effective method of reaching the whole population, so that all social classes benefit without the need for active participation on the part of individuals.[429]

In 2004, the WHO once again affirmed its support, stating that "Water fluoridation, where technically feasible and culturally acceptable, has substantial public health benefits."[430]

In 2007, the 60th World Health Assembly adopted *WHA60.17-Oral health action plan for promotion and integrated disease prevention,*[431] which urges member states:

> (4) for those countries without access to optimal levels of fluoride, and which have not yet established systematic fluoridation programs, to consider the development and implementation of fluoridation programs, giving priority to equitable strategies such as the automatic administration of fluoride, for example, in drinking water, salt, or milk, and to the provision of affordable fluoride toothpaste[431]

In 2016, WHO officials wrote:

> The use of fluoride is a major breakthrough in public health. Controlled addition of fluoride to drinking water supplies in communities where fluoride concentration is below optimal levels to have a cariostatic effect began in the 1940s and since then, extensive research has confirmed the successful reduction in dental caries in many countries.[7]

Many organizations, such as the NDA, the AAP, the AMA, the APHA, and the WHO also have policies that support community water fluoridation.

61. Has the legality of water fluoridation been upheld by the courts?

Answer

Yes. Fluoridation has been thoroughly tested in the United States court system and found to be a proper means of furthering public health and welfare. No court of last resort has ever determined fluoridation to be unlawful. Moreover, fluoridation clearly has been held not to be an unconstitutional invasion of religious freedom or other individual rights guaranteed by the First, Fifth, or Fourteenth Amendments to the US Constitution. And while cases decided primarily on procedural grounds have been won and lost by both pro- and anti-fluoridation interests, to the ADA's knowledge, no final ruling in any of those cases has terminated fluoridation for reasons of safety or effectiveness.

Fact

Despite attempts to prevent community water fluoridation through court challenges and ballot initiatives, it has received consistent approval in the courts as a proper means of advancing public health and welfare. In addition, federal guidelines reinforce longstanding government support for community water fluoridation at safe and effective levels.[432]

The legality of fluoridation in the United States has been thoroughly tested in our court systems. Fluoridation is viewed by the courts as a proper means of furthering public health and welfare.[433] No court of last resort has ever determined fluoridation to be unlawful. The highest courts of more than a dozen states have confirmed the constitutionality of fluoridation.[434] In 1984, the Illinois Supreme Court upheld the constitutionality of the state's mandatory fluoridation law, resolving 16 years of court action at a variety of judicial levels.[435] Moreover, the US Supreme Court has denied review of fluoridation cases more than 13 times, citing that no substantial federal or constitutional questions were involved.[434]

Fluoridation is viewed by the courts as a proper means of furthering public health and welfare. No court of last resort has ever determined fluoridation to be unlawful.

It has been the position of the American courts that a significant government interest in the health and welfare of the public generally overrides individual objections to public health regulation.[434] Consequently, the courts have rejected the contention that fluoridation ordinances are a deprivation of religious or individual freedoms guaranteed under the Constitution.[434,436] In reviewing the legal

aspects of fluoridation, the courts have dealt with this concern by ruling that: (1) fluoride is a nutrient, not a medication, and is present naturally in the environment; (2) no one is forced to drink fluoridated water, as alternative sources are available; and (3) in cases where a person believes that fluoridation interferes with religious beliefs, there is a difference between the freedom to believe, which is absolute, and the freedom to practice beliefs, which can be restricted in the public's interest.[437,438]

Fluoridation is the adjustment of the level of a naturally occurring mineral found in water in order to prevent tooth decay. Courts have consistently ruled that water fluoridation is not a form of compulsory mass medication or socialized medicine.[434,437,438] In fact, water that has been fortified with fluoride is similar to fortifying salt with iodine, milk with vitamin D, and orange juice with calcium, all of which are supplements, not medications.

Interestingly, pro- and anti-fluoridation interests have each won and lost legal challenges regarding which state or local agency has regulatory authority over fluoridation, which of course varies by state and locality.[432]

State law variances have also led to different rulings on other issues, such as whether downstream end users of fluoridation must be given an opportunity to vote on whether to fluoridate. While cases decided primarily on procedural grounds have been won and lost by both pro- and anti-fluoridation interests, to the ADA's knowledge no final ruling in any of those cases has terminated fluoridation for reasons on safety and effectiveness.[432]

Petition to EPA

In November 2016, those opposed to fluoridation filed a legal petition calling for the EPA to ban the addition of fluoridating chemicals to public drinking water on the grounds that a large body of animal, cellular, and human research showed that fluoride is neurotoxic at doses within the range now seen in fluoridated communities in the country (0.7 mg/L).[439] The EPA responded to the petition in February 2017 noting, "After careful consideration, EPA denied the TSCA section 21 petition, primarily because EPA concluded that the petition has not set forth a scientifically defensible basis to conclude that any persons have suffered neurotoxic harm as a result of exposure to fluoride in the (United States) through the purposeful addition of fluoridation chemicals to drinking water or otherwise from fluoride exposure in the (United States)."[439] As allowed under the TSCA process, the petitioners filed a lawsuit challenging the EPA ruling in April 2017 in the US District Court for the Northern District of California at San Francisco. The trial took place in January and February of 2024.[439]

Court Ruling September 24, 2024
United States District Court for the Northern District of California

In the case of "Food & Water Watch, Inc. v. United States Environmental Protection Agency,"[440] the court found that the current levels of fluoride used in community water fluoridation in the United States, specifically 0.7 mg/L, present an unreasonable risk of reduced IQ in children under the Toxic Substances Control Act (TSCA). This ruling was based largely on the systematic review by the National Toxicology Program (NTP), which found generally consistent evidence linking high levels of fluoride exposure at 1.5 mg/L or more to cognitive harm at levels of 1.5 mg/L or higher.[192,301]

The plaintiffs argued that despite these findings, the EPA had dismissed petitions calling for regulatory action. In its defense, the EPA raised a number of objections, including uncertainties regarding the precise hazard level of fluoride and the appropriate metrics for assessing exposure. However, the court ruled these objections were insufficient to override the risk of harm, even without evidence of harm at fluoride levels used in community water fluoridation.

Consequently, the court ordered the EPA to engage in regulatory actions under the TSCA to mitigate these risks. However, the ruling does not prescribe a specific regulatory outcome, leaving the EPA to determine the appropriate response while acknowledging that the risk identified must be addressed.

The District Court's ruling has been criticized widely by major health and scientific authorities for drawing conclusions that are not supported by the best available evidence. For example, the AAP noted that the court drew heavily on the NTP review in its opinion, despite explicit declarations by the NTP that its document did not evaluate a potential risk of harm from drinking water with fluoride at the optimal US level of 0.7 mg/L.[441] Similarly, the American Association for Dental, Oral, and Craniofacial Research noted that the court's decision exceeded what NTP concluded in its systematic review of the evidence.[442] At the time of this document preparation, the EPA has appealed the court's ruling.

62. Why does opposition to community water fluoridation continue?

Answer

Controversies sometimes exist regarding public health interventions. In public health, there can be tension between "public good" and "individual freedoms." Because public health deals with populations, it is all but impossible to resolve issues to achieve approval from 100% of the individuals within the population. When looking at fluoridation, some individuals opposed to fluoridation are sincere in their beliefs. Others ignore what constitutes reputable scientific evidence as defined by the vast majority of the scientific community and choose instead to base their beliefs on personal opinions and studies with flawed methodologies. Community water fluoridation is only one such public health issue that is considered controversial despite overwhelming scientific evidence.

Fact

Community water fluoridation is considered beneficial by the overwhelming majority of the health and scientific communities, as well as the general public.[39,42,416] A vast body of scientific literature endorses water fluoridation as a safe means of reducing the incidence of tooth decay. Support for fluoridation among scientists and health professionals, including physicians and dentists, is nearly universal. Recognition of the benefits of fluoridation by the ADA,[3] the AMA,[5] the AAP,[6] the WHO,[431] governmental agencies,[39] and other national health and civic organizations[417,420] continues as a result of published, peer-reviewed research.

Fluoridation has a long history of being a political issue, as well as a scientific one, with opposition including activists from both the right and the left of the political spectrum. In the late 1940s, opposition to fluoridation began to appear around the nation. Reportedly, one of the first public votes on fluoridation occurred in 1950 in Stevens Point, Wisconsin,[443] when a local activist initiated a campaign to stop the introduction of what he called "poison" into the water system. The campaign quickly moved from being a discussion of the science to a political campaign that included the involvement of a large number of civic groups, unofficial public petitions, calls for a debate, campaign rallies, and numerous letters to the editor that "kept typesetters busy preparing for print the thousands of words that poured into the editor's desk."[443] After 1950 when the PHS and the ADA endorsed fluoridation, proponents became more organized in their efforts to promote fluoridation, while the opposition capitalized on the political nature of the struggle and used lessons learned in Stevens Point.

Of the small faction that opposes water fluoridation for philosophical reasons, freedom of choice is one of the most frequently cited issues.[444] People take the stance that society should not "force" individuals to act in ways that are beneficial to their own health or the health of others. They are opposed to "government interference" in their lives.[444] Some individuals are opposed to community action on any health issue, others are opposed due to environmental or economic concerns, and some are opposed because they are simply misinformed.[444]

Opposition to fluoridation has existed since the initiation of the first programs in 1945 and continues today despite more than 80 years of practical experience showing fluoridation to be safe and effective. An article that appeared in the local newspaper shortly after the first fluoridation program was implemented in Grand Rapids, Michigan, noted that the fluoridation program was slated to commence January 1, but did not actually begin until January 25.[7] Interestingly, health officials in Grand Rapids began receiving complaints of physical ailments, including "teeth falling out and enamel peeling off their teeth," attributed to fluoridation from citizens weeks before fluoride was actually added to the water.[445]

In 1992, a community in Finland opted to stop their fluoridation program at the end of the year in December.[446] However, it was discontinued at the end of November without the public being told. Public surveys conducted in November and December and again in March the following year revealed the occurrence and mean number of symptoms (the most common being itching and dryness of skin) were fairly similar during the periods of actual and supposed fluoridation, indicating the symptoms were not caused by fluoride in the water. Interestingly, those who claimed to be able to taste the fluoride in the water made this claim equally often during actual and supposed fluoridation. A significant reduction in the symptoms occurred after those responding to the surveys became aware that fluoridation had stopped. The authors concluded that the prevalence rates of the symptoms were connected to the psychological rather than physical effects of exposure to fluoride in water.[446]

Over time, leaders and organizations that opposed fluoridation have come and gone, but their basic beliefs have remained the same. These beliefs include that fluoride is toxic and causes numerous harmful health effects; fluoride does not prevent tooth decay; fluoridation is costly; and fluoridation interferes with freedom of choice and infringes on individual rights.

Opposition to water fluoridation is often fueled by criticism that its efficacy in preventing tooth decay has never been subjected to the rigor of a randomized controlled trial (RCT). This changed in 2022 with the initiation of an RCT of fluoridated *bottled* water.[447] The "waterBEST" research study[448] is a phase 2b proof-of-concept, randomized, quadruple-masked, placebo-controlled, parallel group trial designed to estimate the efficacy of fluoridated versus non-fluoridated bottled water for the prevention of dental caries in 4-year-olds. As of 2024, the study had completed enrollment of 200 families with newborn children living in Lenoir and Wayne Counties in North Carolina, with follow-up planned through 2028. The study is being conducted by researchers led by Dr. Gary Slade from the Adams School of Dentistry at the University of North Carolina at Chapel Hill with funding from the NIH/National Institute of Dental and Craniofacial Research. It is registered at *ClinicalTrials.com*[164] and the study protocol[447] has been published by Sanders et al. (2024).

Opinions are seldom unanimous on any scientific subject. In fact, there really is no such thing as "final knowledge" because new information is continuously emerging and being disseminated. As such, the evidence for benefits must be continually weighed against evidence of risks. Health professionals, decision-makers, and the public should be cooperating partners in the quest for accountability where decisions are based on demonstrated benefits measured against verified risks.[449] Dentists are a valuable source of accurate information regarding water fluoridation for their patients and their communities.

63. What are the tactics fluoridation opponents use to provoke opposition to water fluoridation?

Answer

Fluoridation opponents use numerous tactics to evoke fear and disseminate misinformation about water fluoridation. Opponents frequently use scare techniques,[450] present half-truths, downplay the significance of science-based evidence, and use selective reporting of results and studies to support their false allegations.[435] They also use regulatory processes to question the safety of community water fluoridation.

Fact

While many of the arguments against fluoridation have remained relatively constant over the years, fluoridation opponents also have used different emphases and approaches that play upon the popular concerns of the public at the time.[444] For example, in the 1950s, fluoridation was said to be a Communist plot. With America's growing concern for environmental issues in the 1960s, fluoridation was called pollution. After the Vietnam War in the 1970s, fluoridation opponents capitalized on the popularity of conspiracy theories by portraying fluoridation as a conspiracy among the US government, the dental-medical establishment, and industry. As the population became more concerned about their health in the 1980s, fluoridation opponents claimed fluoridation caused AIDS and Alzheimer's disease. In the 1990s, claims of hip fractures and cancer were designed to resonate with middle-aged baby boomers. With the new millennium, overexposure and toxicity, in association with lead poisoning, surfaced as common themes. Since the economic crisis of 2008, discussions about the cost of fluoridation are more commonplace. In the 2010s, neurotoxicity became a constant theme, with charges of lower IQ and autism. Over the years, none of these emphases has ever really disappeared, but instead fluoridation opponents often recycle their message to produce the greatest effect on the intended audience.[444]

The Internet breathed new life into fluoridation opponents' efforts, bringing their messages into voters' homes.[451,456] With just a click of the mouse, search engines can locate a large number of websites denouncing fluoridation, which can give the impression that this is a one-sided argument. Individuals who look to the Internet as a source of valid and reliable information often fail to recognize that these sites frequently contain personal opinion rather than scientific fact. Newspaper stories, press releases, and letters to the editor are often posted as documentation of the "science" behind claims from fluoridation opponents. All too often, the public accepts this type of information as true simply because it is in print. Videos are available from organizations that oppose fluoridation and are shared at no cost via online video platforms, making it possible for every campaign to bring fluoride opponents into their community. Social media is used to spread opposition messaging to the public and to assist in organizing local efforts. These venues have allowed the small faction of fluoride opponents to be linked across the country and around the world to promote their messages quickly, repeatedly, and economically.

Spreading misinformation impacts public policy and costs society in immeasurable ways. The opponents' claims and opinions can escalate to emotional arguments that, in the end, can delay or prevent the introduction of a water fluoridation program or stop an existing program.[453] More people, especially those involved in policy decisions, need to be better informed about these tactics. In making decisions that affect the health of the community, it is important to distinguish between someone's personal opinion disguised as science and information based on the best available scientific evidence. It is perfectly acceptable for individuals to have their own opinion, but it is unacceptable for them to have "their own facts" derived from something less than reputable science.

In making decisions that affect the health of the community, it is important to distinguish between someone's personal opinion disguised as science and information based on the best available scientific evidence.

In 1993, the US Supreme Court issued a landmark decision that can restrict the use of information inferred as science in the federal courts and in those state courts that adopt this reasoning. The court determined that while "general acceptance" is not needed for scientific evidence to be admissible, federal trial judges have the task of ensuring that an expert's testimony rests on a reasonable foundation and is relevant to the issue in question.[8] According to the Supreme Court, many considerations will bear on whether the expert's underlying reasoning or methodology is scientifically valid and applicable in a given case. The Court set out four criteria that judges could use when evaluating scientific testimony:

1. Whether the expert's theory or technique can be (and has been) tested using the scientific method.
2. Whether it has been subject to peer review and publication (although failing this criterion alone is not necessarily grounds for disallowing the testimony).
3. Its known or potential error rate and the existence and maintenance of standards in controlling its operation.
4. Whether it has attracted widespread acceptance within a relevant scientific community, as a known technique that has been able to attract only minimal support may properly be viewed with skepticism.[8]

The scientific validity and relevance of claims made by opponents of fluoridation might be best viewed when measured against these criteria.[8]

Opposition Tactics

The techniques used by fluoridation opponents are well known and have been discussed at length in a number of published articles that review their tactics, as discussed in this section.[434,444,449,450,453-457]

Targeting Politicians and Community Leaders: Opposition websites contain draft letters to be sent to newspaper publishers, water departments, and public officials warning them of their "liability" should they support or endorse water fluoridation. Leaders are urged to remain "neutral" and allow fluoridation decisions to be put to a public vote, therefore relieving the leaders of any and all responsibility in the matter. Fluoridation opponents use the time gained to conduct a public referendum to bombard the public with misinformation designed to turn public opinion against fluoridation.

Unproven Claims: Fluoridation opponents have repeatedly claimed fluoridation causes a laundry list of human illnesses, including AIDS, Alzheimer's disease, cancer, Down syndrome, genetic damage, heart disease, lower intelligence, kidney disease, osteoporosis, and hip fractures. None of these claims has a basis in fact. These allegations are often repeated so frequently during campaigns that the public assumes they must be true. Their appearance in print, even if only in letters to the editor of the local newspaper, reinforces the allegation's credibility. With just a small amount of doubt established, the opposition slogan, "If in doubt, vote it out," often rings true with voters.

Innuendo: The statement, "Fifty years ago physicians and dentists posed for cigarette ads," is an example of innuendo or, more specifically, guilt by association. Even though fluoridation is not mentioned, individuals are expected to make the connection that the medical community changed its position on smoking, so it is possible health professionals are wrong about fluoridation, too.

Outdated Studies and Statements from "Experts": Opposition websites often offer a list of "respected medical professionals and scientists" who have spoken out against fluoridation. One of those often quoted is Dr. Charles Gordon Heyd, who is noted as a past president of the AMA. What is not disclosed is the source of the quote or that Dr. Heyd was president of the AMA in 1936–almost 10 years before water fluoridation trials began. His decades-old quote certainly does not represent the current or previous decades of AMA support for water fluoridation and is characteristic of fluoridation opponents' use of items that are out of date. Additionally, fluoridation opponents have claimed that 14 Nobel Prize winners have "opposed or expressed reservations about fluoridation." It should be noted that the vast majority of these individuals were awarded their prizes from 1929 through 1958.

Statements Out of Context: One of the most repeated fluoridation opposition statements is "Fluoride is a toxic chemical. Don't let them put it in our water." This statement ignores the scientific principle that toxicity is related to dosage and not just to any exposure to a substance. Examples of other substances that can be harmful in the wrong amounts but beneficial in the correct amounts are salt, vitamins A and D, iron, iodine, aspirin, and even water itself.

Conspiracy Theories: Hardly a fluoridation campaign goes by without those opposed to fluoridation bringing up any number of conspiracy theories about it. Whether it is the claim that scientists from the original atomic bomb program secretly shaped and guided the early Newburgh, New York, fluoridation trial or that chemtrails are a government plot to spread fluoride, these claims have no basis in fact. Even the belief that fluoridation was a Communist plot to destroy America was famously parodied in the 1964 movie *Dr. Strangelove*. Over the decades, those opposed to fluoridation have used propaganda schemes and conspiracy theories that reflected the social and political environment of the times. Today, "follow the money" is a common theme as the opposition claims that the beverage industry, the companies supplying fluoride additives, and others are financially backing researchers, as well as dental and medical groups who are promoting fluoridation. None of these claims has a basis in fact.

Treating Correlation as Causation: Many people have heard the phrase that "correlation does not imply causation." In other words, just because two events seem to fluctuate in tandem does not prove that they are meaningfully related to one another. For example, statistics show that sales of ice cream increase in warm summer months. Statistics also show that crime goes up in large cities in the summer. However, it would be ludicrous to draw the conclusion that ice cream causes an increase in crime. Yet this is exactly the type of logic exercised in some arguments and studies promoted by those opposed to fluoridation. For example, the opposition often points to Kentucky as having a large portion of the population on public water supplies receiving fluoridated water. And that's correct. In 2020, Kentucky was ranked the most widely fluoridated state, with 99.9% of its population on public water systems receiving fluoridated water. But the opposition also points to the fact that Kentucky suffers from a large number of people who have lost their teeth. They draw the conclusion that this proves fluoridation does not work—without looking at other factors that influence this outcome. For example, while there is a large number of public water systems that are fluoridated, Kentucky has a large rural population that does not have access to public water supplies. Additionally, and perhaps most importantly, Kentucky's population has a high rate of tobacco use, which is known to be a risk factor for periodontal (gum) disease, which can lead to the loss of teeth.

64. Where can valid, evidence-based information about water fluoridation be found on the Internet?

Answer

There are many reputable sites on the Internet that provide information on fluorides and fluoridation, including the ADA and CDC as well as other reputable health and science organizations and government agencies. These sites provide information that is consistent with the best available scientific evidence.

Fact

One of the most widely respected sources for information regarding fluoridation and fluorides is the ADA Fluoride and Fluoridation website at *www.ADA.org/fluoride*. From the ADA website, individuals can link to other oral health webpages such as:

- CDC
  http://www.cdc.gov/fluoridation
- The Community Guide
  https://www.thecommunityguide.org/findings/dental-caries-cavities-community-water-fluoridation.html
- Fluoride Science
  https://fluorideexposed.org/fluoridescience/
- Campaign for Dental Health
  https://ilikemyteeth.org/
- AAP
  https://www.aap.org/en/patient-care/oral-health/fluoridation/
- American Fluoridation Society
  https://americanfluoridationsociety.org/

The Internet contains numerous sources of information on fluoridation. However, not all "science" posted on the Internet is based on scientific fact. Searching the Internet for "fluoride" or "water fluoridation" directs individuals to numerous websites. Some of the content found on the sites is scientifically sound. Other, less-scientific sites look highly technical, but contain information based on methods that are unconfirmed or have not gained widespread acceptance. In many cases, the information is largely opinion. While everyone is entitled to their opinion, they are not entitled to present that opinion as scientific fact. Commercial interests, such as the sale of water filters, often are promoted.

Today's technology can put the world at your fingertips, but search engine technology can influence what is returned in searches. The first time the search for "fluoridation" is made, it is likely that the returns will include both pro- and anti-fluoridation websites. When you click to view a website, the search engine takes note and on subsequent searches for the same term, the search engine will return items similar to what you chose initially. For example, if you choose a pro-fluoridation website initially, the next time you search for "fluoridation," the search engine will likely return a selection of other pro-fluoridation websites for your review. Of course, the converse is also true. Clicking on fluoridation opposition websites will guide you to future searches laden with similar opposition sites.

65. Why does the public sometimes vote against community water fluoridation when it is put to a public vote?

Answer

Fluoridation votes are sometimes unsuccessful due to voter apathy or low voter turnout due to the vote being held as a special election or in an "off" year, confusing ballot language (a "no" vote sometimes translates to support for fluoridation), blurring of scientific issues, the use of scare tactics by those opposed to fluoridation, long campaigns that lead to "fluoridation fatigue," lack of leadership by elected officials, and a lack of political campaign skills among health professionals.

Fact

The fact is that fluoridation votes in the United States are more often successful than not. In 2016, it was common to see those opposed to fluoridation citing more than "500 success stories" in regard to communities rejecting water fluoridation.[458] What is not made clear is that the number of communities in these statements is a global number. Many of those communities are outside the United States.[458]

Since 2000, nearly 52 million people have been added to the population on US public water systems that enjoys the benefit of optimally fluoridated water.[57,459] In 2000, 65% of the public on public water systems received fluoridated water.[459] In 2022, the percentage had increased to 72.3% of the population.[57] However, despite the continuing growth of fluoridation in this country over the past several decades, millions of people do not yet receive the protective benefits of fluoride in their drinking water. CDC data from 2022 indicated that more than 25% of the population served by public water systems did not have access to fluoridated water.[57] In 2024, 45 of the 50 largest cities were fluoridated.[460] Of the 45 cities, 43 were fluoridated by adjustment and two had naturally occurring fluoride at the recommended levels. The remaining five largest non-fluoridated cities (in order of population largest to smallest) were: Portland, Oregon; Tucson, Arizona; Fresno, California; Colorado Springs, Colorado; and Bakersfield, California.[460]

In 2020, recognizing the ongoing need to improve health and well-being, the HHS revised national health objectives to be achieved by the year 2030.[55] Included under oral health was an objective to significantly expand the fluoridation of public water supplies. Specifically, Objective OH-11 of Healthy People 2030 states that at least 77.1% of the US population served by community water systems should be receiving the benefits of optimally fluoridated water by 2030.[56] As of 2022, 22 states and the District of Columbia met or exceeded the 2030 objective.[57] Although water fluoridation reaches some residents in every state, the coverage is uneven. Data from 2022 indicated that 27 states provided fluoridation benefits to 75% or more of their residents on community water systems while 10 states were at or below 50%.[57]

Fluoridation campaigns can vary greatly from community to community. To paraphrase an old saying, "If you've seen one fluoridation campaign, you've seen one fluoridation campaign." A number of factors commonly come into play when fluoridation is put to a public vote and does not succeed. Among those factors are a lack of funding, public and professional apathy, the failure of many legislators and community leaders to take a stand because of perceived controversy, low voter turnout, and the difficulty faced by an electorate in evaluating scientific information in the midst of emotional charges by opponents. Voters are often unaware of the fluoride content of their water. Unfortunately, citizens sometimes mistakenly believe their water contains the recommended level of fluoride when, in fact, it does not. On the other hand, people sometimes say they have great teeth and don't need fluoridation when, in fact, the major reason they have such good teeth is because they've

had the benefit of fluoride in the water their entire lives. And, in some cases, because fluoridation campaigns often become political campaigns, there are political factors that can sway a vote that have nothing at all to do with fluoridation. Clever use of emotionally charged "scare" propaganda by fluoride opponents creates fear, confusion, and doubt within a community when voters consider the use of fluoridation.[461,462] Defeats of referenda to initiate fluoridation or victories in discontinuance of fluoridation efforts have occurred most often when a small, vocal, and well-organized group has used a barrage of fear-inspiring allegations designed to confuse the electorate.

In addition to attempts to influence voters, opponents have threatened community leaders with personal litigation.[456] While no court of last resort has ever ruled against fluoridation, community leaders can be swayed by the threat of litigation due to the cost, time, and emotional energy involved in defending even a groundless suit, not to mention threats of political fallout. The ADA knows of no cases in which community leaders have been found liable for their pro-fluoridation efforts. In no instance has fluoridation been discontinued because it was proven harmful in any way.[456,462,463]

Defeats of referenda to initiate fluoridation or victories in discontinuance of fluoridation efforts have occurred most often when a small, vocal, and well-organized group has used a barrage of fear-inspiring allegations designed to confuse the electorate.

The adoption of fluoridation is ultimately a choice of state or local decision-makers, whether determined by elected officials, health officers, or the voting public. Fluoridation can be enacted through state legislation, administrative regulation, ordinance, or public referendum. Fluoridation is not legislated at the federal level, but at the state and local levels. As with any public health measure, a community has the right and obligation to protect the health and welfare of its citizens, even if it means overriding individual objections to implement fluoridation. Those opposed to fluoridation sometimes comment that "the government is forcing fluoridation" on the community. But who is "the government?" The fact is, because fluoridation is implemented by votes of elected state legislatures, city councils, county commissions, or directly by the public, the people are "the government."

Experts continue to stress the importance of maintaining fluoridation. As Anne-Marie Glenny, a professor of health science at the University of Manchester and a Cochrane review author,[27] states, "I'm not aware of anything that would support stopping fluoridation where it's already in place. Without considering programs to replace the fluoride people currently get from water, it would be foolish to take fluoride out."[464] These comments underscore the importance of fluoridation as a public health measure to prevent tooth decay, even amid growing political and social challenges.

66. Is community water fluoridation accepted by other countries?

Answer

Yes. According to the British Fluoridation Society, as of 2020, approximately 380 million people in 25 countries worldwide were supplied with water fluoridated by adjustment.[465] Additionally, more than 57.4 million receive naturally fluoridated water at the optimum level. Worldwide, the estimated number of people with access to optimally fluoridated water equates to more than 400 million people.[35]

According to the British Fluoridation Society, as of 2020, approximately 380 million people in 25 countries worldwide were supplied with water fluoridated by adjustment.[465]

Fact

The value of water fluoridation is recognized internationally. Countries and geographic regions with water fluoridated by adjustment include the United States, Argentina, Australia, Brazil, Brunei, Canada, Chile, China (Special Administrative Region of Hong Kong), Fiji, Guatemala, Guyana, the Irish Republic, Malaysia, New Zealand, Panama, Papua New Guinea, Peru, South Korea, Serbia, Singapore, Spain, the United Kingdom, and Vietnam.[466] Major cities outside the United States with fluoridated water include Adelaide, Auckland, Bilbao, Birmingham, Brisbane, Buenos Aires, Cork, Dublin, Edmonton, Ho Chi Minh City (Saigon), Kuala Lumpur, Melbourne, Newcastle upon Tyne, Perth, Rio de Janeiro, San Paolo, Santiago, Seville, Sydney, Toronto, Wellington, and Winnipeg.[466]

Thorough investigations of fluoridation conducted in a number of countries in addition to the United States, including Australia, England, Ireland, New Zealand, as well as by the European Commission and the WHO, support the safety and effectiveness of water fluoridation.[34,35,38,40,41,43]

Considering the extent to which fluoridation has already been implemented throughout the world, the lack of documentation of adverse health effects is remarkable testimony to its safety.[34,38-41] The WHO has endorsed the practice of water fluoridation since 1969.[428] In 1994, an expert committee of the WHO published a report that reaffirmed its support of fluoridation as being safe and effective in the prevention of tooth decay, and stated that "provided a community has a piped water supply, water fluoridation is the most effective method of reaching the whole population, so that all social classes benefit without the need for active participation on the part of individuals."[429] In 2004, the WHO once again affirmed its support.[430] In 2007, the 60th World Health Assembly recommended that countries without access to optimal levels of fluoride or systemic fluoridation programs should consider initiating fluoridation programs.[431]

A scientific evaluation of fluoride was conducted by the Scientific Committee on Health and Environmental Risks (SCHER) upon request by the European Commission (EC).[462] The EC is the European Union's (EU) executive body with responsibility to manage EU policy. The Committee was asked to critically evaluate any new evidence on the hazard profile, health effects, and human exposure to fluoride. The final report, *Critical review of any new evidence on the hazard profile, health effects, and human exposure to fluoride and the fluoridating agents of drinking water,* was released in 2011.[43] It stated that exposure to levels of fluoride used for fluoridation of drinking water does not lead

to unacceptable risks to the environment. Additionally, the report concluded there was insufficient evidence or no evidence that fluoridation was linked to endemic skeletal fluorosis, osteosarcoma, lower IQs in children, or thyroid or reproductive problems.[43]

There are parts of the world where water fluoridation is not common. In some of these instances water fluoridation is not feasible due to the lack of a central water supply, the prioritization of other life-threatening health needs, the lack of trained technical personnel, or insufficient funds for start-up and maintenance costs. In some cases where water fluoridation has not been implemented, countries have chosen instead to institute salt fluoridation programs.

67. Is community water fluoridation banned in Europe?

Answer

No. There is no country in Europe that bans community water fluoridation.

Fact

Under EU laws and regulations, the individual member states can decide whether to fluoridate water. Members of the EU construct their own water quality regulations within the framework of the Drinking Water Directive,[467] adopted in 1998, which outlines the quality of water intended for human consumption. They can also decide whether to add fluoride to milk or salt products. There is no EU-wide obligation to add fluoride to any product consumed by humans, including water, nor is there an EU-wide obligation not to add fluoride to any product, including water.[463]

The Drinking Water Directive provides maximum permissible concentrations for many substances, one of which is fluoride. The directive does not require or prohibit fluoridation; it merely requires that the fluoride concentration in water not exceed the maximum permissible concentration of 1.5 mg/L.[467]

Water fluoridation is not practical in some European countries because of complex water systems with numerous water sources. In many cases, there are also technical, legal, financial, or political reasons that water fluoridation has not been implemented. As an alternative to water fluoridation, many European countries have opted for the use of dietary fluoride supplements or salt fluoridation.

Basel, Switzerland, is one such example.[468] Those opposed to water fluoridation claimed a large victory when Basel voted to cease water fluoridation in 2003. The facts are that Basel was the lone city with fluoridated water surrounded by communities that used fluoridated salt. In the mid-1990s, trade barriers that had prevented fluoridated salt from being sold to those living in Basel fell, and soon it was evident that residents were receiving fluoride from salt as well as from drinking water. The government voted to cease water fluoridation in 2003 because of this availability and the use of fluoridated salt in the community. Basel, Switzerland did not stop providing fluoride. Officials simply chose another type of fluoridation—salt fluoridation.[468]

Those opposed to fluoridation sometimes comment that "most of Europe has rejected water fluoridation." But what is not mentioned is that there are a number of countries in Europe that have opted to use fluoridated salt or milk fluoridation.[467]

Additional information on this topic can be found in the Benefits Section, Question 14.

Section 5

Cost

68. Is water fluoridation a cost-effective and cost-saving method of preventing tooth decay?

Answer

Yes. When compared with the cost of other prevention programs, water fluoridation is the most cost-effective means of preventing tooth decay for children and adults in the United States. A number of studies conducted during the past 15 years have attempted to place a specific dollar value on the benefit of fluoridation. These studies, conducted in different years (and therefore using different dollar values), encompassing different communities and populations, and using different methodologies, have two conclusions in common: (1) for systems that serve more than 1,000 people, the economic benefit of fluoridation exceeds the cost; and (2) the benefit-cost ratios increase as the size of the populations increase largely due to economies of scale.

Fact

The cost of community water fluoridation varies for each community depending on the following factors.[469]

- Size of the community (population and water usage).
- Number of fluoride injection points where fluoride additives will be added to the water system.
- Amount and type of equipment used to add and monitor fluoride additives.
- Amount and type of fluoride additive needed to reach the target fluoride level of 0.7 mg/L; its price, cost of transportation, and storage.
- Expertise and preferences of personnel at the water plant.

The economic benefits of community water fluoridation arise from dental treatment averted that would otherwise have been needed to treat caries that would have occurred in its absence. While all studies have concluded that fluoridation is cost-effective and cost-saving, they vary in the time horizon and discount rate, as well as whether they include time and travel costs to patients to receive care. Because of the decay-reducing effects of fluoride, the need for restorative dental care (fillings) is typically lower in fluoridated communities. Restorations rarely last the entire lifespan and are usually replaced over time by larger and more complex restorations, including root canal fillings in some cases.[470] Therefore, an individual residing in a fluoridated community will typically pay for fewer and less-complex dental restorative services during a lifetime.

Return on Investment Model

In 2016, a study[471] led by researchers from the Colorado School of Public Health created a model of fluoridation program costs, savings, net savings, and return on investment (ROI) for the 2013 US population with access to optimally fluoridated water systems that served 1,000 or more people. The researchers found that national annual savings associated with individuals avoiding tooth decay in 2013 as a result of fluoridation were estimated at $6.8 billion, or $32.19 per person, for the more than 211 million people who had access to fluoridated water through community water systems serving

more than 1,000 people that year. With the estimated cost of the systems to fluoridate ($324 million), the estimated net savings from fluoridation were $6.5 billion and the estimated ROI averaged 20 to 1 across water systems of all sizes (from 1,000 to more than 100,000 people, with an ROI range of 15.5–26.2).

However, it was noted that the cost per person to fluoridate varies significantly among different-sized communities based on a number of the factors outlined in the previous paragraph. Because of those variables, the researchers urged communities to inform their policy decisions by identifying their specific water system's annual cost and comparing that cost to the annual estimated per person savings ($32.19) in averted treatment costs. The researchers noted that in 2013, while 211 million people had access to fluoridated water, more than 78 million people had access to a public water system that served 1,000 or more people that was not fluoridated. The study findings suggested that if those water systems had been fluoridated, an additional $2.5 billion could have been saved as a result of reductions in tooth decay.[471]

Community Preventive Services Task Force (CPSTF) Systematic Review

The economic benefits of fluoridation were also reconfirmed in a systematic review[472] conducted in 2013 by the CPSTF, which sought to update its prior review conducted in 2002[62] that also found that fluoridation saved money. The 2013 review concluded that the then-recent evidence continued to show that the economic benefit of fluoridation programs exceeds their cost, with benefit-cost ratios that ranged from 1.12:1 to 135:1.[62] Those ratios were positively associated with community population size.[472]

Scoping Review

A scoping review of the global literature published in 2020[473] identified 24 relevant studies. All studies concluded that water fluoridation was a cost-effective strategy to prevent tooth decay when it was compared with non-fluoridated communities, independent of the perspective, time horizon, or discount rate applied.

Cost of Dental Restorations

There are various types of dental restorations (fillings) commonly used for the initial treatment of tooth decay (cavities), including amalgam (silver) and composite resins (tooth-colored). In the 2016 study noted earlier,[471] the most commonly used treatment was a two-surface composite resin restoration in posterior (back) permanent teeth. Considering that in the United States the fee[474] for a two-surface composite resin restoration in a permanent tooth placed by a general dentist typically ranges from $207–$278*, fluoridation clearly demonstrates significant cost savings. An individual can enjoy a lifetime of fluoridated water for less than the cost of one dental filling.

An individual can enjoy a lifetime of fluoridated water for less than the cost of one dental filling.

* The survey data should not be interpreted as constituting a fee schedule in any way and should not be used for that purpose. Dentists must establish their own fees based on their individual practice and market considerations. The ADA discourages dentists from engaging in any unlawful concerted activity regarding fees or otherwise.

When it comes to the cost of treating dental disease, everyone pays, not just those who need treatment, but the entire community through higher health insurance premiums and higher taxes. Cutting dental care costs by reducing tooth decay is something a community can do to improve oral health and save money for everyone. With the escalating cost of health care, fluoridation remains a community public health measure that saves money and therefore benefits all members of the community.

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The economic importance of fluoridation is underscored by the fact that the cost of treating dental disease frequently is paid not only by the affected individual, but also by the general public through services provided by health departments, community health clinics, health insurance premiums, the military, and other publicly supported medical programs.[475] For example, results from a New York state study published in 2010[476] that compared the number of Medicaid claims in 2006 for cavity-related procedures in fluoridated counties and non-fluoridated counties showed a 33.4% higher level of claims for fillings, root canals, and extractions in non-fluoridated counties as compared to such claims in fluoridated counties.[476]

Fluoridation contributes much more to overall health than simply reducing tooth decay. It prevents needless infection, pain, suffering, and loss of teeth and saves vast sums of money in dental treatment cost—particularly in cases where dental care is received through surgical intervention (fillings, root canals, prosthodontics, and/or extractions) in a hospital or through hospital emergency services.

In a study[477] conducted in Louisiana, Medicaid-eligible children ages 1–5 years residing in communities without fluoridated water were three times more likely than Medicaid-eligible children residing in communities with fluoridated water to receive dental treatment in a hospital, and the cost of dental treatment per eligible child was approximately twice as high. In addition to community water fluoridation status, the study took into account per capita income, population, and number of dentists per county.[477]

National Preventive Dentistry Demonstration Program

School-based dental disease prevention activities, such as fluoride mouthrinse or tablet programs, professionally applied topical fluorides, dental health education, and placement of dental sealants, are beneficial but are not as cost-effective in preventing tooth decay as community water fluoridation.[478] In 1985, the National Preventive Dentistry Demonstration Program analyzed various types and combinations of school-based preventive dental services to determine the cost and effectiveness of these types of prevention programs.[478] Ten sites from across the nation were selected. Five of the sites had fluoridated water and five did not. More than 20,000 second and fifth graders participated in the study during a period of four years. Students were examined and assigned by site to one or a combination of the following groups:

- Biweekly in-class brushing and flossing plus a home supply of fluoride toothpaste and dental health lessons (10 per year)
- In-class daily fluoride tablets (in non-fluoridated areas)
- In-school weekly fluoride mouthrinsing

- In-school professionally applied topical fluoride
- In-school professionally applied dental sealants
- A control

After 4 years, approximately 50% of the original students were examined again. The study affirmed the value and effectiveness of community water fluoridation. At the sites where the community water was fluoridated, students had fewer cavities as compared to those sites without fluoridated water where the same preventive measures were implemented. In addition, while sealants were determined to be an effective prevention method, the cost of a sealant program was substantially more than the cost of fluoridating the community water, reaffirming fluoridation as the most cost-effective preventive option.[478]

In an effort to balance budgets, decision-makers sometimes make economic choices that amount to being "penny wise and pound foolish." In other words, they cut an expense today that appears to be a sure money saver, but they fail to take a long-term view (or see the big picture) on the consequences of that action. They fail to see how money spent now can provide greater savings in the future. A decision to eliminate funding for a successful community water fluoridation program would be an example of that kind of action.

Often, decision-makers are swayed by the promise of an alternative fluoride delivery system without considering who it will cover (and who it will not cover), how it will be administered, and what it will cost. Examples of these alternative fluoride delivery programs include school-based fluoride mouthrinse programs, dietary fluoride supplements, fluoride varnish, and other professionally applied topical fluorides. Often dental health education programs, including dispensing free toothbrushes and fluoridated toothpaste, are mentioned as an alternative to fluoridation. All these programs can be beneficial but are not as efficient or cost-effective as fluoridation programs because they typically require additional personnel to facilitate the programs and action on the part of the recipient and have much higher administrative and supply costs. Additionally, these programs typically target only children and so do not provide decay-preventing benefits to adults. Fluoridation benefits all members of the community— children and adults—and is more cost-effective.

Health Impact in 5 Years Initiative

The CDC's "Health Impact in 5 Years" (HI-5) initiative[479] launched in 2016 highlighted community-wide approaches that have evidence reporting (1) positive health impacts, (2) results in 5 years, and (3) cost-effectiveness or cost savings over the lifetime of the population or earlier. Fluoridation is one of the community approaches included in the HI-5 Initiative because it helps to keep people healthy as it reaches all members of a community where they live, learn, work, and play.

Documenting the impact of fluoridation can be challenging, partially because the beneficial effect is not immediately apparent.[104] Cost savings from fluoridation would be expected to accumulate over several years' time. The most notable decrease in tooth decay would be anticipated in young children who received the benefits of fluoridation over their lifetime in both their primary teeth and as their adult teeth begin to appear when the children are approximately 6 years old.

Benefits from the prevention of tooth decay include:

- Freedom from dental pain
- A more positive self-image
- Fewer missing teeth
- Fewer cases of poorly aligned teeth aggravated by tooth loss
- Fewer teeth requiring root canal treatment
- Reduced need for crowns, bridges, dentures, and implants
- Less time lost from school or work because of dental pain and/or visits to the dentist

While some of these types of benefits are difficult to measure economically, they are extremely important.[314,480]

Fluoridation remains the most cost-effective and practical form of preventing tooth decay in the United States and other countries with established municipal water systems. It is one of the very few public health measures that actually saves more money than it costs.[46,60,480,481]

69. Why fluoridate an entire water system when the vast majority of the water is not used for drinking?

Answer

It is more practical and less costly to fluoridate an entire water supply than to attempt to treat only the water that will be consumed.

Fact

Water systems treat all the water supplied to communities to the same high standards for disinfection, clarity, or fluoridation, whether the water is to be used for washing, watering lawns, preparing food, or drinking. Although not all that water needs to be disinfected, clarified, or fluoridated, it is more practical and cost-efficient to treat all the water delivered to the customer to the same standard.

Fluoride is only one of more than 40 chemicals and additives that are used to treat water in the United States.[314] Many are added for esthetic or convenience purposes, such as to improve the odor or taste, prevent natural cloudiness, or prevent staining of clothes or porcelain.[36] The cost of additives for fluoridating a community's water supply is very low on a per capita basis; therefore, it is practical to fluoridate the entire water supply. It would be prohibitively expensive and impractical for a community to have two water systems—one that provided drinking water and another for all other water use (watering lawns, laundry, flushing toilets).

Many organizations that are concerned about water use, conservation, and quality support the practice of water fluoridation. For example, the American Water Works Association, an international nonprofit scientific and educational association dedicated to the improvement of drinking water quality and supply, supports the practice of fluoridation of public water supplies.[482]

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Learn more at: **ADA.org/fluoride**

All About Fluoridation

Why fluoridate tap water?

- Continues to reduce cavities by about 25% in adults and children.
- Decreases missed school and work-days to dental-related pain.
- Cost-saving public health practice.
- Reduces cavities in addition to other fluoride products such as toothpaste, rinses, and varnish.

Water fluoridation is regarded as one of 10 great public health achievements of the 20th century by the CDC.

Where can I learn more?

ADA's **Fluoridation Facts** with pages of Q&A format responses to common questions.

MouthHealthy.org has resources written by dentists for parents.

Recent JADA articles related to fluoride.

Fluoridation FAQs

American Fluoridation Society resources, information, and articles

Why should dentists advocate for community water fluoridation?

1. To improve the oral health of the community
2. To promote the best science and evidence related to reducing cavities.
3. To educate patients and staff on the value of this disease prevention measure
4. To positively impact the oral health of the public in an equitable manner

When can I use this information?

LEARN **SHARE** **ADVOCATE**

Our ADA Databases include the latest science, networks, and articles to help you learn about community water fluoridation to better share and defend this practice.

How can I check if my water is fluoridated?

This locally governed health equitable practice is used within supervised community water systems. Learn about your community at **My Water's Fluoride**.

OPTIMAL:

0.7 ppm

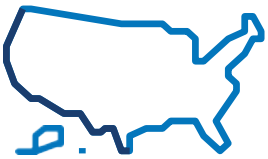
Action for DENTAL HEALTH

ADA American Dental Association®

Questions? Dr. Liz Lense | **lensee@ada.org**
Senior Scientist for Population Health Programs

Learn more at: **ADA.org/fluoride**

How to Take Action on Water Fluoridation



Contact Your State and Component Dental Association

The American Dental Association collaborates with **state and local leaders** to keep you informed and prepared for fluoridation changes.

Talk About Cavities

Share with your patients and community the importance of prevention. This includes **water fluoridation**, dental sealants, pre-natal oral health care, and routine Age-1 dental visits. Look at your local Community Needs Assessment.

Ask Experts About the Evidence

The Council on Advocacy for Access and Prevention has a National Fluoridation Advisory Committee prepared to connect with you. **Contact the ADA** to have your questions answered.

Speak With Your Community

Your local educators, school nurses, pediatricians, public health dept, and community leaders also care about oral health.

Share with Decision-Makers

Your elected officials or utility board often decide if your water is fluoridated. Take time to share with them the best science.

Prepare for a City Council Vote

The best way to take action is to initiate or defend community water fluoridation to reduce cavities.

Action for DENTALHEALTH

ADA American Dental Association®

Questions? Dr. Liz Lense | **lensee@ada.org**
Senior Scientist for Population Health Programs

Communities Benefit from Water Fluoridation

Water fluoridation is safe, effective, and saves communities money.

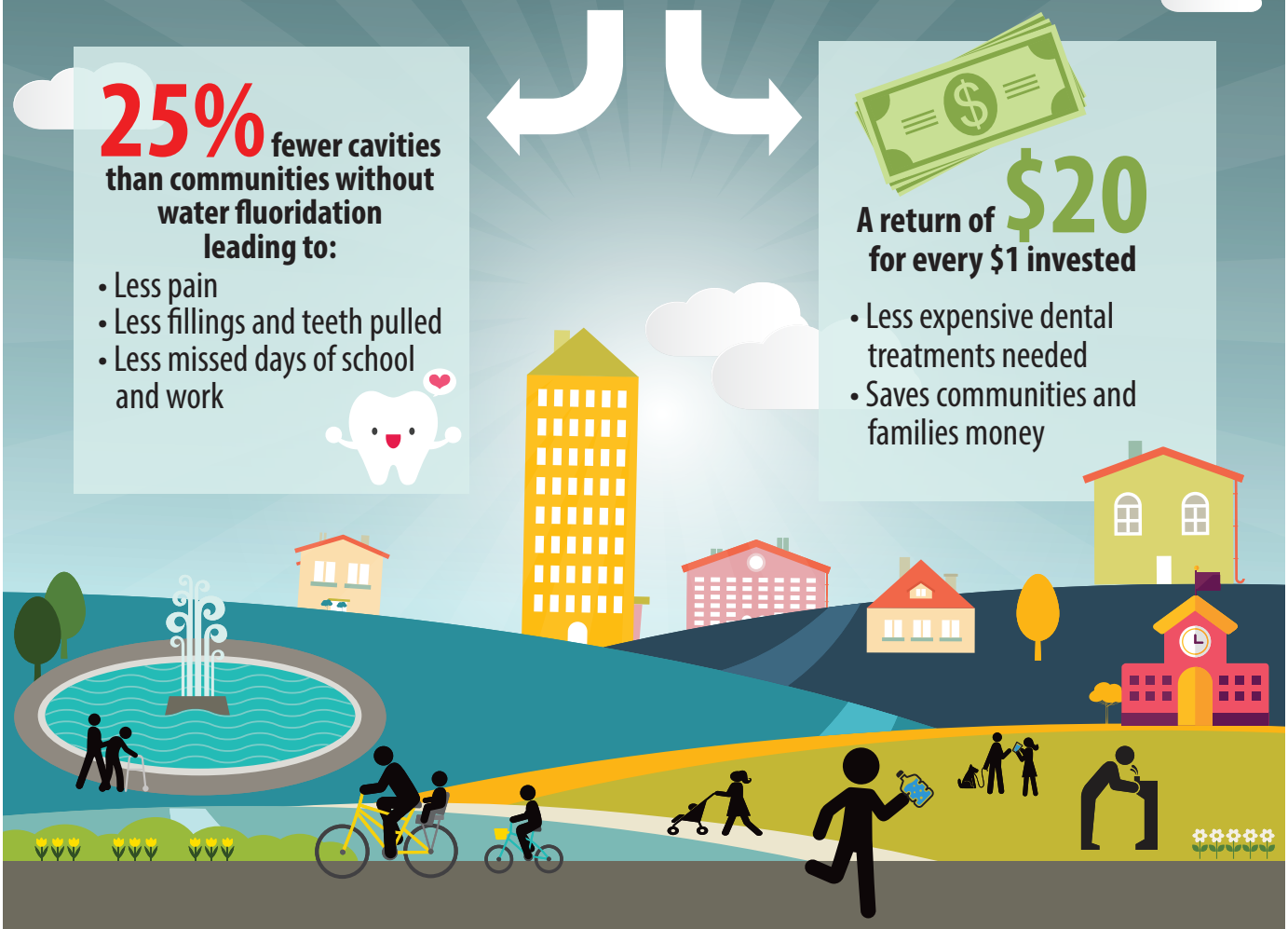
On average, communities with water fluoridation experience:

25% fewer cavities than communities without water fluoridation leading to:

- Less pain
- Less fillings and teeth pulled
- Less missed days of school and work

A return of **$20** for every $1 invested

- Less expensive dental treatments needed
- Saves communities and families money



Water fluoridation improves oral health and reaches everyone in the community.

Visit www.cdc.gov/fluoridation for information about community water fluoridation.

U.S. Department of Health and Human Services
Centers for Disease Control and Prevention

CS289123-C

Fluoride
FAST FACTS

Fluoride is a natural substance that is found in rocks, soil, and water. It prevents tooth decay in children and adults.

Fluoride helps keep teeth healthy by:

- Stopping the growth of bacteria that cause cavities
- Strengthening tooth enamel
- Reversing early tooth decay by replacing and preventing the loss of minerals that make teeth healthy

You can get fluoride by:

- Drinking local tap water that has fluoride in it
- Using fluoride toothpaste/ mouth rinse
- Getting varnish/gel at the dentist's office
- Taking a dietary supplement

The U.S. Public Health Service recommends 0.7 parts per million of fluoride in drinking water, or about 3 drops of fluoride in a 55-gallon barrel, to prevent tooth decay.

After adding fluoride to the community water supply, tooth decay decreased in both children and adults, and complete tooth loss in older adults became much less common.

Today, the majority of the U.S. population receives fluoridated water.*

73%

* Decisions about water fluoridation are made at the state or local level.

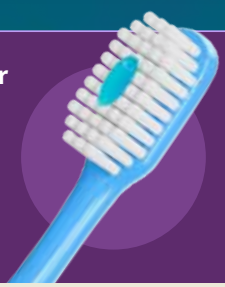
1940s 2014

Tooth Decay in U.S. Schoolchildren

1960-62 2017-19

Complete Tooth Loss in U.S. Adults Ages 65-74

At about age 2 (or sooner if a dentist or doctor suggests it), brush your child's teeth with a tiny amount of fluoride toothpaste.



For children aged 3 to 6, parents should put the toothpaste on the brush. Use only a pea-sized amount of fluoride toothpaste. Encourage your child to spit out the toothpaste rather than swallow it.

Additional resources

National Institute of Dental and Craniofacial Research

ADA American Dental Association®

Learn more at:
ADA.org/fluoride

Fluoride Facts for Water Operators

Why Water Personnel are Oral Health Heroes

Community water fluoridation is a time-tested, cost-effective, and equitable solution for optimal oral health.

Good oral health is essential to overall health. Children with cavities suffer from pain, infections, and poor nutrition. An average of 34 million hours of school are lost per year in the U.S. because of dental problems. Poor oral health in adults also results in pain, infection, and tooth loss, along with difficulty obtaining a job due to the appearance of their teeth, and lost work hours. Dental problems result in a $46 billion/year loss of production to the U.S. economy.[1]

More than 80 years of research and practical experience shows optimal fluoridation of water supplies helps prevent cavities. Studies prove water fluoridation continues to reduce tooth decay by more than 25% in children and adults, even with the use of other fluoride products like toothpaste.[1]

The benefits of community water fluoridation are recognized by the American Medical Association, American Water Works Association (AWWA), U.S. Public Health Service, Centers for Disease Control and Prevention (CDC), and the American Academy of Pediatrics (AAP). The CDC, AAP, and AWWA also provide fluoride information for water operators.[2, 3, 4]

Water facilities and water operators perform a valuable public service by carefully adjusting the level of fluoride in water to improve the oral health of their community.

Almost 73% of the U.S. population on community water systems (209 million people) receive the benefits of fluoridation.[5]

Rules and recommendations for water facilities are designed to ensure operator and public safety.[4]

- OSHA requires **Safety Data Sheets (SDS)** be prepared by the manufacturers and suppliers of additive products. Each water facility should have the most current SDS sheets for the products they use. SDS sheets describe safe handling and use procedures of all materials.
- With the proper use of **Personal Protective Equipment (PPE)**, an operator will not have hazardous exposure to fluoride additive products. Fluoride additives present risks comparable to other water additives commonly used such as hypochlorite, quicklime, aluminum sulfate, sodium hydroxide, and ferrous sulfate. In some cases, the fluoride additives are much less dangerous than many other additives, including chlorine gas.
- The process of **adding fluoride to water has little impact on the acidity or pH of drinking water** and therefore will not corrode water pipes.

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- If a water system is reporting problems with corrosion from evaporating hydrogen fluoride (i.e., the glass in the facility has become "frosted"), there is a leak in the piping. **The storage tank and other locations in the feed system may not be sealed or correctly vented**. All fluoride products storage, handling, and feed systems should be vented to the outside of the building, and the system and piping should be pressure tested (low pressure is sufficient) to identify possible leaks which should be promptly corrected. With no system leaks, there will be no corrosion problems.
- All state requirements, as well as Ten States Standards, require **storage of ALL additives be separate from other additives used in the facility**. It is important to keep different materials separated, as there is the potential to react with each other.
- **The CDC offers a free, online training course for Water Operators to learn more about Fluoridation at *www.cdc.gov/fluoridation-engineering/trainings/index.html.***

More questions? Check out ADA's Fluoridation Facts, or contact Dr. Elizabeth Lense at *lensee@ada.org*.

References:

[1] U.S. Centers for Disease Control and Prevention (CDC). 2024. About Oral Health. *www.cdc.gov/oral-health/about/index.html.*

[2] CDC. 2024. Fluoridation Engineering and Operations. *www.cdc.gov/fluoridation-engineering/?CDC_AAref_Val=https://www.cdc.gov/fluoridation/engineering/index.htm.*

[3] American Academy of Pediatrics. 2024. Helpful Information for Water Operators. *ilikemyteeth.org/waterops.*

[4] American Water Works Association. 2016. *M4 Water Fluoridation Principles & Practices, 6th Ed. www.awwa.org/portals/0/files/publications/documents/m4lookinside.pdf.*

[5] CDC. 2024. 2020 Water Fluoridation Statistics. *www.cdc.gov/fluoridation/php/statistics/2020-water-fluoridation-statistics.html.*

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