Nature & Environment
Vol. 19 (2), 2014: 163-172
Website: www.natureandenvironment.com

ISSN (Print) : 2321-810X
ISSN (Online) : 2321-8738

RESEARCH ARTICLE

Efficacy of Sustainable Technologies for Fluoride Removal from Groundwater Resource: A General View

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Received: 25th March 2014, Revised: 30th April 2014, Accepted: 5th May 2014

ABSTRACT

Fluoride is a non-biodegradable contaminant that accumulates in the entire environmental components like aquatics, plants and human beings. High fluoride concentrations are especially critical in developing countries, because of lack of suitable infrastructure for treatment. Fluoride has a significant mitigating effect against dental caries if the concentration is approximately 1mg/l. However, continuing consumption of higher concentrations can cause dental and skeletal fluorosis. Further, efficiency of novel method is considered necessary to adopt for fluoride removal from wastes, aqueous media and plant sources by membrane and adsorption techniques. The present evaluation emphasized on efficiency of different techniques for the removal of fluoride from water and plants. The result of the exploratory study on different parameters resembling pH, agitation time, fluoride concentration, temperature and particle size are operate for fluoride removal capacity through membrane, adsorption and plant materials.
***Key Words**: Fluoride contamination, Fluorosis,* Defluoridation, *adsorption, fluoride removal*

INTRODUCTION

Fluoride concentration in drinking water due to natural and anthropogenic activities has been renowned as one of the major public health problems in worldwide. The probability of occurrence of high fluoride concentration in ground and surface water was detected in various countries include India, China, Argentina, Mexico, Pakistan, Italy, Iran, Bangladesh, Newzeland, Ethiopia and UK (Amini *et al.* 2008). The dental fluorosis and skeletal fluorosis are endemic in number of countries, they are many countries like USA, Morocco, Algeria, Libya, Egypt, Jorden, Turkey, Franfraq, kenya, Tanzania, South Africa, Australia, Japan, Thailand, Canada, Saudi Arabia, Persian Gulf, Srilanka and Syria. The above said countries are most prominent fluorosis countries in worldwide (Mameri *et al.* 1998).

According to the World Health Organization the maximum acceptable concentration of fluoride ions in drinking water lies below 1.5 ppm (WHO, 1984; 2004). Fluoride if taken in small amount is usually beneficial, but the beneficial fluoride concentration range for human health is very small. Depending on the concentrations and the duration of fluoride intake, it could have positive effect on dental caries. On the contrary, long term consumption of water containing excessive amounts of fluoride can lead to fluorosis of the teeth and bones (Jamodei *et al.*2004). The excessive intake of fluoride may cause dental (Gonzales *et al.* 2004) and skeletal disorders (Solangi *et al.* 2009). Fluoride ion is attracted by positively charged calcium ion in teeth and bones due to its strong electronegativity which results in dental, skeletal and no skeletal forms of fluorosis i.e. high fluoride ingestion, in children as well as adults. Due to high toxicity of fluoride to mankind, there is an urgent need to treat fluoride-contaminated drinking water to make it safe for human consumption.

Fluorosis in mild version can be evidenced by mottling of teeth and in high version by embrittlement of bones and neurological damage , in some of the cases it may even interfere with carbohydrates, proteins, vitamins and mineral metabolism and to DNA creation as well if intake excessively (Zhou *et al.* 2004). Studies have shown that major of the kidney diseases have a great inclination of toxicity of fluoride. On high doses and short term exposure fluoride can exterminate the kidney function.

Workers exposed to high fluoride concentration areas are diagnosed with bladder cancer (Islam *et al.* 2011). Various diseases such as osteoporosis, arthritis, brittle bones, cancer, infertility, brain damage, Alzheimer syndrome, and thyroid disorder can attack human body on excessive intake of fluoride. Fluoride contamination in ground water is a world-wide issue and some cost effective technologies are required to eliminate excess fluoride in water.

Many methods make use of defluoridation of water is ion-exchange (Apambire *et al.* 1997), precipitation with iron (III) (Tressaud 2006), activated alumina (Ghorai and Pant 2005), alum sludge (Sujana *et al.* 1998), calcium (Huang and Liu 1999) is extensively observed. In addition reverse osmosis (Simons 1993) and electro coagulation. Most of these methods used in large scale intention such as high operational and upholding expenditure, generation of toxic products (environmental noxious) and due to complex treatment. Earlier findings conferred pros and cons of different methods for defluorination would be most effective process such that coagulation but it does not facilitate in fetch downhill the fluoride concentration at desired level. On the other hand membrane process is cost effective in terms of installation and operation cost; there are also more chances of fouling, scaling or membrane degradation. The electrochemical techniques are not popular due to high cost during installation and safety.

The most successive and predominant methods for defluoridation (coagulation-precipitation, membrane process, ion exchange, and adsorption processes) that is used in countries like India, Kenya, Senegal and Tanzania is Nalgonda technique. In this technique, calculated quantities of alum, lime and bleaching powder are mixed with water, after mixing the water is processed with flocculation, sedimentation, filtration and disinfection. However, coagulation-precipitation (also known as Nalgonda technique) is an effective and cheap method but its main impenetrability is the generation of harmful waste products. The membrane process is mainly the reverse osmosis technique but it requires high maintenance cost due to fouling, scaling and degradation of membrane. Similarly, the ion exchange process is very costly. Conventionally several techniques available for defluoridation includes coagulation-precipitation, membrane process, ion exchange, and adsorption processes. (Meenakshi and Maheshwari 2006). The adsorption method is considered more appropriate for defluoridation due to its simplicity, effectiveness, and cost-effective (Ali and Gupta 2007).

The important adsorbents that have been tested for the fluoride removal include activated alumina (Tang *et al.* 2009), activated charcoal (Emmanuel *et al.* 2008), zeolite (Sun *et al.* 2011, biosorbents (Kamble *et al.* 2007), and nanosorbents (Kumar *et al.* 2011). Activated charcoal is considered as a universal adsorbent because of its applications and viability. (Tembhurkar and Dongre 2006) studied the removal of fluoride using activated charcoal. Activated alumina is also an efficient adsorbent for fluoride removal from drinking water but it has limited regeneration capacity and slow rate of adsorption (Maliyekkal *et al.* 2006).

Several studies have been assessed to increase the efficiency of activated alumina for defluoridation. In a study, alum impregnated activated alumina was used to remove fluoride from drinking water with the removal efficiency of 99% at pH 6.5 (Tripathy *et al.* 2006). Similarly, another study reports the adsorption equilibrium and kinetics of fluoride removal using solgel derived activated alumina adsorbent. In this study, calcium oxide and manganese oxide coating were done on sol-gel-derived activated alumina to enhance its fluoride removal efficiency.

The main challenge encountered during the adsorption studies is the separation of adsorbent after use from water samples. Generally, filtration is employed for the separation of powdered adsorbents. The aim of the present study was to prepare an immobilized adsorbent in the form of granules that could easily be separated from water without undergoing filtration and centrifugation processes. For this purpose, sol-gel method has been adopted to prepare immobilized activated alumina with uniform surface properties. The immobilized activated alumina has further been modified by adding alum to enhance its adsorption capabilities.

SUSTAINABLE TECHNOLOGIES FOR FLUORIDE REMOVAL

1. COAGULATION-PRECIPITATION, MEMBRANE PROCESS AND ION EXCHANGE

Common techniques used for defluoridation are coagulation-precipitation, membrane process and ion exchange. At present, the most reliable methods used to remove excessive fluoride from drinking water are either too expensive or not suitable for the environments where they are needed most. An effective method to remove fluoride from drinking water that is less expensive than conventional filtration processes and is safe to use.

The removal of fluoride from drinking water using modified immobilized activated alumina (MIAA) resulted in a removal efficiency that was 1.35 times higher than normal immobilized activated alumina (Ramos *et al.* 1999). Modified immobilized activated alumina (MIAA) was added to water that was tainted with fluoride and then analysis was conducted to evaluate the quantity of fluoride that was removed from the water.

2. IMMOBILIZED ADSORBENT ON FLUORIDE REMOVAL

For the preparation of adsorbent, sol-gel method of activated alumina was employed with some modifications. The modified boehmite sol was prepared by dissolving drop-wise 100mL aluminum tri-sec butoxide in 300mL distilled water at 75°C on a hot plate and adding appropriate amount (10g) of alum. In order to find out an appropriate alum dose, several boehmite sols were prepared by varying the amount of alum additive from 5 to 25g. As 10g of dose gave maximum fluoride removal efficiency (85%) and considered as appropriate amount of additive. After dissolution, the solution was heated at 90°C for one hour and 15mL 1M HNO_3 was added in the slurry. The slurry was refluxed (in a closed vial) in a water bath at 90°C for 10 hours to obtain stable modified boehmite sol. The sol was then heated in a petridish at 40°C in an electric oven. The gel was dispensed drop-wise with the help of a syringe (without needle) in the ammonia solution that had a top layer of paraffin oil. The droplets were left in the ammonia solution for 45 minutes in order to turn them into solid granules. The granules were washed thoroughly by distilled water and ethyl alcohol, dried, and calcined at 450°C for three hours to obtain modified immobilized activated alumina (MIAA). For each batch adsorption experiment, a fresh adsorbent was prepared as the stated amount is enough for one batch test. The scanning electron microscope (JEOL JSM-6460, Japan) analysis was performed in order to check the surface of immobilized activated alumina before and after adsorption.

ADSORPTION STUDY

Fluoride adsorption experiments were conducted in order to determine the efficiency of adsorbent and the effect of controlling parameters like dose, contact time and stirring rate (Srimurali *et al.* 1998). The stock solution of 5mg/L of fluoride was prepared by dissolving 0.011g of reagent grade NaF in 1000mL distilled water. All adsorption experiments were carried out in a 250mL conical flask with 100mL test solution at room temperature (20 ± 1°C) using a mechanical shaker. The adsorption experiments were performed at pH = 7 and at 20 ± 1°C only in order to be as close as possible to natural drinking water conditions for fluoride removal. Fluoride ion concentration was measured using both spectrophotometer (DR 2010, Hach, USA) and ion selective electrode (Ion meter Model 25, Hach, USA).

The effect of adsorbent dose of adsorbent on fluoride removal was studied by varying the dose from 0.5 up to 20g/L in test solutions containing initial fluoride concentration, 5mg/L. In order to determine the equilibrium adsorption time, the flasks containing fluoride test solutions (5mg/L) and optimum adsorbent dose were agitated on the shaker for periods of 5, 15, 30, 45, 60, 75, 90, and 120 minutes. Similarly, for the determination of optimum stirring rate, the flasks containing fluoride test solutions (5mg/L) and optimum adsorbent dose were agitated on the shaker by changing stirring rate from 50 to 250rpm. The effect of varying fluoride concentration on adsorption was also studied by changing fluoride concentration from 0.5 to 120mg/L and employing optimum adsorption conditions. All adsorption tests were run in triplicate to check the precision among the results.

The specified amount of fluoride adsorbed (mg/g) was calculated as follows: where is the initial fluoride concentration (mg/L), is the residual fluoride concentration at equilibrium (mg/L), and is the mass of adsorbent in test solution (g/L). To compare the efficiency of MIAA, activated charcoal was chosen as standard. All adsorption tests described above were performed again using activated charcoal adsorbent.

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HERBAL PLANTS

Herbal plant materials such as barks of *Moringa olifera* and *Emblica officinalis*, the roots of *Vetiveria zizanoides* and the leaves of *Cyanodon tactylon* were found to be good defluoridating agents. An exciting and new water treatment breakthrough has been announced that will now make the removal of fluoride from the drinking water supplies of the world's poorest people more affordable than ever. Researchers from Rajasthan University in India have discovered that the Tulsa plant, also known as Holy Basil, can be used to significantly reduce the amount of fluoride in drinking water (Murugan and Subramanian 2006). At present, the most reliable methods used to remove excessive fluoride from drinking water are either too expensive or not suitable for the environments where they are needed most. The method discovered by researchers from Rajasthan University is safe, cheap and readily available, making it an ideal alternative for communities who can't afford to use the more advanced techniques of removing fluoride that are readily available in the West. An experiment was carrying out in the Pappireddipatti village of Dharmapuri district. The researchers sopping 70 mg of Tulsa leaves in 100ml of water that contained 7.0 parts per million of fluoride in the water. After only sopping wet the Tulsa leaves for eight hours, it was exposed that the level of fluoride in the water was reduced from 7.0 parts per million, to only 1.0 parts per million.

At present, the World Health Organization suggests to facilitate the safe level of fluoride in drinking water is between 0.5 to 1 parts per million. The vulnerability of drinking water that contains high levels of fluoride is well known. Some of the known side effects of drinking water that contains fluoride are dental fluorosis, reduced intelligence in children and a damaged nervous system. This new water treatment option could now provide the world's poorest people an opportunity to remove excessive fluoride from their drinking water supplies. Further, to study vital role of the effectiveness of using Tulsa leaves as a means of removing fluoride from drinking water supplies through validation and identification. Taking into consideration the cost effective of the adsorption materials more consistent with water treatment techniques, if the Tulsa plant is conclusively proven to be effective in removing fluoride from drinking water, then we may possibly observe a uprising in water treatment, providing unconventional to areas where none currently exist.

REVERSE OSMOSIS AND DISTILLATION

The process of reverse osmosis will generally remove any molecular compounds smaller in size than water molecules. Such compounds include salt, manganese, iron, fluoride, lead, and calcium (Binnie *et al.*, 2002). Reverse osmosis is extremely efficient at stripping minerals from water, and it is highly valued as a water purification process in the printing industry, in which mineral-free water must be used.

Even though reverse osmosis supplies useful, mineral-free water for printing purposes, it does not provide the healthiest drinking water. The removals of numerous mineral and chemical materials from water, including salt, fluoride, lead manganese, iron, and calcium by bioadsoprtion or reverse osmosis process. Though, reverse osmosis because it confiscates the minerals according to physical size, is non-selective in its removal of dangerous and beneficial minerals. Obviously, mineral contaminants akin to salt, fluoride, and lead should be removed from drinking water, but minerals like iron and manganese, because they are essential to natural body processes and important components of drinking water, should be left in that water. Iron builds and maintains healthy red blood cells while manganese helps in regulating protein, fat, and carbohydrate metabolism. Manganese, like calcium, is also an essential component in the building of bones and the clotting of blood. Though many foods contain these minerals, drinking water can and should be a major source for their intake.

Distillation removes chemicals similar to those removed by reverse osmosis, but in a different manner. Distillation, through its water evaporation process, will remove any chemicals or organic materials with higher boiling points than water. Such chemicals and organic materials with higher boiling points include bacteria, minerals, trace amounts of metals, many volatile organic chemicals (VOCs), and nitrate (Binnie *et al.* 2002). Clearly, distillation is valuable in its removal of the potentially deadly VOCs and nitrate. It strips water of nearly all of its natural minerals, though. Many of the minerals the distillation process removes are vital to the body's natural processes. The distillation process is not selective in its removal of minerals, and it strips water of both dangerous and valuable mineral compounds.

FILTRATION

Filtration is the most effective type of water treatment and purification currently available (Ramstorp and Matts 2003). Carbon and multimedia filters build upon the treatment capabilities of reverse osmosis and distillation. They retain all of the good filtration qualities of these two systems while efficiently removing additional water contaminants. They are able to rid water of the larger compound materials, like salt, while selectively removing much smaller and dangerous chemicals, like chlorine and pesticides, that reverse osmosis and distillation systems cannot remove.

Because carbon and multimedia filters utilize both chemical and physical filtration processes, they are able to selectively remove a large number of drinking water contaminants. Water filters can remove the small, but dangerous pesticide and herbicide chemicals while allowing larger, trace minerals to safely pass through the filter with the water. The retention of trace minerals in water provides a much healthier source of drinking water. The chemical adsorption process, which carbon and multimedia filters use, is the only filtration process that can selectively filter unwanted materials from water. Also, the slow filtration process of carbon and multimedia filters does not require costly energy sources like reverse osmosis and distillation systems. Because carbon and multimedia filtration systems do not require a heat or pressure source, they are fairly cost-effective. Carbon and multimedia water filters waste relatively little water in the filtration process.

Filtration, like reverse osmosis and distillation, is a fairly slow process as it requires several stages of water purification. Although the process is slow, once the water has been through the required stages, it is freer from contaminants than the water product of any other purification technique. Besides the relatively slow process, there are a few other aspects to filtration that may make it less than ideal. Depending upon the type of filter used, water may have limited contact time with the filter media, resulting in only partial removal of drinking water contaminants. Also the type of filter media may affect the number of contaminants that can pass through the filtration process. Rapid filters and granular filters are less effective than solid block carbon filters. Rapid filters allow for only brief contact time with the filter media, limiting the amount of contaminants that may be removed through the adsorption process. Granular filters contain fairly large pores and allow several contaminants to pass through the filter media. For the most reliable and efficient filtration, solid block carbon or multimedia filters should be used. For nanofiltration membranes have slightly larger than pores than those used for reverse osmosis and it offers less resistance to passage both of solvents and solutes (Diawara 2008).

ELECTRO COAGULATION

The word "electrocoagulation" (EC) will be sometimes used with "electroflotation" (EF) and can be considered as the electrocoagulation/flotation (ECF) process. Through the process of electrolysis, coagulating agents such as metal hydroxides are produced. When aluminium electrodes are used, the aluminium dissolves at the anode and hydrogen gas is released at the cathode (Hu *et al.* 2003). The coagulating agent combines with the pollutants to form large size flocs. As the bubbles rise to the top of the tank they adhere to particles suspended in the water and float them to the surface. In fact, a conceptual framework of the overall ECF process is linked to coagulant generation, pollutant aggregation, and pollutant removal by floatation and settling when it has been applied efficiently to various water and wastewater treatment processes (Qianhai *et al.* 2008).

Electrocoagulation is an electrochemical method of extravagance polluted water whereby sacrificial anodes corrode to liberate energetic coagulant precursors (usually aluminium or iron cations) into solution (Hu *et al.* 2003). Accompanying electrolytic reactions develop gas (usually as hydrogen bubbles) at the cathode. Electrocoagulation has a long history as a water treatment technology have been utilizing to remove a wide range of pollutants. However electrocoagulation has never become customary as a 'mainstream' water treatment technology. The lack of a systematic approach to electrocoagulation reactor design/operation and the issue of electrode reliability (particularly passivation of the electrodes over time) have limited its implementation. However recent technical improvements combined with a growing need for small-scale decentralized water treatment facilities have led to a re-evaluation of electrocoagulation. Starting with a review of electrocoagulation reactor design/operation, this article examines and identifies a conceptual framework for electrocoagulation that focuses on the interactions between electrochemistry, coagulation and flotation (Emamjomeh and Sivakumar, 2009). In addition detailed experimental data are provided from a batch reactor system removing suspended solids together with a mathematical analysis based on the 'white water' model for the dissolved air flotation process. Current density is identified as the key operational parameter influencing which pollutant removal mechanism dominates. The conclusion is drawn that electrocoagulation has a future as a decentralized water treatment technology (Holt *et al.* 2005).

BIOSORPTION

In general, Fluoride enters the environment through water, food, industrial exposure, drugs, cosmetics, etc., conversely, drinking water is the major source of daily ingestion (Sarala and Rao 1993). The process of defluoridation was routinely carried out by means of adsorption, chemical treatment; electro-chemical methods, dialysis and ion exchange process (RGNDWM, 1993). The method of adsorption is found to be most efficient, cost effective, environmental friendly and economical in the fluoride removal from ground water (VenkataMohan *et al.* 2002). The previous findings affirmed the biosorption analytes from various types of adsorbents i.e. activated carbon, minerals, Wash bone charcoal coconut shell carbon, rice husk carbon, etc. with divergent degrees of success. (Prabavathi *et al.* 2003; Jayantha *et al.* 2004).

The preparation of biosorbents from the naturally abundant devastates biomass of mainly algae, fungi or bacteria were exploited. (Mann 1990; Kapoor and Viraraghavan 1995). The previous study determine that the occurrence of element functional groups such as hydroxyl, carbonyl, carboxyl, sulfhydryl, theioether, sulfonate, amine amide, imidazole, phosphonate and phosphodiester present on the biosorbent surface to implies in support of biosorption. Too little information of study was permissible on the biological treatment by algal species (fresh and marine water) in spite of their ubiquitous supply and their central role in the fixation and yield of carbon and other nutrient elements (Semple *et al.* 1999; Bhatnagar and Bhatnagar 2000). Among the marine organisms, algae were known to accumulate the highest levels of fluoride and much higher than that occurs in land plants (<5-10mg/kg) (Kesava Rao and Indusekhar 1984; Bhatnagar and Bhatnagar 2000).
The extent of fluoride sorption on the algal sorption system showed a marked decrease as the pH of the aqueous solution increased from 2.0 to 10.5. This specific phenomenon of sorption characteristics could be attributed to the anionic sorption and this further indicated that the adsorbent surface was of H+ (cationic)-type (Venkata Mohan and Karthikeyan 1997). The removal of fluoride study were carried out under a range of experimental conditions such as pH, contact time, initial fluoride concentration, temperature and the presence of counter ions. It was observed that the maximum fluoride removal occurred at pH 6.15 and increased with increase in time and initial fluoride concentration. Fluoride adsorption was not significantly affected by temperature variation but was influenced by ions.
During anionic exchange sorption, the lower pH values possess the surface of the adsorbent turned out to be positively charged and this facilitated sorption of fluoride ions. The basic pH range may be attributing to rose hydroxyl ion which leads to form an aqua-complexes; these aqua complexes retard to the sorption which inhibit the fluoride adsorption onto the surface of the algae (Venkata Mohan and Karthikeyan 2000). Further, the adsorption study accomplished on the non-viable fungal or algal substrate as biosorbents exposes its ability to remove the fluoride from aqueous phase. The method of Batch sorption study is to determine the algal–fluoride system point out wide-ranging fluoride sorption capacity at assorted fluoride concentration.

BIODEGRADATION

Arrays of technologies such as coagulation, ion exchange and adsorption have been making use of for fluoride removal from ground or drinking water. The majority of the materials are micro sized particles. A different technology makes the majority of surface area inaccessible to the contaminants thereby limiting their removal either by biodegradation or adsorbents. The most prominent technologies for fluoride removal from water are ion exchange, electrochemical degradation, precipitation-coagulation, biodegradation and adsorption (Saha 1993; Mameri *et al.* 2001; Singh *et al.* 1999). Ion exchange methods are efficient for fluoride removal, but the tedious and difficult process of preparing of resins, as well as the high cost, necessitated a search for an alternative technique (Sarkar *et al.* 2006). In precipitation-coagulation, trace amounts of fluoride ions tend to remain in aqueous solution. The limitations of the process are the generation of large amounts of sludge and the high pH of the treated water (Meenakshi and Maheswari 2006). The biological method is applicable to low pollutant levels, and this process may not always be possible in water treatment due to its long-term biodegradation. Adsorption has been found to be superior to other techniques for fluoride removal based on initial cost, flexibility and simplicity of design, and ease of operation and maintenance (Sarkar *et al.* 2006; Mariappan *et al.* 2002). A variety of low-cost adsorbents (both natural and synthetic), including activated alumina, red mud, alum sludge, chitosan beads, carbonaceous materials, calcite, montmorillonite and spent bleaching earth (Viswanathan *et al.* 2009; Viswanathan and Meenakshi 2008) have been used for the removal of fluoride from water.

CONCLUSION

In this review the removal of fluoride, using bioadsorbents have been recapitulated in concise method. The efficacy of each adsorbent has been examine and conversed. The following conclusion has been made on the basis of assessment:

1. Using Reverse Osmosis Filtration: This is used to purify several types of bottled water (not all), so some bottled waters are unfluoridated. Reverse osmosis systems are generally unaffordable for personal use.
2. Using Activated Alumina Defluoridation Filter: These filters are used in locales where fluorosis is prevalent. They are relatively expensive and require frequent replacement, but do offer an option for home water filtration.
3. Using Distillation Filtration: There are commercially available distillation filters that can be purchased to remove fluoride from water.
4. Fluoride Treatment Methods: The defluoridation methods are divided into three basic types depending upon the mode of action:
5. Analysis based on some kind of chemical reaction with fluoride: Nalgonda technique, Lime
6. Analysis of adsorption process: Bone charcoal, processed bone, tricalcium phosphate, activated carbons, activated magnesia, tamarind gel, serpentine, activated alumina, plant materials, burnt clay
7. Analysis of ion-exchange process: Anion/Cation exchange resins
8. The present review of this study is support by way of the aim of the tamarind fruit cover in its natural and acid treated forms could be used as a potential biosorbing agent for the removal of fluoride ions from an aqueous media. The maximum uptake of fluoride ions occurs at pH 6.0. An increase in the amount of biosorbent increased the percentage removal of fluoride ions. Moreover, the biosorbent was exemplified by FTIR spectroscopy, porosity and scanning electron microscopy (SEM) techniques.

Carbon based adsorbents have its application in small scale and lack in terms of column operation and/or pilot scale. Various natural adsorbents have potential for defluoridation of water but their difficulties in regeneration and low efficiency have also been reported. Rare earth oxide-based materials have shown high fluoride removal efficiency in batch mode but these materials have been found very expensive.

Biosorption is an environmentally friendly technique for fluoride removal utilizing various biomaterials of low cost. However, there are some disadvantages also, which limited its use for removal of low fluoride concentration. Nanoadsorbents have been attracted considerable attention in the recent years in fluoride removal and these materials have shown higher fluoride uptake capacity. The influence of pH, agitation time, initial fluoride concentration, temperature, particle size, surface area, presence and nature of counter ions and solvent dose were studied for defluoridation with various adsorbents. So, the future research should be concentrated in evaluating the efficacy of adsorbents in terms of cost and feasibility for removal of fluoride. It would be worthwhile to study the suitability of different chemicals to regenerates the spent adsorbents probably will be provide an unconventional process for fluoride removal from contaminated water.

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