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OCCURRENCE OF FLUORIDE IN GUJARAT

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8.1 Properties of fluoride

In a free State it is a pale yellow gas with a pungent, irritating odour. On cooling, it condenses to a liquid boiling at - 188° C, and on further cooling it freezes to a solid melting at - 220° C. It is estimated to be the 13th most abundant element in the earth's crust.

Elemental fluorine exists as a diatomic molecule (consisting of two atoms in a molecule) with a remarkably low dissociation energy (38 K.Cal/mole) as a result, it is highly reactive and has a strong affinity to combine with other elements to produce compounds called fluorides. As the most electronegative of all the elements, fluorine is the strongest oxidizing agent known.

Fluorine was invented by Henri Moissan, Professor of Chemistry at school of Pharmacy in Paris (France) in 1886 for which he got a Nobel prize in 1905.

8.2 Fluorides in the environment

8.2.1 In Soil

Fluorine being the most electronegative of all chemical elements, is never found in nature in the elemental form. It is highly reactive and has a strong affinity to combine with other elements to produce compounds called **Fluorides**. In rocks and soil, fluorine may occur in combined form in a wide variety of minerals, including **Fluorspar, Cryolite, Apatite,** Mica and a number of pegmatites such as Topaz and Tourmaline. Volcanic and Hypabyssal rocks as well as salt deposits of marine origin also contain significant amount of fluoride.

Some fluorine bearing minerals and their probable contents are given below (2).

	Name	Formula	% Fluoride content
A	**Fluorides**		
1	Fluorite	CaF_2	48
2	Sellaite	MgF_2	61
3	Cryolite	Na_3AlE_3	54

B Phosphates

1	Fluorapatite	$Ca_3(PO_4)_3F$	3 to 6
2	Wagnerite	Mg_2PO_4F	5 to 11
3	Amblygonite	(Lina) Al (PO_4) F,OH	12

C Silicates

1	Topaz	$Al(F,OH)_2$ SiO_4	20
2	Vesuvianite	Ca,Mg Silicates with F	3
3	Tourmaline	Borosilicate with F	1.5

D Mica group

1	Muscovite	Potash mica	2
2	Phlogopite	Magnesiun mica	9
3	Lepidolite	Lithium mica	4-8

There is an obvious abundance of fluoride in the world, but most of it is firmly bound to minerals and other chemical compounds and is therefore, not biologically available in its usual form. The availability of free fluoride ions in the soil is governed by the acidity of the soil, the presence of other minerals or chemical compounds and the amount of water present. Fluoride concentrations in soil - increases with depth. In high mountain areas, the fluoride content of the soil is usually relatively low. Owing to the constant erosion of the mountains, the fluoride is removed and like the other halogens, transferred to a lower plateau or to the sea via streams or rivers. This is probably the reason why sea waters has a relatively high fluoride content.

8.2.2 In Water

Owing to the universal presence of fluorides in the earth's crust, all waters contain fluorides in varying concentrations. The fluoride content of water obtained from lakes, rivers or artesian wells is for the most part below 0.5 mg/l. Traces of fluoride occur in many waters and higher concentrations are often associated with underground sources. In areas that are rich in fluoride containing minerals e.g. Fluorapatite, well waters contain high fluoride. Water trapped in sediments since their deposition and thermal waters associated with volcanoes and mineral deposits usually have higher (3 - 6 mg/l) levels of fluorides. Waters with high fluoride content are usually found at the foot of high mountains and in areas with geological deposits of marine origin.

Sedimentary rock (Lime stone and sand stone) and Igneous rock (granite) are responsible for presence of fluoride in ground waters. Fluoride is soluble in pure water at 25°C to the extent of 8.7 mg/l of fluoride. The concentration of fluoride in ground water is attributed to the rocks through which it flows. Granites, which are very coarse grained release fluoride into the water through decomposition.

8.3 Fluoride metabolism

Fluorine being an electronegative element and having a negative charge (F^-) is attracted by positively charged ions like Calcium (Ca^{2+}). Bone and tooth having highest amount of Calcium in the body, attracts the maximum amount of fluoride and is deposited as Calcium Fluorapatite crystals. Considerable amount of fluoride although get bound in the body tissues, some amount is excreted through sweat, urine and stool. The extent of excretion is determined by the level of different hormones and efficiency of kidney function, age of the individual, nutritional status and climatic conditions.

The absorption of most water-soluble fluoride compounds after ingestion is rapid and almost complete and occurs mainly in the stomach. It is passive in nature and no active transport mechanism seems to be involved. When fluoride is taken in conjunction with food, the degree and rate of absorption will decrease. The bioavailability of most dental fluoride preparations is 100%. However if these preparations are taken together with milk products, the bioavailability decreases to about 60 - 70%.

Human blood contains fluorine in both organically bound and inorganic forms. Almost all fluoride in plasma is in ionic form and is not bound to any macro-molecules. Once absorbed, fluoride is distributed within minutes through the extra-cellular fluid to most organs and tissues. The fluoride concentration in most soft tissues is lower than the plasma level except in the healthy kidney where, because of urine production, an occassional fluoride accumulation may result. There is no evidence of binding of fluoride to any soft tissues.

The main route of fluoride excretion is via kidney. The mechanism involved is simple passive diffusion. Both urinary flow and pH are involved in relating the renal clearance of fluoride. High urinary flow and an alkaline urine will result in a rapid clearance of fluoride from plasma while a low urinary flow and an acidic urine will result in a slower renal elimination rate of fluoride. Generally, in an adult 40 - 60% of an ingested dose is found in the urine. Fluoride retention will, in general, be much higher in a child. It is therefore evident that, on a short-term basis, it is the kidney that regulates the overall metabolism of fluoride in the organism. Bone on the other hand, is the corresponding "Organ" for long-term regulation.

The fluoride concentration in saliva reflects that of plasma and is about two-third of the plasma level. There is a limited transfer of fluoride from blood to breast milk.

8.4 How Fluoride acts in the Human System ?

Fluoride is known to act with body tissues in a number of ways.

- Fluoride when ingested or consumed has a tendency to accumulate in almost all the tissues. The highest amount of Fluoride is known to be deposited in one variety of bone-cancellous bone (spongy bone) then the other cortical variety.
- Fluoride is known to inhibit protein-synthesis thereby production of proteins in the body is hampered.
- In the tooth and bone which are hard tissues, the matrices are made up of a special fiber known as collagen protein, on which calcium ions get deposited in a special manner. Fluoride distorts the structure of collagen protein and the process of calcium deposition becomes abnormal and the bone and tooth also become abnormal in their structure and function.
- Fluoride is known to inhibit great majority of enzymes (biological catalyst) and derage the metabolism and as a result many chemical substances are produced in less quantity than that is required. It is also true that certain intermediary products begin to accumulate which is also not a healthy process.
- The chemical machinery of the body is disturbed and the body functions are disturbed too.
- Level of Haptoglobin (Hp) in blood provides information on the susceptibility of a particular individual to the disease. High Hp content in blood is suggestive that the individual is vulnerable to fluoride-toxicity. If the Hp level is low, the individual may not have clinical manifestations even if high fluoride content is ingested or inhailed.
- Biological effects of fluoride in the human body could be summarised as under.

Concentration of F in mg/l	Medium	Effect
1	Water	Dental caries reduction
2 or more	Water	Mottled enamel
8	Water	10% esteoclerosis
50	Food and water	Thyroid changes
100	-- DO --	Growth retardation
120	-- DO --	Kidney changes

8.5 Health Effects

It is considered to be an essential element in some animals for fertility and growth rate improvement in very small dose.

It reduces the solubility of the enamel under acidic conditions and thereby provides protection against dental carries.

Mottling occurs when the level exceeds 1.5 to 2.0 mg/l crippling skeletal fluorosis occurs at high doses for prolonged consumption.

8.6 Fluoride Manifestation

Fluoride when ingested or inhaled in excess can cause several health problems. Some individuals are extremely sensitive to Fluoride and may suffer from mild or severe manifestations. An individual may suffer either from non-skeletal manifestations of skeletal fluorosis or dental fluorosis or a combination of these manifestations.

8.6.1 Non Skeletal manifestations

The following non-skeletal manifestations due to ingestion of Fluoride in excess are known to be present :

- Neurological manifestations
  nervousness, depression, tingling sensation of fingers/toes, excessive thirst and tendency to urinate frequently and excessively
- Muscular manifestations
  muscular weakness, stiffness, muscle spasm and pain in the muscles
- Allergic manifestations
  allergic manifestations can be of various nature; very painful skin rashes which are peri-vascular inflammation has been reported to be common among women and children
- Gastro-intestinal manifestations
  diarrhoea, constipation, acute abdominal pain, nausea and vomitting

  A word of caution in this context is necessary. It should not be misunderstood that the above non-skeletal manifestations are always due to Fluoride Toxicity. Fluoride is one of causative factors. Fluoride was never considered as a causative factor until recent years when researches in the field have provided ample evidence to suggest that Fluoride can cause non-skeletal health problems of the nature mentioned above.

8.6.2 Skeletal Fluorosis

Skeletal Fluorosis affects young and old alike. Fluoride ingested by a mother can accumulate in the skeleton of the growing foetus as there is no placental barrier for Fluoride. There are reports revealing infant mortality shortly after birth with calcification throughout the blood vessels. Fluoride is known to induce calcification of soft tissues viz. ligaments, muscles, tendon and blood vessels.

In India, in endemic States, children at the age of 5 to 6 have revealed classical manifestations of Fluorosis. The major clinical manifestations are severe pain in the backbone[vertebral column], joints and pelvic girdle [hip region]. Calcification of ligaments of the backbone and joints lead to stiffness of the vertebral column and immobile and painful joints respectively. Deposition of Fluoride in the form of calcium fluoroapatite in the skeleton leads to increased girth, thickening and density of the bone. One of the serious repercussions of thickening of bone is constriction of intevertebral foramen [an opening through which the nerves travel to the extremities thus exerting excessive pressure on spinal nerves leading to paralytic condition. There is no treatment or cure for this disease but it can be prevented.

8.6.3 Dental Fluorosis

In Dental Fluorosis, it is possible to identify white or yellow glistening patches on the teeth which may eventually turn brown. The yellow and white patches when turned brown presents itself in horizontal streaks. The brown streaks may turn black and affect the whole teeth and may get pitted, perforated and chipped off at the final stage.

Dental Fluorosis is prevalent in children who are born and brought up in an endemic area for Fluorosis. However, if an individual during adolescence moves from a non-endemic area to an endemic area for Fluorosis, it is unlikely that he/she may get afflicted with Dental Fluorosis but may get afflicted with Skeletal Fluorosis and may also suffer from non-skeletal manifestations. Dental Fluorosis not only poses cosmetic problems but has serious social problems too.

8.6.4 Determinants of Diseases

Fluoride poisoning and the biological response leading to ill-effects depends on the following factors :

- Concentration of fluoride in drinking water; higher the fluoride greater the chances of being afflicted
- Low calcium and high alkalinity of drinking water can also cause severe forms of the disease even if the fluoride concentration are relatively low.

- Total daily intake of fluoride is the cause for concern as the additive of cumulative effect of fluoride results in the disease.
- Duration of exposure to fluoride. It is now established that 6 months to 1 year exposure to fluoride can cause Fluorosis.
- Age of the individual. Low intake of fluoride for a longer duration, will set in the disease as age advances; whereas exposure to high levels of fluoride ingested by a pregnant mother, can lead to the child develop Fluorosis at a relatively young age.
- Fluoride is known to cross the placenta as there is no barrier and it also enters maternal milk. Expectant mothers and lactating mothers are the most vulnerable groups.
- Derangement in hormonal profile either as a result of fluoride poisoning or cause, aggravate the disease. The hormones are: calcitonin, parathormone, vitamin D and cortisol are the important hormones for healthy bone formation and bone function.

The affected individuals are not only a liability on the family and society but also are a drain on the economy of the villages as they are truely unproductive human subjects.

8.7 Routes of exposure

Fluoride enters into the body through a variety of sources. Viz. Water, Food, Air, Medicines and cosmetics.

8.7.1 Water

Fluoride leaches out from the fluoride bearing minerals and contaminates the water. Fluoride present in drinking water would lead to health problems when the concentration of fluoride is greater than 1.5 mg/l. The Bureau of Indian Standards (BIS), in view of the health problems has laid down the maximum permissible standard as 1.2 mg/l for fluoride (IS: 10500 - 1991). Experts however advise that "Lesser the better" as fluoride causes health problems. Crops irrigated with water having high fluoride will also contain high fluoride, which through food will enter the body.

Fluoride ingested through foods appears to be relatively small and constant, hence variations in the total amount of fluoride ingested depends largely upon (a) the concentration of fluoride in the drinking water and (b) the total amount of water ingested. The amount of water ingested is itself dependent upon a number of variables like body size, food habits, environmental temperature and extent of

physical activity. factors which promote increased ingestion of water obviously increase the total fluoride ingested. In addition to the ingestion of water directly, diet also contain high amount of water. Practically all the staples are cooked in water and many of the other food items are eaten with either liquid or semi-liquid containing considerable amount of water.

8.7.2 Food

As the soil and water are contaminated with fluoride, agricultural crops and fodder of live stock have high affinity to absorb fluoride containing salts. Fluoride is stored in different parts of the plant. Different plants are known to behave differently. Some plants store fluoride in leaves, fruits, flowers, grain, stem and tubers.

Various items of food viz. cereals, vegetables, spices, oil, soft drinks, fruits, fish, meat, sugar, salt, dry fruits and a variety of other items have been found to contain fluoride. It is hard to find an item which has no fluoride in it. The fluoride content is more in cooked food compared to uncooked food. It is common knowledge that Indian food is highly spiced and the commonly used spices have a very high fluoride content. Large communities have habit to consume a high quantity of fluoride in the form of chewing either the ereca nut or betal leaf or tobacco, which have a higher fluoride content.

As there is movement of food grains and other agricultural products between different areas, there is considerable possibility that even in non-endemic states health problems exist due to ingestion of fluoride.

It is very well established that fluoride enters the body through various food items. However no more data is available in the country about Fluoride content in various items. The information that is available is based on food analysis of various regions/locations. But data of one region is unlikely to be valid for other regions or locations, because the fluoride content of water and soil varies from location to location.The available data indicates that fluoride content in various food items are given in **Table - 8.1**

8.7.3 Drugs

Fluorine reinforces the action of many chemical molecules and this aspect has been made the element useful in-pharmaceutical industries. The efficacy of a drug frequently depends on how soon the body metabolizes the molecule and terminates its action. By inserting Fluorine at the weak point in the structure of drug, Chemists have made certain pharmaceuticals more resistant to breakdown in the body. thereby reinforcing there action. Some of the most popular Fluorine

containing medications are, Fluorosteroid Fluorouracil, Fluorine containg Antihistaminics, Tranquilizers, Anesthetics and diuretics. Besides, Sodium fluoride either by itself or in combination with Calcium, Vitamin D and estrogen are prescribed for patients of osteoporosis and treatment continues for longtime with a daily dose of 50-80 mg of sodium fluoride per day. Sodium fluoride therapy for otosclerosis is also common. For Dental caries (Cavity formation) fluorine tablets, fluoride mouth rinse, fluoride varnish and fluoride containing tooth-paste are also prescribed and used.

8.7.4 Air

Fluorides are also widely distributed in the atmosphere originating from the dust of fluoride-containing soils, from gaseous industrial waste, from the burning of coal fires, and from gases emitted in areas of volcanic activity.

8.7.5 Industries

A number of industries use hydrofluoric acid and/or fluoride containing salts, in different sections of an industry for one reason or other. The industries use fluoride either as raw material in the manufacturing processes or fluoride arises as a biproduct or it may even be the end product. The industries that use fluoride are

- Aluminium
- Steel
- Enamel
- Pottery
- Glass
- Bricks
- Phosphate fertilizers
- Welding
- Refrigeration
- Rust removal
- Oil refinery
- Plastic
- Pharmaceuticals
- Tooth - Paste
- Chemical
- Automobile

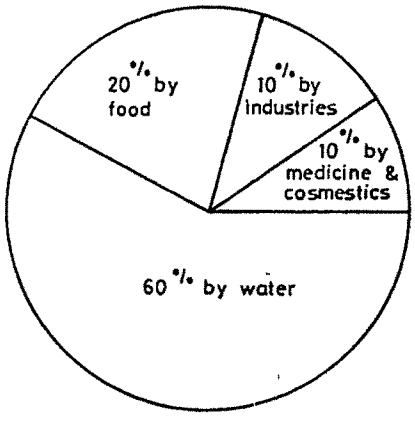
Fluoride dust and fumes, pollute the environment, inhalation of which is as dangerous as consuming fluoride containing food, water and or drugs.

It is now well established that not only the industrial workers get afflicted with skeletal and non-skeletal manifestations, but the people living in the neighbourhood of the industry also get afflicted with fluorosis.

8.7.6 Cosmetics

Almost all brands of toothpastes also contain varying amount of fluoride. 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 material. In the fluoridated brands, there is a deliberate addition of fluoride, which may increase the fluoride level very high.

The mouth rinses that are sold with special brand names, are nothing but fluoridated water of a very high content of fluoride.



Factor contributing fluorosis.

8.8 Prevalence of fluorosis in Gujarat

Incidence of high fluoride and consequent "fluorosis" occurs mostly in the tropical climate areas, contrarory to the fluoride deficiency in temperate climate areas. India being the tropical country is not an exception to this. Several other countries in the world, mostly in Asia, Africa and Latin America (more than 20) are severely affected by the problem of fluorosis. Main reasons for higher incidence of fluorosis in tropical countries are two. One is that the solubility of fluoride in water increases at higher temperature, the other is that total intake of fluoride in body, through water is more. (Due to hot climate).

In India it was detected in Andhra Pradesh in 1930, By 1992, as many as 150 districts of 15 States are reported (Susheela) to be endemic for fluorosis. From the available information on the prevalence of fluorosis, the endemic States could be categories as under.

Category I (Less than 30% of districts affected).

- Jammu & Kashmir
- Delhi
- Kerala
- Orissa

Category II (30 - 50% districts affected)

- Punjab
- Haryana
- Bihar
- Madya Pradesh
- Maharashtra
- Karnataka

Category III (50 - 100% districts affected)

- Uttar Pradesh
- Andhra Pradesh

- Rajasthan
- Tamilnadu
- Gujarat

Thus it will be seen that Gujarat is one of the worst fluorosis affected states in the Country. In addition to the tropical climate of the State following factors are contributing to the high fluoride amount in water.

- Scanty rainfall and poor dilution (recharge)
- Limited perennial surface water sources in affected areas
- Ingress of sea water all along the longest coastal line
- Excessive drawal of ground water for industrial and agricultural uses
- Prevailence of fluoride bearing rocks at many places
- Malnutrition and lack of awareness

Looking at the geohydrology of the State, it is revealed that 47% of the area is having rocky formations. The North Gujarat and Saurashtra-Kutch areas are having the affect of Scanty rainfall and Salinity. These adverse conditions agrevate the problem in State. The problem of fluorosis was first reported in Amreli district of Saurashtra region. Two blocks (Talukas) of this district were experiencing the effects of fluorosis in drinking water. Complaints were received from the people even before the period of independence and arrangements for alternative sources (Sajan-timba regional water supply scheme for 9 villages in Lathi taluka) were made. Having received complaints from many more areas in the State, the Govt. of Gujarat through its Water Supply Board appointed a committee of experts in 1984 to investigate the problem of fluorosis in Gujarat and suggest - remedial measures. The author was the member and Convenor of this committee. The findings of the report revealed that problem of fluorosis was prevalent in many parts and the extent was high in Amreli and Mehsana districts. The committee also - suggested some short term and long term remedial measures which included defluoridation of water. It was also recommended by the committee to carry out a detailed survey and analysis of all sources in the State.

In compliance to the formation of Sub-mission on control of fluorosis under the Water Technology Mission of Govt. of India, the State Govt. also started special drive to control fluorosis. The author had the opportunity to work as the member of National committee on fluorosis control and also Nodal officer for the State activities. Under the water technology sub-mission programme, Health survey, awareness and water analysis (Fluoride estimation) activities were taken up. As a result of this, many of the problem districts were covered. Subsequent to that a detailed survey of all habitation in the State covering all sources of public water supply were covered. Under this survey quality assessment of all sources including fluoride estimation was carried out. Again the author

had the preveledge to work as the **"State Coordinator"** for this survey work. All these assignments provided the author, excellent opportunity of wider exposure to quality aspects of water in Gujarat State with particular reference to fluoride in water. Under the research study also, the fluoride content in all samples collected from various sources was analysed. The results of fluoride content found in the study work are given in **Table - 8.2.** From the various studies, it has been observed that many areas in the State are affected by the excessive amounts of fluoride. As shown in **Table No. 8.3.** The survey carried out under the Water Technology Mission (1991-92) has revealed that except for the Dangs district in the State, all the 18 remaining districts are having effect of fluoride. Out of all the affected districts, Six districts Viz. Banaskantha, Panchmahals, Mehsana, Vadodara, Kheda and Ahmedabad are having more effect of fluorosis. The Survey was carried out for existing sources of public water supply in use only. Many of the villages (about 3000) are covered under regional water supply schemes and hence, though local source may be containing fluoride. Such water is not used by local people and hence actual number of villages affected by fluorosis is considerably less.

8.9 Prevention and control measures

Fluorosis has no treatment, but it can be prevented provided the disease is recognised and detected at an early stage.

8.9.1 Prevention

- Adequate calcium in the diet is one of the most important entities to combat the ill-effects of fluoride poisoning. Calcium reacts with fluoride to form CaF_2 which being large molecule is not absorbed in body but excreted out through faeces. Calcium reach dietary products viz. milk, curd, green leafy vegetables etc. should be consumed.
- Adequate vitamin C (L.ascorbicacid) is an important entity a to meliorate the ill effects of fluoride. Vitamin C promote the production of aminoacids which are the base material of bone and tooth matrix. Amla is an exceptionally rich source of Vitamin C, besides citrous fruits.
- A good balanced diet can combat the ill-effects of fluoride.
- Avoid consuming water contaminated with fluoride more than 1.5 mg/l.
- High fluoride containing products viz. Supari, Tobacco, Black rock salt, Red rock salt, Drugs and cosmetics like toothpaste should not be used.

8.9.2 Control

Individuals already affected and having health problems especially early manifestations, the disease can be controlled by taking following Steps.

- Use of items having sources of fluoride like drinking water, food, drugs, toothpaste, and mouth rinses be avoided.
- Pain in back bone, neck, hip and joints should not be dismissed as casual, hospital intervention should be sought.
- Expectant and lactating mothers who are the most vulnerable groups should only consume defluoridated water.
- Adequate amount of Calcium and Vitamin C in the daily diet be consumed.
- Dental fluorosis causing social and cosmetic problems can be over come by adopting discolouration of the teeth by laminated veneering, capping of the teeth by plastic mould or bleaching.

8.10 Corrective measures taken in Gujarat

Provision of Safe Water (with Fluoride content in permissible levels) from an alternate source or removal of excessive fluoride by suitable method is considered to control the adverse effects of fluoride in water. Following methods are considered for removal of high fluoride from water.

- Diluting high fluoride water with low fluoride water.
- Precipitation of fluoride by chemical method.
- Removal of fluoride by Ion-exchange, and
- Adsorption of fluoride on materials like activated silica.

Out of all these methods, priority based on techno-economical reasons is recommended as under.

- First Priority - is to provide safe water from the good sources that are identified in a village.
- Second Priority - is to provide safe water from the good sources, if it is available in the neighbourhood.
- Third Priority - is to dilute the fluoride concentration by mixing safe water.
- Fourth Priority - is to bring safe water from a distance through pipeline.
- Fifth Priority - is to dig tube wells deeper and there is a chance (50:50) that one may get good water.
- Last Priority - is to remove fluoride (defluoridation).

The State Govt. of Gujarat through its Water Supply Board (GWSSB) which manages the provision of drinking water supply in rural areas has been adopting all the above alternatives to provide safe (with optimum fluoride level) to the communities.

Mention has been made about the Sajantimba regional water supply scheme in Amreli district which was developed to provide safe water from a river source in high fluoride

bearing areas in 1970. Lathi-Lilia scheme in Amreli district for 37 villages under Dutch support is another example of providing safe water to fluoride affected people.

Similarly many other schemes are executed in some of the district details of which with number of villages are given below.

- Amreli - 76
- Rajkot - 17
- Jamnagar - 18
- Sabarkantha - 78
- Banaskantha - 71
- Mehsana - 26

Where alternative safe sources are not available or regional schemes are not feasible, **defluoridation plants** are provided as a **last priority**. 14 defluoridation plants based on community type defluoridation are already installed in the districts of Amreli, Bhavnagar, Mehsana and Kutch. These plants are installed under the financial support of Govt. of India (Rajiv Gandhi National Water Technology Mission - Ministry of Rural Development) and technical collaboration of NEERI (Nagpur) and NIDC (New Delhi). 18 additional defluoridation plants are also sanctioned at a cost of Rs. 10.3 million (1994-95) by Govt. of India, which are under process of erection. Besides, State Govt. has also submitted proposals to Govt. of India (MRD) for providing defluoridation plants for 336 fluoride affected villages (F^- content > 4.0 mg/l) at a cost of Rs. 151.2 million.

The operational and maintenance of such defluoridation plants is looked after by the State Govt. through GWSSB. The maintenance cost for O&M of such plants comes to Rs. 5 to 10 per 1000 liters. of water.

Where defluoridation on community based system is not feasible, or is likely to take more time, particularly due to financial constraints, defluoridation on domestic basis is adopted. 12 villages in Amreli district were taken up on experimental basis where chemicals and guidance (with the support of NGOs) for its use were provided by the Board (GWSSB). Subsequently, as these villages are now included in a regional scheme, defluoridation on domestic basis is not required.

Mehsana is one of the worst affected districts in the state where large number of villages are affected by affect of high fluoride. A regional scheme for 550 villages (including those which are likely to be affected in near future) is posed to the World Bank for financial support and is under consideration by the Bank. It is proposed to provide safe water from Dharoi dam reservoir to these villages.

Simultaneously Training and awareness camps are arranged through out the State by the Board (GWSSB) to caution people about the adverse effects of the menace of fluorosis and also improve knowledge and skill of professionals. People are also advised to adopt preventive measures through use of alternate water sources and improved dietary habits.

The Ministry of Rural Development in Govt. of India under its Rajiv Gandhi National Drinking Water Mission has instituted a sub-mission on **"Control of fluorosis"** to curb the impacts of fluorosis and ameliorate hardship to the people. Under this sub-mission following assistance is provided to various stated affected by fluorosis.

- Provision of funds for developing alternate water supply schemes
- Provision of funds for installing defluoridation plants
- Providing testing equipments to check quality (fluoride level) of water
- Providing funds to create awareness amongst the people to take preventive measures
- Arranging training courses to orient in-service staff for control measures
- Providing technical support where needed through expert agencies/ institutions

The mission directorate is also reviewing the progress of the work at regular intervals.

8.11 Defluoridation

Removal of excess amount of fluoride from water is known as defluoridation. It is considered to be a sound investment when related to the increased cost of dental care, loss of teeth and other health hazards. Numerous substances have been tested and variety of methods devised for removing excess fluoride from drinking water. These processes can be divided into two categories viz. **Precipitation and complexation process (Nalgonda Technique) and Adsorption by fixed bed contact. (Ion-exchange resin or Activated alumina process).** They involve the use of material such as lime, processed bone, tricalcium phosphate, activated carbon, Ion-exchange resin, defluoron-1, defluoron-2, activated magnesia or alumina, serpentine minerals etc. The adsorption methods utilizes the passage of fluoride containing water through a contact bed. Fluoride is removed by ion-exchange resins and adsorption.

Most widely used method for the removal of excessive fluoride at domestic, community and rural water supply levels using precipitation by alumina salts is known as **"Nalgonda Technique"** which is developed by NEERI - Nagpur after extensive testing and observations. This method is simple and economical and recommended for defluoridation by RGNDWM (14).

The mechanism of fluoride removal by Nalgonda technique is a combination of several unit operations and processes incorporating rapid mixing, chemical interaction, flocculation and filtration. Disinfection, if required, could also be accomplished simultaneously. the rapid mixing enables thorough mixing of all chemicals which is provided by an agitator. Consequently, the gentle stirring allows the floc to be formed. Lime or sodium carbonate ensures adequate alkalinity for effective hydrolysis of aluminium salts so that the residual aluminium does not remain in the treated water. it also

accelerates the settling. Bleaching powder is added for disinfection which also keeps the system free from undesirable biological growths. Besides, the removal of fluoride, turbidity, colour, odour, pesticides, organics etc. are also removed by adsorption on the floc. Sedimentation permits the floc loaded with fluoride, turbidity, bacteria etc. to settle. Filter beds will retain unsettled gelatinous flocs. Based on the volume of water to be treated, technique can be applied at the following levels.

- Domestic for individual houses
- Fill and draw type for small communities
- Fill and draw type for rural water supply schemes and
- Continuous flow type for large water supply schemes

Method adopted in Gujarat State for defluoridation is "Nalgonda type". Which is proved simple and acceptable. Schematic diagrams of Domestic level defluoridation, fill and draw type defluoridation and Lay-out plan of Nalgonda Technique or given in **Annexure No. 8.1, 8.2 and 8.3** respectively.

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9. **Fight against fluorosis in Rural Gujarat** by J.M. Barot and M.S. Marfani. Paper published in Journal of Indian Water Works Association - Bombay India. 1986.

10. **Prevention and Control of Fluorosis in India.** Publication of Govt. of India. Ministry of Rural Development (RGNDWM) 1993.

11. **Water quality and Defluoridation Techniques.** Publication of Govt. of India, Ministry of Rural Development (RGNDWM) 1993.

12. **Occurrence of fluoride in ground water in Gujarat.** By S.P. Vyas, Geohydrologist, Gujarat Water Supply and Sewerage Board.

13. **Occurrence of Fluoride in Ground** - Water by S.C. Sharma, Director, Gujarat Water Resources Development Corporation (Govt. of Gujarat), Gandhinagar.

14. **Water Quality and Defluoridation Techniques.** Publication of Govt. of India (RGNDWM), Ministry of Rural Development, New Delhi, Volume - II - 1993.

Table 8.1

Fluoride content in various food items

Sr. No.	Food item	Fluoride in ppm
(A) Cereals		
1.	Wheat	2.5 to 4.6
2.	Rice	3 to 14
3.	Maize	5.6
(B) Pulses		
4.	Gram	3.8 to 14.8
5.	Soyabeen	4.0
(C) Vegetables		
6.	Spinach	0.8 to 4.1
7.	Cabbage	1.2 to 3.3
8.	Tomato	1.0 to 3.3
9.	Brinjal	1.2 to 3.6
10.	Potato	1.2 to 2.9
11.	Carrot	1.9 to 4.9
12.	Onion	1.0 to 3.7
(D) Meat		
13.	Mutton	3.0 to 3.5
14.	Beef	4.0 to 5.0
15.	Pork	3.0 to 4.5
16.	Fish	1.0 to 6.5
(E) Fruits		
17.	Banana	0.8 to 2.9
18.	Dates	4.5
19.	Grapes	0.8 to 1.7
20.	Mango	0.8 to 3.7
21.	Apple	1.0 to 5.7
22.	Figs	4.2

Table 8·1 contd.....

(F) Spices

23.	Cardamom	14.4
24.	Red Paper (Patna)	8.07
25.	Coriander leaves	0.3 to 0.9
26.	Turmeric powder	4.6
27.	Cumin Seed	4.6
28.	Paper (Black)	3.6
29.	Cloves	3.2

(G) Miscellaneous

30.	Areca nut	3.8 to 12
31.	Betal leaf	7.8 to 12
32.	Tabacco	3.1 to 3.8

Table : 8.2

Fluoride content found in Drinking Water Sources of Gujarat during the research study of the author.

Sr No	Location	Village/ City	Taluka	District	F(Mg/l)
1	Milrampura	Walli	Khambhat	Kheda	0.55
2	Lake Water	Saputara	Ahwa	Dangs	0.16
3	Hand Pump	Malegao	Ahwa	Dangs	0.16
4	Satrunji Dam Site	Gariadhar	Palitana	Bhavnagar	1.12
5	Nimeta Head Works	Ajawa	Vaghodia	Vadodara	1.12
6	ESR	Jangaral	Patan	Mehsana	1.0
7	Head Works	Mehsana City	Mehsana	Mehsana	0.57
8	ESR on GH Road	Gandhinagar	Gandginagar	Gandhinagar	0.92
9	Head Works	Kevadia	Rajpipala	Bharuch	0.35
10	WT Plant	Jamnagar	Jamnagar	Jamnagar	0.38
11	Sabarmati Scheme	Vataman	Bavla	Ahmedabad	1.08
12	Mahi French Well	Vadodara City	Vadodara	Vadodara	0.70
13	Tap Water	Amreli City	Amreli	Amreli	0.24
14	Dhadhodar Head Works	Barwala	Dhandhuka	Ahmedabad	1.92
15	Scheme Head Works	Vaghania	Lilia	Amreli	2.8
16	CZBT Head Works	Palej	Bharuch	Bharuch	0.81
17	Dam Site	Ukai	Songadh-Vyara	Surat	0.26
18	Head Works	Kalol City	Kalol	Mehsana	1.84
19	Head works (HW)	Akhol	Deesa	Banashkantha	0.63

contd...Table 8.2

20	Santalpur Scheme (HW)	Shihori	Shihori	Banashkantha	1.73
21	Dudheshwar (HW)	Ahmedabad	Ahmedabad	Ahmedabad	1.0
22	SZBT Head works	Ankleshwar	Ankleshwar	Bharuch	0.59
23	Varachha (HW)	Surat City	Surat	Surat	0.61
24	River -Damanganga	Silvas	Dadara Nagar	Dadra Nagar	0.35
25	ESR - Kalyanbag	Valsad-City	Valsad	Valsad	0.36
26	Tap Water	Pij	Nadiad	Kheda	0.74
27	Tap Water	Bhuj City	Bhuj	Bhuj	1.60
28	RWSS - Banni (HW)	Khavda Fatak	Bhuj	Bhuj	1.15
29	RWWS - Shilakha(HW)	Kumbharia	Rapar	Bhuj	2.6
30	ESR	Godhara City	Godhara	Panchmahal	0.54
31	Tap Water (Nyari Zone)	Rajkot City	Rajkot	Rajkot	0.27
32	Tap water (Aji Zone)	Rajkot City	Rajkot	Rajkot	0.27
33	Tap water	Dabhoi Town	Dabhoi	Vadodara	0.67
34	Private Hand Pump	Idar Town	Ider	Sabarkantha	2.32
35	ESR in Mun. Gardan	Himatnagar	Himatnagar	Sabarkantha	0.48
36	Public Well	Kapurai	Dabhoi	Vadodara	0.53
37	Artisen Well	Dholera	Dhandhuka	Ahmedabad	0.20
38	Kalubhar Head Works	Ranghola	Lathi	Amreli	0.20
39	Umara Head works	Jambusar	Bharuch	Bharuch	1.12

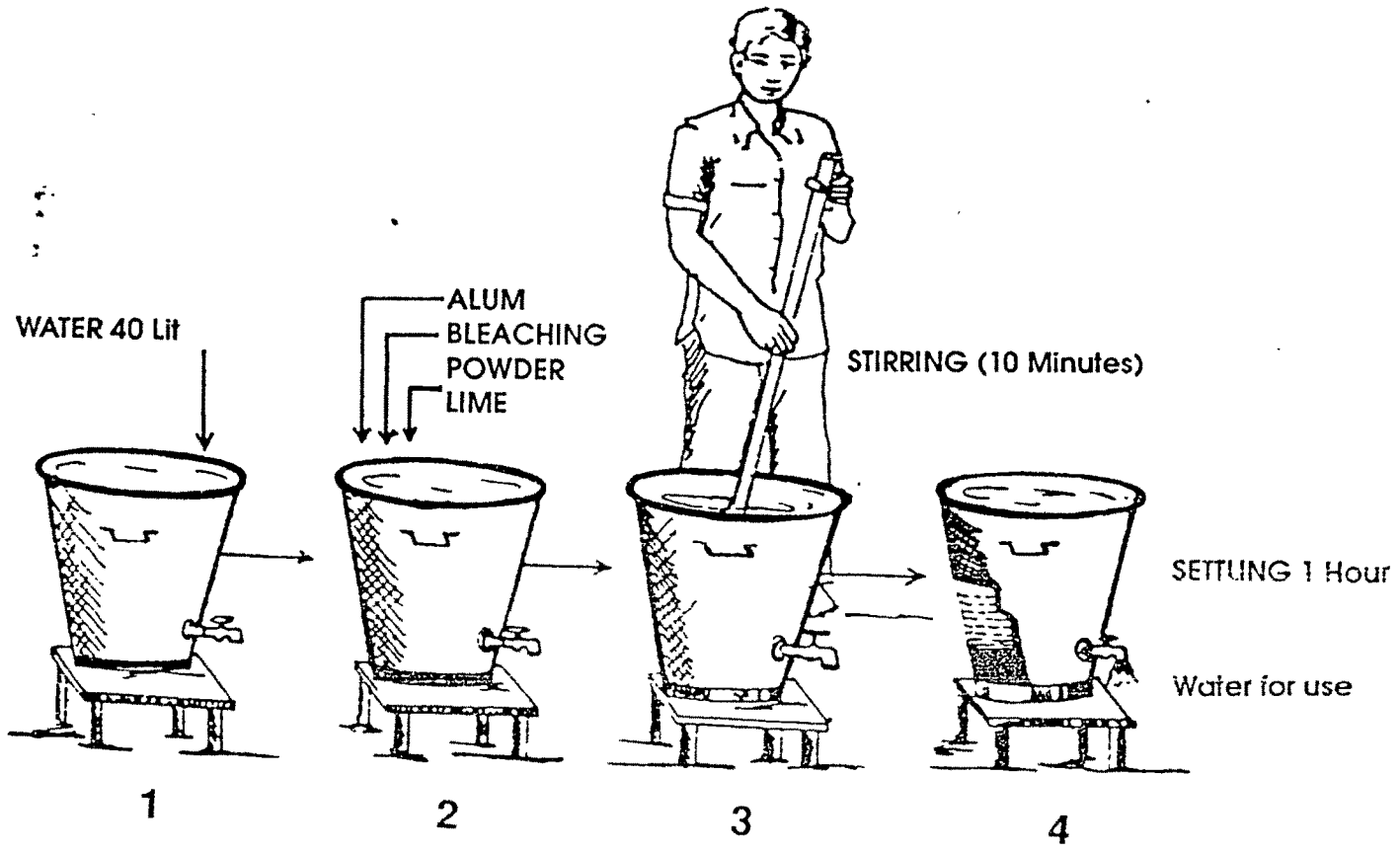
Table 8.3 Villages having excessive amount of fluoride (> 1.5 mg/l)

Sr. No.	District	Total No. of villages *	No. of villages having excessive fluoride	Highest amount reported (mg/l)
1.	Ahmedabad	786	173	10
2.	Amreli	623	70	7.5
3.	Banaskantha	1556	386	12.9
4.	Bharuch	1123	26	8.2
5.	Bhavnagar	919	75	5.5
6.	Dangs	311	NIL	--
7.	Gandhinagar	98	20	2.8
8.	Jamnagar	693	11	4.5
9.	Junagadh	1071	48	4.8
10.	Kheda	973	178	6.6
11.	Kutch	997	4	3.2
12.	Mehsana	1046	301	12.75
13.	Panchmahals	1895	311	6.4
14.	Rajkot	854	15	5.6
15.	Sabarkantha	1847	310	5.45
16.	Surat	1190	23	5.25
17.	Surendranagar	652	41	3.6
18.	Vadodara	1651	261	7.6
19.	Valsad	826	14	3.0
	TOTAL :	**19111**	**2267**	

Note :

1. *Including hamlets having separate source of water (1991-92).
2. Information taken from Rajiv Gandhi National Drinking and Water Survey.

DEFLUORIDATION AT DOMESTIC LEVEL



N.B. in actual practice, there is only one bucket, where the mixing of alum and lime takes place

Annexure 8·2

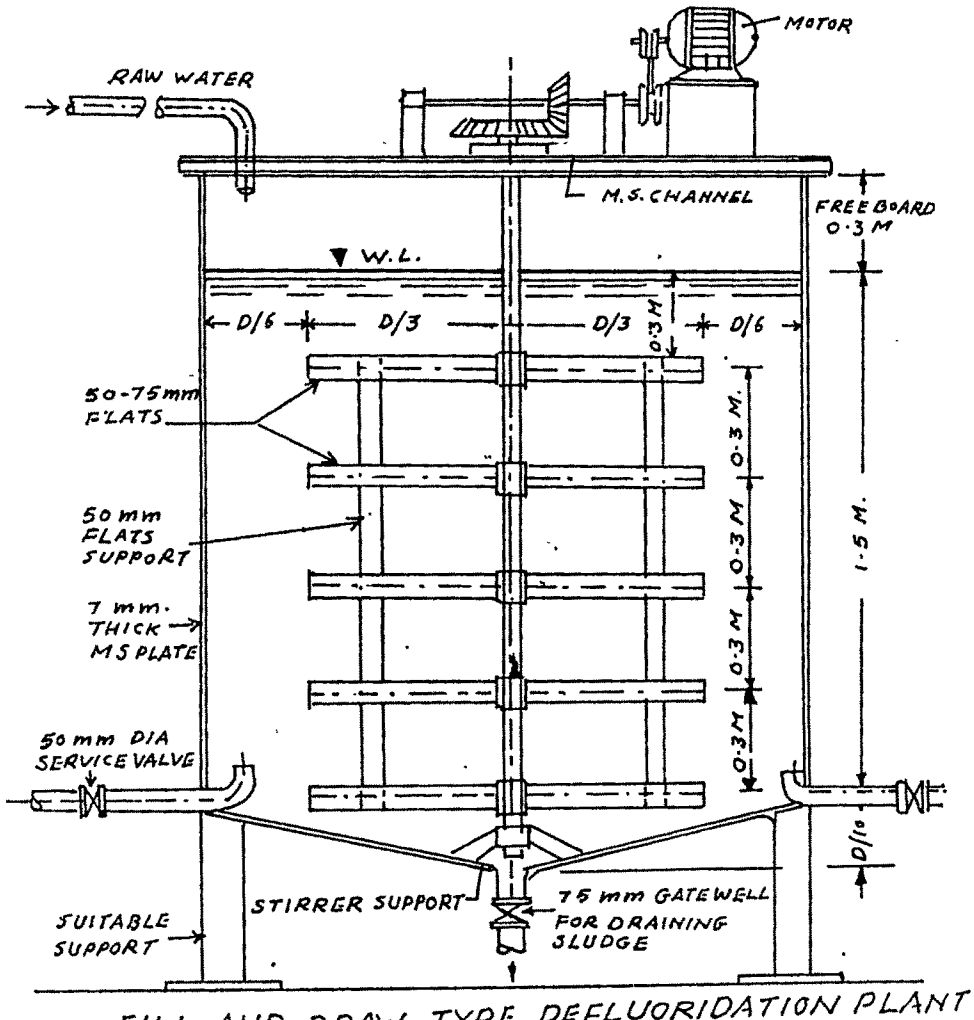
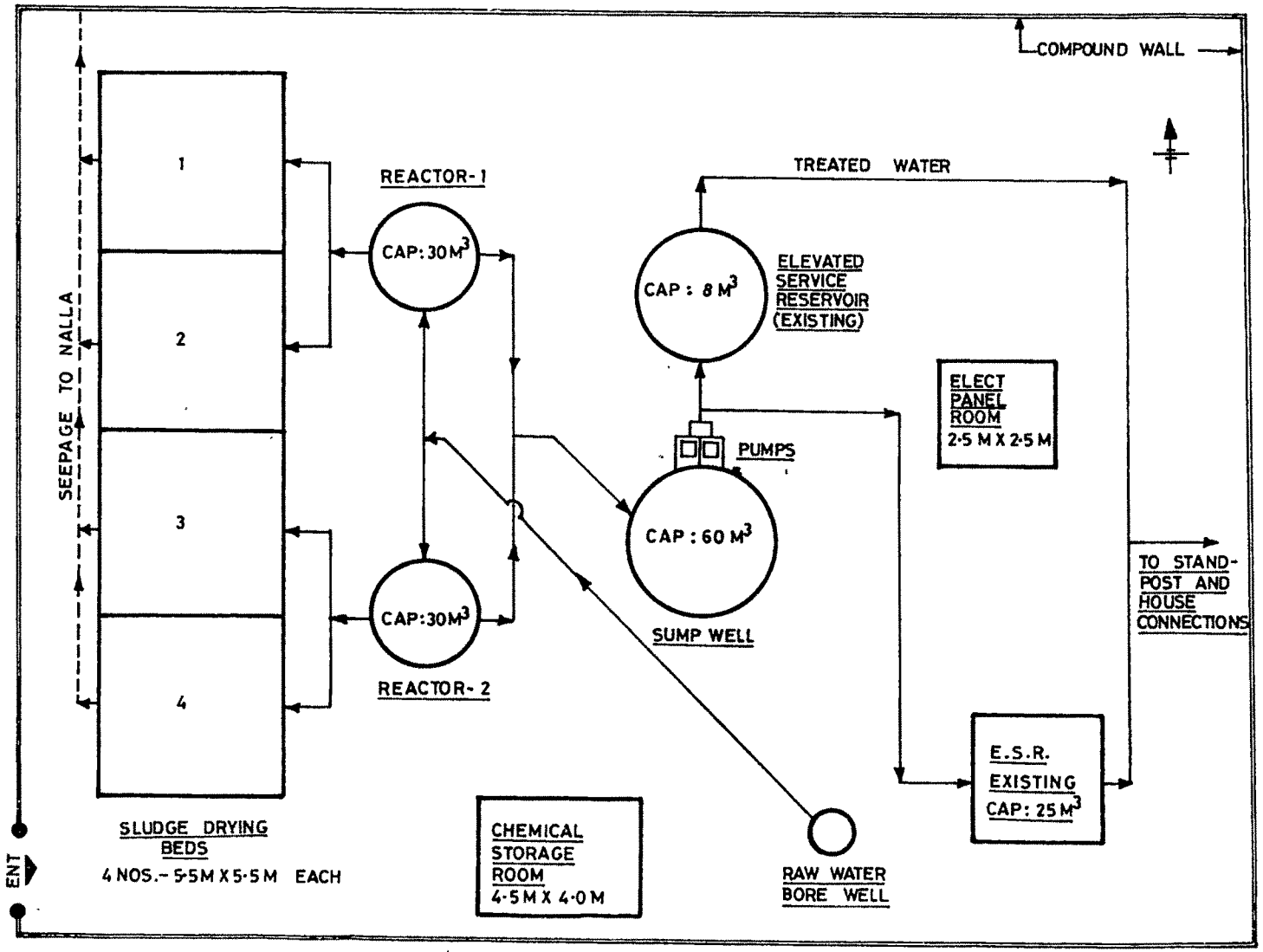


Figure - II

Courtesy: NEERI - Nagpur.



SCHEMATIC LAYOUT PLAN OF FAILL AND DRAW DEFLUORIDATION PLANT IN GUJARAT