
**TECHNICAL
APPLICATION
BULLETIN**

Fluoride

**Recognized Treatment Techniques For Meeting
Drinking Water Regulations For The Reduction
Of Fluoride From Drinking Water Supplies
Using Point-of-Use/Point-of-Entry Devices And Systems**

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TECHNICAL APPLICATION BULLETIN

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Recognized treatment techniques for meeting drinking water regulations for the reduction of fluoride using point-of-use and point-of-entry (POU/POE) devices and systems.

Occurrence

Fluorine is a natural trace element and exists in almost all soils. In elemental form fluorine is a flammable, irritating, and toxic halogen gas that is one of the most powerful oxidizing agents known. It therefore occurs naturally only in the reduced (fluoride, F⁻) form in combination with other minerals. Fluoride is classified as any binary compound of fluorine with another element. Fluoride compounds make up approximately 0.08 percent of the earth's crust. Fluorspar, cryolite, and fluorapatite are the most common fluoride producing compounds known. Fluorspar contains the highest percentage of fluoride by weight, as calcium fluoride (CaF₂), of the minerals mentioned.

Perhaps the most widely known use of fluoride is its addition to public drinking water supplies at about one milligram per liter (mg/L) of a fluoride salt, measured as fluoride, for the purpose of reducing tooth decay. This is achieved at the municipal treatment plant by injecting or feeding a solution of hydrofluosilicic acid, sodium silicofluoride, or sodium fluoride into the treated water stream. It is the fluoride ion in mineral ionic form that occurs in water, bones, teeth, and public drinking water supplies. About 144 million people it was estimated in 1992 drink fluoridated water at levels ranging from 0.7 to 1.2 mg/L.

Health Effects

Some water systems with naturally occurring fluoride must treat their water supply to remove the excess fluoride to comply with the Safe Drinking Water Act limits. Children under nine years of age exposed to levels of fluoride greater than about two mg/L may develop a condition known as mottling or discoloration of the permanent teeth. In certain cases the teeth become chalky white in appearance. The U.S. Environmental Protection Agency has advised a secondary maximum contaminant level (SMCL) limit of two mg/L to protect against this aesthetic or cosmetic adversity from fluorides in drinking water. Further, federal regulations require that fluoride not exceed a concentration of four mg/L in drinking water. This is an enforceable maximum contaminant level (MCL) standard; it has been established to protect public health. Exposure to drinking water levels above four mg/L for many years may result in cases of crippling skeletal fluorosis, which is a serious bone disorder resembling osteopetrosis and characterized by extreme density and hardness and abnormal fragility of the bones (sometimes called "marble bones.")

When a community water system exceeds the MCL of four mg/L, it must notify each of its customers by issuing a public notice to those customers. This notice outlines the limitations and health effects from high fluoride levels in drinking water and points out home treatment systems and bottled water as possible drinking water source alternatives.

Treatment Alternates

For large municipal treatment systems, the use of activated alumina is probably the most commonly used fluoride removal technology. Activated alumina requires a two-step, caustic (NaOH) regeneration followed by acid (H₂SO₄) neutralization, regeneration process. This technology is now being used in exchange tanks for POE (point-of-entry) and disposable filters for POU (point-of-use) applications. For activated alumina to operate most effectively the pH range should be held to 5.5 to 6.5. Activated alumina is generally specific for fluoride and is not affected significantly by the common other competing sulfate, nitrate, or chloride anions in the influent water.

POU reverse osmosis is an excellent choice for the reduction of fluoride. Using a cellulose acetate/cellulose triacetate (CA/CTA) membrane, rejection rates of 80-90 percent are achievable when the pH is in the 4-8.5 range. Thin Film Composite membranes (TFC) will yield a higher rejection rate (up to 95 percent) in the 3-11 pH range. Both the CA/CTA and TFC membranes should be operated at a minimum membrane pressure differential of at least 30 psi.

The use of bone charcoal or bone char (carbonized animal bone) is reported to be an effective means for the reduction of fluoride. Bone charcoal contains a carbon structure while supporting a porous hydroxyapatite matrix (a calcium phosphate hydroxide in crystalline form which is rich in surface ions which can be readily replaced by fluoride ion). Adsorption and ion exchange are thought to be the mechanism for fluoride reduction by bone char. Regeneration of this material can be accomplished by a two percent sodium hydroxide rinse and a backwashing cycle. Reduction of fluoride using bone charcoal is somewhat pH dependent, the challenge water should be below 6.5 pH to suppress any ion competition.

Electro dialysis, deionization, and distillation would also be effective treatment processes.

The treatment methods listed herein are generally recognized as techniques that can effectively reduce the listed contaminants sufficiently to meet or exceed the relevant MCL. However, this list does not reflect the fact that point-of-use and point-of-entry (POU/POE) devices and systems currently on the market may differ widely in their effectiveness in treating specific contaminants, and performance may vary from application to application. Therefore, selection of a particular device or system for health contaminant reduction should be made only after careful investigation of its performance capabilities based on results from competent equipment validation testing for the specific contaminant to be reduced.

<u>Contaminant</u>	<u>MCL, mg/L</u>	<u>Treatment Methods</u>	<u>pH</u>
Fluoride (F-)	MCL = 4.0 SMCL = 2.0	Activated Alumina	5.5-6.5
		Reverse Osmosis:	
		CA/CTA	4.0-8.5
		TFC	3.0-11.0
		Electro dialysis	5.5-6.5
		Deionization	N/A
Distillation	N/A		
		Bone Charcoal	2.0-6.5

Because of the diverse influent water chemistries and product designs, water analysis tests to confirm effective treatment by any of the POE units for fluoride removal is recommended. Only POU units tested and certified for fluoride reduction are recommended to be used for such purposes.

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References:

CDC. “Water Fluoridation – Surgeon General’s Statement on Community Water Fluoridation” <http://www.atsdr.cdc.gov/tfacts11.html>, Dec.14, 1995.

Code of Federal Regulations, Title 40, part 143, section 5; July 1,1999; p560.

Faust,S.D., and Osman M.Aly, “Chemistry of Water Treatment”, Ann Arbor Press., 2nd Ed., 1998, p417.

ACKNOWLEDGEMENT

WQA wishes to express sincere appreciation for the unselfish contributions of the following members of WQA who contributed their time and expertise toward the completion of this bulletin.

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PRINTED IN USA
03/05