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Review on Defluoridation Techniques of Water

[1]piddennavar Renuka, [2]krishnappa Pushpanjali,
[1] *Senior Lecturer, Dept of Public Health Dentistry, ACP Dental College and Hospital Dhule, Maharastra, India*
[2]*Proffesor and Head, Dept of Public Health Dentistry, MS Ramaiah Dental College and Hospital Bengaluru, Karnataka, India*

Abstract

Fluoride is often described as a 'double-edged sword' as inadequate ingestion is associated with dental caries, where as excessive intake leads to dental, skeletal and soft tissue fluorosis- which has no cure. Considering the fact that fluorosis is an irreversible condition and has no cure, prevention is the only solution for this menace. Providing water, with optimal fluoride concentration is the only way by which the generation yet to be born can be totally protected against the disease. Defluoridation was the conventional and widely tested method for supplying safe water to the fluorosis affected communities. Various techniques and materials were tried throughout the world for defluoridation of water. Defluoridation techniques can be broadly classified in to four categories; Adsorption technique, Ion-exchange technique, Precipitation technique, and Other techniques, which include electro chemical defluoridation and Reverse Osmosis. This paper discusses various defluoridation techniques used across world and current status of defluoridation in India.

Key words: Defluoridation techniques, Defluoridation materials, Endemic fluorosis.

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I. Introduction

Fluoride is often described as a 'double-edged sword' as inadequate ingestion is associated with dental caries, where as excessive intake leads to dental, skeletal and soft tissue fluorosis- which has no cure. In fact, the famous 'McKay's discovery' of the connection between excessive content of fluoride in water and endemic mottling of the enamel was one of the main starting points of research into fluorides related hard-tissue physiology and pathology [1]. Water is a major source of fluoride intake. Optimum fluoride concentration in drinking water may be defined as "the one that can arrest the prevalence of dental caries sans causing a insignificant amount of fluorosis"[1]. The 1984 WHO guidelines suggested that in areas with a warm climate the optimal fluoride concentration in drinking water should remain below 1 mg/l (1ppm or part per million), while in cooler climates it could go up to 1.2 mg/l.The latest information shows that fluorosis is endemic in at least 25 countries across the globe (fig.1). Known fluoride belts on land include: one that stretches from Syria through Jordan, Egypt, Libya, Algeria, Sudan, Kenya and Tanzania, and another that stretches from Turkey through Iraq, Iran, Afghanistan, India, northern Thailand and China. There are similar belts in the Americas and Japan [2].

The global prevalence of fluorosis is reported to be about 3.2% [4]. The total number of people affected is not known, but a conservative estimate by UNICEF would number in the tens of millions[3]. Wang Hongtao estimated that in the order of 80 million people worldwide suffer from fluorosis [5]. The highest fluoride concentration ever found in natural water was 2800 mg/l, recorded in Lake Nakuru in the Rift valley in Kenya [4]. Shortt and his colleagues first described it in parts of the erstwhile Madras Presidency. Subsequently, fluorosis was recognized as an endemic problem in large belts of Andhra Pradesh [6] and Punjab [7]. In 1993, 15 of India's 32 states and union territories were identified by UNICEF as endemic for fluorosis.[5] National Oral Health Survey and Fluoride mapping 2002- 2003 analyzed the drinking water samples from 14 states and 3 union territories for fluoride levels [8]. Considering the fact that fluorosis is an irreversible condition and has no cure, prevention is the only solution for this menace. Providing water, with optimal fluoride concentration is the only way by which the generation yet to be born can be totally protected against the disease [9]. It can be achieved by the following methods:

- Removal of fluoride from water (defluoridation), using suitable techniques.
- Locating alternative sources of safe water.
- Bringing in water from a distant, safe source.
- Prevention of industrial fluorosis by rigorous enforcement of procedures for minimizing industrial fluoride pollution.

II. Defluoridation Techniques.

Defluoridation was the conventional and widely tested method for supplying safe water to the fluorosis affected communities. Defluoridation is defined as, 'the downward adjustment of level of fluoride in drinking water to the optimal level'[10]. Various techniques and materials were tried throughout the world for defluoridation of water.

Defluoridation techniques can be broadly classified in to four categories;[11]

1. Adsorption technique
2. Ion-exchange technique
3. Precipitation technique
4. Other techniques, which include electro chemical defluoridation and Reverse Osmosis.

Table 1 shows various materials used as defluoridation agents in these four techniques.

2.1 Adsorption technique of defluoridation

This technique functions on the adsorption of fluoride ions onto the surface of an active agent. Activated alumina, activated carbon and bone char were among the highly tested adsorbing agents.

2.1.1 Activated Alumina

Application of domestic defluoridation plant, based on activated alumina, was launched by UNICEF in rural India[11]. IP grade aluminium hydroxide has some specifications which when not fulfilled are thrown as spoiled batch, which can be procured and used in this technique [12]. Herschel S. Horowitz and Stanley B. Helfetz, in 1972 discussed about a successfully functioning, activated alumina community defluoridation plant, which was commissioned in Bartlet, Texas, USA in the year 1952 [13]. The plant could achieve a marked reduction in the prevalence and severity of dental fluorosis. The disadvantages with activated alumina are;[14] Adsorption of fluoride is possible only at specific pH range, needing pre-and post- pH adjustment of water. Frequent activation of Alumina is needed, which make the technique expensive. Regeneration generates concentrated fluoride solution, causing disposal problems. Adsorption efficiency of the activated alumina diminishes with increasing number of usage-regeneration cycle.

2.1.2 Bone char

Ms. Nutthamon Fangsrekam described the process of Defluoridation by bone char as the ion exchange and adsorption between fluoride in the solution and carbonate of the apatite comprising bone char [15]. The efficacy of the plant depends upon temperature and pH of raw water; duration for which the bone-char is in contact with raw water. The maximum amounts of fluoride adsorbed per gram of bone char surface at 25^o, 35^o and 45^o C are about 21.1, 22.4, and 25.7 μ mol respectively. The optimum time for the adsorption to reach saturation is 9 hours and optimum pH of fluoride solution is between 7.00 and 7.50. Particle size has trivial effect on the adsorption of fluoride. If Calcium is present in the raw water, it precipitates out the fluoride. It is a highly economic technique with a defluoridation percentage of 62 to 66 [15]. Further, the efficiency of the bone-char method of water defluoridation can be improved by pre-treating the raw water with Brushite and Calcium hydroxide[16]. Herschel S. Horowitz et al [17] in 1972 discussed the effectiveness of a defluoridation plant, which used bone char as the active ingredient and was functioning since 1948 in Britton, USA. It caused significant reduction of dental fluorosis in the local communities. Disadvantages of this technique are; The bone char harbors bacteria and hence unhygienic. Without a regular fluoride analysis, nothing indicates when the material is exhausted and the fluoride uptake is ceased. It is a technique sensitive procedure, since the efficiency of bone char as an adsorbent for fluoride is a function of the charring procedure which should be done cautiously. Moreover, the use of bone-char may invite cultural and religious objections [18].

2.1.3 Brick pieces column

The basic principle of functioning of Brick piece column is the same as that of activated alumina. The soil used for brick manufacturing contains Aluminium oxide. During burning operation in the kiln, it gets activated and adsorbs excess fluoride when raw water is passed through. Replacement of filter media is required once in three months if fluoride content in raw water is 2.50 mg/l. In places where high alumina content soil is available, brickbat filter may be one of the options [11].

2.1.4 Mud pot

The raw pots are subjected to heat treatment as in the case of brick production. Hence the mud pot also will act as an adsorbent media. As per treatability-study results a marginal reduction in water fluoride level from 1.8 ppm to 1.5 and 1.4 ppm at the end of 2 days and 4 days respectively, which is practically not significant. The water pH was raised from 7.7 to 8.11 and 8.14 the end of 2 days and 4 days respectively, which is beyond the acceptable limits of alkalinity. The fluoride removal capacity will vary with respect to the alumina content present in the soils used for pot production, which is beyond the control of manufacturer. So, in a practical sense the use of mud pot for defluoridation is not promising. However, people can be advised to use mud pots to store water that is treated by other techniques, which results in partial defluoridation. The major advantages of mud pots are they are economic and readily acceptable for the rural communities [11].

2.1.5 Natural adsorbents

Many natural adsorbents from various trees were tried as defluoridation agents. Seeds of the Drumstick tree, roots of Vetiver grass and Tamarind seeds were few among them. The seeds of the drumstick tree (*Moringa oleifera*) adsorb fluoride from water. Drumstick seeds act as a coagulant. They have long been a traditional method for purification of turbid water in both India and Africa. Researchers at ‘M. S. Swaminathan Research Foundation’ (MSSRF) had shown drumstick seeds to have remarkable defluoridation efficiency, which was higher than that of activated alumina. But, these results were not reproducible. The roots of Vetiver grass (*Vetiveria zizanoides*) are another product that have traditionally been used for water purification. The roots were effective at defluoridation and could remove as much as 70% of the fluoride from a sample. The defluoridation efficiency was higher than activated alumina, and the price was comparable. But, the quantity of grass needed is so high that, a family would need to rise acres of Vetiver grass every year in order to provide enough material for defluoridation [19]. Tamarind seeds were successfully tested for defluoridation by sorption. Since maximum defluoridation is achieved at an optimum pH of 7, post defluoridation pH adjustment is not required. Tamarind seeds, which are otherwise considered a kitchen-waste, can be obtained at much cheaper price [20].

2.2 Defluoridation by Ion-Exchange technique

Synthetic chemicals, namely, anion and cation exchange resins have been used for fluoride removal. Some of these are Polyanion (NCL), Tul-sion A - 27, Deacedite FF (IP), Amberllte IRA 400, Lewatit MIH - 59, and Amberlite XE – 75 [21, 22, 23,]. These resins have been used in chloride and hydroxy form. The fluoride exchange capacity of these resins depends upon the ratio of fluoride to total anions in water. The capacity of Amberlite XE 75 was found to be approximately 88 g/m^3 when fluoride to total anion ratio was 0.05. The capacity increased with increasing ratio. Polyanion removed fluoride at the rate of 862 mg/kg and 1040 mg/kg with initial fluoride concentration of 2.8 and 8.1 mg/L, respectively. Deacedite FF (IP) and Tulsion A - 27 could treat 2270 L and 570 L of water bringing fluoride level from 2.2 to 1.0 mg/L. Benson et al. (1940) used ion exchange process in which sodium ions were removed from the solution by cationic material. The hydrogen fluoride was removed during the second stage. A 10 mg/L fluoride solution was reduced to below 1 mg/L when 2 bed pairs were used in series. Popot et al. (1993) used aluminium form of the amino methyl phosphonic type ion exchanger for fluoride removal. However, the presence of sulphates (100 mg/L) and bicarbonates (200 mg/L) reduced the fluoride removal capacity of the resins to 33%. The resins increased the concentration of chloride in treated water, which can cause corrosion of the water storage utensils. The treated water also had high pH. Staebler (1974) used Amberlite IRA-400, an ion exchange resin consisting of an 8 % cross linked polystyrene matrix of trimethyl benzyl ammonium type for fluoride removal. The basic nature of the material increased the pH of the solution from 6.4 to 11.6. The chloride resins, once exhausted or saturated with fluoride, can be regenerated to their original form by passing a 4 % solution of sodium chloride followed by washing with distilled water until the elute is free from excess chloride ions. However, the regeneration process of cation and anion exchange resins required large volumes of regenerant. The waste produced is also very large. Further, the resins are very complex, contamination prone and expensive [4].

2.3 Defluoridation by Precipitation technique

The two major drawbacks of Ion-exchange and adsorption techniques are: The necessary flow through system is often difficult to arrange where there is no piped water supply and gradual exhaustion of the active agent is not easily detected. In an attempt to overcome these problems the precipitation techniques have been developed [24]. Precipitation methods are based on the addition of chemicals (coagulants and coagulant aids) and the subsequent precipitation of a sparingly soluble fluoride salt as insoluble fluorapatite [11]. Fluoride removal is accomplished with separation of solids from liquid. Aluminium salts (eg. Alum), lime, Poly Aluminium Chloride, Poly Aluminium Hydroxy sulphate and Brushite are some of the frequently used materials in defluoridation by precipitation technique [11, 24]. The best example for this technique is the famous Nalgonda technique of defluoridation.

2.3.1 Nalgonda technique

After extensive testing of many materials and processes including activated alumina since 1961, National Environmental Engineering Research Institute (NEERI), Nagpur has evolved an economical and simple method for removal of fluoride which is referred to as ‘Nalgonda Technique’ (Nawlakhe et al 1974)[1, 40]. Nalgonda Technique involves addition of Aluminium salts, lime and bleaching powder followed by rapid mixing, flocculation, sedimentation, filtration and disinfection. Aluminium salt may be added as aluminium sulphate (alum) or aluminium chloride or combination of these two. It is responsible for removal of fluoride from water. The dose of aluminium salt increases with increase in the fluoride and alkalinity levels of the raw water. The selection of either aluminium sulphate or aluminium chloride depends on sulphate and chloride contents of the raw water to avoid them exceeding their permissible limits. Lime facilitates forming dense flocks for rapid settling of insoluble fluoride salts. The dose of lime is empirically 1/20th of that of the dose of aluminium salt. Bleaching powder is added to the raw water at the rate of 3 mg/l for disinfection. Approximate doses of alum required to obtain water with acceptable limit of fluoride (<1.0 mg/l) at various fluoride and alkalinity levels in raw water are given below (Table 2).Bulusu et al. stated in 1979 that Nalgonda Technique was preferable at all levels because of the low price and ease of handling [25, 26]. The technique is highly versatile and has the applications like; for large communities, fill and draw technique for small communities, fill-and-Draw defluoridation plant for rural water supply, for domestic defluoridation, etc.

2.3.1.2 Mechanism of defluoridation by Nalgonda technique For large communities

This is a combination of the following processes: rapid mixing, chemical interaction, flocculation, filtration, disinfection and sludge concentration to recover water and aluminium salts. Different processes are allowed to take place in different tanks of suitable size [27, 28].

2.3.1.3 Fill and draw technique for small communities

For communities with a population ranging from 200 to 2000, a defluoridation plant of fill and draw type is recommended. The plant consists of a hopper-bottom cylindrical tank with a depth of 2m. The diameter depends upon the quantity of the water to be treated. All unit operations of mixing, flocculation and sedimentation are performed in the same vessel. It has a stirring mechanism, which can be either hand operated or power driven. Raw water is pumped to the unit and required quantity of alum, lime and bleaching powder are added. The contents are stirred for 10 min and allowed to settle for 1-2 hours. The settled sludge is discarded and the defluoridated supernatant is filtered and supplied through stand posts [27].

2.3.1.4 Fill-and-Draw defluoridation plant for rural water supply

The raw water from the source is pumped to the reaction-cum-sedimentation tank which is referred to as reactor. The reactors are made of HDPE, Ferro-cement or RCC; and are circular in shape with dished bottom and epoxy coating, in case of RCC. The top portion of the reactor is covered with a sturdy lid. A manhole with a lid is provided for inspection and to pour chemicals into the reactor. An operation platform is raised on girders 10 cm above the top of the reactor. The stirring mechanism, consisting of motor, reduction gear, paddles, and shaft is mounted on the platform. A ladder with a pipe railing across the platform is provided. The settled water outlet with sluice valve is connected to inlet of sump well. To withdraw the settled sludge once daily and dispose it on the sludge drying beds, a sludge pipe with sluice valve is provided [28].

2.3.1.5 Nalgonda technique for domestic defluoridation

Any container of 20-50 lit capacity is suitable for this purpose. A tap, fitted 3-5 cm above the bottom of the container is useful to withdraw treated water but is not essential. Adequate amount of lime water and bleaching powder are added to raw water and mixed well. Alum solution is added to it and stirred for 10 min. The contents are allowed to settle for 1 hour and the clear water is withdrawn either through the tap or decanted slowly, without disturbing the sediment and filtered [27]. The settled sludge may be discarded away from the source of water or preferably collected and sent for recycling. With domestic treatment, there is no capital investment and the cost of the treatment is only that of the chemicals. Of late, stainless steel defluoridation filters, which function on Nalgonda technique, are developed to use at domestic level [10, 11].

Advantages of Nalgonda technique [27, 28]

- Regeneration of media is not required.
- No handling of caustic acids and alkalies.
- The chemicals required are readily available and are used in conventional municipal water treatment.
- Adaptable to domestic use.
- Economical
- Can be used to treat water in large quantities for community usage.
- Applicable in batch as well as in continuous operation to suit needs.
- Simplicity of design, construction, operation and maintenance.
- Local semi-skilled workers can be readily employed.
- Highly efficient removal of fluorides from high levels to desirable levels.

- Simultaneous removal of color, odor, turbidity, bacteria and organic contaminants.
- Normally, associated alkalinity ensures fluoride removal efficiency.
- Sludge generated is convertible to alum for use elsewhere.
- Little wastage of water and least disposal problems.
- Needs minimum of mechanical and electrical equipment.
- No energy, except muscle power is required for domestic equipment.
- Provides de-fluoridated water of uniform acceptable quality.

Disadvantages of Nalgonda technique [14, 27, 28].

- Desalination may be necessary when the total dissolved solids exceed 1500 mg/l.
- Hardness of the raw water in the range of 200 mg/l to 600 mg/l requires precipitation softening and beyond 600 mg/l becomes a cause for rejection or adoption of desalination.
- Generation of higher quantity of sludge compared to electrochemical defluoridation [14].
- The large amount of alum needed to remove fluoride.
- Careful pH control of treated water is required.
- High residual aluminium is reported in treated water by some authors.

2.11 When to adopt Nalgonda technique?

The Nalgonda technique is normally adopted when the area under consideration has following characteristic features: [28]

- Absence of acceptable, alternate low fluoride source within transportable distance.
- Total dissolved solids below 1500 mg/l
- Total hardness is below 600 mg/l.
- Alkalinity of the water to be treated must be sufficient to ensure complete hydrolysis of alum added to it and to retain a minimum residual alkalinity of 1 - 2 meq/l in the treated water to achieve a pH of 6.5 - 8.5 in treated water.
- Raw water fluorides ranging from 1.5 - 20 mgF/l.

Modifications for Nalgonda technique.

Poly Aluminium Chloride

It is evident that for higher concentrations of fluoride, the removal efficiency of fluoride is higher with Poly Aluminium Chloride (PAC) when compared with Alum. However, since Alum is more affordable and accessible than PAC this alternative is not worth considering [29].

Poly Aluminium Hydroxy Sulphate(PAHS)

A polymeric aluminum compound, poly-aluminium-hydroxy-sulphate(PAHS) is found to require less flocculation time and settling time.Detention time of 20 to 30 minutes will suffice for complete settlement of all flocks. Cost of PAHS is much less than the alum [11].

Two bucket technique in Tanzania

The Nalgonda Technique has been introduced in African villages and studied at pilot scale in Kenya, Senegal and Tanzania [26]. The original technique was modified to overcome the limitations. The designed defluoridator consists of two buckets equipped with taps and a sieve on which a cotton cloth is placed. Alum and lime are added simultaneously to the raw water bucket where it is dissolved/ suspended by stirring with a wooden paddle. The villagers are trained to stir fast while counting to 60 (1 minute) and then slowly while counting to 300 (5 minutes). The flocs formed are left to settle for about one hour. The treated water is then tapped through the cloth into the treated water bucket from where it is collected as needed for drinking and cooking. Investigations had shown that at least some of the fluoride, which has been captured in the flocs, is released slowly back to the water. The use of two buckets should thus ensure that the treated water is separated from the fluoride containing sludge directly after the defluoridation. All physico- chemical processes are thus performed in the raw water bucket, while the treated water bucket is kept only for the storage of the defluoridated water. Both containers are 20 litre plastic buckets, supplied with covers and equipped with one tap each, 5cm above the bottom to enable trapping of sludge. The sieve acts as an extra safety device collecting any flocs which may escape through the tap in the raw water bucket. Normally, the water is completely clear, because the flocculation and sedimentation also remove water turbidity.

IISc method

The Indian Institute of Science (IISc), Bangalore developed a simple defluoridation technique which uses Magnesium oxide, lime and Sodium bisulphate. Magnesium oxide removes dissolved fluoride ions from water samples by precipitating fluoride as insoluble Magnesium fluoride.

$$MgO + H_2O \longrightarrow Mg(OH)_2$$

$$Mg(OH)_2 + 2NaF \longrightarrow MgF_2 + 2NaOH$$

Due to MgO, the pH of treated water is 10-11. It is adjusted to desirable levels (6.5 to 8.5) by adding 0.15 to 0.2 g of Sodium bisulphate per liter water. If bicarbonate ion concentration of water is more than 200 ppm, it interferes with the function of Sodium bisulphate. To overcome this bicarbonate interference, 0.3 mg of lime and 0.8mg of MgO are added per liter water. A simple domestic defluoridation unit was developed to treat 15 liters of fluoride contaminated water by this method.

2.4 Other techniques of defluoridation

Reverse osmosis, electrolysis and electro dialysis are physical methods that are tested for defluoridation of water. Though they are effective in removing fluoride salts from water, there are certain procedural disadvantages that limit their usage on a large scale.

2.4.1 Reverse Osmosis and Electro dialysis.

In reverse osmosis, the hydraulic pressure is exerted on one side of the semi permeable membrane which forces the water across the membrane leaving the salts behind. The relative size of the pollutants left behind depends on the pressure exerted on the membrane. In electro dialysis, the membranes allow the ions to pass but not the water. The driving force is an electric current which carries the ions through the membranes (Hall and Crow, 1993). The removal of fluoride in the reverse osmosis process had been reported to vary from 45 to 90 % as the pH of the water was raised from 5.5 to 7. The membranes are very sensitive to pH and temperature. The economics of the approach also deserves evaluation under specific circumstances. The units are also subject to chemical attacks, plugging, fouling by particulate matter and concentrated and large quantity of wastes. The waste volumes are even larger than the ion exchange process. Sometimes, the pre - treatment requirements are extensive. Electro dialysis is highly energy intensive and expensive. Both processes are very complicated [4].

2.4.2 Defluoridation by electrolysis.

The basic principle of the process is the adsorption of fluoride with freshly precipitated aluminum hydroxide, which is generated by the anodic dissolution of aluminum or its alloys in an electro chemical cell. The process utilizes 0.3 to 0.6 kwh of electricity per 1000 liter of water containing 5 to 10 mg/l of fluoride. The anode is continuously consumed and needs to be replenished. The process generates sludge at the rate of 80-100 gm per 1000 liters [28].

Advantages :

- Does not require addition of chemicals
- No need to pre & post-treatments
- Low volume of sludge.
- Units can be designed for any capacity.
- Units are designed for specific locations & fluoride content of water. But can be operated with varying fluoride concentrations by slightly altering the operating parameters.
- The electrochemical reactor occupies less floor space.
- Operator friendly
- Requires less electric energy (0.3 to 0.6kwh/1000 lts)

III. Current status of defluoridation in India.

UNICEF has worked closely with the Government and other partners in defluoridation programmes in India, where excessive fluoride has been known for many years to exist in much of the nation's groundwater. In the 1980s, UNICEF supported the Government's Technology Mission in the effort to identify and address the fluoride problem. Government of India launched a massive programme, namely ‘Technology Mission on Safe Drinking Water’ in 1986 wit the goal of providing potable water to the people living in rural India. It was renamed as ‘Rajiv Gandhi National Drinking water Mission’ in 1991. A sub-mission on ‘control of fluorosis’ was included in this ambitious program.[48] UNICEF's focus in the Indian programme has been on strengthening the systems for monitoring water quality, facilitating water treatment by households, and advocating alternative water supplies when necessary. Education of households and communities is the key to the strategy. A number of demonstration projects have been initiated in fluorosis-affected areas, with the emphasis currently on introducing household defluoridation. UNICEF has also sponsored research and development on the use of activated alumina for removal of fluoride from water [17]. Under national drinking water scheme of Govt. of India, 16 villages belonging to Siddhpur, Kheralu, Visnagar, Patan, Chanasma and Kadi talukas of Mehsana district, Gujarat were provided with defluoridation plants at the cost of Rs. 106 lakh. However, due to exorbitantly high cost of (approximately Rs1.5 lakh/year) maintenance and repairing, most of the plants are non-functional.[40] Similar situation exists in many other states throughout the country. With a view to resolve the problem of water scarcity and high fluoride concentration in drinking water the Government of Gujarat has identified a few long term schemes. Some of the schemes, based on import of surface water are [28].

3.1 Dharoi Reservoir Dependent Scheme:

371 villages belonging to Kheralu, Sidhpur, Visnagar and Patan taluka will be provided with the 68.86 MLD of water under group water supply scheme, at an estimated cost of Rs. 140 Crore.

3.2 Sabarmati River Dependent Scheme:

109 villages from Vijapur Taluka will be provided with water drawn from Sabarmati river at an estimated cost of Rs. 36 Crore [28].

3.3 Narmada Canal Dependent Scheme:

111 villages belonging to Chanasma Taluka, 118 villages belonging to Kadi Taluka and a large number of villages belonging to Sami and Harij taluka will be provided with the water from Narmada main canal by constructing necessary storage tanks and filtration plants.

The experience of villagers with several existing regional water supply schemes is, however, not very satisfactory for two reasons; (i) the water supply is generally erratic and (ii) the water supply scheme is not under the control of the village community [28].

IV. Conclusion:

Fluorosis is an important public health problem in India. Drinking water is the main source of ingestion of fluoride. The various manifestations of chronic fluoride toxicity are mild to severe dental fluorosis, skeletal fluorosis, genu vulgum, crippling fluorosis and systemic fluorosis, where visceral organs are involved. Though not life threatening, this disease causes impairment of dental esthetics, derangement of skeletal system which results in compromised quality of life. There is no cure to the disease and prevention is the only solution. The first and foremost preventive measure is drinking fluoride-safe water. This can be accomplished by defluoridation of fluoride-contaminated drinking water.Defluoridation should be taken up where there is no alternate source of safe drinking water. Sofar Nalgonda technique is the most suitable technique for Indian rural communities. Governments should establish the community defluoridation plants and sanction sufficient funds for their maintenance. Communities should be educated and encouraged to actively participate in the procedure. The advantage of the community defluoridation over domestic defluoridation is uniformity of the procedure and hence, better quality control. Where community defluoridation is not feasible, the residents of the endemic fluorosis areas should be educated and motivated to adopt domestic defluoridation techniques. Suitable technique for the community should be identified. It should be economic, adoptable and acceptable to the community. Priority should be given to techniques, which utilize locally available materials as defluoridation agents. Regular supply of the materials and equipment should be ensured by means of techniques such as social marketing.

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Figures and Tables:

Figure I. The map showing endemic fluorosis areas of the world [3].

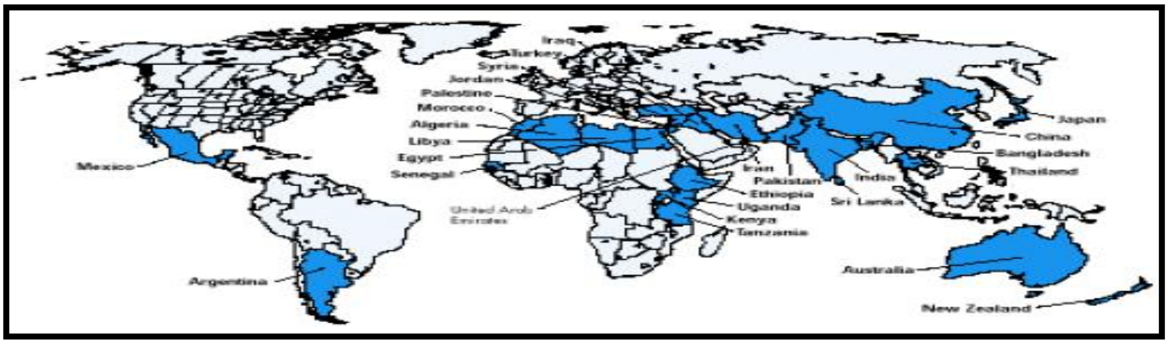

Table 1. Different defluoridation techniques and the materials used [11]

Adsorption	**Ion-exchange**	**Precipitation**	**Others**
Carbon materials, Activated Alumina, Magnesia, Tricalcium phosphate, Calcite, Hydroxy apatite, Wood, Lignite, Activated char coal, Fish bone char, Processed bone, Nut shells, Avaram bark, Paddy husk, Coffee husk, Tea waste, Jute waste, Coir pitch, Fly ash, Bauxite, Serpentine	**Anion exchange resins:** NCL poly anion resin, Tulsion A27, Lewatit-MIH-59, Amberlite IRA-400, Deacedodite FF-IP, Waso resin-14, Polystyrene. **Cation exchange resins:** Defluoron-1, Defluoron-2, Carbion.	Lime, Alum, Lime & Alum (Nalgonda technique), Alum flock blanket method, Poly Aluminium Chloride (PAC), Poly Aluminium Hydroxy Sulphate (PAHS), Brushite.	Electrochemical method (Aluminium electrode), Electro dialysis, Electrolysis, Reverse Osmosis.

Table 2. Approximate alum dose (mg/l) required to obtain acceptable quality of drinking water from raw water at various alkalinity and fluoride Levels.

Test water Fluorides (mg /l)	**Alkalinity (ppm)**							
	125	**200**	**300**	**400**	**500**	**600**	**800**	**1000**
2	145	220	275	310	350	405	470	520
3	220	300	350	405	510	520	585	765
4	*	400	415	470	560	600	690	935
5	*	*	510	600	690	715	885	1010
6	*	*	610	715	780	935	1065	1210
8	*	*	*	*	990	1120	1300	1430
10	*	*	*	*	*	*	1510	1690

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