= Water fluoridation =

Water fluoridation is the controlled addition of fluoride to a public water supply to reduce tooth decay . Fluoridated water has fluoride at a level that is effective for preventing cavities ; this can occur naturally or by adding fluoride . Fluoridated water operates on tooth surfaces : in the mouth it creates low levels of fluoride in saliva , which reduces the rate at which tooth enamel demineralizes and increases the rate at which it remineralizes in the early stages of cavities . Typically a fluoridated compound is added to drinking water , a process that in the U.S. costs an average of about $ 1 @.@ 02 per person @-@ year . Defluoridation is needed when the naturally occurring fluoride level exceeds recommended limits . In 2011 the World Health Organization suggested a level of fluoride from 0 @.@ 5 to 1 @.@ 5 mg / L (milligrams per litre) , depending on climate , local environment , and other sources of fluoride . Bottled water typically has unknown fluoride levels .

Dental caries remains a major public health concern in most industrialized countries , affecting 60 ? 90 % of schoolchildren and the vast majority of adults . Water fluoridation reduces cavities in children , while efficacy in adults is less clear . A Cochrane review estimates a reduction in cavities when water fluoridation was used by children who had no access to other sources of fluoride to be 35 % in baby teeth and 26 % in permanent teeth . The evidence quality was poor . Most European countries have experienced substantial declines in tooth decay without its use . Recent studies suggest that water fluoridation , particularly in industrialized countries , may be unnecessary because topical fluorides (such as in toothpaste) are widely used and caries rates have become low .

Although fluoridation can cause dental fluorosis , which can alter the appearance of developing teeth or enamel fluorosis , the differences are mild and usually not considered to be of aesthetic or public @-@ health concern . There is no clear evidence of other adverse effects from water fluoridation . Fluoride 's effects depend on the total daily intake of fluoride from all sources . Drinking water is typically the largest source ; other methods of fluoride therapy include fluoridation of toothpaste , salt , and milk . The views on the most effective method for community prevention of tooth decay are mixed . The Australian government states that water fluoridation is the most effective means of achieving fluoride exposure that is community @-@ wide . The World Health Organization states water fluoridation , when feasible and culturally acceptable , has substantial advantages , especially for subgroups at high risk , while the European Commission finds no advantage to water fluoridation compared with topical use .

Public water fluoridation was first practiced in the U.S. As of 2012 , 25 countries have artificial water fluoridation to varying degrees , 11 of them have more than 50 % of their population drinking fluoridated water . A further 28 countries have water that is naturally fluoridated , though in many of them the fluoride is above the recommended safe level . As of 2012 about 435 million people worldwide received water fluoridated at the recommended level (i.e. , about 5 @.@ 4 % of the global population) . About 214 million of them living in the United States . Major health organizations such as the World Health Organization and FDI World Dental Federation supported water fluoridation as safe and effective . The Centers for Disease Control and Prevention lists water fluoridation as one of the ten great public health achievements of the 20th century in the U.S. Despite this , the practice is controversial as a public health measure ; some countries and communities have discontinued it , while others have expanded it . Opponents of the practice argue that neither the benefits nor the risks have been studied adequately , and debate the conflict between what might be considered mass medication and individual liberties .

= = Goal = =

The goal of water fluoridation is to prevent tooth decay by adjusting the concentration of fluoride in public water supplies . Tooth decay (dental caries) is one of the most prevalent chronic diseases worldwide . Although it is rarely life @-@ threatening , tooth decay can cause pain and impair eating , speaking , facial appearance , and acceptance into society , and it greatly affects the quality of life

of children , particularly those of low socioeconomic status . In most industrialized countries , tooth decay affects 60 ? 90 % of schoolchildren and the vast majority of adults ; although the problem appears to be less in Africa 's developing countries , it is expected to increase in several countries there because of changing diet and inadequate fluoride exposure . In the U.S. , minorities and the poor both have higher rates of decayed and missing teeth , and their children have less dental care . Once a cavity occurs , the tooth 's fate is that of repeated restorations , with estimates for the median life of an amalgam tooth filling ranging from 9 to 14 years . Oral disease is the fourth most expensive disease to treat . The motivation for fluoridation of salt or water is similar to that of iodized salt for the prevention of mental retardation and goiter .

The goal of water fluoridation is to prevent a chronic disease whose burdens particularly fall on children and the poor . Another of the goals was to bridge inequalities in dental health and dental care . Some studies suggest that fluoridation reduces oral health inequalities between the rich and poor , but the evidence is limited . There is anecdotal but not scientific evidence that fluoride allows more time for dental treatment by slowing the progression of tooth decay , and that it simplifies treatment by causing most cavities to occur in pits and fissures of teeth . Other reviews have found not enough evidence to determine if water fluoridation reduces oral @-@ health social disparities .

Its use presents a conflict between the common good and individual rights . It is controversial , and opposition to it has been based on ethical , legal , safety , and efficacy grounds . Health and dental organizations worldwide have endorsed its safety and effectiveness . Its use began in 1945 , following studies of children in a region where higher levels of fluoride occur naturally in the water . Further research showed that moderate fluoridation prevents tooth decay .

= = Implementation = =

Fluoridation does not affect the appearance , taste , or smell of drinking water . It is normally accomplished by adding one of three compounds to the water : sodium fluoride , fluorosilicic acid , or sodium fluorosilicate .

Sodium fluoride (NaF) was the first compound used and is the reference standard . It is a white , odorless powder or crystal ; the crystalline form is preferred if manual handling is used , as it minimizes dust . It is more expensive than the other compounds , but is easily handled and is usually used by smaller utility companies . It is toxic in gram quantities by ingestion or inhalation .

Fluorosilicic acid (H2SiF6) is the most commonly used additive for water fluoridation in the United States . It is an inexpensive liquid by @-@ product of phosphate fertilizer manufacture . It comes in varying strengths , typically 23 ? 25 % ; because it contains so much water , shipping can be expensive . It is also known as hexafluorosilicic , hexafluosilicic , hydrofluosilicic , and silicofluoric acid .

Sodium fluorosilicate (Na2SiF6) is the sodium salt of fluorosilicic acid . It is a powder or very fine crystal that is easier to ship than fluorosilicic acid . It is also known as sodium silicofluoride .

These compounds were chosen for their solubility , safety , availability , and low cost . A 1992 census found that , for U.S. public water supply systems reporting the type of compound used , 63 % of the population received water fluoridated with fluorosilicic acid , 28 % with sodium fluorosilicate , and 9 % with sodium fluoride .

= = = Recommendations = = =

The Centers for Disease Control and Prevention developed recommendations for water fluoridation that specify requirements for personnel , reporting , training , inspection , monitoring , surveillance , and actions in case of overfeed , along with technical requirements for each major compound used .

Although fluoride was once considered an essential nutrient , the U.S. National Research Council has since removed this designation due to the lack of studies showing it is essential for human growth , though still considering fluoride a " beneficial element " due to its positive impact on oral health . The European Food Safety Authority 's Panel on Dietetic Products , Nutrition and Allergies (

NDA) considers fluoride not to be an essential nutrient , yet , due to the beneficial effects of dietary fluoride on prevention of dental caries they have defined an Adequate Intake (AI) value for it . The AI of fluoride from all sources (including non @-@ dietary sources) is 0 @.@ 05 mg / kg body weight per day for both children and adults , including pregnant and lactating women .

In 2011 , the U.S. Department of Health and Human Services (HHS) and the U.S. Environmental Protection Agency (EPA) lowered the recommended level of fluoride to 0 @.@ 7 mg / L. In 2015 , the U.S. Food and Drug Administration (FDA) , based on the recommendation of the U.S. Public Health Service (PHS) for fluoridation of community water systems , recommended that bottled water manufacturers limit fluoride in bottled water to no more than 0 @.@ 7 milligrams per liter (mg / L) (milligrams per liter , equivalent to parts per million) .

Previous recommendations were based on evaluations from 1962 , when the U.S. specified the optimal level of fluoride to range from 0 @.@ 7 to 1 @.@ 2 mg / L (milligrams per liter , equivalent to parts per million) , depending on the average maximum daily air temperature ; the optimal level is lower in warmer climates , where people drink more water , and is higher in cooler climates .

These standards are not appropriate for all parts of the world , where fluoride levels might be excessive and fluoride should be removed from water , and is based on assumptions that have become obsolete with the rise of air conditioning and increased use of soft drinks , processed food , fluoridated toothpaste , and other sources of fluorides . In 2011 the World Health Organization stated that 1 @.@ 5 mg / L should be an absolute upper bound and that 0 @.@ 5 mg / L may be an appropriate lower limit . A 2007 Australian systematic review recommended a range from 0 @.@ 6 to 1 @.@ 1 mg / L.

= = = Occurrences = = =

Fluoride naturally occurring in water can be above , at , or below recommended levels . Rivers and lakes generally contain fluoride levels less than 0 @.@ 5 mg / L , but groundwater , particularly in volcanic or mountainous areas , can contain as much as 50 mg / L. Higher concentrations of fluorine are found in alkaline volcanic , hydrothermal , sedimentary , and other rocks derived from highly evolved magmas and hydrothermal solutions , and this fluorine dissolves into nearby water as fluoride . In most drinking waters , over 95 % of total fluoride is the F ? ion , with the magnesium ? fluoride complex (MgF +) being the next most common . Because fluoride levels in water are usually controlled by the solubility of fluorite (CaF2) , high natural fluoride levels are associated with calcium @-@ deficient , alkaline , and soft waters . Defluoridation is needed when the naturally occurring fluoride level exceeds recommended limits . It can be accomplished by percolating water through granular beds of activated alumina , bone meal , bone char , or tricalcium phosphate ; by coagulation with alum ; or by precipitation with lime .

Pitcher or faucet @-@ mounted water filters do not alter fluoride content ; the more @-@ expensive reverse osmosis filters remove 65 ? 95 % of fluoride , and distillation removes all fluoride . Some bottled waters contain undeclared fluoride , which can be present naturally in source waters , or if water is sourced from a public supply which has been fluoridated . The FDA states that bottled water products labeled as de @-@ ionized , purified , demineralized , or distilled have been treated in such a way that they contain no or only trace amounts of fluoride , unless they specifically list fluoride as an added ingredient .

= = Evidence = =

Existing evidence suggests that water fluoridation reduces tooth decay . Consistent evidence also suggests that it causes dental fluorosis , most of which is mild and not usually of aesthetic concern . No clear evidence of other adverse effects exists , though almost all research thereof has been of poor quality .

= = = Effectiveness = = =

Reviews have shown that water fluoridation reduces cavities in children . A conclusion for the efficacy in adults is less clear with some reviews finding benefit and others not . Studies in the U.S. in the 1950s and 1960s showed that water fluoridation reduced childhood cavities by fifty to sixty percent , while studies in 1989 and 1990 showed lower reductions (40 % and 18 % respectively) , likely due to increasing use of fluoride from other sources , notably toothpaste , and also the ' halo effect ' of food and drink that is made in fluoridated areas and consumed in unfluoridated ones .

A 2000 UK systematic review (York) found that water fluoridation was associated with a decreased proportion of children with cavities of 15 % and with a decrease in decayed , missing , and filled primary teeth (average decreases was 2 @.@ 25 teeth) . The review found that the evidence was of moderate quality : few studies attempted to reduce observer bias , control for confounding factors , report variance measures , or use appropriate analysis . Although no major differences between natural and artificial fluoridation were apparent , the evidence was inadequate for a conclusion about any differences . A 2007 Australian systematic review used the same inclusion criteria as York 's , plus one additional study . This did not affect the York conclusions . A 2011 European Commission systematic review based its efficacy on York 's review conclusion . A 2015 Cochrane systematic review estimated a reduction in cavities when water fluoridation was used by children who had no access to other sources of fluoride to be 35 % in baby teeth and 26 % in permanent teeth . The evidence was of poor quality .

Fluoride may also prevent cavities in adults of all ages . A 2007 meta @-@ analysis by CDC researchers found that water fluoridation prevented an estimated 27 % of cavities in adults , about the same fraction as prevented by exposure to any delivery method of fluoride (29 % average) . A 2011 European Commission review found that the benefits of water fluoridation for adult in terms of reductions in decay are limited . A 2015 Cochrane review found no conclusive research regarding the effectiveness of water fluoridation in adults . A 2016 review found variable quality evidence that , overall , stopping of community water fluoridation programs was typically followed by an increase in cavities .

Most countries in Europe have experienced substantial declines in cavities without the use of water fluoridation . For example , in Finland and Germany , tooth decay rates remained stable or continued to decline after water fluoridation stopped . Fluoridation may be useful in the U.S. because unlike most European countries , the U.S. does not have school @-@ based dental care , many children do not visit a dentist regularly , and for many U.S. children water fluoridation is the prime source of exposure to fluoride . The effectiveness of water fluoridation can vary according to circumstances such as whether preventive dental care is free to all children .

= = = Fluorosis = = =

Fluoride 's adverse effects depend on total fluoride dosage from all sources . At the commonly recommended dosage , the only clear adverse effect is dental fluorosis , which can alter the appearance of children 's teeth during tooth development ; this is mostly mild and is unlikely to represent any real effect on aesthetic appearance or on public health . In April 2015 , recommended fluoride levels in the United States were changed to 0 @.@ 7 ppm from 0 @.@ 7 ? 1 @.@ 2 ppm to reduce the risk of dental fluorosis . The 2015 Cochrane review estimated that for a ?uoride level of 0 @.@ 7 ppm the percentage of participants with ?uorosis of aesthetic concern was approximately 12 % . This increases to 40 % when considering ?uorosis of any level not of aesthetic concern . In the US mild or very mild dental fluorosis has been reported in 20 % of the population , moderate fluorosis in 2 % and severe fluorosis in less than 1 % .

The critical period of exposure is between ages one and four years , with the risk ending around age eight . Fluorosis can be prevented by monitoring all sources of fluoride , with fluoridated water directly or indirectly responsible for an estimated 40 % of risk and other sources , notably toothpaste , responsible for the remaining 60 % . Compared to water naturally fluoridated at 0 @.@ 4 mg / L , fluoridation to 1 mg / L is estimated to cause additional fluorosis in one of every 6 people (95 % CI 4 ? 21 people) , and to cause additional fluorosis of aesthetic concern in one of every 22 people (95 % CI 13 @.@ 6 ? ? people) . Here , aesthetic concern is a term used in a standardized scale based

on what adolescents would find unacceptable , as measured by a 1996 study of British 14 @-@ year @-@ olds . In many industrialized countries the prevalence of fluorosis is increasing even in unfluoridated communities , mostly because of fluoride from swallowed toothpaste . A 2009 systematic review indicated that fluorosis is associated with consumption of infant formula or of water added to reconstitute the formula , that the evidence was distorted by publication bias , and that the evidence that the formula 's fluoride caused the fluorosis was weak . In the U.S. the decline in tooth decay was accompanied by increased fluorosis in both fluoridated and unfluoridated communities ; accordingly , fluoride has been reduced in various ways worldwide in infant formulas , children 's toothpaste , water , and fluoride @-@ supplement schedules .

= = = Safety = = =

Fluoridation has little effect on risk of bone fracture (broken bones) ; it may result in slightly lower fracture risk than either excessively high levels of fluoridation or no fluoridation . There is no clear association between fluoridation and cancer or deaths due to cancer , both for cancer in general and also specifically for bone cancer and osteosarcoma . Other adverse effects lack sufficient evidence to reach a confident conclusion .

Fluoride can occur naturally in water in concentrations well above recommended levels , which can have several long @-@ term adverse effects , including severe dental fluorosis , skeletal fluorosis , and weakened bones ; water utilities in the developed world reduce fluoride levels to regulated maximum levels in regions where natural levels are high , and the WHO and other groups work with countries and regions in the developing world with naturally excessive fluoride levels to achieve safe levels . The World Health Organization recommends a guideline maximum fluoride value of 1 @.@ 5 mg / L as a level at which fluorosis should be minimal .

In rare cases improper implementation of water fluoridation can result in overfluoridation that causes outbreaks of acute fluoride poisoning , with symptoms that include nausea , vomiting , and diarrhea . Three such outbreaks were reported in the U.S. between 1991 and 1998 , caused by fluoride concentrations as high as 220 mg / L ; in the 1992 Alaska outbreak , 262 people became ill and one person died . In 2010 , approximately 60 gallons of fluoride were released into the water supply in Asheboro , North Carolina in 90 minutes ? an amount that was intended to be released in a 24 @-@ hour period .

Like other common water additives such as chlorine , hydrofluosilicic acid and sodium silicofluoride decrease pH and cause a small increase of corrosivity , but this problem is easily addressed by increasing the pH . Although it has been hypothesized that hydrofluosilicic acid and sodium silicofluoride might increase human lead uptake from water , a 2006 statistical analysis did not support concerns that these chemicals cause higher blood lead concentrations in children . Trace levels of arsenic and lead may be present in fluoride compounds added to water , but no credible evidence exists that their presence is of concern : concentrations are below measurement limits .

The effect of water fluoridation on the natural environment has been investigated , and no adverse effects have been established . Issues studied have included fluoride concentrations in groundwater and downstream rivers ; lawns , gardens , and plants ; consumption of plants grown in fluoridated water ; air emissions ; and equipment noise .

= = Mechanism = =

Fluoride exerts its major effect by interfering with the demineralization mechanism of tooth decay . Tooth decay is an infectious disease , the key feature of which is an increase within dental plaque of bacteria such as Streptococcus mutans and Lactobacillus . These produce organic acids when carbohydrates , especially sugar , are eaten . When enough acid is produced to lower the pH below 5 @.@ 5 , the acid dissolves carbonated hydroxyapatite , the main component of tooth enamel , in a process known as demineralization . After the sugar is gone , some of the mineral loss can be recovered ? or remineralized ? from ions dissolved in the saliva . Cavities result when the rate of demineralization exceeds the rate of remineralization , typically in a process that requires many

months or years .

All fluoridation methods , including water fluoridation , create low levels of fluoride ions in saliva and plaque fluid , thus exerting a topical or surface effect . A person living in an area with fluoridated water may experience rises of fluoride concentration in saliva to about 0 @.@ 04 mg / L several times during a day . Technically , this fluoride does not prevent cavities but rather controls the rate at which they develop . When fluoride ions are present in plaque fluid along with dissolved hydroxyapatite , and the pH is higher than 4 @.@ 5 , a fluorapatite @-@ like remineralized veneer is formed over the remaining surface of the enamel ; this veneer is much more acid @-@ resistant than the original hydroxyapatite , and is formed more quickly than ordinary remineralized enamel would be . The cavity @-@ prevention effect of fluoride is mostly due to these surface effects , which occur during and after tooth eruption . Although some systemic (whole @-@ body) fluoride returns to the saliva via blood plasma , and to unerupted teeth via plasma or crypt fluid , there is little data to determine what percentages of fluoride 's anticavity effect comes from these systemic mechanisms . Also , although fluoride affects the physiology of dental bacteria , its effect on bacterial growth does not seem to be relevant to cavity prevention .

Fluoride 's effects depend on the total daily intake of fluoride from all sources . About 70 ? 90 % of ingested fluoride is absorbed into the blood , where it distributes throughout the body . In infants 80 ? 90 % of absorbed fluoride is retained , with the rest excreted , mostly via urine ; in adults about 60 % is retained . About 99 % of retained fluoride is stored in bone , teeth , and other calcium @-@ rich areas , where excess quantities can cause fluorosis . Drinking water is typically the largest source of fluoride . In many industrialized countries swallowed toothpaste is the main source of fluoride exposure in unfluoridated communities . Other sources include dental products other than toothpaste ; air pollution from fluoride @-@ containing coal or from phosphate fertilizers ; trona , used to tenderize meat in Tanzania ; and tea leaves , particularly the tea bricks favored in parts of China . High fluoride levels have been found in other foods , including barley , cassava , corn , rice , taro , yams , and fish protein concentrate . The U.S. Institute of Medicine has established Dietary Reference Intakes for fluoride : Adequate Intake values range from 0 @.@ 01 mg / day for infants aged 6 months or less , to 4 mg / day for men aged 19 years and up ; and the Tolerable Upper Intake Level is 0 @.@ 10 mg / kg / day for infants and children through age 8 years , and 10 mg / day thereafter . A rough estimate is that an adult in a temperate climate consumes 0 @.@ 6 mg / day of fluoride without fluoridation , and 2 mg / day with fluoridation . However , these values differ greatly among the world 's regions : for example , in Sichuan , China the average daily fluoride intake is only 0 @.@ 1 mg / day in drinking water but 8 @.@ 9 mg / day in food and 0 @.@ 7 mg / day directly from the air due to the use of high @-@ fluoride soft coal for cooking and drying foodstuffs indoors .

= = Alternatives = =

The views on the most effective method for community prevention of tooth decay are mixed . The Australian government review states that water fluoridation is the most effective means of achieving fluoride exposure that is community @-@ wide . The European Commission review states " No obvious advantage appears in favour of water fluoridation compared with topical prevention " . Other fluoride therapies are also effective in preventing tooth decay ; they include fluoride toothpaste , mouthwash , gel , and varnish , and fluoridation of salt and milk . Dental sealants are effective as well , with estimates of prevented cavities ranging from 33 % to 86 % , depending on age of sealant and type of study .

Fluoride toothpaste is the most widely used and rigorously evaluated fluoride treatment . Its introduction in the early 1970s is considered the main reason for the decline in tooth decay in industrialized countries , and toothpaste appears to be the single common factor in countries where tooth decay has declined . Toothpaste is the only realistic fluoride strategy in many low @-@ income countries , where lack of infrastructure renders water or salt fluoridation infeasible . It relies on individual and family behavior , and its use is less likely among lower economic classes ; in low @-@ income countries it is unaffordable for the poor . Fluoride toothpaste prevents about 25 % of

cavities in young permanent teeth , and its effectiveness is improved if higher concentrations of fluoride are used , or if the toothbrushing is supervised . Fluoride mouthwash and gel are about as effective as fluoride toothpaste ; fluoride varnish prevents about 45 % of cavities . By comparison , brushing with a nonfluoride toothpaste has little effect on cavities .

The effectiveness of salt fluoridation is about the same as that of water fluoridation , if most salt for human consumption is fluoridated . Fluoridated salt reaches the consumer in salt at home , in meals at school and at large kitchens , and in bread . For example , Jamaica has just one salt producer , but a complex public water supply ; it started fluoridating all salt in 1987 , achieving a decline in cavities . Universal salt fluoridation is also practiced in Colombia and the Swiss Canton of Vaud ; in Germany fluoridated salt is widely used in households but unfluoridated salt is also available , giving consumers a choice . Concentrations of fluoride in salt range from 90 to 350 mg / kg , with studies suggesting an optimal concentration of around 250 mg / kg .

Milk fluoridation is practiced by the Borrow Foundation in some parts of Bulgaria , Chile , Peru , Russia , Macedonia , Thailand and the UK . Depending on location , the fluoride is added to milk , to powdered milk , or to yogurt . For example , milk powder fluoridation is used in rural Chilean areas where water fluoridation is not technically feasible . These programs are aimed at children , and have neither targeted nor been evaluated for adults . Systematic reviews in 2005 and 2015 found insufficient evidence to support the practice , but also concluded that available studies suggest that fluoridated milk benefits schoolchildren .

Other public @-@ health strategies to control tooth decay , such as education to change behavior and diet , have lacked impressive results . Although fluoride is the only well @-@ documented agent which controls the rate at which cavities develop , it has been suggested that adding calcium to the water would reduce cavities further . Other agents to prevent tooth decay include antibacterials such as chlorhexidine and sugar substitutes such as xylitol . Xylitol @-@ sweetened chewing gum has been recommended as a supplement to fluoride and other conventional treatments if the gum is not too costly . Two proposed approaches , bacteria replacement therapy (probiotics) and caries vaccine , would share water fluoridation 's advantage of requiring only minimal patient compliance , but have not been proven safe and effective . Other experimental approaches include fluoridated sugar , polyphenols , and casein phosphopeptide ? amorphous calcium phosphate nanocomplexes .

A 2007 Australian review concluded that water fluoridation is the most effective and socially the most equitable way to expose entire communities to fluoride 's cavity @-@ prevention effects . A 2002 U.S. review estimated that sealants decreased cavities by about 60 % overall , compared to about 18 ? 50 % for fluoride . A 2007 Italian review suggested that water fluoridation may not be needed , particularly in the industrialized countries where cavities have become rare , and concluded that toothpaste and other topical fluoride are the best way to prevent cavities worldwide . A 2004 World Health Organization review stated that water fluoridation , when it is culturally acceptable and technically feasible , has substantial advantages in preventing tooth decay , especially for subgroups at high risk .

= = Usage = =

As of November 2012 , a total of about 378 million people worldwide received artificially fluoridated water . The majority of those were in the United States . About 40 million worldwide received water that was naturally fluoridated to recommended levels .

Much of the early work on establishing the connection between fluoride and dental health was performed by scientists in the U.S. during the early 20th century , and the U.S. was the first country to implement public water fluoridation on a wide scale . It has been introduced to varying degrees in many countries and territories outside the U.S. , including Argentina , Australia , Brazil , Canada , Chile , Colombia , Hong Kong , Ireland , Israel , Korea , Malaysia , New Zealand , the Philippines , Serbia , Singapore , Spain , the UK , and Vietnam . In 2004 , an estimated 13 @.@ 7 million people in western Europe and 194 million in the U.S. received artificially fluoridated water . In 2010 about 66 % of the U.S. population was receiving fluoridated water .

Naturally fluoridated water is used by approximately 4 % of the world 's population , in countries including Argentina , France , Gabon , Libya , Mexico , Senegal , Sri Lanka , Tanzania , the U.S. , and Zimbabwe . In some locations , notably parts of Africa , China , and India , natural fluoridation exceeds recommended levels .

Communities have discontinued water fluoridation in some countries , including Finland , Germany , Japan , the Netherlands , Sweden , and Switzerland . On August 26 , 2014 , Israel stopped mandating fluoridation , stating " Only some 1 % of the water is used for drinking , while 99 % of the water is intended for other uses (industry , agriculture , flushing toilets etc .) . There is also scientific evidence that fluoride in large amounts can lead to damage to health . When fluoride is supplied via drinking water , there is no control regarding the amount of fluoride actually consumed , which could lead to excessive consumption . Supply of fluoridated water forces those who do not so wish to also consume water with added fluoride . This approach is therefore not accepted in most countries in the world . " This change was often motivated by political opposition to water fluoridation , but sometimes the need for water fluoridation was met by alternative strategies . The use of fluoride in its various forms is the foundation of tooth decay prevention throughout Europe ; several countries have introduced fluoridated salt , with varying success : in Switzerland and Germany , fluoridated salt represents 65 % to 70 % of the domestic market , while in France the market share reached 60 % in 1993 but dwindled to 14 % in 2009 ; Spain , in 1986 the second West European country to introduce fluoridation of table salt , reported a market share in 2006 of only 10 % . In three other West European countries , Greece , Austria and the Netherlands , the legal framework for production and marketing of fluoridated edible salt exists . At least six Central European countries (Hungary , the Czech and Slovak Republics , Croatia , Slovenia , Romania) have shown some interest in salt fluoridation ; however , significant usage of approximately 35 % was only achieved in the Czech Republic . The Slovak Republic had the equipment to treat salt by 2005 ; in the other four countries attempts to introduce fluoridated salt were not successful .

= = History = =

The history of water fluoridation can be divided into three periods . The first (c . 1801 ? 1933) was research into the cause of a form of mottled tooth enamel called the Colorado brown stain . The second (c . 1933 ? 1945) focused on the relationship between fluoride concentrations , fluorosis , and tooth decay , and established that moderate levels of fluoride prevent cavities . The third period , from 1945 on , focused on adding fluoride to community water supplies .

In the first half of the 19th century , investigators established that fluoride occurs with varying concentrations in teeth , bone , and drinking water . In the second half they speculated that fluoride would protect against tooth decay , proposed supplementing the diet with fluoride , and observed mottled enamel (now called severe dental fluorosis) without knowing the cause . In 1874 , the German public health officer Carl Wilhelm Eugen Erhardt recommended potassium fluoride supplements to preserve teeth . In 1892 the British physician James Crichton @-@ Browne noted in an address that fluoride 's absence from diets had resulted in teeth that were " peculiarly liable to decay " , and who proposed " the reintroduction into our diet ... of fluorine in some suitable natural form ... to fortify the teeth of the next generation " .

The foundation of water fluoridation in the U.S. was the research of the dentist Frederick McKay (b 1874- d 1959) . McKay spent thirty years investigating the cause of what was then known as the Colorado brown stain , which produced mottled but also cavity @-@ free teeth ; with the help of G.V. Black and other researchers , he established that the cause was fluoride . The first report of a statistical association between the stain and lack of tooth decay was made by UK dentist Norman Ainsworth in 1925 . In 1931 , an Alcoa chemist , H.V. Churchill , concerned about a possible link between aluminum and staining , analyzed water from several areas where the staining was common and found that fluoride was the common factor .

In the 1930s and early 1940s , H. Trendley Dean and colleagues at the newly created U.S. National Institutes of Health published several epidemiological studies suggesting that a fluoride concentration of about 1 mg / L was associated with substantially fewer cavities in temperate

climates , and that it increased fluorosis but only to a level that was of no medical or aesthetic concern . Other studies found no other significant adverse effects even in areas with fluoride levels as high as 8 mg / L. To test the hypothesis that adding fluoride would prevent cavities , Dean and his colleagues conducted a controlled experiment by fluoridating the water in Grand Rapids , Michigan , starting January 25 , 1945 . The results , published in 1950 , showed significant reduction of cavities . Significant reductions in tooth decay were also reported by important early studies outside the U.S. , including the Brantford ? Sarnia ? Stratford study in Canada (1945 ? 1962) , the Tiel ? Culemborg study in the Netherlands (1953 ? 1969) , the Hastings study in New Zealand (1954 ? 1970) , and the Department of Health study in the U.K. (1955 ? 1960) . By present @-@ day standards these and other pioneering studies were crude , but the large reductions in cavities convinced public health professionals of the benefits of fluoridation .

Fluoridation became an official policy of the U.S. Public Health Service by 1951 , and by 1960 water fluoridation had become widely used in the U.S. , reaching about 50 million people . By 2006 , 69 @.@ 2 % of the U.S. population on public water systems were receiving fluoridated water , amounting to 61 @.@ 5 % of the total U.S. population ; 3 @.@ 0 % of the population on public water systems were receiving naturally occurring fluoride . In some other countries the pattern was similar . New Zealand , which led the world in per @-@ capita sugar consumption and had the world 's worst teeth , began fluoridation in 1953 , and by 1968 fluoridation was used by 65 % of the population served by a piped water supply . Fluoridation was introduced into Brazil in 1953 , was regulated by federal law starting in 1974 , and by 2004 was used by 71 % of the population . In the Republic of Ireland , fluoridation was legislated in 1960 , and after a constitutional challenge the two major cities of Dublin and Cork began it in 1964 ; fluoridation became required for all sizeable public water systems and by 1996 reached 66 % of the population . In other locations , fluoridation was used and then discontinued : in Kuopio , Finland , fluoridation was used for decades but was discontinued because the school dental service provided significant fluoride programs and the cavity risk was low , and in Basel , Switzerland , it was replaced with fluoridated salt .

McKay 's work had established that fluorosis occurred before tooth eruption . Dean and his colleagues assumed that fluoride 's protection against cavities was also pre @-@ eruptive , and this incorrect assumption was accepted for years . By 2000 , however , the topical effects of fluoride (in both water and toothpaste) were well understood , and it had become known that a constant low level of fluoride in the mouth works best to prevent cavities .

= = Economics = =

Fluoridation costs an estimated $ 1 @.@ 02 per person @-@ year on the average (range : $ 0 @.@ 24 ? $ 10 @.@ 82 ; all costs in this paragraph are for the U.S. and are in 2016 dollars , inflation @-@ adjusted from earlier estimates) . Larger water systems have lower per capita cost , and the cost is also affected by the number of fluoride injection points in the water system , the type of feeder and monitoring equipment , the fluoride chemical and its transportation and storage , and water plant personnel expertise . In affluent countries the cost of salt fluoridation is also negligible ; developing countries may find it prohibitively expensive to import the fluoride additive . By comparison , fluoride toothpaste costs an estimated $ 9 ? $ 17 per person @-@ year , with the incremental cost being zero for people who already brush their teeth for other reasons ; and dental cleaning and application of fluoride varnish or gel costs an estimated $ 94 per person @-@ year . Assuming the worst case , with the lowest estimated effectiveness and highest estimated operating costs for small cities , fluoridation costs an estimated $ 16 ? $ 24 per saved tooth @-@ decay surface , which is lower than the estimated $ 92 to restore the surface and the estimated $ 156 average discounted lifetime cost of the decayed surface , which includes the cost to maintain the restored tooth surface . It is not known how much is spent in industrial countries to treat dental fluorosis , which is mostly due to fluoride from swallowed toothpaste .

Although a 1989 workshop on cost @-@ effectiveness of cavity prevention concluded that water fluoridation is one of the few public health measures that save more money than they cost , little high @-@ quality research has been done on the cost @-@ effectiveness and solid data are scarce

. Dental sealants are cost @-@ effective only when applied to high @-@ risk children and teeth . A 2002 U.S. review estimated that on average , sealing first permanent molars saves costs when they are decaying faster than 0 @.@ 47 surfaces per person @-@ year whereas water fluoridation saves costs when total decay incidence exceeds 0 @.@ 06 surfaces per person @-@ year . In the U.S. , water fluoridation is more cost @-@ effective than other methods to reduce tooth decay in children , and a 2008 review concluded that water fluoridation is the best tool for combating cavities in many countries , particularly among socially disadvantaged groups . A 2016 review of studies published between 1995 to 2013 found that water fluoridation in the U.S. was cost @-@ effective , and that it was more so in larger communities .

U.S. data from 1974 to 1992 indicate that when water fluoridation is introduced into a community , there are significant decreases in the number of employees per dental firm and the number of dental firms . The data suggest that some dentists respond to the demand shock by moving to non @-@ fluoridated areas and by retraining as specialists .

= = Controversy = =

The water fluoridation controversy arises from political , moral , ethical , economic , and safety concerns regarding the fluoridation of public water supplies . Those opposed argue that water fluoridation may cause serious health problems , is not effective enough to justify the costs , and has a dosage that cannot be precisely controlled .

With regard to ethics , like vaccination and food fortification , fluoridation pits the common good against individual rights .

Opposition to fluoridation has existed since its initiation in the 1940s . During the 1950s and 1960s , conspiracy theorists claimed that fluoridation was a communist plot to undermine American public health . In recent years water fluoridation has become a pervasive health and political issue in many countries , resulting in changes to public policy regarding water fluoridation .

Public health authorities find a medical consensus that water fluoridation at appropriate levels is a safe and effective means to prevent suffering and promote oral health , and generally support fluoridation . Opponents of fluoridation include some researchers , dental and medical professionals , alternative medical practitioners , health food enthusiasts , a few religious groups (mostly Christian Scientists in the U.S.) , and occasionally consumer groups and environmentalists . Organized political opposition has come from libertarians , the John Birch Society , and from groups like the Green parties in the UK and New Zealand .