

Human Health Effects of Drinking Water Fluoride Contamination: Indian Scenario

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Abstract

Fluoride is one of the main contaminants in groundwater present naturally in many parts of the globe causing a set of human health symptoms known commonly as Fluorosis. India lies in the geographical belt with 225 districts of 19 States having high fluoride concentrations (> 1.5 mg/l) in groundwater. For many rural as well as urban areas in India, hand-pumps and tube-wells are the only source of safe drinking water. With increasing population and increasing demands of water from below the ground, the fluoride contamination is spreading to newer areas every year. About 62 million people in India suffer from dental, skeletal and non-skeletal fluorosis including 6 million children below the age of 14 years. This paper presents quantitative assessment of fluoride contamination in groundwater and the associated fluorosis severity reported from various parts of India. It also summarizes research carried out in the country on reversal of dental and skeletal fluorosis through oral medicines; role of aluminium in aggravation of fluorosis; and dietary interventions in large communities across the country as possible remedies for this serious public health problem.

Keywords: Fluorosis, ground water, public health, India.

1. Introduction

Fluoride is estimated to be the thirteenth most common element in Earth's crust (Mason and Moore, 1982). It is essential for the normal mineralization of bones and the formation of dental enamel. Thus 96% of the fluoride in the body is found in bones and teeth. The principal sources of fluoride are drinking water and certain food items like green leafy vegetables, cabbage, carrots, nuts (especially almonds), etc. In 2011 the World Health Organization suggested a level of fluoride from 0.5 to 1.5 mg/L, depending on climate, local environment, and other sources of fluoride. Fluoride prevents dental caries, by reducing the solubility of the enamel in acids produced by bacteria. A very small amount of it may help in development of tooth, but excess of it causes dental fluorosis-endemic areas. High fluoride concentration in the groundwater and surface water in many parts of the world is a cause of great concern. Around 200 million people from 25 nations have health risks

because of high fluoride in groundwater (Ayoob and Gupta 2006). India lies in the geographical belt of fluoride having 12 million tons of fluoride deposits out of the 85 million tons in Earth's crust affecting 225 districts of 19 States by high fluoride concentrations (> 1.5 mg/l) in groundwater. Dental fluorosis is endemic in 14 states and 150,000 villages in India with the problem most pronounced in the states of Andhra Pradesh, Bihar, Gujarat, Madhya Pradesh, Punjab, Rajasthan, Tamil Nadu, and Uttar Pradesh (Figure 1).

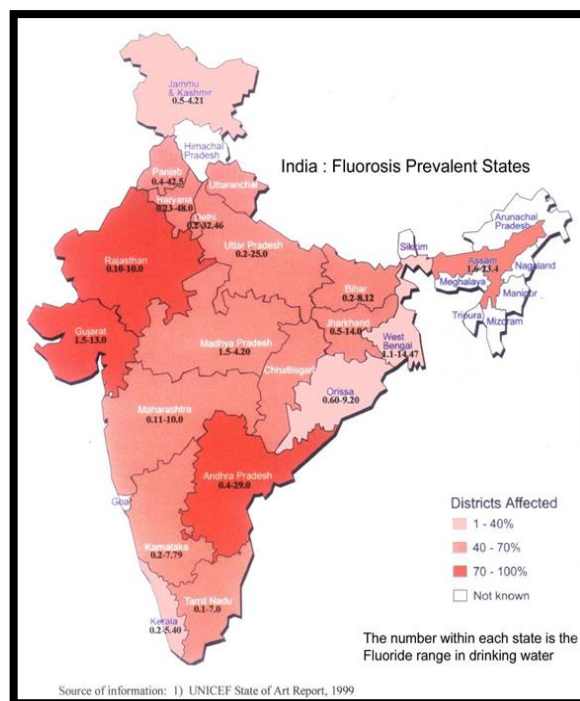


Figure 1. Fluorosis Prevalent States in India

2. Dental Fluorosis

Fluoride is often called as a double-edged sword as an expression for anything that can simultaneously help and hinder. This is because inadequate ingestion of fluoride is associated with dental caries and an excessive intake can

Table 1. Dean's Index of classification

SCORE	CRITERIA
Normal	The enamel represents the usual translucent semivitriform type of structure. The surface is smooth, glossy, and usually of a pale creamy white color.
Questionable	The enamel discloses slight aberrations from the translucency of normal enamel, ranging from a few white flecks to occasional white spots. This classification is utilized in those instances where a definite diagnosis of the mildest form of fluorosis is not warranted and a classification of "normal" is not justified.
Very mild	Small opaque, paper white areas scattered irregularly over the tooth but not involving as much as 25% of the tooth surface. Frequently included in this classification are teeth showing no more than about 1-2 mm of white opacity at the tip of the summit of the cusps of the bicuspid or second molars.
Mild	The white opaque areas in the enamel of the teeth are more extensive but do not involve as much as 50% of the tooth.
Moderate	All enamel surfaces of the teeth are affected, and the surfaces subject to attrition show wear. Brown stain is frequently a disfiguring feature.
Severe	Includes teeth formerly classified as "moderately severe and severe." All enamel surfaces are affected and hypoplasia is so marked that the general form of the tooth may be affected. The major diagnostic sign of this classification is discrete or confluent pitting. Brown stains are widespread and teeth often present a corroded-like appearance.

(Source: Dean, 1942. As Reproduced in "Health Effects of Ingested Fluoride" National Academy of Sciences, 1993)



Source: Fluoridation Forum Report 2002 (Page 126)

Figure 2. Stages of dental fluorosis according to Dean's Index of Classification

Table 2. Different clinical phases depending on the range of fluoride in the bone ash

Phase 1	Sporadic pain; stiffness of joints; osteosclerosis of pelvis and vertebral column (6,000-7,000 ppm F in bone ash).
Phase 2	Chronic joint pain; arthritic symptoms; slight calcification of ligaments; increased osteosclerosis/cancellous bones; with/without osteoporosis of long bones (7,500-9,000 ppm F in bone ash).
Phase 3	Crippling Skeletal Fluorosis: limitation of joint movement; calcification of ligaments/neck and vertebral column; crippling deformities of spine and major joints; muscle wasting; neurological defects/ compression of spinal cord (more than 8,400 ppm F in bone ash).

Source: Fluorine Intoxication. A Clinical-Hygienic Study. H K Lewis, London 1937 pp 213-253.

lead to fluorosis. Dental fluorosis is caused by excessive intake of fluoride during tooth development. It is mainly characterized by mottling of the enamel, which has been reported at levels above 1.5 mg/L intake. And on prolonged continuation of this process the teeth become hard and brittle. It occurs symmetrically within the dental arches; the premolars are usually affected first, followed by second molar, maxillary incisor, canine, first molar and mandibular incisors. Table 1 shows classification of fluorosis according to Dean's Index.

3. Skeletal Fluorosis

Endemic skeletal fluorosis is a chronic metabolic disorder of bone and joints caused by ingesting large amounts of fluoride either through water or from foods (rarely) of the endemic areas. Fluoride leads to resorption of the bone tissue and also affects the hemostasis of the mineral metabolism of the bones. It is generally seen to occur at fluoride levels over 8 ppm. It is most commonly seen in the Punjab State of India. Table 2 shows different clinical phases of skeletal fluorosis depending on the range of fluoride in the bone ash.

4. Prevention of Fluorosis: De-fluoridation of Water

The traditional method of removing fluoride is liming and then precipitating the fluorite. Nalgonda technique is one of the most popular techniques used in the developing countries (India, Kenya, Senegal and Tanzania). Fluoride removal techniques are mainly divided into two broad categories: membrane techniques and adsorption techniques.

4.1. Membrane Techniques

Reverse osmosis and Nano filtration: Reverse osmosis produces extremely pure water. Various methods have been described by Schneiter and Middlebrooks (1983), Fu *et al.* (1995), and Arora *et al.* (2004). Nano filtration works on the same principle as reverse osmosis, the only difference being that the size of pores is larger and provides lesser resistance to both solvent and solute. Retention of solutes occurs due to steric and charge effects (Diawara, 2008). Fluoride is more strongly hydrated as compared to other monovalent anions and along with the steric effects, it gets retained in the nano filtration membranes. Dialysis and electro-dialysis: Unlike reverse osmosis, in dialysis solute is separated by passing the solute through the membrane. The pores are very less restrictive and solute is driven by either Donnan effect (Donnan, 1911) or applied electric field. Electro dialysis is removal of ionic compounds from the aqueous solution through ion exchange membranes under driving electric fields.

4.2. Adsorption Techniques

Surface adsorption techniques of defluoridation have always been in practice because of their greater accessibility and lower cost. Many researchers have continued to improve the efficiency of the adsorbents (Biswas *et al.*, 2007; Jamode *et al.*, 2004). The adsorption of fluoride on solid particles occurs in following three steps:

- Diffusion of fluoride ion to external surface of the adsorbent across the border layer surrounding the adsorbent particles, known as external mass transfer.

- Adsorption of fluoride ion onto the particle surfaces.
- Either the fluoride ions exchange with the structural elements of the adsorbent particles, or are transferred to the internal surfaces for the porous material (intra particle diffusion).

Various materials which have been used for adsorbing fluoride are: activated and impregnated alumina (Das *et al.*, 2005; Lounici *et al.*, 1997; Mohapatra *et al.*, 2004; Wasay *et al.*, 1996a; Yang *et al.*, 1999), rare earth oxides (Raichur and Basu, 2001), activated clay (Agarwal *et al.*, 2003; Puka, 2004), impregnated silica (Wasay *et al.*, 1996b), carbonaceous material (Abe *et al.*, 2004; Li *et al.*, 2003a,b; Ramos *et al.*, 1999), solid industrial wastes like red mud, spent catalysts and fly ash (Cengeloglu *et al.*, 2002; Lai and Liu, 1996; Piekos and Paslawaska, 1999; Chaturvedi *et al.*, 1990), zeolites and related ion exchangers (Rao and Bhaskaran, 1998), bioabsorbents (Mohan *et al.*, 2007), alum (Pinon-Miramontes *et al.*, 2003), and modified chitosan (Jagtab *et al.*, 2009). The most recent ones include layered double hydroxides. Amongst the many adsorbent systems studied, few adsorbents take the fluoride levels to the range of 1-1.5 mg/l, which is required for drinking water (Tripathy *et al.*, 2006).

5. Treatment of Fluorosis: Therapeutic Measures

Therapeutic management of dental fluorosis depends on the severity of the condition. Classification of the severity of dental fluorosis by the Thylstrup and Fejerskov index (TFI) is most suitable for determining the type of treatment because it is based on the biological changes in enamel.

- Mild: TFI = 1-3
- Moderate: TFI = 4-5
- Severe: TFI >6

5.1. Bleaching (Tooth-whitening)

Extrinsic stains on teeth with very mild fluorosis (TFI=1-2) may be removed by bleaching with hydrogen peroxide.

Home bleaching: The bleaching agent (usually carbamide peroxide) is dispensed into a custom-made vacuum-formed vinyl chloride matrix. Patient is instructed to wear the matrix containing the bleaching agent for at least 6 hours daily (preferably at night) for about 1-2 weeks. The carbamide peroxide releases 3 percent hydrogen per-oxide that bleaches the teeth.

In-office technique: The discolored fluoresced teeth are bleached with 35 percent hydrogen peroxide (Superoxol). The discoloured teeth are the notched with 37 percent phosphoric acid for 15-60 seconds to obtain a chalky white enamel surface. After washing off the acid with water, the Superoxol is dispensed on pieces of gauze placed over each of the discoloured teeth. The hydrogen peroxide is then activated by an electric heat-producing unit, photo-flood lamp, halogen curing light or argon laser. This process is repeated a number of times until the desired result is achieved; after which the teeth are washed with water, and then polished with a rubber cup and the fine grades of Soflex discs.



Figure 3. Preoperative (A) and postoperative (B) scenario of mild fluorosis patient

5.2. Micro Abrasion

This is the most reliable method for removing stains of mild fluorosis (TFI= 1-3). The porous sub-surface enamel layer is abraded away together with the entrapped extrinsic stains, using a mixture of pumice and 18 percent hydrochloric acid. Commercial kits for micro-abrasion are available on the market, e.g. Prema (premier Dental Products). The kits comprise small jars containing 15 percent hydrochloric acid-pumice paste as well as specially designed plastic applicators for rubbing the paste on the labial surfaces of the fluoresced teeth.

5.3. Veneering

Pitted fluoresced teeth (TFI: 5) are difficult to be successfully managed by micro-abrasion, especially when the pits are coalescent. Such cases are therefore restored with composite resin or porcelain laminate veneers. Residual staining may sometimes be seen on the prepared surfaces of teeth for laminate veneers. Such stains are better removed by in-practice vital bleaching before final placement of composite or porcelain laminate veneer.



(a)



(b)

Figure 4. Before (A) and after (B) veneering in a mild-moderate case of fluorosis.

6. Conclusions

Although fluoride is an important element in the body, but increased fluoride exposure in the past two decades has increased the prevalence of fluorosis (may it be dental or skeletal). The effect of fluoride is cumulative, rather than requiring a specific threshold dose, depending on the total fluoride intake from all the sources and the duration of exposure. Therefore it is very much important to know the safe limits of fluoride usage and steps for early prevention

of the disease. Early diagnosis can help in the prevention and therapeutic management of fluorosis.

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