



Fluoride and Environment - An Overview

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ABSTRACT

Presence of excess fluoride in water causes health hazards to humans and animals. Presence of fluoride in exceeding limits and its related problems to drinking water prevailing in many parts of India are well presented. Like any other pollutant, fluoride pollution can also occur due to, both natural and man-made sources. Fluoride in drinking water is known for both beneficial in detrimental effects on human health. Many solutions to solve fluoride problems have been recommended. Fluoride from water or wastewater can be removed by precipitation, adsorption and ion exchange methods. The ion exchange/adsorption process can be applied for fluoride removal under certain conditions. The method amenable for a given condition needs to be carefully selected keeping various aspects in mind. The paper presents the current knowledge of fluoride in environment including chemistry of fluoride, fluorides in the Indian scenario, effects of fluoride, and available methods of defluoridation.

INTRODUCTION

Water is essential natural resource for sustaining life and environment, which we have always thought to be available in abundance and free gift of nature covering nearly three-fourths of the surface of the earth. Pure water is scarce and not easily available to all sections of people. Deprived sections of the society consume contaminated water and take ill periodically, often resulting in epidemics. The water may be contaminated by natural sources or by industrial effluents. One of such most significant contaminants is fluoride. The presence of fluoride, in quantities in excess of limits, is a serious matter of concern from public health point of view. Like any other pollutant, fluoride pollution can also occur due to both natural and man-made sources.

Fluoride in drinking water is known for both beneficial and detrimental effects on human health with only a narrow range between intakes associated with these effects. The fluoride research in past decades suggests that concentrations below 1 ppm are beneficial in prevention of dental caries or tooth decay, about above 1.5 ppm increase the severity of the incurable disease fluorosis. It is estimated that in India, 80% of domestic needs in rural areas and 50% in urban areas are met by groundwater and is under threat from problems due to excess fluoride, arsenic, nitrate, iron and salinity. While arsenic problem prevails only in 3136 habitations, fluoride is endemic in 36,988 habitations, depicting its dominance (Fejerskov et al. 1990). Fluoride is more toxic than lead but less toxic than arsenic, and is an accumulative toxin. The 1984 WHO guidelines suggested that in areas with a warm climate, the optimal fluoride concentration in drinking water should remain below 1 ppm while in cooler climates it could go up to 1.2 ppm. The differentiation derives from the fact that we perspire more in hot weather and consequently drink more water. The guideline value (permissible upper limit) for fluoride in drinking water was set at 1.5 ppm. The WHO guideline

value for fluoride in water is not universal. India, for example, lowered its permissible upper limit from 1.5 ppm to 1.0 ppm in 1998.

Since fluoride in drinking water does not change its colour, smell or taste, normally there is no way to detect it unless tested analytically. The victims of fluorosis are often helpless and continue to suffer without their disease being diagnosed, undergo treatment with medicines of different kinds; some even undergo surgical interventions, adding to their desolations with no sign of healing or relief to the pain or disability (Susheela 2003). As we are in the “decade of water for life” as proclaimed by the United Nations from 2005 to 2015, it is important to mention that, for the millions of people in the rural areas of endemic fluorosis, the right to safe water still remains a promise unfulfilled. Hence, this paper aims at sharing the information on fluoride in the environment and its chemistry, effects on human health and available methods of defluoridation.

CHEMISTRY OF FLUORIDE

Fluoride is a salt of the element fluorine. Fluorine is highly reactive element of halogen family. Fluorine is ninth element in the periodic table belonging to the group VII A with atomic weight 18.9984. It is a chemically reactive pale yellow green irritating gas with a sharp odour, which rarely occurs naturally in elemental state as it combines with every other element except inert gases forming strong electronegative bonds (Cotton & Wilkinson 1988, Mackay & Mackay 1986). It is widely dispersed in the environment accounting for 0.38g/kg of the earth's crust (WHO 2004). Most fluoride associated with monovalent cations such as NaF and KF is water soluble, while the one formed with divalent cations such as CaF_2 and PbF_2 are generally insoluble.

FLUORIDE IN ENVIRONMENT

Fluorides like many other minerals are originated in the earth's crust due to volcanic and plutonic activities. They exist in many forms viz., fluor spar or calcium fluoride (CaF_2), apatite or rock phosphate [$\text{Ca}_5\text{F}(\text{PO}_4)_3$], cryolite or sodium aluminium fluoride (Na_3AlF_6), topaz ($\text{Al}_2\text{SiO}_4(\text{OH},\text{F})_2$), sellaite (MgF_2), villianmite (NaF), fluorine hydro silicates, etc. The minerals containing fluoride are given in Table 1.

As fluor spar is found in sedimentary rocks and as cryolite in igneous rocks, these fluoride minerals are nearly insoluble in water. The fluoride content in soil normally ranges from 200 to 300 ppm. It is observed that fluoride content in soil increase with depth, and only 5 to 10% of the total fluoride in soil is water soluble (MRC 2002, Kunin & McGarvey 1948, Srinivasan 1959). Application of fertilizers for irrigation results in the presence of Cl^- , SO_4^{2-} and F^- in groundwater.

Fluoride enters human food and beverage chain in increasing amounts through consumption of tea, wheat, spinach, cabbage, carrots and other Indian foods (Cao et al. 1998). It has been observed that many agricultural products from Andhra Pradesh in India were containing fluoride ranging from 0.20-11.0 mg/kg (Rao & Mahajan 1991). The fluoride content of tea leaves is about 1,000 times the soluble fluoride content of soil and 2 to 7 times the fluoride in soil (Fung et al. 1999).

The sources of fluoride in the environment also include industrial plants manufacturing hydrofluoric acid, phosphate fertilizers, glass, brick and tile works, textile dyeing, plastic factories and industries consuming high sulphur non-coking coal like thermal power plants, and cigarettes with an average 236 ppm fluoride contributing significantly to fluoride intake by humans (Ceciloni 1974, Okamura & Matsuhisa 1965). Fluoride in water may initiate leaching of aluminium from cooking utensils and copper from pipe works at normal and high concentrations respectively (MRC 2002).

Table 1: Fluoride bearing minerals.

Mineral	Chemical Formula	% Fluorine
Sellaite	MgF ₂	61%
Villianmite	NaF	55%
Fluorite (Fluorspar)	CaF ₂	49%
Cryolite	Na ₃ AlF ₆	45%
Bastnaesite	(Ce, La) (CO ₃)F	9%
Fluorapatite	Ca ₅ (PO ₄) ₃ F	3-4%

Fluoride is also present in seawater (0.5-1.4 ppm), in mica and in many drinking water supplies (Ayoob & Gupta 2006).

It is reported that a certain quantity of fluorine is essential for formation of caries-resistant dental enamel and for normal process of mineralization in hard tissues. The element is metabolized from both electrovalent and covalent compounds. Low fluoride concentrations stabilize the skeletal systems by increasing size of apatite crystals and reducing their solubility (Ayoob & Gupta 2006). About 95% of fluoride in the body is deposited in hard tissues and it continues to be deposited in calcified structures even after other bone constituents (Ca, P, Mg, CO₃ and citrate) have reached a steady state. Age is an important factor in deciding to what extent fluorine is incorporated into the skeleton. The uptake almost ceases in dental enamel after the age of about 30 years. It is evident from the information that between 0.02 and 0.048 mg/kg/day for adults living in areas with 1.0 ppm fluoride in water and in areas with less than 0.3 ppm fluoride in water, the adult dietary intake ranges from 0.004-0.014 mg/kg/day (Ayoob & Gupta 2006). In children, the dietary intake ranges from 0.03-0.06 mg/kg/day in areas with fluoridated water, and 0.01-0.04 mg/kg/day in areas without fluoridated water. It is suggested that a “no-observed-effect level (NOEL)” of 0.15 mg fluoride/kg/day and a “lowest observed adverse-effect level (LOAEL)” of 0.25 mg fluoride/kg/day in human, through these levels are currently subject to scientific debate.

FLUORIDES IN THE INDIAN SCENARIO

India is one among the 23 nations in the world, where fluoride contaminated groundwater is creating health problems. A report of UNICEF confirms the fluoride problem in 177 districts of 20 States of India. Andhra Pradesh is also one of the fluorosis endemic States. Today India is the seventh largest, second most populous country in the world with a land mass of 3.29 million square km with more than 1.04 billion people (Planning Commission, India 2002, Planning Commission, India on website <http://planningcommission.nic.in/plans/mta/mta-9702/mta-ch20.pdf>). Total population of India will exceed 1330 million in 2020 with water consumption expected to move up by 20-40%. India possesses 16% of the world's population but with just 4% of its water resources. Though, surface water in India is scarce and groundwater is deep and difficult to reach (UNICEF 2002), almost 90% of drinking water needs are met with from groundwater only. The scarcity of groundwater and presence of excess fluoride can be treated as the two most crucial issues in the Indian system of sustainable drinking water supply.

Many rivers flowing through more than half of the States in India are reported to have fluoride contents varying from 0.1 to 12.00 ppm (Bulusuet al. 1979). Similarly, occurrence of fluoride bearing waters was reported by many in A.P. (Ram Mohan Rao & Bhaskaran 1964), Rajasthan (Bhakuni et al. 1969), Maharashtra (Bhakuni 1970), Tamilnadu (Deslunukh 1974), Karnataka (Ziauddin 1974),

Madhya Pradesh (Adyalkar & Radha Krishna 1974), Gujarat (Viswanadham & Murthy 1974) and Uttar Pradesh (Pathak 1974). In early 1930s fluorosis was reported only in 4 States of India, in 1986 it was in 13 States, in 1992 in 15 States, in 2004 in 17 States, and now in 20 States, indicating that endemic fluorosis has emerged as one the most alarming public health problems of the country. People in several districts of Rajasthan (Agarwal et al. 1999) and Assam (WHO 2005) are forced to consume water with fluoride concentration up to 44 ppm and 23 ppm respectively. The mega city of New Delhi is endemic for fluorosis with quite higher fluoride concentration (Lakdawala & Punekar 1973, Susheela & Bhatnagar 1999). In Andhra Pradesh, the places like Nalgonda, Anantapur and some parts of the Kadapa district are affected places by fluorosis. The place like Anantapur witnesses considerable cases of fluorosis. The socially and economically marginalized rural population in Anantapur district has been chronically vulnerable to fluorosis due to presence of excess fluoride in underground water sources.

EFFECTS OF FLUORIDE ON HUMAN BEINGS

Effects of fluoride on human beings are in the form of dental effects, skeletal effects, neurological manifestations, muscular manifestations, allergic manifestations, gastrointestinal problems, headache and loss of teeth (edentate) at an early age.

Dental effects of fluoride: Dental Effects of fluoride are broadly classified as dental caries and dental fluorosis.

Dental caries: It is an infectious and multifactorial disease, which is characterized by demineralization of inorganic components of teeth and dissolution of organic substances of microbial aetiology (Ayoob & Gupta 2006). Caries is the result of bacterial growth in unhygienic oral cavity, leading to acid (lactic acid, propionic acid and acetic acid) production by fermentation, which etches away the enamel leaving black spots or cavity in teeth. The prevalence of these cavities can be effectively qualified by using dmft (number of decayed, missing, or filled teeth) or dmfs (number of decayed missing, or filled tooth surfaces) index developed by oral epidemiologists (Kunin & Mc Garvey 1948).

Dental fluorosis: It is an irreversible toxic effect on the tooth forming cells, ameloblasts, which is an early sign of fluoride attack visible to naked eye. Histologically, it presents a hypocalcification, which clinically ranges from barely visible white striations on teeth to gross defects and staining of the enamel (MRC 2002).

Long term consumption of water containing 1 mg of fluoride per litre leads to dental fluorosis. White and yellow glistening patches on teeth are seen, which may slowly turn brown. The yellow and white patches when turned brown present itself as horizontal streaks (Ayoob & Gupta 2006). The brown streaks may turn black and affect the whole tooth and may get pitted, perforated, and chipped off at the final stage. Dental fluorosis not only poses cosmetic problems but has serious social problems too, especially in terms of matrimonial problems of children (Bulusu et al. 1979). Severely fluorised enamel is more porous, pitted, discoloured and is prone to wear and fracture because the well mineralized zone is very fragile to mechanical stress (Den Besten & Thariani 1992, Fejerskov et al. 1969, Fejerskov et al. 1990).

Several methods have been developed for quantify the severity of dental fluorosis (Dean 1934). Depending on the level of exposure and nutritional status of the child, Dean (1934) classified fluorosis on a scale frame of 0 to 4 as follows: Class 0, no fluorosis; Class 1, very mild fluorosis (white areas irregularly covering about 25% of the tooth surface); Class 2, mild fluorosis (white areas cov-

ering about 50% of the tooth surface); Class 3; moderate fluorosis (all surfaces affected, with some brown spots and marked wear on surfaces subject to attrition); and Class 4, severe fluorosis (widespread brown stains and pitting).

Skeletal effects of fluoride: Fluoride is one of the consistent elements of human skeletal system and its long-term chronic intoxication leads to skeletal fluorosis. It has been observed in persons when water contains more than 3-6 mg/L of fluoride. Skeletal fluorosis affects young and old alike. Fluoride can also damage the fetus if the mother consumes water and food with high concentration of fluoride during pregnancy/breast feeding. Infant mortality due to calcification of blood vessels can also occur (Bulusu et al. 1979). Other symptoms of fluoride toxicity include severe pain in backbone, joints and the hip region, shiftiness of backbone, immobile/stiff joints, increased density of bones, calcification of ligaments, constriction of vertebral canal and intervertebral pressure on nerves, and paralysis. Effects on bones (skeletal fluorosis and fracture are considered as the most relevant outcomes in assessing the adverse effects of long term exposure of human to excess fluoride (WHO 2002).

Non-skeletal effects of fluoride: This aspect of fluorosis is, sometimes, ignored because of the misconception prevailing that fluoride will only affect bone and teeth. Fluoride, when consumed in excess, can cause several other ailments besides skeletal and dental fluorosis (Bulusu et al. 1979). Some important fluoride related ailments are as below.

Neurological manifestations: Nervousness, depression, tingling sensation in fingers and toes, excessive thirst, tendency to urinate frequently (polydipsia and polyurea are controlled by brain-appears to be adversely affected).

Muscular manifestations: Muscle weakness and stiffness, pain in muscles and loss of muscle power.

Allergic manifestations: Very painful skin rashes, which are per vascular inflammation - present in women and children, pinkish, red or bluish red spots on the skin that fades and clear up in 7-10 days, they are round or oval shape (Rao 2003).

Gastrointestinal problem: Acute abdominal pain, diarrhoea, constipation, blood in stools, bloated feeling (gas), tenderness in stomach, feeling of nausea and mouth sores.

Headache: Excess fluoride in water leads to constant headache for long period.

Loss of teeth (edentate) at an early age: Excess fluoride in water leads to loss of teeth at an early age leading to socioeconomic problem.

The relation between concentration of fluoride and the biological effects are summarized in Table 2 (Sri Murali et al. 1998).

FLUORIDE REMOVAL FROM WATER

The process of fluoride removal is generally termed as defluoridation or defluorination. Numerous methods have been described employing various materials for the fluoride removal. Based on the nature of processes, the defluoridation can be grouped under following categories.

- i. Precipitation (chemical reaction)
- ii. Adsorption
- iii. Ion exchange method
- iv. Advanced methods

Precipitation methods: Method involving addition in sequence of an alkali, chlorine and aluminium

Table 2: Concentrations of fluorides and biological effects (Rao et al. 2003).

Concentration of Fluoride, ppm	Medium	Effect
1	Water	Dental fluorosis
2 or 3	Water	Mottled enamel
8	Water	10% Osteosclerosis
50	Food and water	Thyroid changes
100	Food and water	Growth retardation
120	Food and water	Kidney changes

* In water medium ppm can be taken as equivalent to mg/L.

sulphate or aluminium chloride or both was developed (Bulusu et al. 1979). It is inexpensive and used widely in India.

Alum: Aluminium sulphate is used for defluoridation, but in this process, sludge production is high, treated water is acidic and aluminium is present as residual. Lime is also an established process but production of sludge and treated water is alkaline in nature. Alum and lime (Nalgonda technique) are extensively used methods (RGNDWM 1993). It is simple in construction, operation and maintenance but high chemical dose, sludge production and aluminium is present as residual. No regeneration of media and maintenance of pH are main disadvantages. Use of gypsum and fluorite is a simple method but requires highly skilled operators. Low efficiency and high residuals of CaSO_4 are demerits.

Lime: The fluorides in water containing magnesium when treated with lime are absorbed on magnesium hydroxide flocs enabling fluoride removal (Savinelli & Black 1958, Dean & Elvolve 1938, Maier 1953).

In this case the water must be treated to an alkalinity of 30mg/L, a pH of 10.5 or above and as such recarbonation is necessary (Venkateswarlu & Rao 1953). Magnesia and calcined magnesite have also been used for fluoride removal from water and fluoride removal capacity was reported to be better at high temperature (Kunin & Mc Garvey 1948).

Adsorption methods: These include use of several bone formulations, synthetic tricalcium phosphate and hydroxyl apatite and a variety of adsorbent materials. Some of them are discussed below.

Bone charcoal: The uptake of fluoride onto the surface of bone was one of the early methods suggested for defluoridation of water supplies. The process was reportedly of the ion exchange in which carbonate radical of the apatite comprising bone $\text{Ca}(\text{PO}_4)$ (Bhakuni et al. 1969) and CaCO_3 was replaced by fluoride to form an insoluble fluorapatite. Base char produced by carbonizing bone at temperature of 1100-1600°C had superior qualities than those of unprocessed bone, and hence replaced bone as defluoridating agent.

Tricalcium phosphate: Tricalcium phosphates, natural or prepared synthetically by reacting milk of lime and phosphoric acid, have been used for defluoridation. It has a capacity to remove 700 mg fluoride/L. The medium is regenerated with 1% NaOH solution followed by a mild acid rinse (Savinelli & Black 1958, Swope & Hess 1937).

Florex: A mixture of tricalcium phosphate and hydroxy-apatite, commercially called florex, showed a fluoride removal capacity at 600 mg fluoride per litre. It can be regenerated with 1.5% sodium hydroxide solution. Owing to high attritional losses, florex was not successful and the pilot plants using the material were abandoned (Babovich 1957, Mckee & Johnson 1934).

Activated carbon: Most of the carbons prepared from different carbonaceous sources showed fluoride removal capacity after alum impregnation. High fluoride removal capacities of various types of activated carbons has been reported (Venkataraman 1960).

Alkali digested alum impregnated paddy husk carbon was an efficient defluoridating agent (Srinivasan 1959). Alkali digested (1% KOH) and alum soaked (2% alum) carbon removed 320 mg fluoride per kg and showed maximum removal efficiency at pH 7.0 (Bhakuni & Sharma 1962).

Investigations have shown that carbonized saw dust when quenched in 2% alum solution forms an excellent defluoridating carbon (Evolve 1940). The defluoridating process is stoichiometric and equilibrium is established between carbon and fluoride. Exhaustion results after continued use and the carbon can be regenerated by passing 0.2 to 0.5% alum solution though it.

Activated carbon prepared by other workers from cotton waste, coffee waste, coconut waste, etc. was tried for defluoridation but all these materials proved to be of academic interest only (Bulusu et al. 1979).

Activated magnesia: Investigation was conducted to study the usefulness of magnesia in fluoride removal (Bulusu et al. 1979). The study established that magnesia removed the excess fluorides, but large doses were necessary (Viswanadhan et al. 1974). Moreover, the pH of the treated water was beyond 10 and its correction by acidification or recarbonation was necessary. The acid requirement can be to the extent of 300 mg/L expressed in terms of CaCO_3/L .

The high initial cost, large concentrations required, alkaline pH of the treated water and complexity of the preparation of magnesia are the inhibitive factors to render it acceptable in the field (Venkateswarlu & Narayana Rao 1953).

Activated alumina: Defluoridation of water by activated alumina is the method of choice in the developed countries. Its affinity for fluoride is very high. It is a porous material with the surface comprised largely of active sites. It is prepared by dehydration of $\text{Al}(\text{OH})_3$ at the temperature of 300-600°C. The advantages of using activated alumina are mainly the minimum contact time, high regeneration capacity, inexpensive, and independent of temperature.

Activated alumina can be regenerated with HCl, H_2SO_4 , alum or NaOH. The use of NaOH needs to be followed by neutralization to remove residual NaOH from the bed. Fluoride removal by activated alumina is strongly pH dependent. Batch adsorption data (Paul 1978) showed very little removal at pH 11.00 and optimum removal at pH 5.0. Hence, raw water pH and regenerated bed pH and generated bed pH need to be adjusted accordingly (Wu & Nitya 1979). The use of activated alumina in a continuous flow fluidized system is an economical and efficient method for defluoridating water supplies (Smith & Smith 1937).

Plant materials: The plant materials such as barks of *Moringa olifera* and *Emblica officinalis*, the roots of *Vetiveria zizanoides* and the leaves of *Cyanodon dactylon* were found to be good defluoridating agents.

Burnt clay: Burnt clay obtained from brick chula, prepared by burning a mixture of 70% clay and 30% red soil was observed to possess commendable defluoridation property. Clay with particle size 500 microns exhibited maximum defluoridation efficiency. At low pH range, the defluoridation efficiency was more compared to that at high pH range (Karthikeyan et al. 1999).

Anion exchange resins: Anion exchange resins are found to remove fluorides either by hydroxyl cycle or chloride cycle, along with other anions (Runaska et al. 1951, Robertson 1939). Polyanion

exchange resin, Tulsion A-27, Deacodite FF (IP), Lawatit MIH-59 and Amberlite IRA400 are few examples.

Cation exchange resins: Cation exchange resins impregnated with alum solution have been found to act as defluorinating agents. "Avaram bark" based cation exchange resins have been reported to work effectively in removing fluoride from water (Bhakuni & Satry 1964). Performance of saw dust carbon (defluoron-1), carbion, wasoresin-14 and polystyrene cation exchange resins for fluoride removal were compared.

Use of limestone, special soils and clay, etc.: Recently limestone and heat treated soil were tried for fluoride removal (Zeven Bergew et al. 1997). Limestone was used in a two column continuous flow system (limestone reactor) to reduce fluoride concentration from wastewaters to below the MCL (maximum contaminant level) of 4 mg/L. Calcite was forced to dissolve and fluorite to precipitate in the first column. The degassing condition in the second column caused precipitation of the calcite dissolved in the first column, thus, returning the treated water to its approximate initial composition.

Attempts were made to use local Kenyan soil derived from volcanic ash (Ex: ando soils or soils with acidic properties) as a fluoride sorbent (Agarwal et al. 1998). It is concluded that the use of ando soils appears to be an economical and efficient method for defluoridation of drinking water on a small scale in rural areas of Kenya and other regions along the Rift zone.

Fluoride sorption studies were carried out on two clay minerals, montmorillonite KSF and kaolin, and a silty clay sediment series (SCSS, used in earthenware making) (Sri Murali et al. 1998). Removal of fluoride by adsorption on to low cost materials like kaolinite, bentonite, charfines lignite and nirmali seeds was investigated (Piekos & Paslawska 1999).

Electro-coagulation/Electrochemical methods: Electro-coagulation process with aluminium bipolar electrodes was used for defluoridation process. The influence of parameters such as inter-electrode distance, fluoride concentration, temperature and pH of the solution were investigated and optimized with synthetic water in batch mode.

A technology of defluoridation through electrochemical rate has been developed (To Kunaga et al. 1999). The basic principal of the process is adsorption of fluoride with freshly precipitated aluminium hydroxide, which is generated by anodic dissolution of aluminium or its alloys, in an electrochemical cell. This process generates sludge at the rate of 80-100 g per 1000 litres. Electricity is the main raw material, and hence, whenever electricity is not available a suitable polar panel can be installed. These are the major constraints in this technology.

Use of rare earth based materials: New water treatment processes have been developed for removal of hazardous ions such as fluoride, arsenic, selenium species and phosphate from water using rare earth based materials, which have not been efficiently utilized by industry in spite of their abundance (Zhong-Zhi et al. 2002).

A rare earth metal-based inorganic adsorbent, cerium-iron adsorbent (CFA), was developed and its performance for fluoride removal from water was evaluated (Raichur & Jyoti Basu 2001). The characteristics of the adsorbent were summarized. Experimental results show that rare earth metal adsorbents has a relatively high adsorption capacity and good kinetic property for fluoride ion removal.

An adsorbent, which is a mixture of rare earth oxides was found to adsorb fluoride rapidly and effectively. The effect of various parameters such as contact time, initial concentration, pH and adsorbent dose on adsorption efficiency was investigated. More than 90% of the adsorption occurred

within the first 5-10 minutes. Adsorption was found to be dependent on the initial fluoride concentration and optimum pH. The adsorbed fluoride could be easily desorbed by washing the adsorbent with a pH 12 solution (Rao 2003). This study clearly shows the applicability of naturally occurring rare earth oxides as selective adsorbent for fluoride from solutions.

The removal of fluoride was attempted using natural materials such as red soil, charcoal, brick, etc. Each material was set up in a column for a known volume and the defluoridation capacities of these materials were studied with respect to time. It is concluded that red soil has good fluoride removal capacity as compared to other adsorbents.

SUMMARY

Fluoride in drinking water is known for beneficial and detrimental effects on human health. The chief source of fluoride in groundwater is its leaching from the fluoride bearing minerals of earth's crust. Many rivers flowing through more than half of the States in India are reported to have fluoride contents varying from 0.1 to 12.00 ppm. Fluoride levels in drinking water possess the greatest threat to human health as evidenced by the endemic of fluorosis in India.

Dental fluorosis is an irreversible toxic effect on teeth forming cells. Long term consumption of water containing 1 mg of fluoride per litre leads to dental fluorosis. Depending upon the amount and period of consumption, skeletal fluorosis would occur. The socioeconomic aspects of fluorosis insist upon the most urgent attention and gracious concern of the global scientific community for sustainable solutions, as the life of victims are frustrating, painful and often hopeless as fluorosis makes them physically, culturally and socially disturbed.

The detrimental effects of excessive fluoride can be controlled by defluoridation of natural waters. Numerous methods of defluoridation are available, however, not all the methods are suitable for all situations, and hence, proper justification is required for selection of amenable method. Various existing methods of defluoridation like precipitation, adsorption, ion-exchange and their limitations are well documented.

Certain under exploited but abundantly available materials like rare earth minerals have shown significant potential for fluoride removal. Investigative studies can be conducted to develop inexpensive, simple to use technologies based on these materials.

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