

FLUORIDE AND FLUOROSIS

1.0 INTRODUCTION

The disease fluorosis is caused by an element known as fluorine, the 13th most abundant element available in the earth crust.

Chemical Properties of Fluorine

- 1 Element of Halogen group with molecular weight 19 and atomic number 9.
- 1 Fluorine is the most electro negative of all elements
- 1 This fluorine exists as a diatomic molecule with remarkably low dissociation energy (38 K cal/mole). As a result it is highly reactive and has strong affinity to combine with other elements to produce compounds known as Fluoride.

Fluorosis

To a certain extent (as per WHO;0.6 ppm) fluoride ingestion is useful for bone and teeth development, but excessive ingestion causes a disease known as Fluorosis. While the WHO standards¹ and BIS:10500-1991² permit only 1.5 mg/l as a safe limit of fluoride in drinking water for human consumption. People in several districts in Rajasthan are consuming water with fluoride concentrations of up to 24 mg/l.

Fluorosis continues to be an endemic problem. More and more areas are being discovered regularly that are affected by fluorosis in different parts of the country. Children in the age group of 0 to 12 years are most prone to fluorosis as their body tissues are in formative / growth stage during this period. Expectant mothers are also to be protected, as there is growing concern about effects of fluoride on fetus.

Fluorosis, which was considered to be a problem related to teeth only, has now turned up to be a serious health hazard. It seriously affects bones and problems like joint pain, muscular pains etc. are its well-known manifestations. It not only affects the body of a person but also renders them socially and culturally crippled.

In spite of the progressive spread of disease so far no established data exists to determine the extent of disease, no specialized water testing facilities are available and even the doctors do not have specific orientation to correlate the disease with specific symptoms. In these areas the response of the people is reactive rather than pro-active.

2.0 EXTENT OF PROBLEM

International Status³

The following countries have been identified for the problem of fluorosis: Pakistan, Bangladesh, Argentina, United States of America, Morocco, Middle East countries, Japan, South African Countries, New Zealand, Thailand etc.

In India³

The problem has reached alarming proportions affecting at least 17 states of India:

- (I) 50-100% districts are affected - Andhra Pradesh, Tamil Nadu, Uttar Pradesh, Gujarat, Rajasthan
- (II) 30-50% districts are affected - Bihar, Haryana, Karnataka, Maharashtra, Madhya Pradesh, Punjab, Orissa, West Bengal
- (III) < 30 % districts are affected - J & K, Delhi, Kerala

In Rajasthan

Fluorides in drinking water of Rajasthan have been found to originate from indigenous rocks, which extend from Delhi to Gujarat. The geological distribution of rocks in Rajasthan reveals that fluorotic ores occupy large areas of eastern and southeast parts of this state, in constricted synclinal bands in the central region of Aravali synchronium. Secondly, around the mica mines, ground water is rich in fluorides and Rajasthan is a rich source of mica.⁴

All the 32 districts have been declared as fluorosis prone areas. The worst affected districts are Nagaur, Jaipur, Sikar, Jodhpur, Barmer, Ajmer, Sirohi, Jhunjhunu, Churu, Bikaner, Ganganagar etc.

PHED Habitation Survey 1991-93⁵

	Villages	Habitations	Total
Villages/Habitations in State	37889	45311	83200
Fluoride more than 1.5 mg/l	9741	6819	16560
Fluoride more than 3.0 mg/l	3280	2181	5461

PHED Habitation survey 1997-98

Out of 15133 samples analyzed for fluoride in 19 districts, 4603 (30.41%), were indicated fluoride more than 1.5 ppm

3.0 SOURCES OF FLUORIDE

Sources of fluoride in environment³

Usually the surface water is not contaminated with high fluoride, whereas ground water may be contaminated with high fluoride because the usual source of fluoride is fluoride rich rocks. When water percolates through rocks it leaches out the fluoride from these rocks. The rocks rich in fluoride are:

Fluorspar- CaF_2 (Sedimentary rocks, lime stones, sand stones);

Cryolite- Na_3AlF_6 (Igneous, Granite);

Fluorapatite- $\text{Ca}_3(\text{PO})_2\text{Ca}(\text{FCl})_2$

Sources of fluoride for human exposure:

Main sources of fluoride for human are Water, Food, Air, Medicament, Cosmetic etc.

Water

Although there are several sources of fluoride intake, it is roughly estimated that 60% of the total intake is through drinking water. This is the most assimilable form of fluoride and hence the most toxic.

Food

The fluoride of food items depends upon the fluoride contents of the soil and water used for irrigation, therefore the fluoride content of the food items may vary from place to place. The details of fluoride rich food have been given in annexure 1^{6&7}

Drugs³

Prolonged use of certain drugs has been associated with the chronic adverse effects of fluoride e.g. sodium fluoride for treatment of osteoporosis, Niflumic acid for the treatment of rheumatoid arthritis, use of fluoride mouth rinse (Proflo) to render the tooth stronger.

Air³

The use of fluorides in industry leads to occupational exposure e.g. inorganic fluoride compounds are used in the production of aluminum. Fluorides are also released during the manufacture and the use of phosphate fertilizers.

Cosmetics viz. Toothpaste's & Mouth Rinses

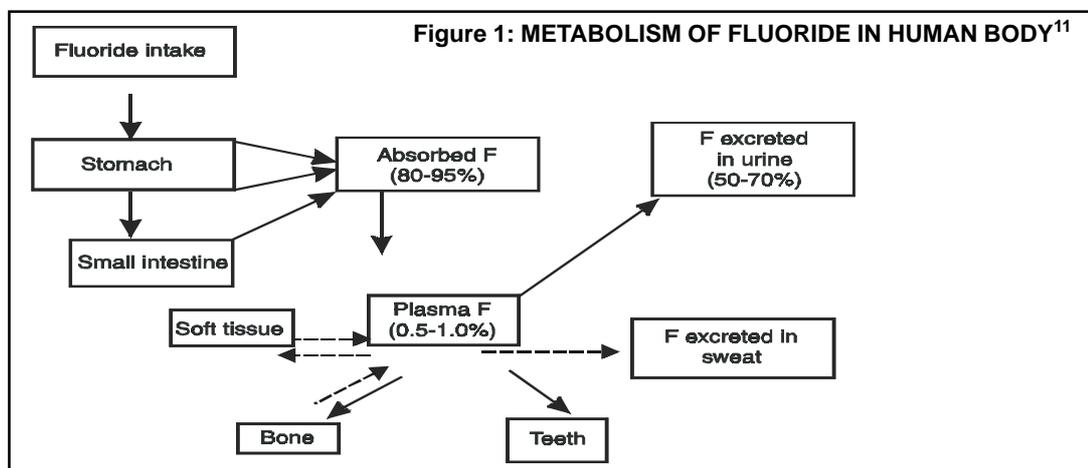
Highly significant associations were found between estimated fluoride ingestion from toothpaste and fluorosis^{8&9}. The fluoride content arising from the raw material used for the manufacturing of paste viz. calcium carbonate, talc and chalk have high fluoride arising as a contaminant from raw materials, can be as high as 800-1000 ppm. In the fluoridated brands, there is a deliberate addition of fluoride, which may range from 1000-4000 ppm.³

Other

1. Inorganic fluoride compounds are used in the production of aluminum and use of phosphate fertilizers.³
2. Apart from the available drinking water supply the bottled mineral water may also be a source of excessive fluoride ingestion. Villena-RS *et al.*¹⁰ in their study reported that specific bottled waters contained: Significant concentrations of fluoride not reported by the producer. It is therefore concluded, that a sanitary regulatory system for the control of the level of fluoride in the bottled mineral waters marketed is necessary.

4.0 CHEMOBIOKINETICS AND METABOLISM^{11,12,13}

- 1 Ingested fluoride is rapidly absorbed through gastrointestinal tract and lungs. The peaks are reached after 30 min in blood.
- 1 The rapid excretion takes place through renal system over a period of 4 to 6 h. In children less than three years of age only about 50% of total absorbed amount is excreted, but in Adults and children over 3 years - about 90% is excreted.
- 1 Approximately 90% of the fluoride retained in the body is deposited in the skeleton and teeth
- 1 The biological half-life of bound fluoride is several years.
- 1 Fluoride also passes through the placenta and also appears in low concentrations in saliva, sweat, and milk.



5.0 QUANTIFICATION OF FLUORIDE TOXICITY ON HUMAN HEALTH

Smith & Hodge¹⁴ have related the concentrations or doses of fluoride to the biological effects indicated in the tabulation below:

Fluoride Concentration (mg/l)	Source	Effects
0.002	Air	Destructive effect on plants
1.00	Water	Prevention of Dental caries
>= 2	Water & Water	effect dental enamel
>= 8	Water & Water	effect Bones and muscles
>50	Food & Water	Changes in Thyroid
>100	Food & Water	defective development
>120	Food & Water	Changes in Kidney

6.0 FACTORS INFLUENCING THE ONSET OF THE DISEASE (DETERMINANTS OF DISEASE)¹⁵

Fluoride poisoning and the biological response leading to ill-effects depends on the following factors: Concentration of fluoride in drinking water, food, cosmetics etc.; low calcium and high alkalinity of drinking water, age of the individual, duration of intake, pregnancy, lactating mother, derangement in hormonal profile either as a result of fluoride poisoning or cause, aggravates the disease. The hormones are: calcitonin, parathormone, vitamin D and cortisol are the important hormones for healthy bone formation and bone function.

7.0 CLINICAL PRESENTATIONS

The clinical presentation of fluoride intoxication may be of two types:

1. Acute Fluoride intoxication
2. Chronic Fluoride intoxication

7.1 Acute fluoride intoxication¹⁶

The acute effects of the ingestion of massive doses of fluoride are first those of an irritant poison, and later become apparent in enzyme systems such as those engaged in metabolism, energetic, and cellular respiration and in endocrine functions. However, no system of the body can be considered exempt. Thus, in cases of acute poisoning, early involvement of the alimentary, cardiovascular, respiratory and central nervous systems, with corresponding symptoms, is a characteristic feature and such cases commonly have a fatal outcome in two to three days.

After ingestion of fluorine compounds in high doses, there is diffuse abdominal pain, diarrhoea and vomiting. There is excessive salivation, with thirst, perspiration and painful spasms in the limbs.

Lethal dose:

The acute lethal dose of fluoride for man is probably about 5 g as NaF.

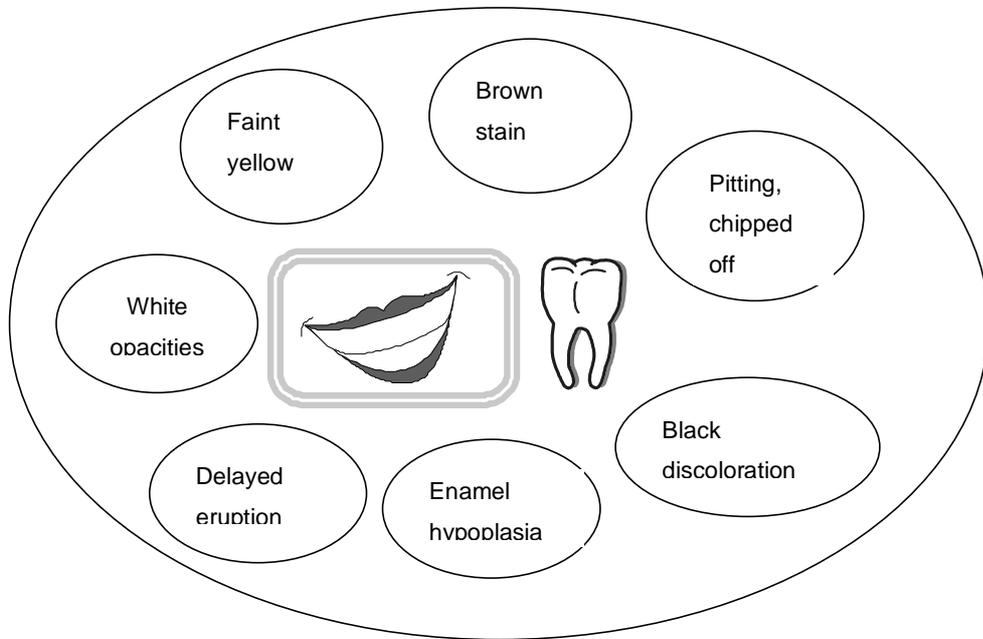
Treatment of acute toxicity:

1. Monitor and support vital signs, including cardiac monitoring.
2. Gastric lavage, if emesis has not occurred. Charcoal is probably not of benefit.
3. Monitor serum electrolyte, calcium, and magnesium levels.
4. Treat hypocalcemia, hypomagnesemia and hyperkalemia or hypokalemia.
5. Administer milk, oral calcium salts, or aluminum or magnesium based antacids to bind fluoride.
6. Consider hemodialysis in-patients with significant toxicity.
7. Treat arrhythmia, especially in the presence of refractory hyperkalemia.
8. Consult a regional poison center for the latest treatment recommendations.

7.2 Chronic Fluoride Ingestion³

Toxic effects on human beings: Fluorosis may cause Skeletal Fluorosis, Clinical Fluorosis, Dental Fluorosis, Non Skeletal manifestations, or any combination of the above and in final stages it causes premature aging.

DENTAL FLUOROSIS¹⁷

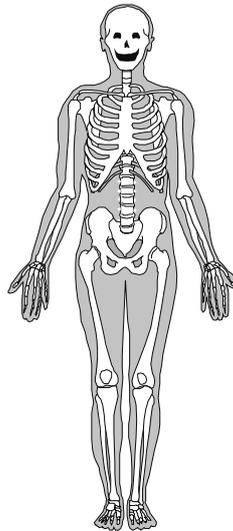


Incidences of mottled teeth was observed even with range of 0.7-1.5 mg F/l in drinking water. The minimal daily fluoride intake in infants that may cause very mild or mild fluorosis in human beings was estimated to be about 0.1 mg per kg body weight.

SKELETAL FLUOROSIS^{18,19,20}

RADIOLOGICAL PRESENTATIONS

- Osteosclerosis
- Periosteal bone formation
- Calcification of interosseous membrane, ligaments, capsules, muscular attachments, tendons.
- Exostoses
- Osteophytosis
- Associated metabolic bone disease



CLINICAL PRESENTATION

- Heel pain
- Painful and restricted joint movements
- Deformities in Limbs
- Hunch back

IN EXTREME CASES

- Paralysis,
- Muscular wasting,
- Premature aging

NON SKELETAL MANIFESTATIONS³

Neurological manifestation



- 1 Nervousness & Depression
- 1 Tingling sensation in fingers and toes
- 1 Excessive thirst and tendency to urinate Frequently (Polydypsia and plyurea): The Control by brain appears to be adversely affected.

Muscular manifestations



- 1 Muscle Weakness & stiffness
- 1 Pain in the muscle and loss of muscle power

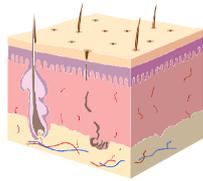
Urinary tract manifestations

Kidney'



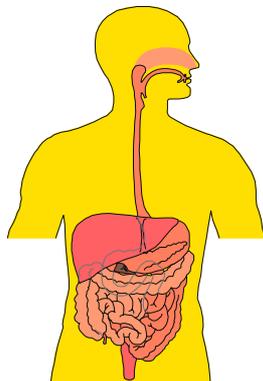
- 1 Urine may be much less in volume
- 1 Yellow red in colour
- 1 Itching in the region of axilla.

Allergic manifestation



- 1 Very painful skin rashes, which are peri vascular inflammation. Prevalent in women and children.
- 1 Pinkish red or bluish red spot, round or oval shape on the skin that fade and clear up within 7-10 days.

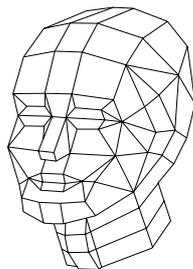
Gastro - intestinal problems



- 1 Acute abdominal pain
- 1 Diarrhoea
- 1 Constipation
- 1 Blood in Stool
- 1 Bloating feeling (Gas)
- 1 Tenderness in Stomach
- 1 Feeling of nausea
- 1 Mouth sores

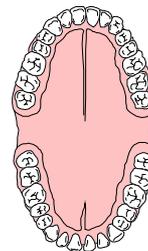
The complaints with the G-I system in endemic areas are now established as early warning signs of fluoride toxicity. Fluoride is known to combine with hydrochloric acid of the stomach and is converted to hydrofluoric acid ($F+HCl \rightarrow HF + Cl$). Hydrofluoric Acid is highly corrosive and hence the stomach and intestinal lining (mucosa) is destroyed with loss of microvilli^{21,22}

Headache



Edentate

(Losses Teeth at an early age)



Red Blood cells³

It is now known that when fluoride is ingested, it will also accumulate on the erythrocyte membrane, which in turn loses calcium content. This change causes formation of **echinocytes**. The life span of these echinocytes is less than the normal life span of RBC, and hence early destruction of the RBCs in form of echinocytes causes anemia.

Ligaments and Blood Vessel Calcification

A unique feature of the disease is soft tissues like ligaments, blood vessels tend to harden and calcify and the blood vessels will be blocked.

Fluoride and mental efficiency²³

A study on 157 children, aged 12-13, born and grew up in a coal burning pattern endemic fluorosis area indicated that

- (1) Excessive fluoride intake since early childhood would reduce mental work capacity (MWC) and hair zinc content:
- (2) The effect on zinc metabolism was a mechanism of influence on MWC by excessive fluoride intake
- (3) Excessive fluoride intake decreased 5-hydroxy indole acetic acid and increased norepinephrine in rat brain; whether this is also a mechanism of the influence on MWC awaits confirmation.

Fluoride and thyroid²⁴

Fluoride has inhibitory effect on iodine uptake. It has been observed that in high iodine and high fluorine areas, the thyroid enlargement prevalence rate among inhabitants and that among children were 3.8% and 29.8%, respectively.

Fluoride and Cancer²⁵

The results of the studies suggested that sodium fluoride promoted the growth of precancerous lesions of the liver induced by DEN in rats, and this has provided some data to the understanding of the relationship between fluorosis and neoplasm's.

Fluoride and diabetes²⁶

The study showed that chronic fluoride toxicity in humans could result in significant abnormalities in glucose tolerance, which are reversible upon removal of the excess fluoride.

Fluorosis and lactation²⁷

The effect of fluorosis on lactation, lactotroph function and ultrastructure were studied in lactating rats. The results were as follows:

- 1) Inhibition of lactation in lactating rats
- 2) During chronic fluorosis serum prolactin level was decreased.

Fluoride and Alkaline phosphatase activity

Fluoride at micromolar concentrations significantly and dose-dependently stimulated [3H] thymidine incorporation into DNA in DP-1, DP-2 (normal human dental pulp cells) and TE-85 cells (human osteoblastic osteosarcoma cell line). Fluoride significantly increased the enzyme's activity in DP-1 and TE-85 by 177 +/- 12% and 144 +/- 12.3%.

Fluoride and proteoglycan²⁸

Collagen fiber, glycosaminoglycans (Proteoglycans) and glycoprotein are integral part of the teeth, bones, tendons and muscles. Irrespective of the fact that cancellous and cortical bones are structurally and biochemically different, the bone matrices are constituted of collagen fiber, glycosaminoglycans (Proteoglycans) and glycoprotein. The bone and teeth are the only two tissues in the body where 80-85% of the matrix comprises of collagen protein. The remaining 15-20% of the mass is constituted of glycoprotein and glycosaminoglycans (Proteoglycans)²⁹

Normally the glycosaminoglycans (GAG) content in normal cancellous bone is three times that in the cortical bone and increases further after chronic F- ingestion. Most of the detected form of GAG was in form of Dermatan sulphate (also termed as chondroitin sulphate B - a sulphated isomer of glycosaminoglycan)³⁰

Fluoride in excess anywhere in an ecosystem has been shown to have potentially harmful effects on the body systems. All three components of bone and teeth that is collagen, proteoglycans and calcium are adversely affected by ingestion of high quantity of fluoride for prolonged duration^{31,32} The net result of this leads to degradation of collagen and ground substance in bones and teeth and thus leads to symptoms of fluorosis like, delayed eruption of teeth, dental fluorosis, clinical fluorosis, premature aging etc³³

Based on the changes in ground substance due to high fluoride intake, elevated content of glycosaminoglycans (Mucopolysaccharides³⁴ - synonymous with the term "Seromuroid" used by Winzler)) in bone and its reflection in serum is considered as an index to assess fluoride toxicity and fluorosis at very early stages^{30,31}

The ratio of N- Acetyl neuraminic acid in serum (Serum sialic acid-SSA) to GAG has been found as a sensitive index to detect fluoride toxicity at very early stages both in human and animal models. The ratio of SSA/GAG revealed a 30-50% reduction in human sera in fluoride poisoning^{30,31}

8.0 DIAGNOSIS

The diagnosis of fluorosis needs the following evaluations

- 1 High fluoride contents of the drinking water
- 1 Endemicity of the fluorosis in the area
- 1 Clinical manifestations of fluorosis in the population: Dental, Clinical, Skeletal fluorosis
- 1 Clinical examination: Examination of teeth and three simple diagnostic tests.³
 - a. The individual is made to bend and touch the toes without bending the knees. If there is pain or stiffness in the backbone, hip and joints, this exercise will not be possible.
 - b. The individual is made to touch the chest with the chin. If there is pain or stiffness in the neck, this exercise will not be possible.
 - c. The individual is made to stretch the arms sideways, fold the arm and try to touch the back of the head. If there is pain or stiffness in the shoulder joint and backbone, this exercise will not be possible.
- 1 Biochemical evaluation
- 1 Radiological evaluation
- 1 Histopathological evaluations e.g. bone biopsy, muscle biopsy etc.

The details of grading of dental, skeletal and Clinical fluorosis have been appended in annexure 2.

9.0 Differential diagnoses

All three types of presentations in fluorosis need to be differentiated from simulating illnesses:

Dental fluorosis:

Like any other organs in the body; teeth are also affected by various factors leading to diseases. The differential diagnosis of fluorosis should be done for two aspects:

1. Related to the pitting and chipping in fluorosis
2. Related to discoloration of teeth

Common dental diseases relating to the pitting and chipping in fluorosis are:

1. Dental caries or decay/ cavity formation.
2. Periodontal disease or pyorrhea
3. Dental Fluorosis

Caries appear as black spots or cavity in the tooth when decay reaches dentin. Person complains of sensitiveness and acute pain when decay reaches pulp.

Pyorrhea is caused by action of bacteria present in the mouth on food, resulting in the form of brownish hard deposit on the surface of teeth near gum.

Periodontal disease is the inflammation of gingival gum and periodontal ligament leads to deposition of inorganic salts known as tartar, it irritates gum resulting in bleeding of gums and bad breath. Tartar cannot be removed by brushing. Periodontal disease is more common amongst persons suffering from diabetes mellitus, nutritional deficiency, especially protein and Vitamin C deficiency.

Fluorosis affects permanent teeth though decay of temporary teeth is also reported.

Diseases related to discoloration of teeth

There may be two types of staining of teeth: a) Internal staining b) external staining

Fluorosis causes internal staining of teeth, whereas other causes like Brinjal eating, Banana biting, Palm leaf biting, Coconut leaf chewing cause external staining of teeth and may be mistaken for dental fluorosis.

Skeletal fluorosis:

In the early stages of skeletal fluorosis patients complain of arthritic symptoms, which have to be differentiated from those caused by such diseases as rheumatoid and ankylosing spondylitis. For early diagnosis of skeletal fluorosis, microradiographic techniques are more helpful than conventional skiagrams. In doubtful cases a bone biopsy (though tedious) for estimation of fluoride content provides conclusive evidence.

In later stages skeletal fluorosis is marked by restriction of spine movements and hence can be easily diagnosed.

In the case of children residing in endemic regions these symptoms need to be differentiated from rickets, and sometimes from renal osteodystrophies, including congenital malformations. In all such cases urinary and serum levels of fluoride and radiographs of skeleton will clinch the diagnosis. When sclerosis of the vertebral column is not marked, calcification of the interosseous membranes in the fore arm clearly indicate the diagnosis of fluorosis, on radiography.

Non Skeletal fluorosis

The preskeletal stage of fluoride intoxication poses problems for diagnosis. In these cases radiograph of the skeleton will neither show sclerosis or calcification of the ligaments nor significant elevation of urinary levels of fluoride. Moreover the symptoms that are manifested are so varied that they may be identifiable with those of various other diseases. The complaints of the victims in this regard are so common place that they may be easily mistaken for those resulting from other ailments e.g. muscle/neurological involvement in children may be mistaken for Poliomyelitis.

10.0 Fluorosis and Diet^{28,35,42}

Role of diet in fluorosis has a double sword action. Intake of high fluoride in diet increases the toxic manifestations of fluorosis, whereas intake of diet rich in calcium and vitamin C helps in overcoming the toxicity of fluorosis.

The observations have also indicated that dietary fluoride is playing a secondary role in causation of fluorosis, whereas the primary role is related to the drinking water fluoride concentration and in liquid diets, because:

1. In food the fluoride is present in two forms a) Organically bound form and b) in inorganic form. The chances of toxicity due to bound form of fluoride are much less than the inorganic form of

fluoride. In water most of the fluoride is present in inorganic form thus making it more harmful than the dietary fluoride.

2. The liquid form of food is more prone to have high content of fluoride in inorganic form. The available data indicate that in general, various food items contain fluoride in different concentration. A brief list has already been mentioned. Plants and vegetables grown in soil and water rich in fluoride. This is because of the fact that the fluoride of food items depends upon the fluoride contents of the soil and water used for irrigation, therefore, the fluoride content of the food items may vary from place to place. More details of fluoride rich food have been given in *Annexure 1*.
3. On an average, the intake of fluoride from food ranges from 2 to 8.0 mg per day, depending on the type of food consumed.
4. Even with the above facts, the fluoride ingestion from food does not vary much from area to area, but total fluoride intake depends mainly on water fluoride concentration.

Drinking water fluoride concentration	Fluoride from food (Average)	Fluoride from water*	Total fluoride intake	Water: Food ratio
4 ppm	5 mg per day	10 mg per day	15 mg per day	66.6:33.3
8 ppm	5 mg per day	20 mg per day	25 mg per day	80:20

*Considering 2.5 litre consumption per day per person

5. Presence of Calcium, protein and Vitamin C in food has preventive role in fluorosis, because the diet can have two fold action:
 - a. Reduce the intake of fluoride by avoiding the intake of fluoride rich food.
 - b. As it is always not possible to avoid the intake of fluoride from food, the simultaneous ingestion of dequate Protein, Vitamin C (ascorbic acid) and Calcium diet plays a vital role in prevention of fluorosis.
 - c. Adequate calcium in the diet is one of the most important entities to combat the ill effects of fluoride poisoning. Calcium interacts with fluoride to form calcium fluoride (CaF) which is an insoluble salt and being a larger molecule is not absorbed from GI tract. Such large molecules of fluoride are then excreted through feces. An expectant and lactating mother and a growing child should normally have 3 gms of calcium in diet. An adult should have 1.5 gms of calcium in the daily diet. Calcium is most essential for laying down of a normal, healthy and strong bone and tooth. Calcium rich dietary products viz., milk, curd, green leafy vegetables, cheese (paneer) etc should be consumed in plenty (calcium rich food given in *annexure 3*).
 - d. Adequate vitamin C (ascorbic acid) in the diet is yet another important entity to ameliorate the ill effects of fluoride. Vitamin C, acts as a cofactor or co-enzyme in the process of hydroxylation of prolein, one of the most important amino acids of the collagen, the base material of bone and tooth matrix. If the bone and tooth have to be well calcified strong and normal, healthy collagen protein need to be laid down. 500-1000 mg of vitamin C a day is normally recommended in fluoride prone areas. Unlike other vitamins, vitamin C is not produced in the body and one is totally dependent on vitamin C intake through dietary sources. Special efforts ought to be made to consume Vitamin C rich fruits and vegetables daily Amla is an exceptionally rich source of Vitamin C, besides citrus fruits (Vitamin C rich food given in *annexure 4*).
 - e. A good balanced diet can combat the ill effects of fluoride. It is for this reason, the disease is seen highly prevalent in the economically backward strata of the society and those who are uneducated and unaware of the importance of good nutrition and balanced diet.
6. The studies conducted²⁸ in fluoride afflicted areas of Rajasthan have shown that:
 - 1 The average protein intake in these areas was about 0.5 – 0.76 gm per Kg day.
 - 1 The Daily calcium (average 230 – 430 mg/ day) and vitamin C (less than 100 mg/day) intake was less than the desired amount in these areas.
 - 1 Clinical presentations in these areas varied with the total fluoride intake.
 - 1 There is abrupt increase in severity of dental fluorosis in area with drinking water fluoride concentration 13.6 ppm, and total average daily fluoride intake is about 30.00 mg.
 - 1 The severity of clinical and skeletal fluorosis starts rising as the total fluoride intake exceeds 12

mg per day (Fluoride from food – 14%), but as the total daily fluoride increases more than 25 mg (Fluoride from food – 7%), the severity of clinical and skeletal fluorosis increases abruptly.

Considering the above observations the following conclusions can be drawn^{38,39}

1. These observations indicated that food fluoride plays a vital role in causation of dental fluorosis even in areas with low fluoride in drinking water. Whereas it has substantial role in causing clinical and skeletal fluorosis, where drinking water fluoride is playing its major role.
2. These observations indicated that simple restriction of ingestion of dietary fluoride in areas with less fluoride concentration in drinking water will prevent people from developing the dental fluorosis.
3. In areas with high fluoride concentration in drinking water, restrictions of dietary fluoride have to be supplemented with defluoridation of drinking water and vitamin C and Calcium rich diet.

11.0 TREATMENT AND PREVENTION

There is a crying need to overcome the problem of fluorosis. Three approaches are suggested:

1. Health education
2. Treatment of the children,
3. Preventive measures.

Health Education

Creating awareness about the disease

The main area of interest will be

a. Creating disease awareness

Creating awareness about the disease should be in form of graphic presentation of the final consequences of the disease to the extent possible.

If required live presentation of the patients, who are suffering from the severe form of the disease, in areas where the gravity of problem has not reached to that extent. It may be of use, to demonstrate the most severe extent of the disease and to motivate them to use the preventive or therapeutic measures.

b. Creating awareness about the sources of the fluoride

The creation of awareness will help in implementing the need based preventive measures in the affected community.

Treatment of the disease

Vitamins C and D, and, salts of Calcium, Magnesium or Aluminum were prescribed in an attempt to reverse these effects^{16,43-48} Published results were, however, inconclusive and largely negative. Recent studies conducted in Rajasthan under Rajasthan DST sponsored studies indicated that fluorosis could be reversed, at least in children^{28,49,50,51,52}, by a therapeutic regimen (Calcium, Vitamin C and Vitamin D) which is cheap and easily available.

The choice of the reported therapy was logical. The presence of calcium in gut directly affects the absorption of fluoride ions and will also improve serum calcium levels as observed by Teotia et al⁵³ Vitamin D₃ in low doses enhances calcium absorption and retention without causing hypercalcemia and thus directly affects the absorption of fluoride ions. It also inhibits the excessive release of parathyroid hormone thereby preventing excessive activation of osteoblasts thus preventing hyperosteoidosis and osteopenia. Ascorbic acid controls collagen formation, maintains the teeth structure and is also essential for bone formation. These structures are adversely affected by higher fluoride intake.



Prevention

a. Providing defluoridated water for drinking purpose

Methods of defluoridation recommended so far are aimed at bringing the fluoride levels to the WHO standards (Details have been appended in *annexure 5*).

Desirable characteristics of defluoridation process

- 1 Cost-effective
- 1 Easy to handle/operate by rural population - the major sufferer
- 1 Independent of input Fluoride concentration, alkalinity, pH, temperature
- 1 Not affect taste of water
- 1 Not add other undesirable substances (e.g. Aluminum) to treated water (Details of toxicity relating to aluminum have been depicted in *annexure 6*).

It is estimated that the daily consumption of water for all purposes per capita is about 135 lpcd in urban areas and about 40 lpcd in rural areas, whereas for drinking and food preparing purposes it is only 8 lpcd.

Keeping in view the cost involved in defluoridating the water it is desirable that the defluoridation of water should be restricted to drinking water only. Hence the only economical and practicable choice left is Domestic defluoridation.

It is now desirable to test the various domestic defluoridation processes, especially in terms of acceptance by people without the need of any supervising agency, and recommend suitable alternatives so that effective long-term implementation can be achieved.

b. Changing the dietary habits

Defluoridation of drinking water alone shall not bring the fluoride level to a safe limit. It would be necessary to overcome the toxic effects of the remaining fluoride ingested through other source. This can be done by effecting minor changes in the diet and dietary habits of the population compatible with their social system and available resources. The main aim should be to

- 1 Restrict use of fluoride rich food
- 1 avoiding use of fluoride rich cosmetics
- 1 Use of food rich in calcium, vitamin C and proteins ((Details have been appended in *annexure 3,4*).

c. Water harvesting (alternative water source)

Fluoride not only affects the people but it also affects the animals. Therefore it is desirable that the animals should also be provided with fluoride free water for maintaining their longevity. Defluoridation of drinking water for animals will be too costly and not feasible, and therefore the only solution of this problem is water harvesting. The water harvesting technologies should be aimed not only to provide fluoride free water to human beings but also to animals.

Rainwater storage can be a major source of fluoride free drinking water for the animals.

This three pronged attack can prove to be a blessing for the population especially for the younger generation living in fluoride rich areas having no choice except to drink the water contaminated with fluoride and suffer the inevitable consequences including permanent deformities.

This may make this program

“By the people-For the people”

FLUORIDE CONTENT IN AGRICULTURAL PRODUCTS AND OTHER EDIBLE ITEMS
(Fluoride in ppm)

Food Item	A Sengupta	B Lakdawala and Pal & (1971)	Food Item	A Sengupta	B Lakdawala and Pal & (1971)
Puneaker (1973)			Puneaker (1973)		
Place of study	Calcutta	Bombay	Place of study	Calcutta	Bombay
Fluoride content in drinking Water (ppm)	0.4	0.15-0.48	Banana	2.9	0.84-1.58
Cereals and Tubers			Dates	4.5	--
Cereal	4.6	2.59-3.3	Grapes	--	0.84-1.74
Wheat	5.9	3.27-14.03	Figs	4.2	--
Rice	--	1.72-2.23	Mango	3.7	0.8-1.80
Maize	5.6	--	Apple	5.7	1.05-2.2
Pulses & Legumes			Guava	5.1	0.24-0.52
Bengal Gram	6.2	3.84-4.84	Nuts & Oil seeds		
Green Gram Dal	2.5	2.34-4.84	Almond	4.0	--
Red Gram Dal	3.7	2.34-4.84	Cashewnut	4.1	--
Soyabean	4.0	--	Coconut	4.4	--
Leafy Vegetables			Mustard Seeds	5.7	--
Spinach	2.0	0.77-4.14	Groundnut	5.1	--
Cabbage	3.3	1.28-2.29	Beverages		
Amaranth leaves	5.8	4.91-7.14	Tea (Dry leaves)	--	39.8-68.59
Lettuce	5.7	--	Tea infusion (1 gm boiled for 5 min. in 125 ml. water)	--	18.13-56.19
Mint	4.8	--	Tea infusion (1 gm in 125 ml) of hot water)	--	11.13-37.34
Bathua Leaves	6.3	--	Aerated drinks	--	0.77-1.44
Chowli leaves	--	1.79-7.33	Coconut Water	--	0.43-0.60
Other Vegetables			Spices & Condiments		
Cucumber	4.1	2.57-3.58	Corriander	2.3	--
French beans	--	1.07-1.96	Cumin Seeds	1.8	--
Tomato	3.4	1.00-2.08	Garlic	5.0	--
Brinjal	1.2	1.62-2.48	Ginger	2.0	--
Ladies finger	4.0	2.2-3.62	Tamarind pulp	3.8	--
Snake Gourd	2.3	2.16-3.44	Termeric	3.3	--
Roots & Tubers			Food from Animal sources		
Beet root	4.2	--	Mutton	--	3.0-3.5
Carrot	4.1	1.9-4.9	Beef	--	4.0-5.0
Potato	2.8	1.27-2.92	Pork	--	3.0-4.5
Onion	3.7	1.00-3.00	Fish	--	1.0-6.5
Sweet Potato	3.2	--			
Fruits					

Dental fluorosis⁵⁴

Type	Weight	Description
Normal Enamel	0	The enamel presents the usual translucent semi-vitriform type of structure. The surface is smooth, glossy, and usually of a pale, creamy-white color.
Questionable fluorosis	0.5	Slight aberrations from the translucency of normal enamel seen, ranging from a few white flecks to occasional white spots. This classification is used in instances where a definite diagnosis of the mildest form of fluorosis is not warranted and a Classification of "Normal" not justified.
Very mild fluorosis	1	Small opaque, paper-white areas scattered irregularly over the tooth but not involving as much as approximately 25% of the tooth surface. Frequently included in this classification are teeth showing no more than about 1-2mm of white opacity at the tip of the summit of the cusps of the bicuspids or second molars.
Mild fluorosis	2	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 fluorosis	3	All enamel surface of the teeth are affected and surfaces subject to attrition show marked wear. Brown stain is frequently a disfiguring feature.
Severe fluorosis	4	All enamel surface are affected and hypoplasia is so marked that the general form of tooth may be affected. The major diagnosis of this classification is the discrete or confluent pitting. Brown stains are widespread, and teeth often present a corroded like appearance.

Clinical Grading⁵⁵

- 1 Grade I: Mild - generalized bone and joint pain.
- 1 Grade II : Moderate - generalized bone and joint pain, stiffness and rigidity, restricted movements at spine and joints.
- 1 Grade III: Severe - symptoms of moderate grading with deformities of spine and limbs, knock knees, crippled or bedridden state.

Grading of skeletal fluorosis :(Radiological examination)⁵⁵

Grade I: Mild - osteosclerosis only.

Grade II: Moderate - osteosclerosis, periosteal bone formation, calcification of interosseous membrane, ligaments, capsules, muscular attachments, tendons.

Grade III: Severe - findings as in moderate with exostoses, osteophytosis and associated metabolic bone disease.

Note: The classification given for skeletal fluorosis is based on radiological findings, whereas the classification of clinical fluorosis is based on clinical examination, which is in fact a mixed presentation of skeletal and non skeletal fluorosis.

CALCIUM RICH FOOD (mg/100 gm)⁵⁶

Ajwayan	1525	Imli	170	Rice bran	67
Til	1450	Bakri ka doodh	170	Bhindi	66
Skimmed milk powder	1370	Karonda	160	Sem	60
Mar (agathi)	1130	Mirch dry	160	Arwi ki dandi	60
Jira	1080	Methi	160	Bara sem	60
Khoa (skimmed buf milk)	990	Sarson-ka-sag	155	Murgi ka anda	60
Whole milk powder	950	Urad dal	154	Bhuna chana	58
Kantewali chaulai	800	Bakri ka gosht	150	Arhar, tender	57
Long dry	740	Haldi	150	Chane-ki-dal	56
Shalgam ka sag	710	Bathua sag	150	Sayan ki phalli	51
Hing	690	Dahi	149	Muli	50
Dhania	630	Pista	140	Zimikand	50
Phool gobee sag	626	Elaychi	130	Sem	50
Bachuva	520	Munakka	130	Fras bean	50
Rai	490	Guar ki phalli	130	Kathal seeds	50
Panner	480	Falsa	129	Lasson	50
Kali mirch	460	Mung	124	Supari	50
Coconut dry	400	Gay ka doodh	120	Kaju	50
Chaulai sag	397	Khajur	120	Amla	50
Chukandar ka sag	380	Kalni sag	110	Atta	48
Methi sag	395	Imli patte	101	Tamator	48
Kaddu ka sag	392	Sarson ki dandi	100	Pyaz (onion) big	46
Ari	380	Akhrot	100	Shakarkand, Sweet Potato	46
Chumli sag (arai keera)	364	Katchua ka anda	93	Chotee gobee	43
Bargad ka phal	364	Chilgoza	91	Bajra	42
Madua (ragi)	344	Moong phali	90	Gehun	41
Chana sag	340	Neembu	90	Wheat gram	40
Gajar sag	340	Kishmish	87	Arwi	40
Samp machli	330	Bel (bael fruit)	85	Pyaz small	40
Kala til	300	Matar roasted	81	Mausambi	40
Lobia	290	Gadhe ka doodh	80	Rusbhary	40
Kulthi (horse gram)	287	Gud (cane)	80	Band gobee	39
Chironji	279	Lauki ka sag	80	Wheat bulgar (parboiled)	37
Mooli ka sag	265	Gajar	80	Amra	36
Rajmah	260	Anjeer	80	Phul gobi	33
Cholai-ki-dandi	260	Matar dry	79	Kharbooja	32
Bhatmas (soyabean)	240	Mung dal	75	Kangni (italian millet)	31
Pan ka patta	230	Lobia	77	Shalgam	30
Badam	230	Arhar dal	73	Mirch green	30
Bhains ka doodh	210	Palak	73	Lehson dry	30
Chana	202	Nimbu bada	70	Malta	30
Moth	202	Shahtoot	70	Suar ka gosht	30
Gendhri	200	Bathak ka anda	70	Lassi	30
Pudina	200	Masur dal	69	Makhan	00
Hara dhania	184	Gai ka ghosht	68		

VITAMIN C RICH FOOD (mg/100 gm)⁵⁶

Amla	600	Bhindi	13
Shalgam ka sag	180	Lehson dry	13
Hara dhania	169	Bachuva	13
Mar (agathi)	135	Bara sem	12
Band gobee	124	Shahtoot	12
Mirch green	111	Ari	11
Chaulai sag	99	Lasson	11
Mooli ka sag	81	Pyaz (onion) big	11
Gajar sag	79	Cholai-ki-dandi	10
Chotee gobee	72	Gadhe ka doodh	10
Chukandar ka sag	70	Bel (bael fruit)	8
Neembu	63	Coconut dry	7
Phul gobi	56	Lobia	4
Malta	54	Pan ka patta	5
Methi sag	52	Anjeer	5
Mirch dry	50	Skimmed milk powder	5
Mausambi	50	Whole milk powder	4
Guar ki phalli	49	Chana	3
Shalgam	43	Imli patte	3
Nimbu bada	39	Gajar	3
Kalni sag	37	Arwi ki dandi	3
Bathua sag	35	Jira	3
Kantewali chaulai	33	Imli	3
Sarson-ka-sag	33	Khajur	3
Rusbhary	30	Samp machli	3
Palak	28	Moth	2
Tamator	27	Pyaz small	2
Pudina	27	Suar ka gosht	2
Sem	27	Gay ka doodh	2
Kharbooja	26	Chane-ki-dal	1
Arhar, tender	25	Kulthi (horse gram)	1
Shakarkand,sweet potato	24	Munakka	1
Fras bean	24	Kishmish	1
Falsa	22	Bhains ka doodh	1
Amra	21	Bakri ka doodh	1
Muli17		Dahi	1
Kathal seeds	14		

COMMONLY USED DOMESTIC DEFLUORIDATION PROCESSES

Various commonly used processes available for defluoridation with basic advantages and disadvantages are given below.

1) Nalgonda process:⁵⁷

It looks a cumbersome technique not suitable for use by less-educated population - the section that needs it the most. The process can be used only for water having a fluoride content of less than 10 ppm and turbidity less than 1500 ppm. There is a high residual aluminum content in output drinking water. It is reported that the residual aluminum ranges from 2.01ppm to 6.86ppm. It is relevant to note that Aluminum is a neurotoxin and concentration as low as 0.08ppm of aluminum in drinking water is reported to have caused Alzheimer's disease. The ISO 10500 for drinking water sets an absolute maximum limit of 0.2ppm for Aluminum, which is well below the minimum reported in the output water, generated by this technique. Also the taste of the output water is generally not acceptable.

2) Activated Alumina process:⁵⁸⁻⁶¹

Reactivation of filter material is cumbersome and it can be done only with the help of trained persons generally not available in most of our villages. This process also results in high residual aluminum in output water ranging from 0.16ppm to 0.45ppm.

3) Other processes:

Processes like Electro-dialysis, Reverse Osmosis etc. require special equipment, a lot of power, specially trained persons to operate, require a lot of maintenance and are very expensive.

4) KRASS Process.⁶²⁻⁶⁵

In this process the fluoride contaminated water is passed through a bed of specially designed filter media to get the defluoridated water.

This process differs from the known processes in its simplicity, cost effectiveness and only traces of residual aluminum in outlet water. There is no limit on fluoride concentration in input water. Temperature, pH, alkalinity and Total Dissolved Solids of input water do not effect this process. It is a practical approach especially for our rural population.

The importance of the process is a defluoridation process, which is easy to use by illiterate villagers, requires minimal involvement of technical personnel, is harmless and is cost effective.

In the process, once the filters are laid the only expenditure is in terms of recharging with alum. This process has been verified by CSIR and PHED of Rajasthan. The large scale field installation of plants of KRASS is under process.

INTERACTION OF FLUORIDE AND ALUMINUM: A CAUSE OF CONCERN?

Aluminum was regarded as neither essential nor toxic to the human body till a few years back. While some studies indicate that relation between aluminum and Alzheimer's disease is not conclusively established⁶⁶, a few recent reports have shown aluminum as a cause of neurotoxicity and bone toxicity⁶⁷⁻⁷¹.

The presence of residual aluminum in drinking water has become a major concern for public health. The present the WHO limit⁷² for aluminum in drinking water is 0.2 mg/L which may undergo further revision due to these reports on neurotoxicity.

ALUMINUM IN WATER

Desirable Limit : 0.03 mg/L

Permissible Limit : 0.2 mg/L

TOXIC EFFECTS OF ALUMINUM⁷³

CNS:	Neuro-toxin, Alzheimer's Disease, Encephalopathy, Impaired Cognitive & motor function, Peripheral Neuropathy, Myopathy,
BONES:	Osteomalacia, Rickets, Pathological fracture
X-ray of BONE:	Non healing fracture, Osteopenia, Reduction in calcified tissue
ALLERGY :	Itchy dermatitis in axilla
RESP. TRACT:	Pulmonary Fibrosis, Asthma, Chronic Bronchitis.
BLOOD:	Microcytic Anemia

Aluminum salts have been commonly used as coagulants in water treatment. A small amount of residual aluminum may remain in treated water. Driscoll and Letterman⁷⁴ reported that approximately 11% of the aluminum input remained in the finished water as residual aluminum and is transported through the distribution system without any significant loss.

Under normal circumstances this residual aluminum forms only a small part of the total daily intake, but this is largely uncomplexed in nature. This uncomplexed form of residual aluminum gets absorbed from gastrointestinal tract in preference to the complexed forms, which are found in other dietary sources

Aluminum compounds are used in most of the defluoridation technologies used on a field scale. The concentration of these compounds for defluoridation is much higher than that required for general coagulation purposes. The Nalgonda technique⁷⁵ of defluoridation, which is largely used for field application in India, involves addition of alum along with lime to the fluoride rich water followed by flocculation and sedimentation or filtration. It has been reported that the treated water from Nalgonda technique contains residual aluminum in the range of 2.1 to 6.8 mg/L under various operating conditions⁷⁶. This concentration of uncomplexed aluminum in treated water for drinking purpose can result in a grave public health problem.

In a recent study⁶³ residual aluminum was analysed in the treated water from activated alumina and KRASS processes. The raw water F in activated alumina process was 24.1 ppm and the treated water showed 1-1.5 ppm F & 0.18-0.45 ppm aluminum in effluent. It was observed that in composite effluent through KRASS process both fluoride and aluminum were in traces for raw water F of 10 & 24.1 ppm.

Fluoride ions in the presence of trace amounts of aluminum form Aluminofluoride compounds and may act with powerful pharmacological effects. Aluminofluoride complexes appear to be a new class of phosphate analogs for laboratory investigations. Experimental data clearly indicate that aluminofluoride complexes stimulate various G proteins (details given below). These metallofluoride complexes may thus mimic or potentiate the action of numerous extracellular signals and significantly affect many cellular responses. With the appearance of acid rain and due to the widespread use of aluminum in industry, there has been a dramatic increase in the amount of reactive aluminum appearing in ecosystems, food, and water sources.⁷⁷⁻⁷⁹ Together with the increase of fluorides now in the environment and food chain, the possibility exists that the near future dangers of fluoride and trace amounts of aluminum would be evident in human race.

G proteins. Knowledge about the role of G proteins in signal transduction has expanded enormously during the last decade, as over one hundred G protein-coupled receptors have been described.^{80,81} G proteins couple membrane-bound heptahelical receptors to their cellular effector systems.

A recent study⁸² revealed that the performance indicators in school children of two villages of Sanganer, Jaipur wherein the drinking water contained the same level of fluoride (approx 6 ppm) but a very different levels of Aluminum (0.03 and 0.11 ppm) were significantly different. The village with higher Aluminum showed a poor performance and also a much higher severity of skeletal fluorosis. This gave strong support to the hypothesis that fluoride and aluminum have synergistic effects, a fact very essential to consider while designing a suitable defluoridation technology.

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