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Overview on Fluoride Concentration in Drinking Water

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ABSTRACT: Fluoride compounds are salts that form when the element, fluorine, combines with minerals in soil or rocks. Fluoride is a chemical element that has shown to cause significant effects on human health through drinking water. Different forms of fluoride exposure are of importance and have shown to affect the body's fluoride content and thus increasing the risks of fluoride-prone diseases. Fluoride has beneficial effects on teeth at low concentrations of 1 mg/L by preventing and reducing the risk of tooth decay. Concentrations lower than 0.5 mg/L of fluoride however have shown to intensify the risk of tooth decay. Fluoride can also be quite detrimental at higher concentrations exceeding 1.5–2 mg/L of water. High concentrations of fluoride pose a risk of dental fluorosis as well as skeletal fluorosis and osteoporosis. Skeletal fluorosis is a significant cause of morbidity in certain regions of the world. This of course depends on the level and period of exposure of fluoride by any given individual. Fluoride has been known to be found most frequently in groundwater at higher concentrations, depending on the nature of rocks and natural fluoride-carrying minerals at certain depths. Thus high fluoride concentrations generally can be expected from calcium-poor aquifers and where cation exchange of sodium for calcium occurs. In hotter climates where water consumption is much more frequent, the dosage of fluoride within the drinking water needs to be modified based on average daily intake. Thus diet and exercise also play a large role on the quantity of body's fluoride intake within a day. There has also been a direct correlation which shows that high altitudes can increase fluoride retention within the body and can thus have an effect on dental and skeletal appearance and structure, independent of fluoride intake and exposure. International standards for drinking water have been placed by organizations such as the World Health Organization (WHO), however local conditions determine the nature of the standards that are to be legislated by different countries, and thus fluoride limits in drinking water Standards may differ from one country to another. This paper investigates the potential health risks involved with both lower and higher concentrations of fluoride in drinking water, as well as posing possible measures of mitigation to eliminate such harmful threats. It also provides a survey of fluoride content in several bottled water samples around the World.

Keywords: Groundwater, Fluoride, Fluorosis, Mottled teeth, Defluorination.

I. INTRODUCTION

Water fluoridation is the controlled addition of fluoride to a public water supply to reduce tooth decay.[1] 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 [3] of about $1.02 per person-year. Defluoridation is needed when the naturally occurring fluoride level exceeds recommended limits. A 1994 World Health Organization expert committee suggested a level of fluoride from 0.5 to 1.0 mg/L (milligrams per litre), depending on climate. Bottled water typically has unknown fluoride levels, and some domestic water filters remove some or all fluoride. Dental caries remain a major public health concern in most industrialized countries, affecting 60–90% of school children and the vast majority of adults.

Water fluoridation prevents cavities in both children and adults, with studies estimating an 18–40% reduction in cavities when water fluoridation is used by children who already have access to toothpaste and other sources of fluoride. Studies suggest that the use of water fluoridation particular in industrialized countries may be unnecessary for caries prevention, because topical fluorides (such as in toothpaste) are widely used and caries has become low. Although fluoridation can cause dental fluorosis,[2] which can alter the appearance of developing teeth or enamel fluorosis, most of this is 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. Studies on adverse effects have been mostly of low quality. 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. Water fluoridation, when feasible[4] and culturally acceptable, has substantial advantages, especially for subgroups at high risk.

II. 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.

1. 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.

2. Fluorosilicic acid (H_2SiF_6) is the most commonly used additive for water fluoridation. 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.

3. Sodium fluorosilicate (Na_2SiF_6) 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. The Centers [9] 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. Since 1962, the U.S. had 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. This standard, adopted in 1962, is not appropriate for all parts of the world and is based on assumptions that have become obsolete with the rise of air conditioning and increased use of soft drinks, processed food, and other sources of fluorides. In 1994 a World Health Organization expert committee on fluoride use stated that 1.0 mg/L should be an absolute upper bound, even in cold climates, 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. In 2011, the U.S. lowered its recommended level of fluoride to 0.7 mg/L. 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.

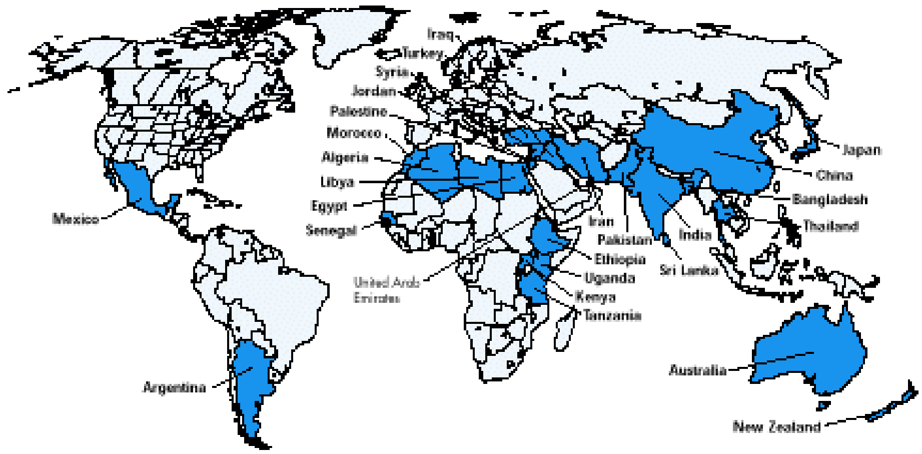


Fig. 1. Geographical areas associated with groundwater having over 1.5 mg/L of naturally occurring fluoride, which is above recommended levels.

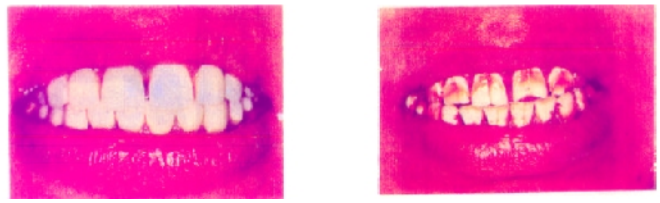
Because fluoride levels in water are usually controlled by the solubility of fluorite (CaF_2), high natural fluoride levels are associated with calcium-deficient, alkaline, and soft waters. Defluoridation is needed when the naturally occurring fluoride level exceeds recommended limits. It can be accomplished by percolating water [7] through granular beds of activated alumina, bone meal, bone char, or tri calcium phosphate; by coagulation with alum; or by precipitation with lime. Pitcher or faucet-mounted water filters do not alter fluoride; the more-expensive reverse osmosis filters remove 65–95% of fluoride, and distillation removes all fluoride.

III. 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. A Finnish study published in 1997 showed that fear that water is fluoridated may have a psychological effect with a large variety of symptoms, regardless of whether the water is actually fluoridated. 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. 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 over fluoridation that causes outbreaks of acute fluoride poisoning, with symptoms[6]thatinclude nausea, vomiting, and diarrhea. 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.[64]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[10] 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.

IV. DENTAL FLUOROSIS

Tooth enamel is principally made up of hydroxyapatite (87%) which is crystalline calcium phosphate [18]. Fluoride which is more stable than hydroxyapatite displaces the hydroxide ions from hydroxyapatite to form fluoroapatite. Fluorosis of dental enamel occurs when excess Fluoride is ingested during the years of tooth calcification-essentially during the first 7 years of life.



NORMAL DENTAL FLUORISIS

Fig. 2. Normal and Mottled teeth.

It is characterised by mottling of dental enamel, which has been reported at levels above 1.5 mg/L intake. On prolonged continuation of this process the teeth become hard and brittle. This is called dental fluorosis. Dental fluorosis in the initial stages results in the tooth becoming coloured from yellow to brown to black. Depending upon the severity, it may be only discolouration of the teeth or formation of pits in the teeth.

V. RECOMMENDATIONS

High fluorine consumption leads to the fluorosis of the bones which is generally found in Asian region but it is more acute in India. Hence, possibilities of reducing the high fluorine content of groundwater by defluorination process / dilution with the surface water is one very simple technique but addition of Ca^{++} ions to solution in contact with fluorite when experimented in distilled water caused appreciable decrease in fluoride concentration which appears to be more suitable solution to high fluoride problem in an otherwise water scarce India. In areas of high concentration. easily available local raw materials, such as clay, serpentine and marble can he used to reduce the fluoride content if geological and geochemical investigations be carried out prior to the implementation of water supply schemes.

VI. CAUTION

A much elevated concentration of fluoride, ranging from more than 1.5 ppm to 20 ppm in surface, subsurface and thermal waters in nine States in India, is beyond the permissible limit fixed by the WHO for human beings, the consumption of which is bound to yield the deadly Fluorosis disease. It may also cause harm to the ecosystem and vegetation, if used for irrigation.

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