

Kip Duchon, retired, was the national fluoridation engineer for the US Centers for Disease Control and Prevention (www.cdc.gov), providing national technical direction for water fluoridation practice.

Water Fluoridation Basics: What Operators Need to Know

Fluoride can greatly reduce the incidence of tooth decay among children. However, to achieve fluoridation’s maximum benefits, the optimal fluoride concentration in the water supply must be continuously maintained.

BY KIP DUCHON

THIS YEAR MARKS the 75th anniversary of the start of water fluoridation, and generations of people in the United States, Canada, and dozens of other countries on every continent benefit with improved oral health and reduced tooth decay. Water fluoridation entails adjusting the fluoride level in water to optimize oral health. According to the US Centers for Disease Control and Prevention (CDC), 72.8 percent of the US population served by public water systems (PWSs) had

fluoridated water in 2016 (www.cdc.gov/oralhealth). The number of people benefiting from fluoridated water continues to increase each year as additional systems initiate water fluoridation.

FLUORIDE FACTS

Fluoride is safe, healthy, and effective for improving oral health and reducing tooth decay. There are thousands of fluoride studies that support its use as an essential health benefit. The 0.7 mg/L fluoride level recommended in drinking

water by the US Public Health Service has no adverse health effects. AWWA joins the CDC, US Public Health Service, US Office of the Surgeon General, World Health Organization, and many other professional organizations in the medical community that recommend water systems should adjust fluoride in drinking water to the suggested level.

Fluoride benefits all ages of people and all socioeconomic levels. As the 13th-most abundant element in the Earth’s crust, fluorine, from which fluoride is derived, can be found in many rock ores and soils. As shown in Figure 1, fluoride leaches into natural surface waters, which commonly have a natural fluoride level of 0.1 to 0.2 mg/L, which is consistent with rainwater’s fluoride level. Groundwaters may have fluoride levels varying from 0.1 to more than 10 mg/L, depending on local geological rock ores. Seawater’s fluoride level is typically 1.2 mg/L but can vary between 0.8 and 1.5 mg/L, depending on proximity to fresh water sources and local evaporative effects.

ORAL HEALTH BENEFITS

Early in the 20th century, a dentist, Frederick McKay, practicing in Colorado Springs, Colo., observed that people using certain springs for their water supply had discoloring stains on their teeth, but they retained their teeth to old age. This was a surprise, as most people in that era rarely retained their teeth.

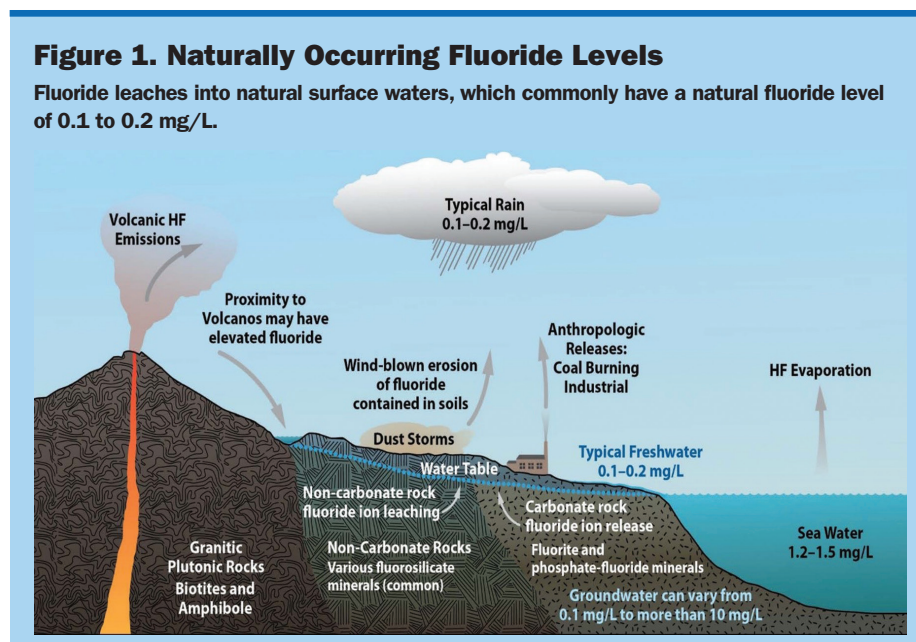
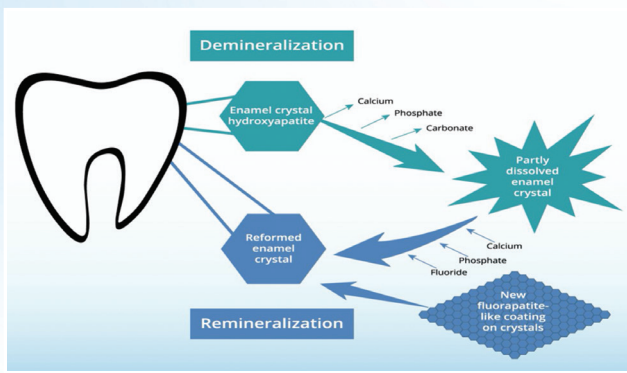


FIGURE: CDC



Fluoride is an essential element for good oral health, as it helps to remineralize tooth enamel to create a more decay-resistant surface (inset).

Subsequent studies during the next several decades by the US Public Health Service identified it was fluoride in local water sources that caused the enamel staining and provided decay resistance.

By the 1940s, it was established that an “optimum” level of fluoride in water was around 1 mg/L. At that level, users could reduce tooth decay and avoid undesirable enamel staining. Naturally occurring fluoride at a beneficial level is rare, so obtaining fluoride’s benefits for reducing tooth decay requires exposure above insufficient natural levels. The first community to adjust the fluoride in its water supply was Grand Rapids, Mich., which first added fluoride in January 1945.

Early trials were conducted in several cities as part of joint research among AWWA, the American Dental Association (ADA), and the National Research Council of the National Academies of Sciences. After six years of data were analyzed and found to have compelling health benefits, the US Surgeon General, ADA, and AWWA all issued a policy recommendation that communities should

adjust fluoride to the beneficial level for oral health. All three partners in fluoridation continue to issue policy statements supporting and promoting water fluoridation; the current AWWA statement can be found at <https://news.awwa.org/fluoridation>.

When community water fluoridation was first initiated, almost everyone had tooth decay and no one knew how to prevent it. About half of older Americans (age 65+) had lost all their natural teeth. Now fluoride is considered an essential element for good oral health, as it helps to remineralize tooth enamel to create a more decay-resistant surface. Teeth are part of the skeleton system, comprising calcium, carbonates, phosphate, hydroxide, and fluoride. Because teeth experience continual demineralization and remineralization, fluoride is essential to promote remineralization, as shown in the inset figure above. Fluoride and hydroxide have the same atomic diameter, so they can replace each other within the crystal matrix; as the proportion of fluoride increases, tooth enamel gains hardness and decay resistance.

OPERATIONAL CONCERNS

The benefits in reducing tooth decay increase as fluoride in water increases up to 2 mg/L, at which point the maximum decay benefit is achieved. However, most of the benefit is achieved at 0.7 mg/L; incremental benefit above that level is small. Thus, the recognized beneficial range for fluoride in water is 0.6 to 1.0 mg/L; levels below that are insufficient to provide decay resistance at the desired level.

For fluoride to be most effective, it’s important for the concentration to be as close to 0.7 mg/L as possible. The CDC evaluated the operational capabilities of 4,251 PWSs reporting to the CDC Water Fluoridation Reporting System, a national database for managing and monitoring water fluoridation. That evaluation showed that water systems can be expected to achieve an operational tolerance of plus or minus 0.2 mg/L, and they tend to trim the feed on the lower side of the operational range to minimize additive cost. The CDC is currently developing an operational range based on this tolerance to guide the best operational practices for

Public Health

water operators. It's anticipated that this will be finalized by the end of 2020.

Although the benefit to reducing tooth decay increases up to 2 mg/L, it's important to avoid fluoride levels higher than 1 mg/L, as the potential exists for newly developing tooth enamel in children to hypomineralize. Such a condition is called *fluorosis* and causes white spots to appear on a tooth's surface, as shown in Figure 2. According to a CDC fact sheet with frequently asked questions about fluorosis, only children under the age of 8 can develop fluorosis while teeth are forming.

It's important to understand that the instantaneous fluoride level isn't important; it's the chronic long-term exposure that counts. The body attenuates high and low instantaneous fluoride levels. The kidneys efficiently remove roughly half the fluoride consumed, and the other half is adsorbed by the skeleton, which is the body's fluoride sink. If a higher exposure is experienced, the skeleton will adsorb more fluoride; conversely, the bones will leach fluoride if the body experiences a lower exposure. This results in the potential for fluorosis to occur as a function of the fluoride level over many weeks, not many days. Thus, it's important to maintain a fluoride level as close to 0.7 mg/L as possible to reduce tooth decay.

FLUORIDE REGULATIONS

The CDC encourages water treatment plant operators to adjust fluoride to a beneficial level for good oral health, but the US Environmental Protection Agency (USEPA) focuses on limiting high naturally occurring fluoride to a safe level. Fluoride has a maximum contaminant level (MCL) of 4 mg/L to avoid skeletal fluorosis, a rare condition of excessive fluoride deforming bones, and a secondary MCL (SMCL) of 2 mg/L to minimize moderate to severe enamel fluorosis in children. Skeletal fluorosis is rare in the United States, with fewer than a dozen cases reported in the past 25 years. It normally takes decades of excessive fluoride consumption to result in skeletal fluorosis.

Figure 2. Enamel Fluorosis

Natural fluoride levels up to 2 mg/L are beneficial and don't result in undesirable fluorosis.

Most common: change in enamel appearance characterized by lacy white markings, <35% of population



Rare: moderate (brown staining) or severe (pitting), <1% of population



According to USEPA Safe Drinking Water Information System reporting, less than 3.5 percent of people served by community PWSs have naturally occurring fluoride at or above 0.6 mg/L. There are no drinking water surface sources in North America with natural fluoride exceeding 0.3 mg/L because streams reflect fluoride in rainwater, which is generally 0.2 mg/L or less. Moreover, there are only a small number of groundwater sources exceeding 0.5 mg/L. During the past 25 years, the number of PWSs and the number of people served by those systems with natural fluoride exceeding the MCL and SMCL have decreased because water utilities work diligently to comply with regulatory criteria.

KEY TAKEAWAYS

Depending on a water source's natural fluoride levels, water treatment plant operators should keep the following things in mind:

Fluoride Less Than 0.6 mg/L. Only 25 percent of the US population is served by a PWS with inadequate fluoride. These systems need to advise their customers that they aren't getting the recommended amount of fluoride for good oral health and they should consult with their dentist or medical provider on what they should do to protect their family's health.

Fluoride Between 0.6 and 2 mg/L.

About 75 percent of the US population is served by a PWS with a fluoride level that provides beneficial fluoride level for good oral health. Natural fluoride levels up to 2 mg/L are beneficial and don't result in undesirable fluorosis.

Fluoride Greater Than 2 mg/L but Less Than 4 mg/L.

Less than 0.3 percent of the US population is served by a PWS with fluoride levels that exceed 2 mg/L. In such cases, children under 8 years of age may have an increased potential for fluorosis. Parents should consider obtaining alternative drinking water for such children to reduce that risk. The water system should contact its state drinking water administrator for specific language on notifying customers about the fluoride content.

Fluoride Greater Than 4 mg/L. Less than 0.01 percent of the US population is served by a PWS with fluoride that exceeds 4 mg/L. The water system should contact its state drinking water administrator for specific language on notifying customers about the fluoride content.

For more information on water fluoridation, check out AWWA's Manual of Water Supply Practices M4, *Water Fluoridation Principles & Practices*, available at the AWWA Store (www.awwa.org/store). 