Fluoride

Fact Sheet for Health Professionals

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This is a fact sheet intended for health professionals. For a general overview, see our consumer fact sheet.

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Introduction

Fluoride, a mineral, is naturally present in many foods and available as a dietary supplement. Fluoride is the ionic form of the element fluorine, and it inhibits or reverses the initiation and progression of dental caries (tooth decay) and stimulates new bone formation [1].

Soil, water, plants, and foods contain trace amounts of fluoride. Most of the fluoride that people consume comes from fluoridated water, foods and beverages prepared with fluoridated water, and toothpaste and other dental products containing fluoride [2,3].

Approximately 80% or more of orally ingested fluoride is absorbed in the gastrointestinal tract [1]. In adults, about 50% of absorbed fluoride is retained in the body, taken up by bones and teeth than in adults [1].

Individual fluoride status is not typically assessed, although fluoride concentrations can be measured in plasma, saliva, urine, bones, nails, hair, and teeth [4,5]. Criteria for adequate, high, or low levels of fluoride in the body have not been established.

Recommended Intakes

Intake recommendations for fluoride and other nutrients are provided in the Dietary Reference Intakes (DRIs) developed by the Food and Nutrition Board (FNB) at the National Academies of Sciences, Engineering, and Medicine [1]. DRI is the general term for a set of reference values used for planning and assessing nutrient intakes of healthy people. These values, which vary by age and sex, include the following:

- Recommended Dietary Allowance (RDA): Average daily level of intake sufficient to meet the nutrient requirements of nearly all (97%–98%) healthy individuals; often used to plan nutritionally adequate diets for individuals
- Adequate Intake (AI): Intake at this level is assumed to ensure nutritional adequacy; established when evidence is insufficient to develop an RDA
- Estimated Average Requirement (EAR): Average daily level of intake estimated to meet the requirements of 50% of healthy individuals; usually used to assess the nutrient intakes of groups of people and to plan nutritionally adequate diets for them; can also be used to assess the nutrient intakes of individuals
- Tolerable Upper Intake Level (UL): Maximum daily intake unlikely to cause adverse health effects

The FNB found the data insufficient to derive EARs for fluoride. Therefore, the board established AIs for all ages using estimated intakes shown to maximize reductions in the incidence of dental caries without unwanted side effects, such as dental fluorosis, a chronic condition resulting from the consumption of too much fluoride when teeth are developing [1]. Table 1 lists the current AIs for fluoride for healthy individuals.

Table 1: Daily Adequate Intakes (AIs) for Fluoride [1]

Age	Male	Female	Pregnancy	Lactation
Birth to 6 months	0.01 mg	0.01 mg		
7–12 months	0.5 mg	0.5 mg		
1–3 years	0.7 mg	0.7 mg		
4–8 years	1 mg	1 mg		
9–13 years	2 mg	2 mg		
14–18 years	3 mg	3 mg	3 mg	3 mg
19+ years	4 mg	3 mg	3 mg	3 mg

Sources of Fluoride

Food

Brewed tea typically contains higher levels of fluoride than most foods, depending on the type of tea and its source, because tea plants take up fluoride from soil [1,3]. Fluoride levels can range from 0.3 to 6.5 mg/L (0.07 to 1.5 mg/cup) in brewed tea made with distilled water [3].

Fluoride concentrations in breast milk are so low that they cannot always be detected; when these levels can be measured, they range from less than 0.002 to 0.01 mg/L, even when mothers live in communities with fluoridated water [3]. Fluoride concentrations in cow's milk are also very low, ranging from 0.007 to 0.086 mg/L [3]. Fluoride levels in infant formulas in the United States vary, depending on the type of formula and the fluoride content of the water used to prepare the formula [3]. The typical fluoride concentration is less than 0.2 mg/L in milk-based infant formula and 0.2 to 0.3 mg/L in soy-based infant formula (not including contributions from tap water used to prepare the formula).

Only trace amounts of fluoride are naturally present in most foods, and most foods not prepared with fluoridated water provide less than 0.05 mg/100 g [1,6].

A variety of types of foods and their fluoride levels per serving are listed in Table 2.

Table 2: Fluoride Content of Selected Foods [3,6,7]

Food	Milligrams per Serving
Tea, black, brewed, 1 cup	0.07 to 1.5*
Coffee, brewed, 1 cup	0.22*
Shrimp, canned, 3 ounces	0.17
Bottled water with added fluoride, 1 cup	≤0.17
Raisins, ¼ cup	0.08
Oatmeal, cooked, ½ cup	0.08*
Grapefruit juice, ¾ cup	0.08
Potatoes, russet, baked, 1 medium	0.08
Rice, cooked, ½ cup	0.04*

Cottage cheese, ½ cup	0.04
Pork chop, baked, 3 ounces	0.03
Yogurt, plain, low-fat, 1 cup	0.03
Lamb chop, cooked, 3 ounces	0.03
Tortilla, flour, 1 tortilla, approx. 10" diameter	0.02
Corn, canned, ½ cup	0.02
Beef, cooked, 3 ounces	0.02
Tuna, light, canned in water, 3 ounces	0.02
Cheese, cheddar, 1½ ounces	0.01
Bread, white or whole wheat, 1 slice	0.01
Asparagus, cooked, 4 spears	0.01
Chicken, cooked, 3 ounces	0.01
Milk, fat-free or 1%, 1 cup	0.01
Apple, raw, with skin, 1 medium	0.01
Avocado, raw, ½ cup sliced	0.01
Macaroni, plain, cooked, ½ cup	0.00*
Tomato, raw, 1 medium	0.00
Banana, 1 medium	0.00
Egg, cooked, 1 large	0.00
Carrots, raw, 1 medium	0.00
Peanut butter, 1 tbsp	0.00

*Amounts of fluoride might vary by levels in the water used to prepare these foods and beverages.

Fluoridated drinking water

Since 1962, the U.S. Public Health Service has recommended the addition of fluoride to drinking (tap) water to reduce the risk and severity of dental caries, one of the most common chronic diseases in children [8]. Many countries around the world now adjust the fluoride concentration of community drinking water supplies to the level recommended for the prevention of dental caries [9].

Although the U.S. Public Health Service recommended fluoride concentrations of 0.7 in warmer climates (where children were expected to drink more water) to 1.2 mg/L in cooler climates to prevent dental caries in 1962, it amended its recommended level in 2015 to 0.7 mg/L to maintain the ability to prevent caries while minimizing the risk of dental fluorosis [8,10]. In 1986, guidelines from the U.S. Environmental Protection Agency (EPA) established a maximum allowable concentration of 4.0 mg/L fluoride in public drinking water systems to prevent adverse effects from fluoride exposure (such as bone disease) and a recommended maximum concentration of 2.0 mg/L to prevent dental fluorosis [3,11]. A review of this regulation is a currently a low priority for the EPA [12].

Fluoridated municipal drinking water—including water that people drink as well as foods and beverages prepared using municipal drinking water—accounts for about 60% of fluoride intakes in the United States [3,8]. In 2020, 62.9% of the U.S. population had access to a fluoridated community water system [13]. The fluoride additives used to fluoridate drinking water in the United States are fluorosilicic acid, sodium fluorosilicate, and sodium fluoride [14]. The Centers for Disease Control and Prevention has a webpage that lists fluoride levels in tap water by county [15]. Because of differences in amounts of fluoride in groundwater, private water sources (including well water) have variable fluoride concentrations [11].

Fluoride is not typically added to bottled drinking waters. However, when fluoride is added, the U.S. Food and Drug Administration (FDA) stipulates that the total amount of fluoride (added plus naturally occurring) cannot exceed 0.7 mg/L [7]. Previously allowable levels ranged from 0.8 to 1.7 mg/L. FDA notes that this rule does not apply to bottled water without added fluoride that contains fluoride naturally from its source water. The amount of fluoride contained in bottled water is not required to be listed on the product label unless the label makes a claim about the product's fluoride content [16].

Dietary supplements

Only a few dietary supplements contain fluoride, usually in the form of sodium fluoride [17]. Most of these products are multivitamin/mineral supplements, multivitamins plus fluoride, or supplements containing trace minerals only. Some fluoride supplements, usually intended for children, are in the form of drops. The most common amount of fluoride in supplements is 0.25 mg, although a few products contain 0.5 or 1 mg per serving [17].

Dental products

Most toothpaste sold in the United States contains fluoride in the form of sodium fluoride or monofluorophosphate, most commonly at a level of 1,000 to 1,100 mg/L (about 1.3 mg in a quarter teaspoon, a typical amount of toothpaste used for one brushing) [3]. The amount of fluoride ingested from toothpaste depends on the amount used, the person's swallowing control, and how often the person uses toothpaste. Estimated typical amounts of fluoride ingested daily from toothpaste are 0.1 mg to 0.25 mg for infants and children age 0 to 5 years, 0.2 to 0.3 mg for children age 6 to 12 years, and 0.1 mg for adults [3]. Fluoride in toothpaste, regardless of its form, is well absorbed [1].

Other dental products that provide fluoride include mouth rinses for home use, topical fluoride preparations applied in dentists' offices or through school-based programs, and dental devices (e.g., orthodontic bracket adhesives, glass-ionomer and some composite resin dental restorative materials, and some dental sealants and cavity liners) [3,18]. Gels used by dentists are typically applied one to four times a year and can lead to ingestions of 1.3 to 31.2 mg fluoride each time; varnishes are least likely to produce a high bolus of fluoride [3].

Medications

Some prescription medications contain fluoride, but not as the active ingredient. For example, voriconazole (VFEND or Vfend) is an oral antifungal medication used to treat several infectious conditions, including invasive aspergillosis, candidemia, and candidiasis [19]. Fluoride is a constituent of voriconazole and long-term use (e.g., for 4 months or more) of this medication can lead to high fluoride concentrations in serum and plasma [20-24]. The prescribing information for voriconazole advises discontinuation of voriconazole if skeletal fluorosis or periostitis (inflammation of the membrane surrounding and protecting the bones) develops [19].

Fluoride Intakes and Status

Most people in the United States consume adequate amounts of fluoride through foods containing naturally occurring fluoride, fluoridated tap water, and food products made with fluoridated tap water. According to the EPA, typical daily fluoride intakes in the United States from foods and beverages (including fluoridated drinking water) are 1.2 to 1.6 mg for infants and toddlers younger than 4 years, 2.0 to 2.2 mg for children age 4–11 years, 2.4 mg for those age 11–14 years, and 2.9 mg for adults [10].

Fluoride and Health

This section focuses on two conditions in which fluoride might play a role: dental caries and bone fractures.

Dental caries

Dental caries occurs when cariogenic bacteria in the mouth ferment foods and produce acids that dissolve tooth mineral [25]. Over time, this tooth decay can cause pain and tooth loss. Without treatment, dental caries can cause infections, impair growth and weight gain during childhood, affect school performance, impair quality of life, and possibly result in death [26-29]. Adequate fluoride intakes reduce the risk of dental caries in its initial stages by inhibiting demineralization and the activity of bacteria in dental plaque and by enhancing tooth remineralization [27].

Impact of water fluoridation on dental caries

Water fluoridation protects teeth in two main ways—by preventing the development of caries through ingestion of drinking water during the tooth-forming years and through direct contact of fluoride with teeth throughout life [30,31].

A 2015 Cochrane Review included 20 prospective observational studies (most conducted before 1975) [9]. The results showed that children receiving fluoridated water had 35% fewer decayed, missing, and filled primary (baby) teeth, and 26% fewer decayed, missing, and filled permanent (adult) teeth than children receiving unfluoridated water. Fluoridation also increased the number of children with no decay in their baby teeth by 15% and the number of children with no decay in their permanent teeth by 14%. The authors concluded that water fluoridation is effective for reducing dental caries rates in both primary and permanent teeth in children. However, the reviewers were unable to assess the effectiveness of water fluoridation for preventing caries in adults because no evidence met the review's inclusion

However, the reviewers were unable to assess the effectiveness of water fluoridation for preventing caries in adults because no evidence met the review's inclusion criteria (which required studies to include at least two groups, one receiving fluoridated water and one receiving unfluoridated water).

United States [32]. The authors analyzed data on 7,000 children age 2 to 8 years and 12,604 children and adolescents age 6 to 17 years who participated in the National Health and Nutrition Examination Study (NHANES) from 1999 to 2004 and 2011 to 2014, respectively. The results showed that living in a county in which 75% or more of the drinking water contained at least 0.7 mg/L fluoride was associated with a 30% reduction in the rate of caries in primary teeth and a 12% reduction in the rate of caries in permanent teeth.

Some evidence shows that the addition of fluoride to drinking water can also prevent dental caries in adults. An observational study included 3,779 individuals in Australia age 15 and older who participated in the Australian 2004–2006 National Survey of Adult Oral Health [33]. In adults exposed to fluoridated community water supplies for at least 14 years, rates of decayed, missing, or filled teeth were 11%–12% lower than in adults whose drinking water during this period had negligible amounts of fluoride. An earlier study in 876 Australian Defence Force members age 17–56 years found that the average rate of decayed, missing, and filled teeth was 24% lower in those with access to water containing 0.5 to 1 mg/L fluoride for at least half of their lifetime than in those exposed for less than 10% of their lifetime [34].

These findings show that fluoridated drinking water can prevent dental caries in children and adults.

Impact of fluoride dietary supplements on dental caries in children

Some studies have assessed the impact of fluoride supplements on caries development in children. For example, a 2011 Cochrane Review of 11 randomized or quasi-randomized studies in a total of 7,196 children (most living in communities lacking access to fluoridated drinking water) found that 0.25–1 mg/day supplemental fluoride for 24–55 months reduced rates of decayed, missing, and filled tooth surfaces by 24% [35]. The authors concluded that fluoride supplements were associated with a lower caries incidence rate in permanent teeth. A 2013 systematic review found an even greater preventive effect of fluoride supplements on the basis of one randomized and four nonrandomized clinical trials in children [28]. The results showed that 0.25–1 mg/day fluoride supplementation reduced caries incidence rates in primary teeth by 48%–72% in areas where water fluoridation levels were lower than 0.6 mg/L. In two of these trials that monitored the children for 6–10 years, supplements were associated with a 33%–80% reduction in the incidence of caries at age 7–10 years.

The U.S. Preventive Services Task Force (USPSTF) and the American Dental Association have issued fluoride supplement recommendations for children whose water supply contains little or no fluoride [26]. These recommendations are summarized in Table 3.

Table 3: Expert Panel Recommendations for Fluoride Supplementation in Children

Source	Age Range	Recommendation
USPSTF [26]	6 months and older	• Fluoride supplement (dose not specified) for children whose water supply contains little or no fluoride*
American Dental Association [36]**	6 months to 3 years	• Fluoride supplement (0.25 mg/day) for children whose water supply contains less than 0.3 ppm (0.3 mg/L) fluoride
	3–6 years	• Fluoride supplement (0.5 mg/day) for children whose water supply contains less than 0.3 ppm (0.3 mg/L) fluoride • Fluoride supplement (0.25 mg/day) for children whose water supply contains 0.3 to 0.6 ppm (0.3 to 0.6 mg/L) fluoride
	6–16 years	• Fluoride supplement (1 mg/day) for children whose water supply contains less than 0.3 ppm (0.3 mg/L) fluoride • Fluoride supplement (0.5 mg/day) for children whose water supply contains 0.3 to 0.6 ppm (0.3 to 0.6 mg/L) fluoride

*No studies have addressed the dosage or duration of oral fluoride supplementation in this population.
**Recommended doses are based on poor-quality evidence.

Overall, the available evidence suggests that dietary supplements containing fluoride can reduce rates of dental caries in children who lack access to fluoridated drinking water. No studies have assessed the impact of fluoride supplements on caries development in adults.

Fluoride dietary supplements in pregnant women

Like other nutrients, fluoride is transferred from a pregnant woman to her fetus, so a few studies have evaluated the use of fluoride supplements by pregnant women to prevent dental caries in their children. However, the authors of a 2017 Cochrane Review found only one randomized controlled trial published in 1997 that met the review's inclusion criteria [37]. This study assessed caries rates in 798 3-year-old children whose mothers had received 1 mg/day fluoride during the last 6 months of pregnancy [38]. The results showed no significant difference in the proportions of children who had decayed or filled primary tooth surfaces or who had caries. The authors of the Cochrane Review concluded that the 1997 study was of very low quality and that no evidence shows that fluoride supplementation in pregnant women prevents dental caries in their offspring.

Bone fractures

Because fluoride helps stimulate the formation of new bone, researchers have hypothesized that fluoride supplements might reduce bone fracture risk. However, research to date has provided only limited evidence supporting this hypothesis [39-41].

The findings of observational studies on the impact of fluoride levels in water on bone mineral density (BMD) and fracture risk have been mixed. A study of 7,129 white women found no significant differences in bone mineral density or risk of hip, vertebral, wrist, or humerus fracture between those exposed and those not exposed to fluoridated water between 1950 and 1994 [40]. In contrast, in a study in 8,266 Chinese residents age 50 years or older, people with access to water fluoride levels of approximately 1 mg/L had a lower overall risk of fractures, but not of hip fractures, than those with access to water containing negligible fluoride levels [41].

Clinical trials have also had conflicting findings about the efficacy of fluoride dietary supplements to prevent bone fractures. For example, a meta-analysis of 25 randomized controlled trials in a total of 954 participants (four of the studies included people with osteoporosis) showed a significant reduction in vertebral and nonvertebral fracture risk with daily doses of up to 20 mg fluoride (in the form of monofluorophosphate or sodium fluoride), but not with higher doses [42]. A more recent randomized controlled trial found that 2.5, 5, or 10 mg/day fluoride for 1 year in 180 postmenopausal women did not change BMD at any site assessed [43].

Health Risks from Excessive Fluoride

Long-term ingestion of excess fluoride in infancy and childhood, when the teeth are being formed, can lead to dental fluorosis [44]. The characteristics of this chronic condition usually vary from almost imperceptible white lines or flecks to white or brown stains on teeth [2]. Severe dental fluorosis can lead to pitting in tooth enamel. The risk of dental fluorosis increases with fluoride intakes above recommended amounts [45]. Severe enamel fluorosis is rare and there is no indication that it is caused by the recommended level of fluoride in public tap water [3,31].

Analysis of 1999–2004 NHANES clinical exam data showed that 20.8% of people age 6 to 49 had mild or very mild dental fluorosis, 2.0% had moderate fluorosis, and less than 1% had severe fluorosis [44]. The prevalence of any dental fluorosis was highest, 40.6%, in adolescents age 12 to 15 and lowest, 8.7%, in those age 40 to 49.

Subsequent analyses of NHANES data from 2001–2002 and 2011–2012 found that rates of dental fluorosis (from very mild to severe) increased during this 10-year period [46,47]. However, a report from the Centers for Disease Control and Prevention concluded that the reported increase in dental fluorosis prevalence between NHANES 2001–2004 and 2011–2014 is not biologically plausible [48]. The authors suggested that there may have been a change over time in how the examiners evaluated the level of fluorosis [48,49].

Analyses of more recent NHANES 2015-2016 data showed that about two-thirds of children and adolescents age 6 years and older had some dental fluorosis, most of which was very mild or mild [48,50,51]. Research indicates that very mild or mild fluorosis does not negatively affect oral health-related quality of life [52,53]. Moreover, fluorosis severity tends to decline during adolescence and young adulthood [54,55]. Based on NHANES 2015-2016 data, only 1.4 to 1.8% of children and adolescents age 6 years and older have moderate or severe fluorosis [48,50,51], and no evidence indicates that the recommended level of fluoride in public tap water leads to severe fluorosis [3,31].

High doses of fluoride (typically from rare accidents resulting in excessively high levels of fluoridation of water, unintentional ingestion of fluoride products intended for topical use in dentists' offices, or fluoride supplements inappropriately given to children) can result in nausea, vomiting, abdominal pain, diarrhea, periostitis, and even death in rare cases [3,19,56]. According to one estimate, the acute dose that could cause serious systemic toxicity for fluoride is 5 mg/kg (e.g., 375 mg for someone who weighs 75 kg [165 pounds]) [56]. This dose would be virtually impossible to achieve from water or toothpaste containing standard levels of added

fluoride.

Chronic, excess intakes of fluoride are also associated with skeletal fluorosis [57]. Its effects can range from occasional joint pain or stiffness to osteoporosis, muscle wasting, and neurological defects [1,58]. However, skeletal fluorosis is extremely rare in the United States and no evidence indicates that it is caused by the recommended level of fluoride in public tap water [1,57].

One study found an association between higher maternal urinary fluoride concentration (based on one spot urine sample) during the third trimester of pregnancy and higher rates of neurobehavioral problems in the child at 3 years of age [59]. However, another study found no association between exposure to fluoridated water during early childhood and subsequent emotional or behavioral development and executive functioning [60]. Other evidence suggests that higher fluoride intakes during early development, including during gestation, might be associated with a lower IQ and other cognitive impairments (e.g., delays in cognitive development) in children [61-64]. However, many experts, including the authors of a National Academies of Sciences, Engineering, and Medicine review, consider this evidence to be weak and methodologically flawed [65-76]. A 2023 meta-analysis of 8 studies found that fluoride exposure at concentrations similar to that used in fluoridated community drinking water in the United States is not associated with lower IQ scores [77]. Reported associations between exposure to higher levels of fluoride and neurodevelopment warrant additional research [77,78].

The FNB has established ULs for fluoride from all sources for healthy individuals (Table 4) based on levels associated with dental and skeletal fluorosis [1].

Table 4: Daily Tolerable Upper Intake Levels for Fluoride [1]

Age	Male	Female	Pregnancy	Lactation
Birth to 6 months	0.7 mg	0.7 mg		
7–12 months	0.9 mg	0.9 mg		
1–3 years	1.3 mg	1.3 mg		
4–8 years	2.2 mg	2.2 mg		
9–13 years	10 mg	10 mg		
14–18 years	10 mg	10 mg	10 mg	10 mg
19–51 years	10 mg	10 mg	10 mg	10 mg
51+ years	10 mg	10 mg		

Interactions with Fluoride

Fluoride has no known, clinically relevant interactions with medications [79].

Fluoride and Healthful Diets

The federal government's 2020–2025 *Dietary Guidelines for Americans* notes that "Because foods provide an array of nutrients and other components that have benefits for health, nutritional needs should be met primarily through foods. … In some cases, fortified foods and dietary supplements are useful when it is not possible otherwise to meet needs for one or more nutrients (e.g., during specific life stages such as pregnancy)."

For more information about building a healthy dietary pattern, refer to the *Dietary Guidelines for Americans* and the U.S. Department of Agriculture's *MyPlate*.

The *Dietary Guidelines for Americans* describes a healthy dietary pattern as one that

- Includes a variety of vegetables; fruits; grains (at least half whole grains); fat-free and low-fat milk, yogurt, and cheese; and oils.
- Includes a variety of protein foods such as lean meats; poultry; eggs; seafood; beans, peas, and lentils; nuts and seeds; and soy products.
- Limits foods and beverages higher in added sugars, saturated fat, and sodium.
- Limits alcoholic beverages.
- Stays within your daily calorie needs.

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