Fluoride and Fluorosis – An Overview

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INTRODUCTION

Systemic fluorosis is an endemic problem in several developing countries (India, Pakistan, Africa, Far-east countries etc.) and has been reported sporadically in other parts (Argentina, Japan, Canada etc.) of the world. In India 17 states are endemic for fluorosis, of these 5 states have indicated hyperendemicity for fluorosis. Rajasthan is one state where all the 32 districts have been identified as endemic for fluorosis. While the WHO and IS 10500 (1991) standards permit [1, 2] only **1.5 mg/L and 1.0 mg/L respectively as a safe limit** for human consumption people in several districts are consuming water with fluoride concentrations of up to **24 - 44 mg/l**.

EXTENT OF PROBLEM

International Status [3]

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 India [3]

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 1991-93 [5]

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 then 1.5 ppm

SOURCES OF FLUORIDE

Fluorine

The disease fluorosis is caused by an element known as fluorine, the 13th most abundant element available in the earth crust. This is halogen group of element, Molecular weight is 19, and Atomic number is 9. Fluorine is the most electronegative of all elements. Fluorine in the free state is a pale yellow gas with a pungent , irritating odour. On cooling it condences to liquid boiling at -188 0C and on further cooling it freezes to a solid melting at -220 0C.

This fluorine exists as a diatomic molecule with a remarkably low dissociation energy (38 K cal/mole) . As a result it is highly reactive and has stong affinity to combine with other elements to produce compounds known as Fluoride.

Sources of fluoride in environment [3]

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:

Flurospar- CaF 2 (Sedimentary rocks, lime stones, sand stones);
Cryolite- Na 3 AlFPO 6 (Igneous, Granite);
Fluorapatite- Ca 3 (PO)2 Ca (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 [6,7]

The fluoride of food items depends upon the fluoride contents of the soil and water used for irrigation, therefore the fluoride contenet of the food items may vary from place to place. The available data indicates that in general the fluoride content of the various food items is as follows (given in decreasing amount of fluoride) :

Cereals > leafy vegetables> pulses> FISH> Meat> Fruits

Few examples of fluoride rich food items are: Water,Tea, Fluoridated toothpaste, Plants and vegetables grown in soil and water rich in fluoride, Pan, Supari,Tobacco, Green garlic, Onion Cabbage, Soyabean, Carrot, Corn,Potato Baking powder, egg, Cows liver & kidney.

Drugs [3]

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.

Air [3]

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 form
1000-4000 ppm.[3]

Other

Inorganic fluoride compounds are used in the production of aluminum and use of phosphate fertilizers.[3]
Apart from the available drinking water supply the bottled mineral water may also be a source of excessive fluoride ingestion. [10]

CHEMOBIOKINETICS AND METABOLISM [11,12,13]

Ingested fluoride is rapidly absorbed through gastrointestinal tract and lungs. The peaks are reached after 30 min in blood. 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. Approximately 90% of the fluoride retained in the body is deposited in the skeleton and teeth. The biological half-life of bound fluoride is several years. Fluoride also passes through the placenta and also appears in low concentrations in saliva, sweat, and milk.

Quantification of fluoride toxicity on human health [14]

Smith & Hodge 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

DETERMINANTS OF THE 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.

CLINICAL PRESENTATIONS

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

1. Acute Fluoride intoxication
2. Chronic Fluoride intoxication

Acute fluoride intoxication [16]

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, diarrohea 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.

Chronic Fluoride Ingetion [3]

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 fluorosis [17]

White opacities, Faint yellow stain, Pitting, chipped off, Black discoloration, Enamel hypoplasia, Delayed eruption.

Incidences of mottled teeth were 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 [18-20]

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, Mucular wasting, Premature aging

Non skeletal manifestations [3]

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

Muscular manifestations : Muscle Weakness & stiffness, Pain in the muscle and loss of muscle power

Urinary tract manifestations : Urine may be much less in volume, Yellow red in colour, Itching in the region of axilla.

Allergic manifestation : Very painful skin rashes, which are peri vascular inflammation. Prevalent in women and children. 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 : Acute abdominal pain, Diarrohea, Constipation, Blood in Stool

Headache

Edentate (Losses Teeth at an early age)

Red Blood cells [3]

It is now known that when fluoride is ingested, it will also accumulate on the erythrocyte membrane, which in turn looses 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 ecchynocytes 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 efficiency [23]

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 thyroid [24]

Fluoride has inhibitory effect on iodine uptake. It have 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 Cancer [25]

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 diabetes [26]

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 lactation [27]

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 proteoglycan [28]

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]

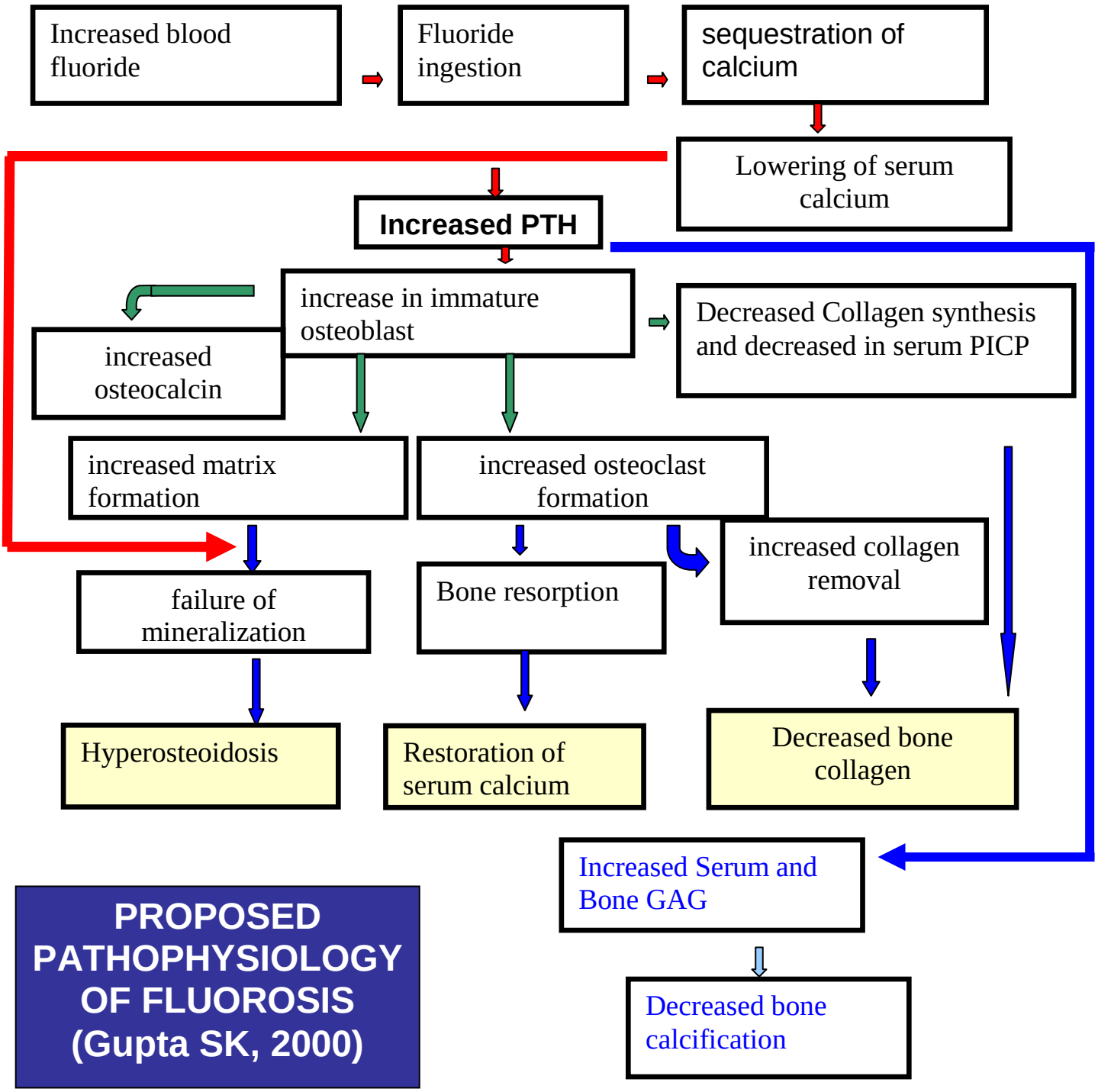
Normally the glycosaminoglycans (GAG) content in normal cancellous bone is three times that in the cortical bone and increases further after chronic F- ingestion. Most of the detected form of GAG was in form of Dermatan sulphate (also termed as chondroitin sulphate B - a sulphated isomer of glycosaminoglycan)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

Based on the changes in ground substance due to high fluoride intake, elevated content of glycosaminoglycans (Mucopolysaccharides[34] - synonymous with the term "Seromucoid" 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]

PATHOPHYSIOLOGY OF FLUOROSIS



Ingestion of fluoride causes decrease in the ionised calcium. This hypocalcemia leads to changes in internal milieu of the body to maintain the calcium levels and leads to secondary hyperparathyroidism. The increased parathyroid hormone causes increased activity of Osteoclasts in bone by activating membrane bound 3'5' Cyclic AMP (30). This increased osteoclastic activity causes, increases in citric acid and lactic acid release from ruffled border of osteoclasts. This causes increase in hydrogen ion concentration, and hence lysis of lysosomes. Release of lysosomal enzymes viz. acid protease, collagenase, hyaluronic acid in bone and other tissues of the body, (31,32) which catalyzes the reactions favoring the depolymerization of the glycoprotein of bone and of cartilage. This causes breakdown of hydroxyproline, which is responsible for stabilization of collagen triple helix (33). As the protein polymer desegregates and dissolves, the mineral-binding capacity is also reduced and calcium is liberated, which helps in maintaining the serum calcium level. As a result the solubility of hydroxyappetite crystals also increases, causing its breakdown. (6,8) along with reduced laying down of collagen by reducing Hydroxylation of proline and lysine. This event simultaneously led to the elevation of the serum mucoprotein or polysaccharide levels (34,35). The net result of degradation of ground substance in, bones and other calcified tissues like teeth leads to symptoms of fluorosis like, delayed eruption of teeth, dental fluorosis, clinical fluorosis, premature aging etc. (36).

DIAGNOSIS

High fluoride contents of the drinking water
Endemicity of the fluorosis in the area
Clinical manifestations of fluorosis in the population: Dental, Clinical, Skeletal fluorosis
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.

Biochemical evaluation
Radiological evaluation
Histopathological evaluations e.g. bone biopsy, muscle biopsy etc.

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 flluorosis 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.

TREATMENT AND PREVENTION

Fluorosis not only affects older persons but there is ample evidence that even newborn baby and children of younger age have also been its victims. It not only affects the body of a person but also renders them socially and culturally crippled. There is a need develop a well thought out strategy to attack this problem which requires an urgent attention from both medical as well as of social workers.

Considerable work has been done all over the world on treatment of Fluorosis. Unfortunately the results indicated that the effects of fluorosis are irreversible. According to the author this condition can be cured, at least in children, by a treatment which are inexpensive and easily available. Numerous people have conducted surveys on the problem of fluoridation and treatment options available for defluoridation processes, but however a safe, efficient and cost effective defluoridation technique / process needs to be developed in order to prevent the occurrence of fluorosis.

To summaries 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, 49-52] 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 al [53] Vitamin D_3 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 deflouridation recommended so far are aimed at bringing the fluoride levels to the WHO standards (Details have been appended in *annexure1).*

Desirable characteristics of defluoridation process

Cost-effective
Easy to handle/operate by rural population - the major sufferer
Independent of input Fluoride concentration, alkalinity, pH, temperature
Not affect taste of water
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

Deflouridation 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

- Restrict use of fluoride rich food
- avoiding use of fluoride rich cosmetics
- Use of food rich in calcium, vitamin C and proteins

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.

Annexure 1

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.