Fuloride Removal from Water – A Review

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Abstract— The major source of fluoride in ground water is the leaching of fluoride from the rock minerals of the earth's crust. Presence of fluoride in low concentration (<1.5 mg/l) is beneficial to the people for the calcification of dental enamel and maintenance of healthy bones. On the other side, its presence in higher concentration become a monster and can cause dental, skeletal fluorosis and also non-skeletal problems. Many investigators conducted experiments and developed various low-cost technologies to remove fluoride from water and wastewater. However, selection of appropriate treatment method depends on local situation. This review paper presents the information on fluoride, sources of its occurrence, its effects on human & animal health and various control methods for the removal/reduction.

Key words - adsorption, adsorbent, defluoridation, fluoride, human health, isotherm, low cost material, skeletal fluorosis

1 INTRODUCTION

WATER is one of an essential commodity for the survival of all forms of lives on the earth. The population explosion and rapid industrial growth demands huge quantity of fresh water to meet various requirements. Of the total quantity of water (1.38x109km3) available on the earth, 3% only is the fresh water. Of this 3% of fresh water, 1.74% is in glacier form, 1.7% as ground water and the rest in the other forms. Very small quantity of water (i.e 0.0132% of total water) only is available in the rivers and lakes and most of these water sources are getting polluted due to waste disposal and human activities [1]

India is one among the 23 nations in the world, where the fluoride contaminated groundwater is creating the health problems. Fluorosis was first detected in early 1930s in four states of India. In 1986, 13 states and in 1992, two more states were added to this list. It has been reported as many as 177 districts in 19 states and Union Territories of India have already been affected by fluorosis [2].

The most seriously affected states in India are Andhra Pradesh, Punjab, Haryana, Rajasthan, Gujarat, Tamil Nadu and Uttar Pradesh [3], [4]. The highest concentration observed to date in India is 48 mg/l in Rewari District of Haryana [5].

Most of the rural population depends on the ground water sources for drinking purposes which generally contain underground deposits such as salts and minerals. One such is the fluoride which causes an adverse impact on human as well as animal health if fluoride concentration is higher [6]. Consumption of water having excess fluoride over a prolonged period leads to a chronic ailment known as fluorosis. According to the recent study, 62 million people are affected by various degrees of fluorosis in India alone. Out of these; 6 million are affected with a dental, skeletal and non-skeletal form of fluorosis and associated health problems [7]. Fluorine is often called as two-edged sword. The positive side is about 96% of fluoride in the human body is found in bones and teeth. Fluorine is essential for the normal mineralisation of bones and formation of dental enamel. On the negative side, prolonged ingestion of fluoride through drinking water in excess of the daily requirement is associated with dental and skeletal fluorosis [8].

Standards prescribed by various regulatory bodies for fluoride concentration in drinking water are different according to their climatic conditions. According to the World Health Organization (WHO), the standard prescribed for fluoride ion concentration in drinking water is 1.0 mg/l [9] whereas by Bureau of Indian Standards (BIS) it is 1.0mg/l [10],[11]. Fluoride in smaller dose (0.8-1.0mg/l) helps to prevent dental caries particularly in the children below 8 years of age. Fluoride in higher concentration causes dental fluorosis (1.5 -2.0mg/l) and skeletal fluorosis (>3.0mg/l) [12]. This paper describes the effects fluoride on health at various fluoride concentrations, its presence in various forms and controlling methods.

2 SOURCES OF FLUORIDE

The amount of fluoride stored across the world in the ground is estimated to 85 million tons and nearly 12 million tons are located in India [13]. The principal sources of fluorine were drinking water and food such as sea fish, cheese and tea [14]. Fluoride is present in all waters particularly in ground water with higher concentrations.

There has been an escalation in daily fluoride intake via the total human food and beverage chain. Carbonated soft drinks have considerable amounts of fluorides. Beers brewed in locations with high fluoride water levels may contribute significantly to the daily fluoride intake and sweetened iced teas contain significant amounts of fluoride. A single serving of chicken sticks alone would provide about half of a child's up-

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per limit of safety for fluoride. Children's ingestion of fluoride from juices and juice-flavoured drinks can be substantial and a factor in the development of fluorosis [15]. Fluoride is also present in most of everyday needs, viz. toothpastes, drugs, cosmetics, chewing gums, mouthwashes, and so on [16].

The most common fluorine-bearing minerals, which constitute natural source for fluoride in drinking water are fluorite (CaF_2), apatite ($Ca_{10}(PO_4)6F_2$), rock phosphate and topaz ($Al_2(F,OH)2SiO_4$) [17]. Artificially high soil F levels can occur through contamination by application of phosphate fertilizers or sewage sludges, or from pesticides [18].

Rocks in southern India are rich with fluoride which forms the major reason for fluoride contamination in groundwater [19], and the granites in the district of Nalgonda, Andhra Pradesh contain much higher fluoride than the world average fluoride concentration of 810 mg/kg [20].

Fluoride content in fresh water sources, agricultural crops, edible items, minerals & soils are presented in Tables 1, 2&3

Table 1: Fluoride Content in Fresh Water Sources [21]

Source	Average Fluoride Content (ppm)
Rain	0.008
Surface Waters (e.g., lakes, river, springs)	0.05
Bottled Water	0.1

(Source: http://fluoridealert.org/content/fresh_foods/)

Table 2: Fluoride Content in Minerals & Soils [22]

Minerals	Fluoride Content (ppm)
Basalt	100
Sand stone	270
Shale	740
Meteolites	28-30
High Calcium	520
Deep sea clays	1300
Alkali Rocks	1200-8500

(Source: http://fluoridealert.org/content/fresh_foods/)

Table 3: Fluoride Content in Agricultural Crops and Other Edible Items [22]

Food Items	Fluoride (ppm)			
	Senguupta & Pal (1971)	Lakdawala & Punekar (1973)	Chari et.al (1975)	Rajya Laxmi (1982)
Wheat	4.6	2.59-3.3	-	-
Rice	5.9	3.27-14.03	2.9	-
Bajra	-	1.72-2.23	2.82	7.4
Soyabean	4	-	-	-
Red gram dal	3.7	2.34-4.84	-	5.28
Cabbage	3.3	1.28-2.29	-	
Lettuce	5.7	-	-	
Tomato	3.4	1.0-2.08	0.33	
Ladies Finger	4	2.2-3.62	1.74	
Brinjal	1.2	1.62-2.48	1.24	
Carrot	4.1	1.9-4.9	-	
Potato	2.8	1.27-2.92	-	
Onion	3.7	1.0-3.0	-	
Banana	2.9	0.84-1.58	0.84	
Grapes	-	0.84-1.72		
Mango	3.7	0.8-1.80		
Apple	5.7	0.24-0.52		
Almond	4	-		
Coconut	4.4	-		
Groundnut	5.1	-		
Tea(dry leaves)	-	39.8-68.59		
Tea infusion	-	11.13-37.34		
Aerated drinks	-	0.77-1.44		
Mutton	-	3.0-3.5		
Beef	-	4.0-5.0		
Fishes	1.0-6.5	-		

(Source: http://fluoridealert.org/content/fresh_foods/)

3 Effects of Fluoride

Chemically, the fluorine is the most electronegative element and it is always present in a combined state as fluoride because of its high chemical reactivity. The fluoride is a great calcium-seeking element and it can disturb the calcified structure of bones and teeth in the human body at higher concentration resulting dental fluorosis or skeletal fluorosis [23]. Similar kinds of effects are found in animal body parts also. The effects of fluoride on human and animal are shown in Fig. 1 & 2 [24].

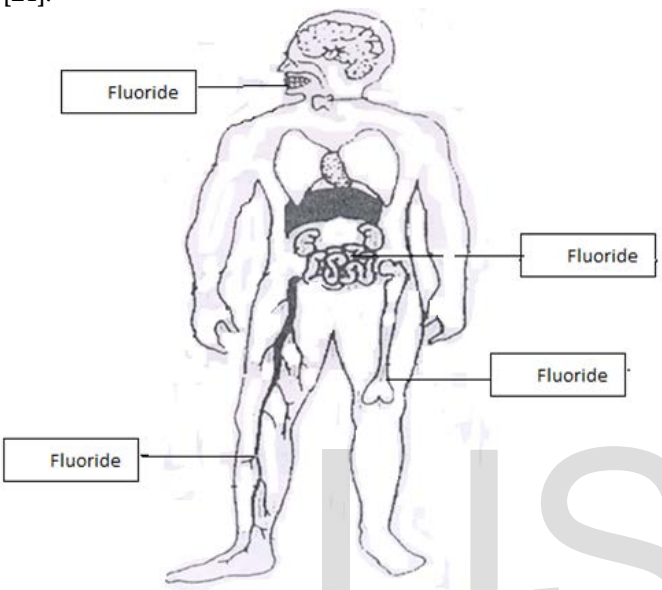

Fig. 1 Effects of Fluoride on Human [21]

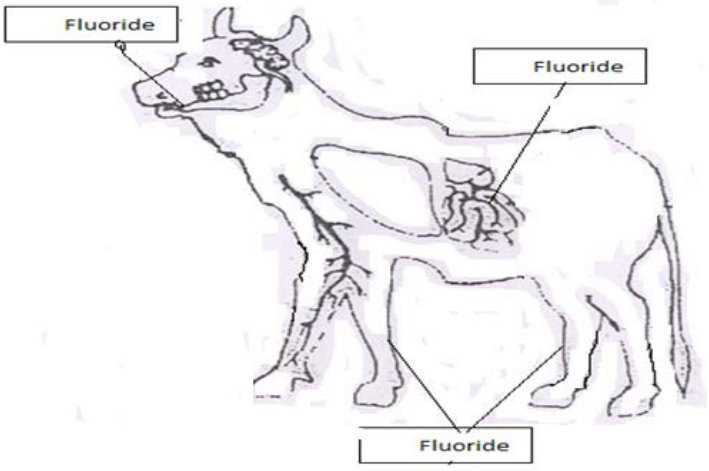

Fig. 2 Effects of Fluoride on Animal [21]

Though a small amount of it is beneficial for human health for preventing dental caries, it is very harmful when present in excess of 1 mg/L. World Health Organization (WHO) and IS : 10500 recommend that the fluoride content in drinking water should be in the range of 1-1.5 mg/L. An intake of more than 6 mg/d of fluoride, results in multidimensional health manifestations, the most common being dental and skeletal fluorosis [25].

Fluoride concentrations beyond the standards cause dental and skeletal fluorosis. Fluoride toxicity can also cause non-skeletal diseases like aches and pain in the joints, non-ulcer dyspepsia, Polyurea (tendency to urinate more frequently) and polydipsia (excessive thrust), muscle weakness, fatigue, anemia with very low hemoglobin levels, etc besides other reasons [15].

4 Methods of Defluoridation

Defluoridation is the process of removal of fluoride ion from water or wastewater. This can be possible in two ways:

(i) Blending the existing water supply with the water containing low concentration of fluoride

(or)

(ii) treating the fluoride contained water in two ways;

(a) Centralized treatment method - This method is best suited in developed nations where cost is not a factor. Usually defluoridation process is carried out on a large scale along with other treatment processes at the water works.

(b) Decentralized method (ie. at the community, village or household level) - This option suits where group of villages/houses are scattered especially in rural areas. Various simple treatment methods available are followed at village or household level. The advantage of these methods is the treatment cost is lower since water required for drinking and cooking only treated. The major drawback of these methods is generation of huge quantity of sludge

Various methods used to remove fluoride from water or wastewaters are:

- Chemical precipitation
- Ion exchange
- Adsorption
- Miscellaneous methods including RO, electro-dialysis, etc.

Most of these methods have high operational and maintenance cost, low fluoride removal capacities, lack of selectivity for fluoride, undesirable effects on water quality, generation of large volumes of sludge and complicated procedures involved in the treatment [15], [26]. Nalgonda technique developed by NEERI is commonly preferred at all levels because of its low price and ease of handling [27]. Adsorption techniques have been quite popular due to their simplicity and availability of wide range of adsorbent materials. Many bio-sorption techniques have been employed for the treatment of drinking water. Researchers worked on various locally and abundantly available materials like aloe vera and CaCl2 [23], fish bone charcoal [28],[29], red mud [30],[31], Clays [32], fly ash [33],[34], synthetic zeolites [35],[36], neem bark powder [37], activated alumina [38] etc.

5 CONCLUSIONS

People living in villages with poor infrastructure facilities are unaware of the meaning of safe drinking water. They opined that the ground water is the filtered form of water and free from bacteriological impurities and hence prefer to use for drinking and cooking purposes. They are unaware of that the groundwater might have contaminated with minerals and salts like fluoride. Most of the people who got affected with fluorosis may be living in villages or spent their childhood there. Sometimes we pay attention on attractive packing or advertisements rather than necessity and buy fluoride contained products without understanding whether suits to our health or not. Hence an awareness in the form of education is necessary. In rural areas, converting the government land into water storage reservoirs for the use of drinking water also help to some extent.

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