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Fluoride Toxicity and Its Control – A Review

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Water is an essential natural resource for sustaining life and environment which we have always thought to be available in abundance and free gift of nature. However, chemical composition of surface or subsurface, geothermal or non-thermal is one of the prime factors on which the suitability of the water for domestic, industrial or agricultural purpose depends. Ground water forms a major source of drinking water in urban as well as in rural areas. More than 90% of the rural population use groundwater for domestic purposes. Potable and safe drinking water means that the water should be free from chemical substance, pleasant to taste and fit for domestic life. More than 50% of illness in India is due to unprotected drinking water alone.

Among minerals, fluoride is one of the contaminents of water. Fluoride is an essential trace element for human beings and animals. Fluoride is the 13th most abundant element present in the earth's crust. It belongs to the halogen group of elements and is found naturally in water, soil, animals, and plants. Fluoride is one of the most reactive and ubiquitously present in nature. It is present in trace amounts in all mineralized tissues of the body such as enamel, dentin, and bone. In small amounts fluoride is beneficial as it is believed to impart stability to bone and enamel, thereby preventing dental carries and osteoporosis to some extent but its higher concentration is highly toxic to humans and animals alike. The permissible limits of fluoride in drinking water as suggested by Bureau of Indian Standards (BIS)(1) varies between 0.6 to 1.2 ppm and World Health organization (WHO)(2) permits a maximum of 1.5 ppm of it. As fluoride is found in small quantities in almost all foods, it enters the human body mainly through the oral route along with food and water. It can be rapidly absorbed by passive diffusion through stomach, small intestine, mouth, lungs and skin (3). Chronic exposure to fluoride above the permissible limits, it causes a disease called "Fluorosis". Fluorosis in an important clinical and public health problem in several parts of the world. The global prevalence of fluorosis has been reported to be about 32% (4). There are several million people in

India exposed to drinking water sources with high fluoride content. Fluorosis, a disabling disease, is caused by drinking fluoride contaminated water. In India, more than one lakh villages and over 10 million people stand to face disability due to high fluoride content in water. Fluorosis affects children and women the most. Pregnant mothers are most vulnerable to this disease. There are two types of Fluorosis – Dental and Skeletal. In Dental Fluorosis, the effect of fluoride can be seen on the teeth enamel and in Skeletal Fluorosis, the bones are affected the most. Apart from these, patients also get affected by neurological problems, thyroid imbalance and nutritional deficiencies.

Fluorosis – A Global issue

Drinking water is responsible for 65% of endemic fluorosis in the world and this is called as hydrofluorosis (5). An estimated 103 million people around the world live in areas where optimal fluoride concentrations occur naturally (6). Fluorosis is endemic in 25 countries around the world. Drinking water containing fluoride is the major source of fluorosis due to geological crust contamination. The daily fluoride intake through food and water varies greatly from country to country, and even within countries (7). The optimum level of the fluoride in drinking water cannot be generalised as the effect varies depending on the climatic conditions of the place. This was the reason that some of the authors deemed the WHO limits of 1.5 ppm of fluoride in drinking water unsuitable for their respective countries (8) especially in hot and dry climate.

The guide lines followed for fluoride content in drinking water in most of the countries are based on the W.H.O. norms. According to the WHO, the desirable upper limit for fluoride in drinking water is 1.5 mg / L. Senegal is the first country to reduce the upper permissible limit of fluoride in drinking water from 1.5 mg / L to 0.6 mg / L. The reason for such drastic change is due to the high prevalence of dental fluorosis in children with 1.5 mg / L fluoride in drinking water. India has reduced the upper limit of fluoride in drinking water from 1.5 mg / L to 1.0 mg /L.

Fluorosis in India

Fluorosis is worldwide in distribution and endemic at least in 25 countries. It has been reported from fluoride belts: one that stretches from Syria through Jordan, Egypt, Libya, Algeria, Sudan and Kenya, and another that stretches from Turkey through Iraq,

Iran, Afghanistan, India, northern Thailand and China. There are similar belts in the Americas and Japan.

High levels of Fluoride were reported in 230 districts of 20 States of India (after bifurcation of Andhra Pradesh in 2014). The population at risk as per population in habitations with high fluoride is 11.7 million as on 1.4.2014. Rajasthan, Gujarat and Andhra Pradesh are worst affected states. Punjab, Haryana, Madhya Pradesh and Maharashtra are moderately affected states while Tamil Nadu, West Bengal, Uttar Pradesh, Bihar and Assam are mildly affected states.

The first case of endemic fluorosis in humans from India was reported by (Short) (9) from Prakasam district of Andhra Pradesh in 1937. In 1950 only four states in India- Andhra Pradesh, Tamil Nadu, Punjab and Uttar Pradesh were identified with people suffering from fluorosis. By 1986, 13 states were found as endemic for fluorosis and during 1990-92, two additional states, i.e. Kerala and Jammu & Kashmir had also joined the list. A report published by Rajiv Gandhi National Drinking Water Mission (1994), identified 14 states and Delhi as endemic for fluorosis.

Presently, 20 Indian states which are endemic for fluorosis are: Andhra Pradesh, Telangana, Karnataka, Tamilnadu, Punjab, Haryana, Maharastra, Gujarat, Rajasthan, Kerala, Uttar Pradesh, Jammu & Kashmir, New Delhi, Assam, Bihar, Orissa, Madhya Pradesh, West Bengal, Jharkhand and Chattisgarh. North Eastern states are also affected by fluorosis.

Types of Fluorosis

Fluorosis mainly manifests in three forms – Dental, skeletal and non-skeletal.

A) Dental Fluorosis

Fluoride can prevent carries and enamel fluorosis. Caries is the demineralization of the enamel by acids produced by plaque bacteria, leading to cavitation. Enamel fluorosis is a subsurface hypomineralization of the dental, enamel caused by chronic ingestion of high fluoride concentration while the dentition is forming (10).

Ingestion of fluoride is the cause of dental fluorosis. Fluoride in drinking water, tooth paste, mouthrinses, and sodium fluoride tablets administered on prescription, can

contribute to the fluoride burden of the body leading to dental fluorosis. Dental fluorosis occur in children during the developmental stages when the teeth are exposed to fluoride.

The discoloration of teeth may progress from white, yellow, brown and black. The discoloration may be in spots, oral streaks in variably horizontal in orientation, since new layers of the matrix are added horizontally during tooth development.

Calcium rich constituents of teeth viz. enamel and dentin have strong affinity for fluoride. Fluoride affects (a) central incisors (b) lateral incisors (c) molar of the permanent dentition. Fluorosis affects both inner and outer surfaces of the teeth.

B) Skeletal Fluorosis

The effect of fluoride on bones and skeletal system depends on the type of bone and its inorganic and organic constituents.

Skeletal fluorosis is characterized by severe pain and stiffness in the neck, backbone and joints. The individual can not touch the toes with out bending the knees. X-ray shows increased girth, thickening and density of bone.

The stage at which skeletal fluorosis becomes crippling usually occurs between 30 and 50 years of age in the endemic regions. New comers to a hyperendemic region may sometimes, develop symptoms of skeletal involvement within 40 years of their arrival (11). Men suffer more than women from severe affects of the disease presumably because their work is usually more strenuous than that of women (11 & 12). The factors which govern the development of skeletal fluorosis are (a) the prevalence of high levels of fluoride intake, (b) continual exposure to fluoride, (c) strenuous manual labour, (d) poor nutrition and (e) impaired renal function due to disease (13).

C) Non-skeletal Fluorosis

The conventional belief that fluoride affects only bone and tooth has been negated in recent years as the evidences on the involvement of the soft tissues/organs/systems of the body are convincing.

Susheela (14) reported that not only teeth and bone of the body are affected by fluoride but also persistent intake of fluoride can adversely affect the soft tissue. High fluoride intake results in impaired kidney functions (15) and affects functioning of parathyroid by alterting serum calcium and phosphates (16).

Fluorine is responsible for metabolic disorders in systems, organs, tissues and individual cells (17&18). Inorganic fluoride can lead to acute poisoning, neurological, muscular, allergic, gastrointestinal, urinary tract disorders and some effects on tissues and systems as it get deposited on or bound to tissues (19).

Table : Fluoride concentration and symptoms of fluorosis

Concentration of fluoride	Medium	Effects
1 ppm	Water	Dental caries reduction
2 ppm or < 2 ppm	Water	Mottled enamel (dental fluorosis)
8 ppm	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

Source: Madhu Tripathi (20).

Fluoride Chemistry

Fluorine is a halogen with the lowest mass and ion radius and the highest electronegative potential and reactivity (21). Fluorine ranks thirteen in order of abundance of the elements and constitutes about 0.3 g/ kg the of earth's crust (22).

Fluoride bearing Minerals in India

Fluoride is part of the minerals fluorospar (CaF_2 – calcium fluoride), the principal fluorine containing mineral, cryolite (Na_3AlF_6 – Sodium aluminium fluoride) relatively a rare mineral and fluorapatite (CaF_2. $3Ca_3$ $(PO_4)_3$. Other fluoride containing minerals are relatively simple salts such as chiolite ($Na_5Al_3F1_4$) matockite (PbFCl), sellaite (MgF_2), villaumite (NaF) and Wagnerite ($Mg_2(PO_4)$).

Table : Fluoride bearing minerals in India

Name	Formula	% F Content Analytic
A. Fluorite		
1. Fluorite	CaF_2	48.18-48.61
2. Fluocerite	$(CeLaDy)F_3$	19.49-29.44
3. Cryolite	Na_3AlF_6	53.55-54.88
B. Phosphates		
4. Fluor-Apatile	$Ca_5(PO_4)F$	2.57-5.60
5. Wagnerite	$Mg_2(PO_4)F$	5.06-11.48
6. Triplite	$(Mn, Fe, Mg, Ca)_2 FPO_4$	6.02-9.09
C. Silicates		
7. Topaz	$(Al[F.OH]_2)SiO_4$ sheet silicates with $(OH, F)_4$	13.23-20.37
D. Mica group		
8. Phlogopite	Magnesium Mica	0.56-9.20
9. Lepidolite	Lithium Mica	4.93-8.08

Routes of Exposure

Air

Fluorides are emitted into the air in both gaseous and particulate forms. Particulate fluoride in the air around aluminium smelters vary in diameter from 0.1 μm to around 10 μm (23). This means that penetration into the lung alveoli is possible with resultant health effects.

Drinking Water

In temperate areas, the optimum level of fluoride was established at 1 mg / litre and this level was connected with a low prevalence of dental caries (24). Some mineral waters containing fluoride at a concentration of 8.5 mg / litre have been associated with skeletal fluorosis (25).

Food

Comprehensive determinations of fluoride in foods were reported from Finland (26) and other European countries (27). Highest values were reported in fish; fish bone fluoride contributed to these, especially in canned fish (0.9-8.0 mg/kg fresh weight) (26).

Various food stuffs prepared with fluorinated water may contain a fluoride concentration of 0.6-1.0 mg/kg as compared to the usual concentration of 0.2-0.3 mg/kg (28). One cup of tea contains 1-4 mg of fluoride (29). Fluoride in various beverages may contribute to dental fluorosis in children (30).

Exposure of plants to air borne fluorides leads, to deposition on the outer surface and uptake into plant tissue. Fluoride in vegetation contributes to human and animal dietary fluoride. Longterm exposure to concentration of more than 0.2 $\mu g/m^3$ may cause injury to plants (24).

Table: Fluorine content of various food stuff (31)

Food	**Fluorine content (ppm)**
Animal tissue	
Cow's liver, dry weight	5.20-5.0
Chicken liver, fresh weight	0.7-1.29
Cow's kidney, dry weight	6.9-10.1
Cow's heart muscle, dry weight	2.3-2.7
Meat	
Chicken	1.40
Beef	2.00
Pork	<0.2
Lamb	1.2
Mutton	<0.2
Fish	
Fish fillets	1.5
Mackerol	
Fresh	26.89
Dried	84.47
Canned	12.10
Shrimps canned	4.4
Edible portion	0.9
Crab meat canned	2.0
Eggs	

Whole	1.2
White	1.5
Yolk	0.6
Whole milk	0.007-0.22
Tea	3.2-178.8
Average of the samples	97.0
Citrus fruits	
Grape fruit	0.36
Edible portion	0.36
Fresh	0.12
Lemon fresh	0.028, 0.051, 0.174
Orange fruit fresh	0.17-0.07
Non-citrus fruits	
Apples fresh weight	0.22-1.32
Apples dry weight	0.13-0.43
Banana fresh	0.23
Banana dry	0.65
Fig	0.21
Cherry	0.25
Pineapple	0.14
Watermelon	0.11
Cerals and ceral products	
Corn	8.0-11.0
Wheat whole	0.53
Bran	0.33
Cream of wheat	0.55
Fluor whole wheat	1.32
Bread white	0.54
Soya beans	4.00
Rice unspecified	0.76
Oats	3.0
Vegetables and Tubers	

Beans	0.64
Cauliflower fresh	0.45
Cabbage (foreign)	15.38
Carrots	6.92
Onions green	10.11
Mustard	3.0-4.8
Potatoes	0.96
Radish	0.8
Tomatoes	2.40
Peanuts	1.36
Almonds	0.90
Coconut fresh	0.00
Sugar	0.32
Honey	1.00
Glucose	0.50
Malt	1.0-1.5
Coffee	0.2-1.6
Cheese	1.62

Fluoride and Bone Damage

Incorporation of fluoride in bone and tooth is reported (32). There are three stages of mechanism to describe the entry of ions into apatite crystal lattice. The crystallite was considered to be surrounded by a hydration shell and the incorporation of fluoride into crystal lattice prefaced by polarized molecules present in this loosely integrated shelf.

The second stage involved in the exchange of fluoride in the hydration shell with an ion (or) group at the surface of the apatite crystal, could be not only by hetero-ionic exchange with hydroxy or biocarbonate group but also by iso-ionic exchange with fluoride already present in the crystal (33). Finally, ions present in the crystal surface might migrate slowly into vacant places in the crystal interior during recrystallization.

The weight of evidence indicates that, although fluoride might increase bone volume, there is less strength per unit volume (34). The evidence suggests that NaF induced BMD increases may be associated with increased fracture risk (35).

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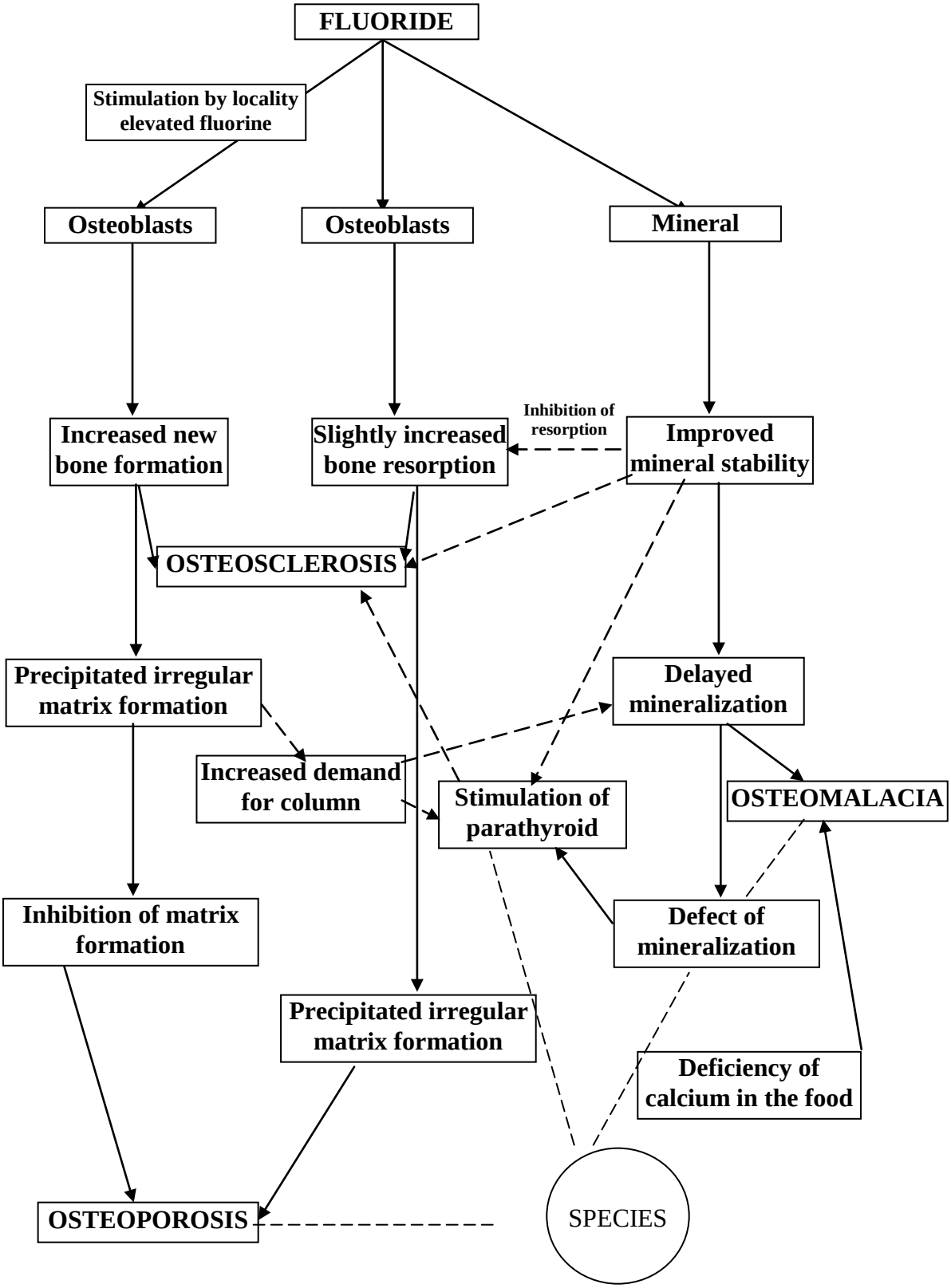
Action of Fluoride on Bone



(Franke Halle, 1979) (36)

Fluoride Interactions with Enzymes

Fluoride has been found to inhibit the activity of many important enzymes such as enolase, lipase, phosphofructokinase, pyruvate kinase, glycogen synthatase, succinate dehydrogenase, cytochromoxidase, various phosphatases, ATPase, ureas and cholinesterases to name a few (37;38). The clinical toxicology of commercial products (39) accounts for the toxication of fluoride by the fact that fluoride ions act as enzymatic poisons, inhibiting enzyme activities and ultimately interrupting metabolic processes.

Structural Susceptibility of Biomolecules

The impact of strong hydrogen bonding is that proteins, which consist of a repetitive sequence of amide linkages are particularly susceptible to this type of hydrogen bonding. The end results of this type of interaction are two-fold. The lesser effect is that the carbonyl-nitrogen (amide) bond in proteins may become more susceptible to cleavage eventhough fluoride itself is a less nucleophilic anion. The second and probably enormously greater effect is that the spatial arrangement or macromolecular structure of these materials depends heavily upon normal hydrogen bonding to produce the secondary stereochemical structure required for appropriate enzymatic activity to take effect.

- Fluoride inhibits metalloproteins (40).
- Fluoride inhibits DNA polymerase (41).
- Fluoride induces chromosome abbreviation (42).
- Fluoride affects the adenyl cyclase system (43).
- Fluoride inhibits yeast enolase (44).
- Fluoride inhibits protein synthesis enzymes (45).
- Fluoride inhibits glycolytic enzymes (46).
- Fluoride inhibits cells growth enzymes (47).
- Fluoride inhibits testosterone synthesis (48).

Fluoride Toxicity

In areas with high fluoride rocks, the most significant exposure to the general population is through abnormal levels of fluoride in water and food (49). Fluoride makes entry into human system through dietary and non-dietary sources. In a community where fluoride is normally undetectable or not obvious, the total dietary intake, considering the most reliable values, ranged between approximately 0.43 to 0.91 mg F/day (50).

Once fluoride entered into the human system, fluoride readily gets absorbed through gastrointestinal tract or lungs, based on the route of exposure. After coming in contact with the systemic circulation, part of it is primarily excreted through renal system and the remaining is predominantly taken up by the mineralized tissues. Chronic exposure to fluoride causes discoloration of teeth, and severe hypoplasia of enamel and dentine (dental fluorosis) and in extreme cases it results in skeletal abnormalities (osteofluorosis) leading to genuvalgum commonly called as knock-knee syndrome. Fluoride is an ardent bone seeker in extricably linked with skeletal system where the mineral component of the bone is predominantly hydroxyaptite [Ca_{10} $(OH)_2$ $(PO_4)_6$]. Exposure to fluoride causes the hydroxyl group to be replaced by fluoride producing a compound similar to the naturally occurring mineral (Walton, 1988). Fluoride has also been termed as an osteogenic agent by Takada *et al.* (51). Fluoride has also been established as a neurotoxicant (52;53).

Carcinogenicity

There was evidence of carcinogenic activity of sodium fluoride in male rats based on the occurrence of a small number of osteosarcomas in treated animals (54) and not carcinogenic in Sprague-dawley rats (55).

Cecilioni (56) established a relationship between atmospheric fluoride emissions and incidence of lung cancer in the vicinity of a steel industry situated in Hamilton. Increased, incidence of respiratory cancer from occupational fluoride exposure was also reported by Grandjean *et al.* (57). Excess cancer rates have been documented in various occupational groups exposed to fluorides.

Fluoride and the Brain

Fluoride's ability to damage the brain represents one of the most active areas of research on fluoride toxicity today. The impact of fluoride on children's IQ has been documented even after controlling for children's lead exposure, iodine exposure, parental education and income status and other known factors that might impact the results (58). The animal studies have also documented considerable evidence of direct toxic effects of fluoride on brain tissues, even at levels as low as 1 ppm fluoride in water (59). These effects include:

- Reduction in nicotinic acetycholine receptors.
- Reduction in lipid content.
- Impaired anti-oxidant defense systems.
- Damage to the hippocampus
- Damage to the purkinje cells.
- Increase uptake of aluminium.
- Formation of beta-amyloid plaques
- Exacerbation of lesions induced by iodine.
- Accumulation of fluoride in the pineal gland.

Allergy / Hypersensitivity to Fluoride

Hypersensitive reactions to fluoride have been reported for both topical fluorides and ingested fluorides. In hypersensitive individuals, fluorides occasionally cause skin eruptions such as atopic dermatitis, eczema or utricaria. Gastric distress, headache and weakness have also been reported. These hypersensivity reactions usually disappear promptly after discontinuation of fluoride (60).

Fluoride and Pineal gland

The pineal gland is located in between the two hemispheres of the brain that regulates the protection of the hormone melatonin. Melotonin is a hormone that helps to regulate the on set of puberity and helps to protect the body from cell damage caused by free radicals. The pineal gland is the primary target of fluoride accumulation with in

humans, Luke (61) found that animals treated with fluoride had lower levels of circulating melatonin, as reflected by reduced levels of melatonin metabolites in the animals urine.

Fluoride and Thyroid

Fluoride was reported to affect negatively some endocrine organs, particularly the thyroid, in animal studies (62). Rats administered 0.5 mg fluoride / kg / day via drinking water during two months showed decreased thyroxine levels and an increased T3-resin uptake ratio (63)

Reproductive Toxicity

A positive correlation between infertility in animals and human beings associated with fluoride toxicity has been reported. Infertility has been found among married males in highly endemic areas for fluorosis in India (64). An increase in the occurrence of oligospermia and azoospermia has been found in male workers suffering, from industrial fluorosis (65). Alterations were also observed in other accessory sex organs (66;67).

Fluoride as Teratogen

Fluoride anion like other organophosphorous and methyl carbomate (68) compounds might have caused the development of the abnormalities in the skeletal apparatus during embryogenesis and the effect of the same possible be carried further with greater intensity in the adult bird impairing its normal life, as was being noticed in the fluoride, toxicosis in animals and humans (69;70) thus suggesting fluoride induced teratogenicity.

Module for detection of fluorosis

A module has been developed for early detection of fluorosis. Following guide lines may help to detect fluorosis at an early stage. Pain in the joints without visible signs of fluid accumulation may be due to fluoride toxicity. Non-ulcer dyspepsia characterized by nausea, vomiting, pain in abdomen constipation followed by diarrhoea may be due to fluoride toxicity manifestations beside other reasons. Muscle weakness, fatigue, anaemia with very low haemoglobin level may be seen in fluoride toxicity. Complaints of repeated abortions / still birth in patients from endemic areas may be due to fluoride toxicity, as fluoride is known to calcify, harden blood vessels, and there by hamper blood flow to the growing foetus.

Any discoloration of the enamel surface in the front row of teeth of patients away from the gums and seen as horizontal streaks or spots is invariably due to dental fluorosis. Children with short stature, funny face, deformed bones, knock-knee bowed leg, rickets, low IQ, deaf-mutism may be due to fluoride toxicity besides other reasons.

PREVENTION AND CONTROL OF FLUORIDE POISONING

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 ground water.

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.

Rain water

Rain water 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 ground water

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 endemic areas for fluorosis.

Removal of fluoride from drinking water

Several methods have been suggested from time to time for removing excess fluoride from water and several models were developed. Various defluoridating methods

available, include chemical reactions (Nalgonda technology and activated alumina technology), ion exchange process and reverse osmosis.

Nalgonda technology

Indeed, one of the most sustainable forms of appropriate technology water treatment developed for the removal of fluoride. The Nalgonda technique, was pioneered and still in use in the Nalgonda region of Andhra Pradesh (71).

Nalgonda technique, involves addition of two chemicals, lime and alum to water followed by flocculation, sedimentation and filtration. Bleaching powder can be added simultaneously for disinfection. The quantities of alum and lime required depend on dissolved solids, alkalinity and fluoride content of raw water.

Activated alumina technology

The activated alumina procedure essentially involves removal of fluoride by adsorption of the ion on the surface of the activated alumina. Activated alumina has been successfully applied as a defluoridation medium. There are several advantages of using alumina at it has relatively high exchange capacity for fluoride ion. This capacity is not affected by the concentration of SO_4^{-2} or Cl^- contents of water and the materials has low cost. Activated alumina acts as anionite, charged with chloride ions when regenerated with hydrochloric acid or with OH^- ions when regenerated with sodium hydroxide. The adsorption capacity of the material may theoretically restored up to 100%. Multiple reuse of regeneration solution (1% NaOH) is possible and the duration of regeneration cycle does not exceeds 1 hr (72).

Ion exchange resin based approach

Resin based ion exchange process for removal of fluoride from ground water is also available in India. Strong anion exchange resins are not considered for fluoride removal because of their low capacity and relative high cost. Ion exchange process can be effective only if the fluoride concentration is less than 10mg/L (72).

Reverse Osmosis

It is a process where in water is forced through a semipermeable membranes by applying strong pressure, thereby allowing only fine water molecules to pass through it. All contaminants including heavy metal and chemical poisons are removed.

Defluoridation by Bone Char

In this method defluoridation is done by using bone char. Bone char is a material, which has shown successful results in the removal of fluoride. Bone char is made from bones from animals and are then crushed and burned at high temperature. The fluoride binding is an adsorption process, which means binding to the surface of the material (73).

Combination of alum and lime with bone char

In this method the water to defluoridised is pre treated with small quantity of alum and lime. After addition of these chemicals and flocculation on followed by sedimentation water is filtered through bone char column (74).

Defluoridation studies using laterite material

A study is being done by Jayantha *et al., (73)* to remove excess fluoride in drinking water based on the concept of adsorption using locally available material like laterite, sand and gravel. The studies were being conducted in a column with varying depths of laterite by keeping constant gravel depth. The flow is varied for all the depths and the results obtained were found to be quite encouraging as compared to some of the established costly techniques. This technique can be employed in rural areas and places where expensive techniques cannot be adopted.

Defluoridation using Bark of *Sapindus trifoliatus*

This method developed by Thakare *et al.* (75) out of the various methods available today for defluoridation purpose the bark of *Sapindus trifoliatus* based technology is one of the promising treatment option under practical situation, encountered in the field.

CONTROL

The disease can be controlled as stated below. However, those who have developed fluorosis have to undergo the suffering from the problems.

(i) Avoid all possible sources of fluoride;

(ii) Pain in back bone, neck, hip and joints should not be dismissed as casual matter;

(iii) Adequate quantity of calcium vit. A, C and D should be included in daily diet;

(iv) Expectant and lactating mothers and children who are most vulnerable should take special care by way of using water only from India Mark-II Handpumps; and

(v) Only "Defluoridated" water should be used for drinking and cooking food, if otherwise no safe source is available. Defluoridation is a technique, which eliminates fluoride from water either by chemical or by physical methods.

Action plan for supply of fluoride free water

All sources are safe	**Safe and unsafe sources co-exist**	**Sources marginally contaminated**	**Sources highly contaminated**
Action: To create awareness among the community on the importance of consuming safe drinking water. To advice to not to cross the village and collected water from other villages, as there may be fluoride in excess in water sources.	Action: To lable safe sources 'safe' and if contaminated with fluoride 'unsafe'. To use safe sources for consumption. To use unsafe sources for other purpose. To popularize dual system of water usage among the community.	Action: To carry out healthy survey one affected with fluorosis should have better nutrition. To counsel on diet to consume more of calcium, vitamin C, E and antioxidants containing food to reduce to risk of fluorosis.	Action: To compile information on hydro geochemical aspects, rainfall terrain and population. Digging tube well deeper if the deeper aqifer has safe water. Harvesting rainwater if rainfall is adequate. Bringing safe water from distance if economically viable. If none of above is possible then treating water for fluoride removal.

Source : Thakare *et al.*, (76).

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