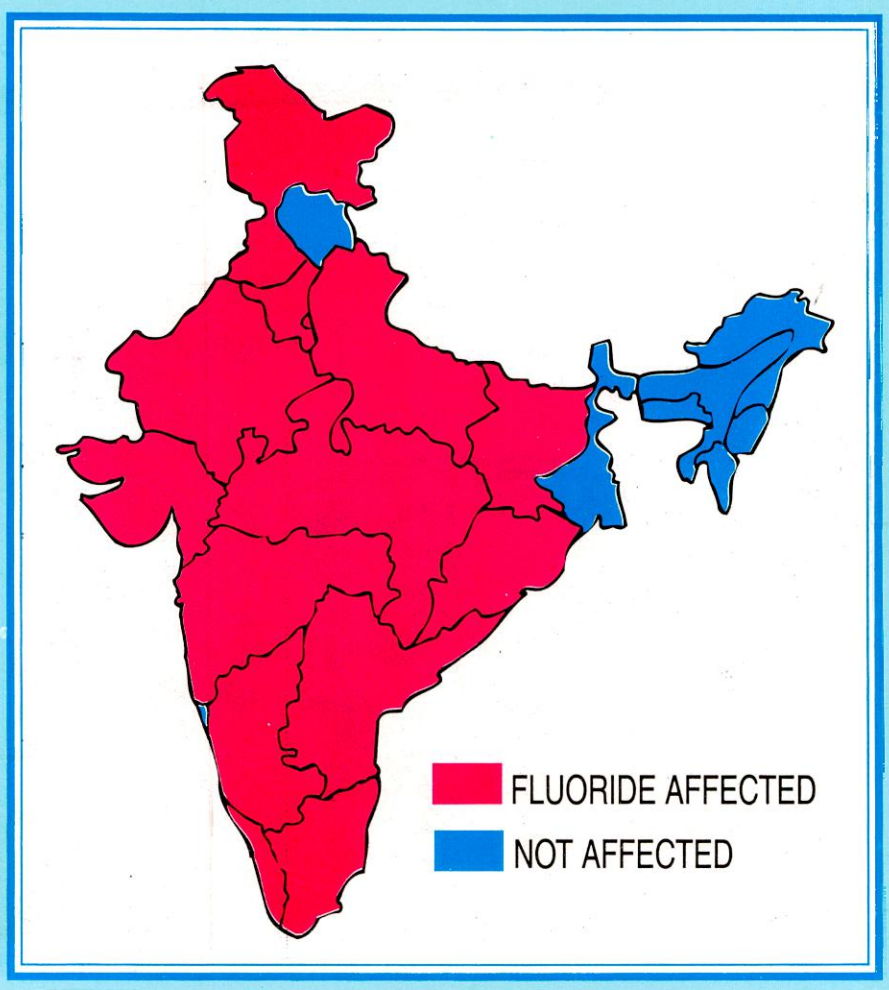
ENDEMIC OF FLUOROSIS



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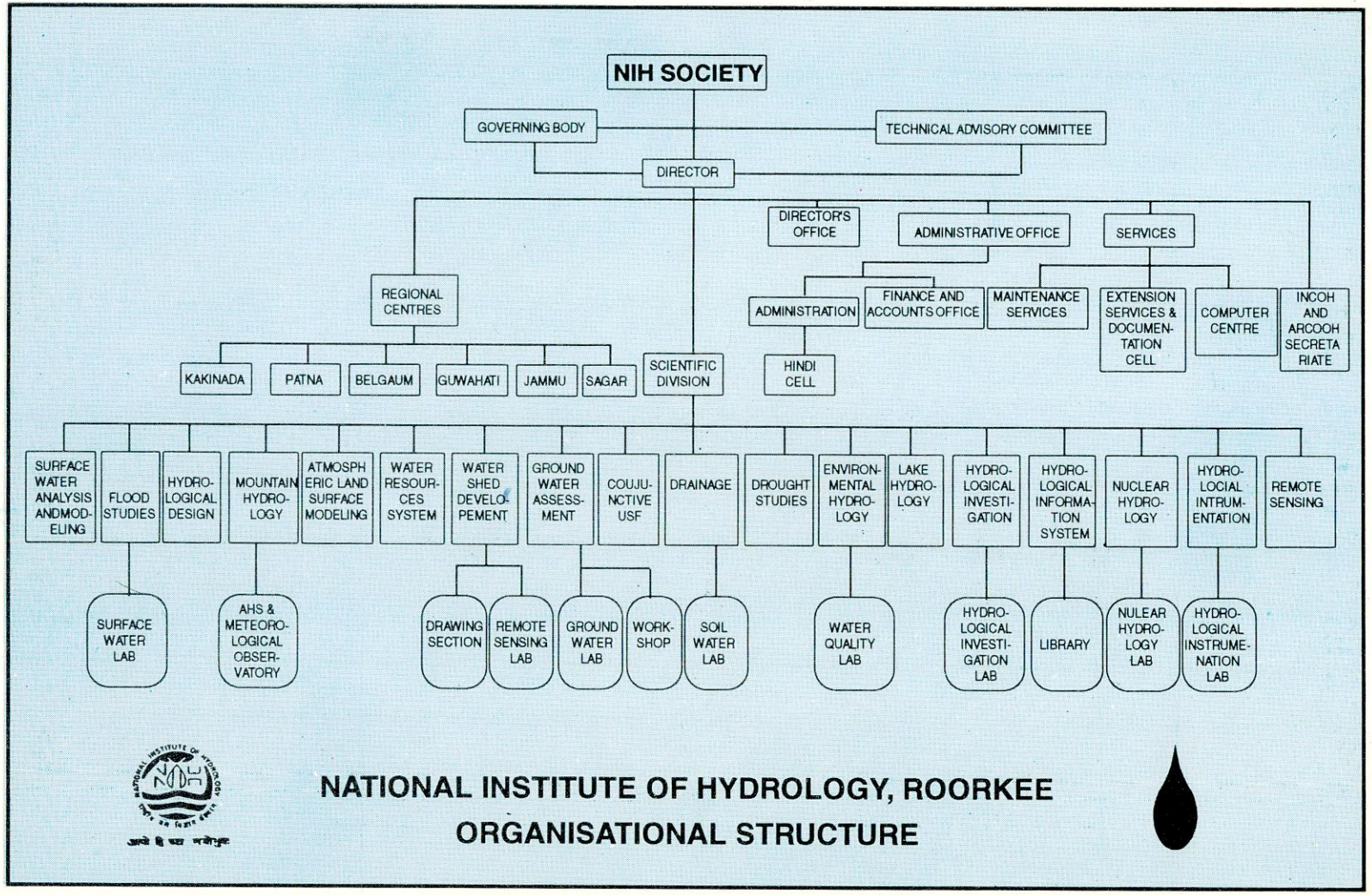

NATIONAL INSTITUTE OF HYDROLOGY, ROORKEE

ORGANISATIONAL STRUCTURE

ENDEMIC OF FLUOROSIS

NATIONAL INSTITUTE OF HYDROLOGY
JALVIGYAN BHAWAN
ROORKEE - 247 667
INDIA

FOREWORD

Water is an integral part of our life and has been well recognised as nectar. Water is nectar but becomes a curse when contaminated by toxic and other fatal contaminants. Therefore conservation and management of both its quality and quantity on sound lines is necessary for general well being of all life. The primary sources of water are the surface water and ground water. The surface water pollution is visible and hence easily detectable whereas ground water pollution is invisible and hence more difficult to detect and manage. Also, the ground water pollution is much difficult a problem as this pollution is known only when significant damage has already been done. The treatment technology for purifying polluted ground water are very costly and still needs more R&D efforts to bring it at operational level.

Fluoride problem in ground water is not a new problem. Many countries in the world have experienced menace of fluoride pollution in water and large number of people have been affected. Causes of this pollution have been well documented. However the main source of fluoride pollution in water has been thought to be natural occurrence and subsequent degradation of the environment. In India fluoride contents upto 90 mg/litre have been reported in Rajasthan, Andhra Pradesh etc. whereas the maximum allowable limit prescribed by Bureau of Indian Standards is 1.0 mg/l. The effects of consuming such high dosages of fluoride contaminated water can be frequently seen in number of areas of Rajasthan where people including new born children have been affected by dental, gut and skeletal fluorosis.

Realising the urgent and crucial need of awareness in this important area, it was considered appropriate to bring out this Information Brouchre. The main purpose of the Information Brouchre Series, to which this Brouchre belongs, is to present information on a topical area as well as to provide information on hydrological technique for the use of interested persons/general public. This Brouchre has been prepared by Dr. K.K.S. Bhatia, Dr. C.K. Jain and Sri M.K. Sharma of Environmental Hydrology Division of the Institute. It is hoped that this series will furnish material of both practical and theoretical interest to water resources engineers and scientists as well as general readers.

(S.M. Seth)
Director,

ENDEMIC OF FLUOROSIS

INTRODUCTION

One of the serious health problems facing the country today is the prevalence of the disease known as fluorosis involving lakhs of people which arises primarily due to excess of fluoride in drinking waters. Fluorosis was first detected in India when the disease was prevalent in four states, viz., Andhra Pradesh, Tamil Nadu, Punjab and Uttar Pradesh. During the Period 1960-1986 nine more states have been identified as endemic for fluorosis. However during 1990-1992 two additional states, Kerala and Jammu and Kashmir have also been identified as endemic for the disease. Thus the total number of states endemic for fluorosis at present are fifteen (Fig. 1).

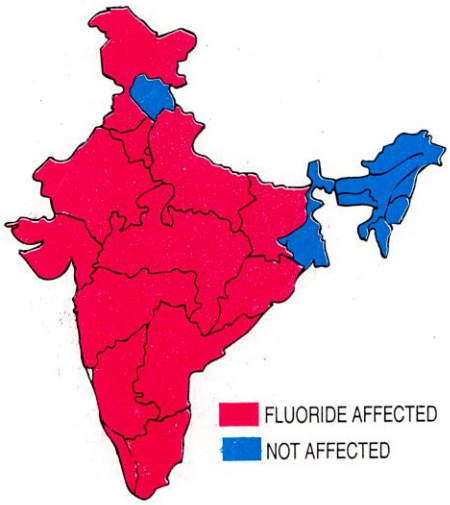

FIG. 1 : MAP OF INDIA SHOWING FLUORIDE AFFECTED STATES

- Andhra Pradesh,
- Bihar,
- Delhi,
- Gujarat,
- Haryana,
- Jammu and Kashmir,
- Karnataka,
- Kerala,
- Madhya Pradesh,
- Maharashtra,
- Orissa,
- Punjab,
- Rajasthan,
- Tamil Nadu, and
- Uttar Pradesh,

In India, more than 76% of the population live in rural areas. The problem of endemic fluorosis occurs with varying intensity in different parts of the country. An extensive survey of the community water supplies has shown that around 25 million people in rural areas consume water with fluoride content more than the maximum permissible concentration of 1.5 mg F/L.

SOME TYPICAL INDIAN EXAMPLES

* Fluoride content upto 20 mg/L have been reported in drinking water in Ananthapur, Nalgonda, Prakasam and Krishna districts of Andhra Pradesh.

* Thirty four percent population of village Gudalur in Tamil Nadu shows mild to severe form of dental fluorosis due to presence of high fluoride content (4.3 to 6.4 mg/L).

* The fluoride content in district Agra in Uttar Pradesh varied from 0.28 to 22 mg/L.

* The fluoride content in drinking water sources of J and K state ranged from 1 to 27 mg/L.

* Ninety percent population of district Doda in J and K are suffering from Dental fluorosis. Sixty percent of persons above the age of 25 years are suffering from gut fluorosis.

* As high as 90 mg/L of fluoride was found in ground water of western Rajasthan.

* The fluoride content in Udaipur District varied from 0 to 11.6 mg/L.

* The fluoride concentration in district Nagpur, Maharashtra varied from 0 to 44 mg/L.

The fluoride content much higher than the permitted maximum limit (1.5 mg F/L) have been found in many areas throughout the world such as USA, Italy, The Netherlands, Spain, France, Germany and Switzerland. The problem is serious in India and other such developing countries because major portion of population living in rural areas have to depend on available ground or surface water sources for their water requirement.

FLUORIDE - A TWO-EDGE SWORD

Fluoride is often called a two-edge sword. Fluoride in small dosages has remarkable influence on the dental system by inhibiting dental carries, while in higher dosages causes dental and skeletal fluorosis.

About 96% of the fluoride in the body is found in bones and teeth. Fluoride is essential for the normal mineralization of bones and formation of dental enamel. Calcium rich constituents of teeth, viz., enamel and dentine have strong affinity for fluoride during the formation of teeth. Fluoride combines with calcium forming calcium fluoroapatite crystals during the mineralization of teeth. The principle sources of fluoride to the physiology of man are water and food.

Fluoride is beneficial to certain extent when present in concentration of 0.8-1.0 mg/L for calcification of dental enamel especially for the children below 8 years of age. Once fluoride is incorporated into teeth, it reduces the solubility of the enamel under acidic conditions, and thereby provides protection against dental carries. At higher concentrations (1.5-2.0 mg F/L) fluoride effects adversely and leads to dental fluorosis. The teeth loose their appearance and chalky black, grey or white patches develops on them. This is known as mottled enamel. In several cases loss of enamel is accompanied by pitting which gives the tooth a corroded appearance.

At still higher concentration (3-6 mg F/L) skeletal fluorosis occurs. The disease affects the bone and ligaments. The effect ranges from stiffness and rheumatism to a permanent crippling skeletal rigidity. Early symptoms are tingling sensation in legs and feet followed by pain and stiffness of the neck. Intakes of 20-40 mg F/day over long period have resulted in crippling skeletal fluorosis.

Out of 6 lakh villages in India, at least 50% have fluoride content in drinking water exceeding 1.0 mg/L. More than one million people in India are affected with skeletal fluorosis and several times more than this figure are exposed to the risk of developing skeletal fluorosis.

The Geological Survey of India has brought out considerable data which reveal that fluorite, topaz, appetite, rock phosphate, phosphatic nodules and phosphorites are wide spread in India and contain high percentage of fluoride. As a result of rich mineral content, fluoride leaches out and contaminates the water and earth soil, thereby contaminating agricultural crops as well. Several natural fluoride bearing minerals identified in India include fluorides, fluorites and cyrolite; phosphates, fluorapatite and wagnerite; silicates and topaz; and mica group, magnesium mica and lithium mica.

The degree of manifestation of fluorosis has been related to concentration of fluoride in drinking water and the period of consumption. In endemic areas fluoride from other sources may intensify the clinical manifestation of fluorosis. Fluoride content of 1.0 mg/L in drinking water has no biological side effects. However in endemic areas around the world various levels of fluoride in drinking water above 1 mg/L have been recorded. Studies in these areas revealed that fluoride level between 1.5 to 3.0 mg/L in the drinking water and consumed over a period of 5-10 years caused mild form of dental fluorosis, between 4-8 mg/L and consumed over a period of 15-20 years caused severe form of dental fluorosis and mild form of skeletal fluorosis, if it exceeded 8 mg/L and consumed over a period of 5-10 years or more caused severe form of dental as well as skeletal fluorosis.

INDIAN STANDARDS

The Bureau of Indian Standards (BIS), formerly known as Indian Standards Institution (ISI), in view of the health problems has laid down the Indian standard as 0.6 to 1.2 mg/L as the desirable limit. The Indian Council of Medical Research (ICMR) has recommended the highest desirable level as 1.0 mg/L and maximum permissible limit as 1.5 mg/L. This means that the body may tolerate fluoride upto a certain limit of 1.5 mg/L depending upon the nutritional standards and body physiology. There will be traces of fluoride in any water sample. Therefore, though ICMR has laid down the upper limit as 1.5 mg/L, it is further specified that 'lesser the better' as the fluoride causes not only the health problem in higher concentration but together are large number of cases where even 0.4 ppm fluoride in drinking water has caused dental fluorosis.

The permissible limits for fluoride content in drinking water recommended by various authorities are given in Table 1.

Table 1. Permissible limit of fluoride in drinking water prescribed by various organisations

Name of the organisation	Desirable limit (mg/L)
Bureau of Indian Standards (BIS)	0.6-1.2
Indian Council of Medical Research (ICMR)	1.0
The Committee on Public Health Engineering Manual and Code of Practice, Government of India	1.0
World Health Organisation (International Standards for Drinking Water)	1.5

Concentrations of fluoride in drinking water in different parts of the country varies from 0.5 to 50 mg/L. Excessive ingestion of fluoride for a prolonged period (six month to several years) causes fluoride toxicity in the form of dental, skeletal and gut fluorosis. The latter is also known as fluoride toxicosis, osteo-fluorosis, hydrolfluorosis, fluoride osteopathies and endemic fluorosis. Fluoride toxicity also affects the soft tissues and the enzyme system but its effect on teeth, bones and gut only are of practical importance.

TYPES OF FLUOROSIS

Presence of fluoride in water is a mixed blessing. It is a unique substance for which there are both lower and upper limits of concentration in drinking water, with identified health effect and benefits for man. In low concentration (less than 0.6 mg F/L) it is recommended for preventive treatment of dental carries, however higher concentrations (more than 1.5 mg F/L) lead to the dental fluorosis or mottled enamel, excessively high concentration may lead to crippling fluorosis.

The fluoride content more than 1.5 mg/L in drinking water lead to the following four three types of fluorosis depending upon the amount of fluoride present in the water.

- Dental fluorosis
- Skeletal fluorosis
- Gut fluorosis
- Combination of the above

Dental Fluorosis

It is an aesthetic and social problem. It develops during the calcination of teeth only if infants and children are exposed to high intake of fluoride (1.5 to 2.0 mg F/L). Normal teeth are translucent, smooth and glossy. The discolouration of the teeth may start from white, yellow, brown to black. The changes are of two kinds. First, the enamel is abnormally opaque and chalky white. White blotchy areas are usually interspersed with areas of more or less normal enamel, a condition which has aptly acquired the descriptive term of mottling. This change is observable at the eruption of the tooth. Secondly, after eruption, an irremovable brown or black pigmentary substance is deposited in the defective enamel. The coloured areas form irregular patches or more regular transverse bands. Dental mottling or discolouration due to fluorosis can be classified into four grades.

Grade-I	:	White opacities, faint yellow lines
Grade-II	:	Grade I + brown stain
Grade-III	:	Brown line, pitting and chipped off edges
Grade-IV	:	Brown, black and fall of teeth

In severe cases of mottling, there is discrete or confluent pitting and the teeth often appear corroded. Carries in the mottled teeth is rare, but the enamel is rather brittle and inclined to chip off in the severe cases (Fig. 2).

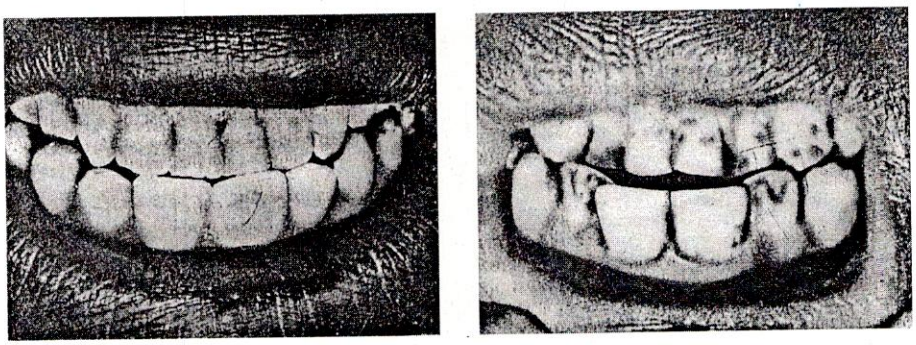

FIG. 2 : EXAMPLE OF DENTAL FLUOROSIS

Symptoms

- Severe pain in the back bone
- Severe joint pain

- Severe pain in hip region
- Stiffness in back bone
- Stiff/immobile joints
- Increased girth
- Constriction of vertebral canal
- Paralysis

SKELETAL FLUOROSIS

Manifestations of skeletal fluorosis are seen in young as well as in adults. The usual complaints are pain in the neck, back, joints and rigidity with restricted movements of cervical and lumbar spine, knees and pelvic joints as well as shoulder joints. In severe cases of fluorosis there is complete rigidity of the joints, resulting in stiff spine described as 'Bamboo spine' and immobile knee, pelvic and shoulder joints. Crippling deformity is associated with rigidity of joints and includes kyphosis, scoliosis, flexion deformity of knee joints, para-plegia and quadriplegia (Fig. 3)

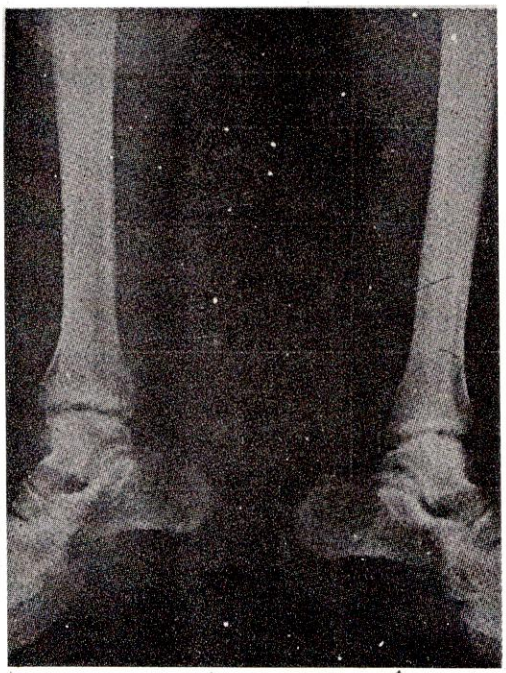

FIG. 3 : EXAMPLE OF SKELETAL FLUOROSIS

Symptoms

- Yellowish white, glittering teeth become dull, loose their shine and develop spots
- Yellow white spots turn brown and present itself in horizontal streaks
- If the brown streak is at the tip of teeth, it indicates that the child has been exposed to high fluoride upto the age of 2 years

- If the brown streak is in the middle of teeth, it indicates that the child has been exposed to high fluoride during 2-4 years
- If the brown streak is in the upper part of the teeth, the exposure has been between 4-6 years of age
- In late stage whole teeth will become black

Gut Fluorosis

Acute abdominal pain, diarrhoea, constipation, blood in stool, abdominal fullness, nausea, vomiting, epigastric burning and mouth sores and loss of appetite are common complaints due to fluoride poisoning. The complaints with gastrointestinal system in the endemic areas are now established as early warning signs of fluoride toxicity. Fluoride is known to combine with hydrochloric acid of stomach and is converted into hydro-fluoric acid which is highly corrosive.

Though gut fluorosis is a very serious disorder, yet it is often overlooked because of wrong notion prevailing that fluoride will only affect teeth, joints and bones. Fluoride when consumed in excess may cause:

- Neurological manifestations: Depression, nervousness, excessive thirst and tendency to urinate frequently
- Muscular manifestations: Muscle weakness, stiffness, loss of muscle power
- Gastro-intestinal problem: Acute abdominal pain, diarrhoea, constipation, blood in stools, feeling of nausea and mouth sores
- Urinary tract manifestations: Urine will be much less in volume, yellow-red in colour, itching in the region
- Headache

PREVENTION AND CONTROL

The most important aspect of prevention and control of endemic fluorosis is to up-date and create awareness among population on fluoride action on body tissues and on the disease itself. While the emphasis should be on community participation to develop and implement water and sanitation programmes in a sustainable way, attention has to be paid to the important role played in this process by the governmental and non-governmental organisations.

There are several methods which have been advocated for defluoridation of drinking water. These methods can be broadly divided into two categories, viz., those based upon the addition of some material to the water during the softening or coagulation processes, and those based upon ion-exchange or adsorption processes.

Adsorption or ion exchange processes are recommended for low concentration treatment. These processes are performed by using lime and alum, bone char and synthetic bone, activated carbon and bauxite, ion exchange, activated alumina and reverse osmosis. Among these materials, activated alumina is supposed to

be the most effective and economic adsorbent for fluoride removal from drinking water in lower concentration range.

Lime and Alum

This method is known as Nalgonda technique. It involves the addition of sodium aluminate or lime, bleaching powder and the filter alum. The chemical reaction involving fluoride and aluminium species is complex. It is a combination of polyhydroxy aluminium species complexation and adsorption of complexes on polymetric alumino-hydroxy floc. Lime or sodium aluminate ensures adequate alkalinity and bleaching powder ensures disinfection. The method has been successfully used for domestic as well as for community water supplies in India.

Aluminium Sulphate and other aluminium salts have also been used for defluoridation of water successfully with insoluble compounds in contact beds or as constituents of floc which is removed by settling and filtration. Fluoride can be removed by the formation of aluminium fluoride complexes by adsorption on the floc.

The operating cost of the Nalgonda technique is also very low. This technique practically removes only a smaller portion of fluoride (18-33 %) in the form of precipitate and converts a greater portion of the ionic fluoride (67-82 %) into soluble aluminium fluoride complex ion, which itself is toxic.

Bone Char and Synthetic Bone

The use of bone material for removing fluoride has long been known but taste problems have been reported to be associated with this kind of treated water. The removal is based on the affinity of bone for fluoride. This affinity may be explained on the basis on anion exchange properties of apatite. The carbonate anion (CO_3^-) present in the bone is replaced by fluoride anion (F) present in the water and fluoride removal accomplished by adsorption together with the formation of fluoroapatite.

Bone char is ground animal bones which have been charred to remove all organic matter. It is considered better than the bone itself because the taste problem of treated water are minimised. However, it has certain drawbacks, viz., arsenic interference and media loss. Arsenic is readily adsorbed on bone char and causes irreversible changes in its structure, ultimately rendering it useless.

Synthetic bone is made by reacting phosphoric acid with lime to produce tricalcium phosphate [$Ca_3(PO_4)_2$] and hydroxyapatite (synthetic bone). It is cheaper than bone char and can be readily produced in the form of coarse granules that are suitable for use. But this material has not been widely used.

A low cost home defluoridator using charcoal and bone char has been developed by Intercountry Centre for Oral Health of the Chulalongkorn University,

Bangkok and the WHO. The device has been successfully tested in the northern Thailand where the natural fluoride concentration in water ranges 3-7 mg F/L.

Activated Carbon and Bauxite

Activated carbon is also used for the removal of fluoride at a pH of around 3.0. The defluoriding activity deceases with constant use of carbon which can be regenerated with 1% alum sulphate. The removal mechanism is an ionic adsorption and fluoride formation insoluble complex.

This method is not effective in the removal of fluorides, since the sites present on the surface of activated carbon are not fluoride specific. Many activated carbons have a very narrow optimal pH range for fluoride removal. The method therefore becomes uneconomic. Use of bauxite is considered superior to that of activated carbon. Although its use is also pH dependent but other chemical species apparently do not normally interfere with fluoride removal with bauxite.

Moreover, fluoride ions have a high affinity for metals, the sites on the surface of non-metallic solids like carbon may have weaker attraction for fluoride than those on the surface of metallic solid, viz., activated alumina and activated bauxite. In solution having high salinity, the activated carbons are not effective for fluoride removal.

Ion Exchange

In this method, fluoride is removed from water with metal chloride silicate in exchange of chloride ions. The effectiveness of the treatment depends upon the concentration of fluoride. The method has certain limitation and is relatively expensive. A major problem is the competition that exists between fluoride ion and other ions present in the water for the ion exchange resin. Amberlite XE-75 has been reported to be quite effective for fluoride removal. Defluoron-2 is reported to have been successfully used in India. It is a cation exchange medium prepared by sulphonating coal, and alum is used for regeneration.

Activated Alumina

Defluoridation by activated alumina is one of the widely used and favoured methods. Activated alumina is a granular, highly porous material, consisting essentially of aluminium trihydrate (Al_2O_3). It is regarded as an excellent material for fluoride removal. Levels as low as 0.1 mg F/L can be achieved. The method is well tried and operates well for most types of waters.

The exhausted alumina can be regenerated by a 2% sodium hydroxide solution followed by neutralization of the excess alkali with dilute hydrochloric acid. It can also be regenerated using dilute solution of filter alum.

Activated alumina is the most effective adsorbent with regard to removal

efficiency and removal capacity among all adsorbents currently in use. The removal by activated alumina is virtually unaffected by salinity and other chemical species such as sulphate and dissolved silica.

It may be noted that the initial fluoride concentration has a direct effect on the fluoride removal capacity. This can be attributed to the utilization of less accessible or energetically less active sites because of increased diffusivity and activity of fluoride when initial concentration of fluoride is increased. The pH and alkalinity of water also has a marked influence on removal capacity. Higher removal capacities can be achieved in water with low pH and low alkalinity.

PREVENTIVE MEASURES

(i) If the water has fluoride content more than 1.5 mg/L, do not use such water for cooking or drinking purpose
(ii) Expectant mothers should always use defluoridated water
(iii) If any symptoms (as desired earlier) are detected, avoid the major source of fluoride intake
(iv) Intake of Vitamin C in large amounts is helpful
(v) Diet should have adequate calcium
(vi) Drinking more milk, calcium rich vegetables like methi, drumstick etc. help
(vii) Pain in back, hip or joints should not be dismissed as casual

SIMPLE METHOD FOR REMOVAL OF FLUORIDE

A simple method for removal of fluoride is employed in the Nalgonda Technique. It involves the use of aluminium salts for the removal of fluoride. This technique can be used for domestic as well as community water supply schemes.

At domestic level, treatment can be carried out in a container (bucket) of 40 L capacity with a tap 3-5 cm above the bottom of the container for the withdrawal of treated water after precipitation and settling (Fig. 4). The first step in the treatment is to get the raw water sample analysed for its alkalinity and fluoride content. These tests can be carried out at the Public Health Engineering Departments. The raw water is then taken in the container and is mixed with the adequate amount of lime or sodium carbonate, bleaching powder and aluminium sulphate (alum), depending upon its alkalinity and fluoride content. Lime or sodium carbonate solution is added first and mixed well with water. Alum dose is than added and the water stirred slowly for ten minutes and allowed to settle for nearly one hour and is withdrawn. The supernatant which contains permissible amount of fluoride is withdrawn through the tap for consumption and the settled sludge is discarded. The amount of alum (in mg/L) required to obtain is permissible limit (1 mg F/L) of fluoride in water at various alkalinity and fluoride levels is given in Table 2. For example, a water having 300 mg/L alkalinity and 5 mg/L of fluoride, the dose of alum will be 507 mg/L (Table 2). For small communities and rural water supply, Fill and Draw type defluoridation plant consisting of hand-operated or power driven

stirring mechanism can be used (Water Supply and Treatment, Akalank Publications, New Delhi, 1997).

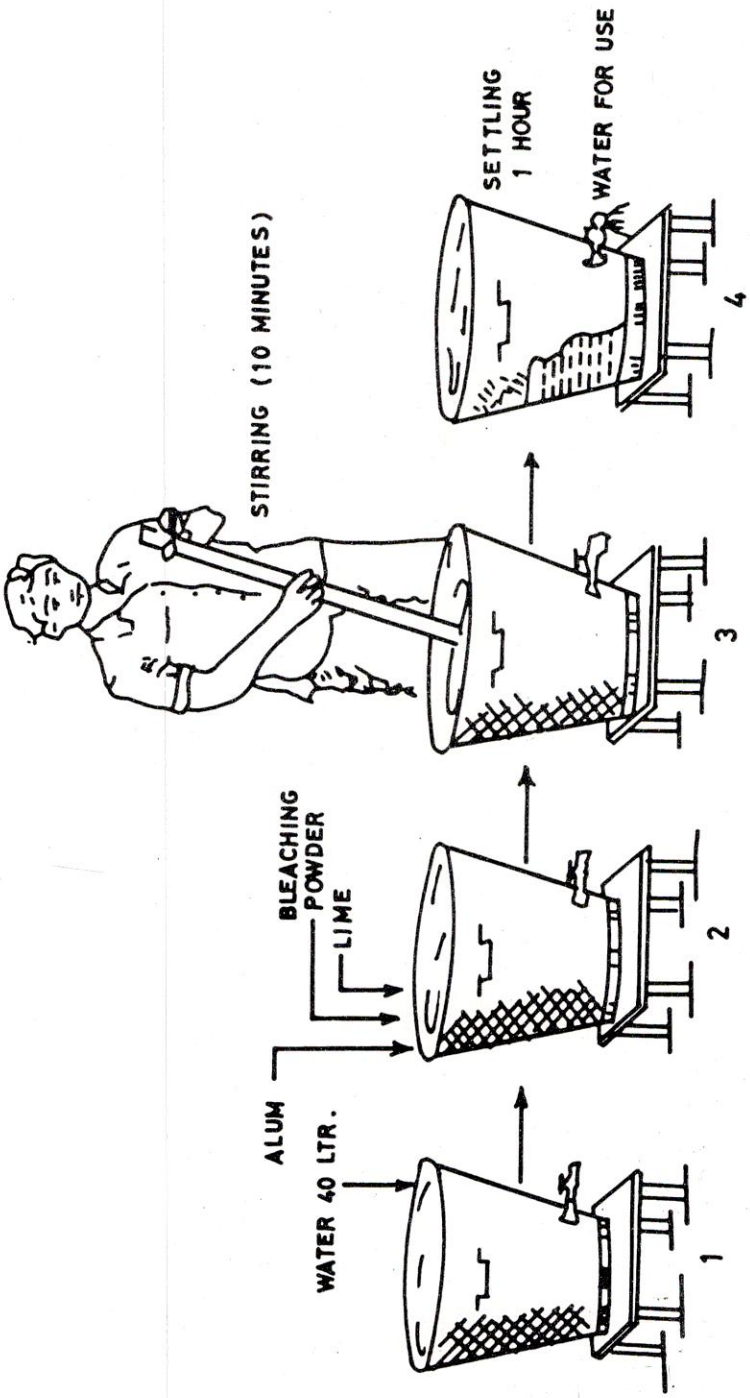

FIG.4: DEFLUORIDATION AT DOMESTIC LEVEL

Table 2. Alum dose for different fluorides and alkalinity levels

Test water Fluoride mg F/L	Test water alkalinity, mg $CaCO_3$/L							
	125	200	300	400	500	600	800	1000
2	143	221	273	312	351	403	468	520
3	221	229	351	403	507	520	585	767
4	*	403	416	468	559	598	689	936
5	*	*	507	598	689	715	884	1010
6	*	*	611	715	780	936	1066	1209
8	*	*	*	*	988	1118	1300	1430
10	*	*	*	*	*	*	1508	1690

Note: *To be treated after increasing the alkalinity with lime or sodium carbonate.

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* In-situ soil salinity measurement
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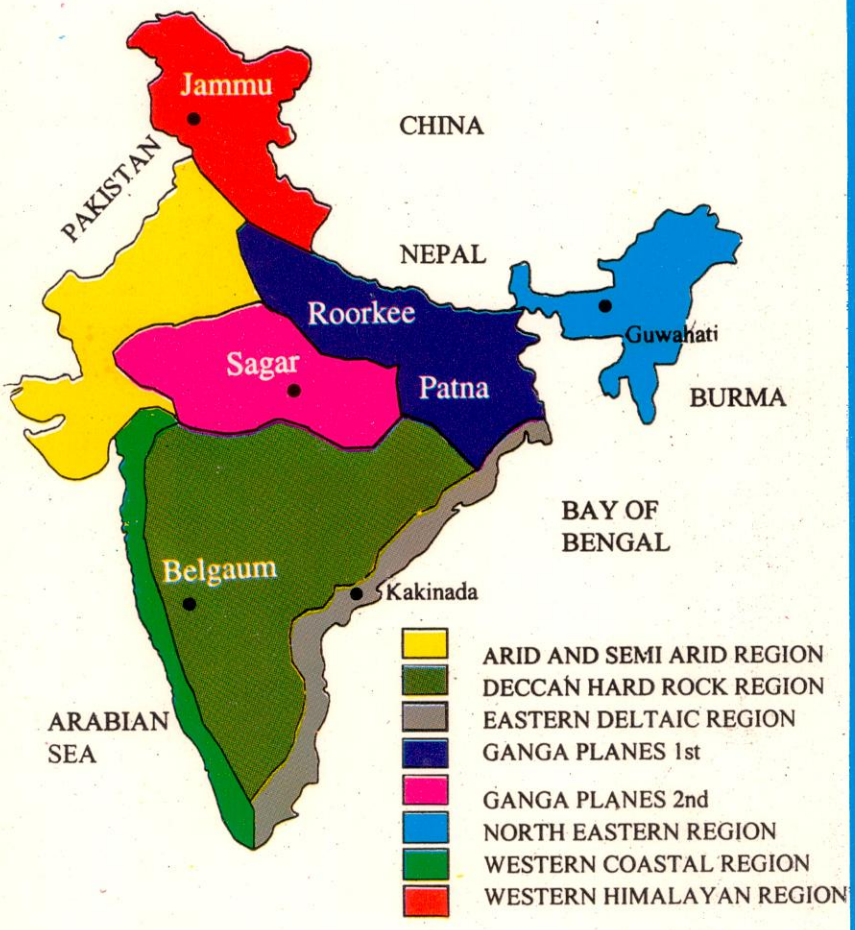

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