Defluoridation of Drinking Water : Efficacy and Need

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Abstract

Fluorine is the 13th most abundant naturally occurring element in the Earth's crust and is the lightest member of the halogens. It is the most electronegative and reactive of all the elements and as a result, elemental fluorine does not occur in nature but found as a fluoride mineral complexes. Exposure to fluoride beyond the recommended level for longer duration causes fluorosis. Several physical and chemical defluoridation methods have been designed to treat high fluoride concentration in ground water. There is need to develop such methods for defluoridation which would be cost effective and biodegradable.

Key Words : Fluoride ,defluoridaton, Fluorapatite, efficacy, & anthropogenic.

Introduction

Water is frequently referred to as a universal solvent, because it has the ability to dissolve almost all substance; that comes in its contact. Some elements are essential in trace amount for human being while higher concentration of the same can cause toxic effects. Fluoride is one of them. Due to rapid urbanization and growth of modern industries (anthropogenic source of fluoride) as well as geo chemical dissolution of fluoride bearing minerals (natural source of fluoride), fluoride concentration is increasing in the environment including water resources. The high concentration in the drinking water leads to destruction of enamel of teeth and causes a number of conditions referred to collectively as fluorosis. The problem of high fluoride in groundwater has now become one of the most important toxicological and geo environmental issues in India. During the last three decades high fluoride concentration in water resources resulting in the disease called "Fluorosis" is being highlighted considerably throughout the world. Over the years rapid strides have been made in India to mould the availability of water to match country's manifold potable water demand. It is a conclusive fact that concentration between 0.6 to1.2 mg/L is essential to protect teeth decay, while higher concentration (beyond 1.5 mg/L) can cause teeth mottling and still higher concentration of fluoride may lead to different major health hazards.

Fluorosis has attained an alarming dimension all over the world. It is wide spread in certain developing countries like Kenya, China , Algeria ,Argentina ,Morocco, Senegal, Turkey and Thailand and also in developed countries like Japan and USA. In India, one of the serious

health problems is prevalence of fluorosis. A report published by Rajiv Gandhi National Drinking Water Mission in 1983 identified 15 states including Delhi as endemic for fluorosis. Presently, 17 states which are endemic for fluorosis are: Andhra Pradesh, Karnataka, Tamil Nadu, Haryana, Maharashtra, Gujrat, Rajasthan , Kerala, J&K , Himachal Pradesh and Chandigarh states are also affected by fluorosis.

Susheela has reported the present over all status of ground water fluoride concentration and suffering of the people in India. The report states that an estimated 62 million people in India are affected with dental, skeleton /non skeleton fluorosis.

Human beings have been suffering fluorosis since ages. How ever, the cause of this disease is intake of high content of fluoride was ascertained only a few decades ago. Problem is increasing day by day as fluoride level is gradually getting higher than the prescribed maximum desirable limits. The fluoride level in water in India ranges from 2-29 ppm , where as the permissible level in drinking water according to WHO standard is 1.0 - 1.5ppm. High incidence of endemic fluorosis in India is due to fact that large area of the country's water supplies are having high level of fluoride. In tropical countries, skeletal fluorosis occurs even with drinking low level of fluoride. Epidemiological observation revealed that nutritional status might influence chronic fluoride toxicity.

People are consuming fluoride in water up to 18 mg/L. It is easily absorbed by the body from contaminated drinking water. After absorption, fluoride ion is quickly distributed throughout the body, easily crossing the membranes and going into tissues. It accumulates in body due to high reactivity of fluoride ion with calcium of teeth and bones. It forms calcium fluorophoshate (Fluorapatite) crystal and leaves unbound calcium in the same tissue, which gets calcified and in turn results in stiffness of tissues and joints. This finally leads to skeletal fluorosis in later stage. That's why fluoride is called as bone seeking mineral and bones as sink for fluoride. About 90% of the fluoride retrieved in body is associated with calcified tissues

Various Health Impacts of Fluoride :-

- Fluoride inhibits enzymes that breed acid-producing oral bacteria whose acid eats away tooth enamel. This observation is valid, but some scientists now believe that the harmful impact of fluoride on other useful enzymes far outweighs the beneficial effect on caries prevention.
- Fluoride ions bind with calcium ions, strengthening tooth enamel as it forms in children. Many researchers now consider this more of an assumption than fact, because of conflicting evidence from studies in India and several other countries over the past 10 to 15 years. Nevertheless, agreement is universal that excessive fluoride intake leads to loss of calcium from the tooth matrix, aggravating cavity formation throughout life rather than remedying it, and so causing dental fluorosis. Severe, chronic and cumulative overexposure can cause the incurable crippling of skeletal fluorosis.

Fluoride being an electronegative element and having a negative charge is attracted by positively charged ions like calcium (Ca^{++}). Bone and tooth having highest amount of calcium in the body attracts the maximum amount of fluoride and is deposited as Calcium Fluoroapatite crystals . Intake of fluoride above 1.5 mg/L may lead to serious manifestations;

Dental fluorosis *:-*

Incidences of mottled teeth has been observed even with range of 0.7 – 1.5 mg F / l in drinking water. The minimal daily intake of fluoride that can cause very mild or mild fluorosis is estimated to be about 0.1 mg/kg body weight. Dental fluorosis is the loss of luster and shine of the dental enamel . The discoloration starts from white yellow, brown to black. (Discoloration is either as spots or horizontal streaks). Enamel matrix is laid down on incremental lines before and after birth . Hence dental fluorosis is invariably seen on horizontal lines or on bands on the surface of the teeth . Fluorosis is seen as mild moderate and severe depending on the amount of fluoride ingested during the stages of formation of the teeth .

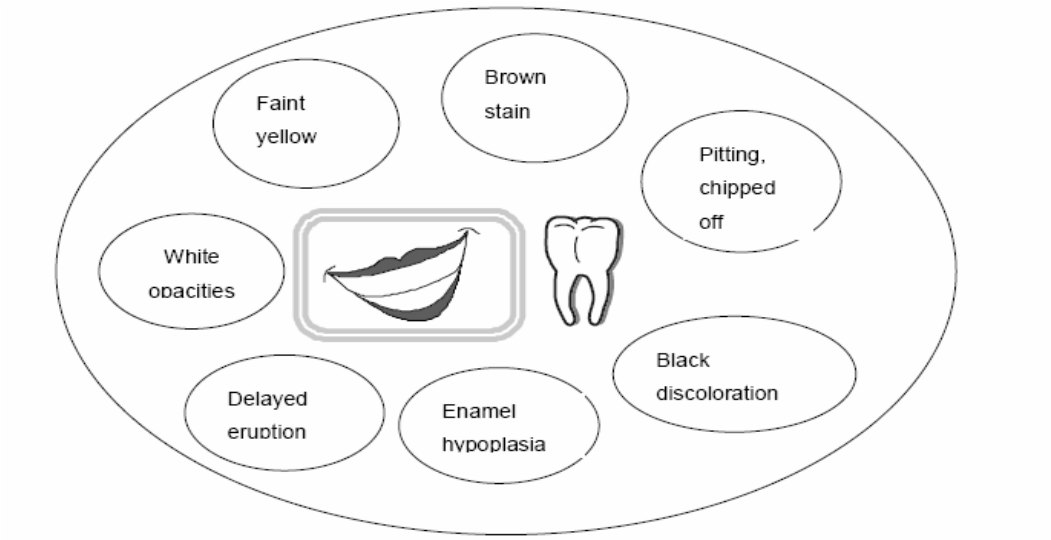

Figure: 1

Teeth commonly affected by fluorosis are central incisors , lateral incisors and the molars of the permanent dentition. It affects both the inner and the outer surfaces of teeth. The symptoms of dental fluorosis are as given below:

Dullness of the teeth and loss of shine with developed white and yellow spots.

Discoloration of teeth , turning into brown and black streaks or spots on the enamel surface

Loss of teeth at early age:

The teeth, once affected by dental fluorosis, cannot be reversed to normal. Only discolored teeth can be masked by the methods as prescribed below :

Bleaching of teeth , Filling with high cure material and laminated veneering.

Capping or crowning of teeth with metals like chrome , cobalt , gold , porcelain and acrylic.

Skeletal fluorosis *:-*

Excessive quantity of fluoride deposited in the skeleton , which is more in cancellous bone than cortical bone .Fluoride poisoning leads to severe pain associated with rigidity and restricted movements of cervical and lumber spine , knee and pelvic joints as well as shoulder joints . In severe cases of fluorosis , there is complete rigidity of the joints resulting in stiff spine described as “bamboo spine ” , and immobile knee , pelvic and shoulder joints. Crippling deformity is associated with

rigidity of joints and includes kyphosis , scoliosis , flexion deformity of knee joints , paraplegia and quadriplegia.

The symptoms of skeletal fluorosis are as given below:

Pain in neck, back bone or joints, Stiffness in the neck, backbone or joints
Severe pain and rigidity in the hip region (pelvic girdle)
Construction of vertebral canal and intervertebral forearm exerts pressure on nerves and blood vessels leading to paralysis and pain. Skeletal fluorosis is an irreversible process as the dental fluorosis.

Non – skeletal fluorosis *:-*
This kind of fluorosis is often overlooked due to misconception that fluoride affects only bone and teeth. Fluoride when consumed in excess can cause several other kind of manifestations;

Neurological : Nervousness, depression , tingling sensation of fingers and toes , excessive thirst and tendency to urinate more frequently.
Muscular : Muscle weakness , stiffness , pain in muscles and loss of muscle power

Allergic : Very painful skin rashes , which are perivascular inflammation prevalent in women and children, pinkish red or non- persistant oval shaped bluish - red spots on the skin.

Gastro-intestinal : Acute abdominal pain , diarrhea , constipation , blood in stool tenderness in stomach

Urinary tract : Urine may be less in volume, red in colour and passed with itching sensation.

Drug induced fluorosis *:-*
The prolonged use of drugs containing sodium fluoride is known to cause skeletal fluorosis. During 1982, two cases of drug induced skeletal fluorosis were reported from Switzerland . Patients of rheumatoid arthritis received uninterrupted and prolonged treatment with niflumic acid . The daily dose of drug administered was 3 capsules of 250 mg niflumic acid (Nifluril , UPSA Laboratories ,France .
Fluoridated toothpastes and mouth rinses recommended for mouth hygiene may cause drug induced fluorosis, particularly if the user is exposed to high fluoride water consumption . The blood vessels in the oral mucosa and the sublingual blood vessel absorb fluoride from these preparations . The commercial mouth rinses are generally fluoridated preparations with very high fluoride content .

Industrial fluorosis :
A number of industries use hydrofluoric acid and fluoride containing salts , in the different sections of an industry for one reason or other . The industries that use fluoride are;

1) Aluminium 2) Steel 3) Enamel 4) Pottery 5) Glass 6) Bricks 7) Phosphate Fertilizer 8) Welding 9) Refrigeration 10) Rust Removal 11) Oil Refinery 12) Plastic 13) Pharmaceutical 14) Tooth paste 15) Chemical Industries 16) Automobile Industry etc. Fluoride dust and

fumes , pollute the environment ; inhaling the dust and fumes is as dangerous as consuming fluoride containing food , water or drugs .

Table -1

Concentration of fluoride	Medium	Effects
1 ppm	Water	Dental caries reduction
2 ppm or < 2 ppm	Water	Mottled enamel (dental fluorosis)
8ppm	Water	10% osteosclerosis
20-80 mg/day	Water or food	Crippling skeletal fluorosis
50 ppm	Water or food	Thyroid changes
100 ppm	Water or food	Growth retardation
125 ppm	Water or food	Kidney changes
2.5-5.0 g	Acute dose	Death

Industrial fluorosis is a serious problem in the developed western and other industrialized countries . However , due to rapid industrialization in India , the problem of industrial fluorosis is reaching an alarming state and is compounding the problem of endemic , water and food borne fluorosis .

Prevention and control :

Fluoride poisoning can be prevented or minimized by using alternative water sources, by removing excessive fluoride from drinking water, and by improving the nutritional status of populations at risk.

Alternative water sources:

These include surface water, rainwater, and low-fluoride groundwater.

Surface water :

Particular caution is required when opting for surface water, since it is often heavily contaminated with biological and chemical pollutants. Surface water should not be used for drinking without treatment and disinfection. Many water treatment technologies are available, but the most effective are usually too expensive and complex for application in poor communities. Simple and low-cost technologies, such as sand filtration, ultraviolet water disinfection or chlorine water disinfection, are adequate in some but not all cases. Community capacity is an essential factor in ensuring successful utilization of these technologies. Water chlorination at household level is widely used only in emergencies.

Rainwater :

Rainwater is usually a much cleaner water source and may provide a low-cost simple solution. The problem, however, is limited storage capacity in communities or households. Large storage reservoirs are needed because annual rainfall is extremely uneven in tropical and subtropical regions. Such reservoirs are expensive to build and require large amounts of space.

***Low-fluoride groundwater*:**

Fluoride content can vary greatly in wells in the same area, depending on the geological structure of the aquifer and the depth at which water is drawn. Deepening tube wells or

sinking new wells in another site may solve the problem. The fact that fluoride is unevenly distributed in ground water, both vertically and horizontally, means that every well has to be tested individually for fluoride in areas endemic for fluorosis: extrapolating sample tube well tests to a larger area does not provide an accurate picture.

***Defluoridation of water*:**
There are basically two approaches for treating water supplies to remove fluoride: flocculation and adsorption.

Flocculation
The Nalgonda technique (named after the village in India where the method was pioneered) employs this principle. Alum (hydrate aluminium salts) - a coagulant commonly used for water treatment - is used to flocculate fluoride ions in the water. Since the process is best carried out under alkaline conditions, lime is added; bleaching powder can also be added to disinfect the water. After a thorough stirring, the chemical elements coagulate into flocs that are heavier than water and settle to the bottom of the container. The operation can be carried out on a large or small scale, and the technique is suitable for both community or household use.
One household version uses a pair of 20-litre buckets, with a settling time of one hour and not more than two hours: after coagulation and settling are complete, the treated water is withdrawn through a tap 5 cm above the bottom of the first bucket, safely above the sludge level, and stored for the day's drinking in the second bucket.

Adsorption
The other approach is to filter water down through a column packed with a strong adsorbent, such as activated alumina (Al_2O_3), activated charcoal, or ion exchange resins. This method, too, is suitable for both community and household use. When the adsorbent becomes saturated with fluoride ions, the filter material has to be backwashed with a mild acid or alkali solution to clean and regenerate it. The effluent from backwashing is rich in accumulated fluoride and must therefore be disposed of carefully to avoid re contaminating nearby groundwater. Both the community and household defluoridation systems have pros and cons. Defluoridation equipment connected to a community hand pump is theoretically cheaper per capita than a household unit because of economies of scale; but ensuring proper maintenance of a commonly owned facility is often problematic, so good community organization is necessary. The household units are more convenient for filtering the small amounts of water intended for drinking only, and people usually take better care of them; but an extensive and efficient service system is required to ensure that the filters are replaced or regenerated at the right time. Technology is only part of the issue: local capacity building, including entrepreneurial capabilities, can be a far more critical and difficult task.

Better nutrition
Clinical data indicate that adequate calcium intake is clearly associated with a reduced risk of dental fluorosis. Vitamin C may also safeguard against the risk. In consequence, measures to improve the nutritional status of an affected population - particularly children - appear to be an effective supplement to the technical solutions discussed above.

Conclusion
Natural contamination of groundwater by fluoride causes irrepairable damage to plant and human health (table-1). High oral intake of fluoride results in physiological disorders, skeletal and dental fluorosis, thyroxine changes and kidney damage in humans. High fluoride levels

inhibit germination, cause ultra structural malformations, reduce photosynthetic capacities, alter membrane permeability, reduce productivity and biomass and inflict other physiological and biochemical disorders in plants. Several physical and chemical defluoridation methods have been designed to treat high fluoride waters. However ion exchange and chemical treatments are cost intensive, while physical methods suffer limitations like frequent change of defluoridant beds and inability to reduce fluoride to non-toxic levels. Biological defluoridation methods/technically design upgraded methods can serve as a best alternative to the conventional methods of defluoridation. Community should adopt such methods of defluoridation which would be cost effective and efficient.

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