



Research Journal of Pharmaceutical, Biological and Chemical Sciences

Fluoride and Fluorosis in Context to Gujarat State of India: A Review

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ABSTRACT

Many states in India, like many other countries of the world have alarming fluoride contamination condition. Gujarat along with other 14 states of India has fluoride contamination level above permissible level. 18 districts out of 27 districts are facing fluoride menace. This review highlights status of fluoride contamination in Gujarat, its geological consideration and incidences of fluoride diseases.

Key words: Fluoride, Fluorosis, Fluorinated Water, Water Pollution

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INTRODUCTION

The reaction of man with environment is necessarily symbiotic and equilibrium between the two should be made at all costs. Fluoride related health hazards are major problem in many regions of the world. It has been reported that apart from India, there are about 20 other developed and developing nations which have come under the threat of fluorosis. These are Argentina, USA, Morocco, Algeria, Libya, Egypt, Jordan, Syria, Turkey, Iraq, Iran, Pakistan, Kenya, Tanzania, South Africa, China, Australia, New Zealand, Japan, and Thailand. In India over 25 million people from 15 states namely Rajasthan, Gujarat, Tamilnadu, Maharastra, Madhya Pradesh, Punjab, Haryana, Andhra Pradesh, Bihar, Delhi, Jammu and Kashmir, and Kerala are suffering from fluoride. This does not rule out the possibility that even the remaining states and union territories are free from fluoride poisoning in the country. Gujarat is one of the most severely affected states in the country considered to be endemic to fluorosis, where about 18 out of a total of 24 districts are prone to fluorosis due to high fluoride content in drinking water. In Gujarat various districts namely Patan, Mehsana, Ahmedabad, Amreli, Sabarkantha, Baroda, and Banaskantha are affected by high fluoride concentrations. Mehsana, Patan, and Banaskantha districts located in North Gujarat and near to each other are considered to be the most affected districts apart from Amreli, Ahmedabad, Sabarkantha and Baroda.

Worse still, a government report says 8,252 out of 18,822 villages face problems of high salinity and fluoride and nitrate content in water. The study by the Gujarat Water Supply and Sewerage Board (GWSSB) indicates that 4,341 villages suffer from high fluoride content in water, 2,571 from salinity and 1,336 from nitrate [1]. Past surveys suggest that the problem of fluoride content in water has been deepening. The Gujarat Ecology Commission's draft Action Environmental Programmed, prepared last year, said in 1991 just 831 villages had fluoride levels in groundwater higher than permissible limit. In 1997, the figure reached 2,836. Now, the GWSSB survey says the number of such villages have nearly doubled to 4,341 in 2010. This is part of our research going on assessment of fluoride and its toxicity in towns of Gujarat in relation to other states of India [2-5].

Occurrence of Fluoride

Geological considerations of fluoride incidence

Fluoride concentration in ground water depends on factors viz. geological, chemical, and physical characteristics of water supplying areas, the consistency of soil, porosity of soil, rain fall, nature and composition of soil, pH, depth of water table etc. Three major sources of fluoride incidence [6] in ground waters are identified as under.

- (a) Fluorspar mineralization
- (b) Granite, gneisses and other crystalline rocks having many fluoride bearing minerals as their essential and accessory mineral composition like biotic, muscovite, apatite etc.
- (c) Residual soil including micaceous sand.

The weathering and leaching processes by percolating water in soil belts play an important role in the incidence of fluoride in ground water. The various factors that govern release of fluoride into water by fluoride bearing minerals/soil [7] are given as under

- (a) The chemical composition of water
- (b) The presence and accessibility of fluoride mineral to water
- (c) Time of contact of source mineral and water

Unfortunately, the utilization of surface water resources of the state is very meager (only 2.65 MHM as compared to 69 MHM in the country). Again this is unevenly distributed. South Gujarat has been blessed with abundant water while North Gujarat, Saurashtra and KACHCH are semi- arid and suffer from frequent draughts. Ground water scenario is also disappointing. The eastern hilly and tribal belts are rocky terrains with insignificant ground water. The ground water bowl of North Gujarat is being continuously emptied due to over extraction in absence of adequate surface waters. As a result water table has gone down to 200 to 300 meters deep and excessive fluorides are now found in the groundwater of all areas. Reliable water sources have disappeared. Large part does not need sufficient groundwater. Water from the Narmada River through pipelines is the only solution as groundwater pollution has become a permanent feature.

Other sources of fluoride incidence

There is a big list of products which can be source of fluoride [8,9], Some of them have not been proven scientifically as the causes of poisoning, but they are still of interest because some people state they are can be cases of fluoride poisoning caused by accidental ingestion or by indirect ways. Industrial Air pollution, Automobile wheel-cleaning products, Glass-etching, or Chrome-cleaning agents like ammonium bifluoride, contaminated beverages and food products. Dietary supplements [10] that contain sodium fluoride include fluoridated milk, fluoridated salt, Soya products, Tea, Fluoridation of public water supplies, Fluoride tablets, Ground water pollution, Household products, Insecticides containing sodium fluoride, Mattresses emitting fluoride gases, Scotchgard, Rodenticides containing sodium fluoride, Teflon in non sticking kitchenware's, Toothpaste or other oral dental products (containing sodium monofluorophosphate, sodium fluoride (NaF), sodium fluorophosphates, tin(II) fluoride (SnF_2), and amine fluoride), Vaccine contamination, Anesthetics, Antibiotics etc. are sources of fluoride incidence. When used in very low concentrations (on the order of 1-3 parts per million), fluorides are used in human health applications; specifically, fluorides such as sodium fluoride (NaF), sodium fluorophosphate (SMFP), tin(II) fluoride (SnF_2), and amine fluoride are common ingredients in toothpaste. Many dentists also give their patients semiannual fluoride treatments. But in Gujarat, fortunately industrial and agricultural activities has done no addition, it is only natural ground water quality and food habits which is responsible for fluoride menace.

Chemistry of fluoride

Fluorine is most abundant in earth's crust (0.065%) among halogens and forms concentrated deposits in such minerals as fluorite or flourspar, cryolite and fluorapatite. Only the isotope ^{19}F in nature with half life of 109.7 minutes is radioactive. Fluorine is chemically most reactive of all the elements and combines directly at ordinary or elevated temperatures with all most all elements except oxygen, nitrogen and noble gases. It attacks organic compounds and break them to fluorides. The low F-F bond energy, small size, and high nuclear charge make it highly unstable and reactive [11]. It being a halogen, and chemically related to iodine but very much more active, displaces iodine, so the uptake of iodine is compromised by the replacement of the iodine by fluorine.

Fluoride concentrations and permissible limit

Fluoride is best known for its use in small quantities to help reduce dental caries (cavity) frequency in teeth. A debate continues about whether fluoride ions (F^-) are a trace element beneficial or detrimental to humans for other reasons. Fluoride compounds, usually calcium fluoride, are naturally found in low concentration in drinking water and some foods, like tea. Fluoride ions replace hydroxide ions in calcium hydroxyapatite, $\text{Ca}_5[(\text{PO}_4)_3\text{OH}]$, in teeth, forming calcium fluoroapatite, $\text{Ca}_5[(\text{PO}_4)_3\text{F}]$, which is more chemically stable and dissolves at a pH of 4.5 compared to 5.5 pH for calcium hydroxyapatite. This is generally believed to lead to fewer cavities, since stronger acids are needed to attack the tooth enamel [12]. The Candian Public Health Association (ADA) [13], World Health Organization [14] and some other health organizations recommend fluoridation of municipal water supplies to a level between 0.7 and 1.2 ppm. On the other hand, UNICEF [15] warns against water fluoridation, water fluoridation is a highly controversial practice and banned in most countries in Europe, China, India, and Japan.

Table 1: Effect of fluoride in water

Fluoride in water (ppm)	Effects
<1.5	No effect and may prevent dental caries
1.5 -3.0	Dental Fluorosis
3.0- 6.0	Skeletal Fluorosis
>6.0	Crippling fluorosis and changes

Fluoride toxicity and symptoms

Even if it was beneficial, fluoridation isn't something you get to choose or not choose [16]. In high concentrations, as with almost all substances, fluoride compounds are toxic. 5 grams of full strength sodium fluoride will kill most adult humans; a lethal dose is approximately 75 mg per kilogram of body mass. The acute toxic dose of fluoride is believed to be from 2 to 8 milligrams per kilogram of body mass.

Poisoning most commonly occurs following ingestion (accidental or intentional) of products that contain fluoride. Fluoride toxicity is characterized by a variety of signs and

symptoms. Symptom onset usually occurs within minutes of exposure. Severity of symptoms can depend on the amount of fluoride compounds ingested [17,14].

Gastrointestinal: When poisoned by fluoride, gastrointestinal signs predominate like abdominal pain, diarrhea, dysphasia, hyper salivation, mucosal injury, nausea, vomiting etc.

Electrolyte abnormalities: Hyperkalemia, hypocalcaemia, hypoglycemia, hypomagnesaemia

Neurologic effects: Headache, hyperactive reflexes, muscle weakness, muscular spasm, paresthesia, seizures, tetanic contractions, tremor.

Cardiovascular: Cardiac arrest, shock, widening of QRS, various arrhythmias

Skin diseases: In hypersensitive individuals, fluorides occasionally cause skin eruptions such as atopic dermatitis, eczema or urticaria, gastric distress, headache and weakness have also been reported. These hypersensitive reactions usually disappear promptly after discontinuation of the fluoride.

Fluorosis

It is a condition caused by excessive intake of fluorine compounds over an extended period of time, and can cause yellowing of teeth, hypothyroidism, or brittling of bones and teeth. The definition of excessive intake mean significantly higher than the 0.7 to 1.2 ppm amounts recommended for fluoridated water. However, dosage is crucial to adverse effects, and therefore, what concentration is problematic will depend on the amount of fluoride ingested, how much is absorbed, and the weight of the person ingesting it. For this reason, many doctors have advised against using fluoridated water to make up formula for infants. People with kidney problems, or those on dialysis, are also advised not to ingest fluoridated water.

Fluorosis is a dreadful disease, owing to the slow withering process, to which people remain unaware about it. The most frightening aspect of it is that once it finds home in the body, it does not leave. It starts destruction immediately and sometimes it takes 2 to 3 decades for the disease to develop.

Dental fluorosis: It develops in infants and children, if high concentration of fluoride is taken. Adults are also prone to this. Symptoms of dental fluorosis are loss of shine and luster, discoloration of teeth, yellowing of teeth, dental mottling and finally loss of teeth [18].

Skeletal Fluorosis: Fluoride replaces hydroxide in bones and is deposited in bones and cause chronic effect called as skeletal fluorosis. This disease is prevalent in many villages of Sicily, Turkey and India. In children skeletal fluorosis is not seen because in early stages fluoride affects teeth only and not skeletal system but as age increases, prevalence of skeletal fluorosis

increase if a person is continuously exposed to the chronic fluoride concentration. As result of skeletal fluorosis, bones become soft, crumble, and chalky white [19].

In advanced stages, stiffness, inability to move the spine, and neurologic symptoms are observed. Deformities are found particularly in limbs, flexion deformity of knee and hip being most common. In many rural areas people are not even able to bend the neck.

Osteoporosis: It is condition of dense and brittle bones. It affects millions of the people all around the world because of undetected bone loss for years disabling of fractures of the spine, hip, wrist and other bones can occur. A survey has revealed that those who suffer from osteoporosis related hip fractures die within 6 months. Results have shown that women are at four times greater risk of developing the osteoporosis than men.

Stillborn miscarriages: FDA (Food and Drug administration) scientist has reported that fluoride adversely affects fertility rates in women. The rate of stillborn miscarriages by 4 months of pregnancy is extremely high in fluorotic regions.

Premature Aging: Premature aging is the overall effect of intake of fluoride for a long period of time. Young men are bent over and crippled with pain in their joints and hips. Their skin gets wrinkled and they look 60 at the age of 30 or 40. The acceleration of the aging process occurs due to unusual biochemical reaction.

In Gujarat 18.2% of population showed the symptoms of backache, joint pain, and stiffness, 35.3 % dental fluorosis, 38.1 % 4ppm urinary fluoride level and 71% radiological changes in the area where fluoride level in drinking water was 0.5-4.0 ppm [20].

The districts severely affected by fluoride contamination are Mehsana, Patan, and Sabarkantha. A survey conducted in 14 villages in Patan district reveals that 30 per cent of the population suffer from dental fluorosis and 8 to 10 per cent of them from skeletal fluorosis. In Mehsana district, where groundwater mining takes place unabated, a detailed epidemiological survey showed that of the 559 villages surveyed, 236 reported the prevalence of fluorosis [21]. The results [22] showed (1) the prevalence of fluorosis increase with age. (2) Women show higher prevalence rates as compared to men (3) The age group 46-60 years and above 60 years, 8-15% of the people interviewed had become crippled (4) Bhils (poor tribal people) showed higher prevalence rather starting from younger age compared to other people in North Gujarat observed [23].

Considerable work has been done all over the world on treatment of fluorosis. Unfortunately results indicate that effects of fluorosis are irreversible and incurable. The condition can be improved among children by treatment or prevention.

Human physiology and fluoride

Physiologically, fluoride is a potent enzyme inhibitor (comparable to lead and to cyanide ion) that accumulates in bones and teeth and is readily transported to sensitive soft tissues [24]. The powerful toxic properties of fluorine came into special prominence in 1931 with the discovery that the fluoride ion in drinking water is responsible for the endemic dental defect known as mottled enamel. Previously, the devastating effects of volcanic and industrial fluoride emissions on livestock and vegetation had been recognized, and the acute human toxicity of fluoride in decigram amounts was well known, but the chronic, cumulative toxicity of fluoride to humans at milligram levels of intake still awaited investigation. When ingested directly, fluoride compounds are readily absorbed by the intestines; over time, the compound is excreted through the urine and the half-life for concentration of fluorine compounds is on an order of hours. Fluoride is taken out of circulation by the body and trace amounts bound in bone [25].

Persons in poor health and those who have allergy, asthma, kidney disease, diabetes, gastric ulcer, low thyroid function, and deficient nutrition are especially susceptible to the toxic effects of fluoride in drinking water. In addition, fluoride in beverages (especially tea), food, air, drugs, and tobacco, toothpaste, and mouth rinses can also precipitate or contribute to such intoxication.

Tests for fluoride

When the illness is caused by fluoride in the drinking water, and is not too far advanced, the symptoms promptly disappear or subside without medication simply by substitution of distilled or other low fluoride water for all drinking and cooking and avoidance of high fluoride foods, such as mechanically de-boned meat, skin of chicken, bony ocean fish, tea, and gelatin prepared with fluoridated water. Likewise, they immediately return when the use of fluoridated water is resumed. In many cases medical diagnosis has been fully confirmed by blind or double blind challenge tests with coded bottles of fluoridated and no fluoridated water.

Urine tests are a good indication of high exposure to fluoride compounds in the recent past. There is no firsthand test to determine fluorosis. Physical appearance and symptoms are the only way to explain fluoride content.

Ways to remove fluoride from water

Wide range of treatment systems have been reported for monitoring excess of fluoride in water. Some are very expensive and some are inefficient in certain type of water quality and only laboratory studies are available. Several reviews are available on defluoridation techniques [26]. These are widely divided into three categories.

Precipitation methods: This method involves the addition of soluble chemical to water which leads to fluoride precipitation and or adsorption of fluoride formed on already formed

precipitate. It generally involves water treatment by chemicals such as lime, alum or combination. Some of them are Lime treatment Alum Treatment, Nalgonda technique.

Adsorption/ ion exchange methods: In this method, the raw material is passed through the bed containing defluoridating material. Fluoride is retained by material due to physical, chemical or ion exchange interactions. A number of materials have been tried as absorbents for fluoride uptake, to some of them are

(i) Activated carbon (ii) Ion exchange resin (iii) Bone char (iv) Brick (v) Activated Alumina.

Miscellaneous: Separation technologies such as reverse osmosis and elect dialysis have also been developed for the separation of small ions from drinking water. Reverse osmosis is very effective and lowers fluoride by 13.3%. It removes not only fluoride but also soluble ions present in the water. Reverse osmosis systems are generally unaffordable for personal use.

In Gujarat, a large number of cottage type Reverse Osmosis (RO) plants came to be marketed for supplying good and safe water to the consumers under 'packed drinking water' category, and a big market has emerged. There are many plants in various districts of Gujarat like in Mahsana, Patan, Banaskantha etc. These plants cater to the needs of villages situated in rural areas and have rural clientele and sells water in pouches within a radius of 100 kms.

Steps to reduce fluoride exposure

Don't take fluoride supplements. Use only bottled beverages which are made by using distilled or reverse-osmosis water, they are probably made with fluoridated public water. Use unfluoridated toothpaste, Avoid drinking black or red tea. There are many health benefits associated with chemical compounds found in tea, but this may be a beverage to avoid if you need to reduce your fluorine intake. Black and red tea comes from two different types of plants, but both leaves naturally contain high amounts of fluorine. Beware of tinned fish and canned food items. Avoid usage of Fluoride as a preservative. Stop chewing tobacco. Avoid long term use of medication that contains fluorine. People should take calcium and vitamin c rich dietary products. Take water with fluoride only in permissible limit.

Awareness regarding the fluorosis problem in fluorotic regions, level of fluoride in water bodies, ill effects caused by fluoride affected water, precautions to take less fluoridated products should be made time to time.

Unfortunately, because of vigorous denials by health authorities committed to promoting fluoridation, fluoride illness of this nature is not generally recognized by either the public or the medical profession. Yet even the Physicians' Desk Reference or dentist should warn of such toxic reactions to prescription supplements containing the amount of fluoride.

Public awareness programs should be organized by media, government, and NGO's. Both government and non government organizations should fight fluoride menace on war footing for a long standing solution for it.

CONCLUSION

Fluoride that we put in water today will still be in water tomorrow. Fluoride doesn't magically disappear from water once it has been added. Its presence and accumulation have profound implications for aquatic and terrestrial ecosystems. It is not a simple matter to remove the fluoride from water or from the plants and animals that ingest it. Fluoride is poisonous. Fluoride is called as a two edge sword - in small dosages, it has remarkable influence on the dental system by inhibiting dental carries, while higher dosages cause dental, and skeletal fluorosis. Relatively low concentrations taken for longer period time have even shown conclusively detrimental effects on human and animal development. It is impossible to control the dose because people drink different amounts of water. So the fluoride dose cannot be regulated. Fluoridation is also objectionable in the eyes of many because it deprives the individual of the right of freedom of choice in a matter of personal health care. It imposes an inescapable, demonstrably toxic, prophylactic treatment on each person in the community for a noncontiguous condition; regardless of his or her desire to be so treated. The water supplier (municipality) has the responsibility to make the water as safe as possible to drink, not to make it a vehicle to affect the body of the consumer. There is no detailed study accepted at diagnostic level which can relates amount of fluoride to type Fluorosis. So the principle of precaution is better than cure is the only and best solution to handle the Fluoride menace.

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