

Defluoridation of ground water using adsorbent

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Abstract

Fluoride ion in trace amount is essential for the growth of human bones but, the excess intake of this ion creates a toxic effect in the body. The acceptable limit for fluoride ion in the drinking water should be less than 1.5 mg/L. Over and above 200 million people all over the world are suffering severe health hazards like crippling fluorosis, mottling of teeth, anaemia due to the consumption of fluoride contaminated water. In India, more than 60 million people across 20 states are suffering from this toxicity. Several years of research shows the applicability of the adsorption process for the defluoridation of water. Here the study presents the suitability of inexpensive leaf adsorbents to effectively remediate fluoride-contaminated water. The efficiency of the sorption of fluoride ion is affected by contact time, pH and particle size of adsorbents. Treated leaf powder was studied at various pHs & contact time with aqueous solutions containing 10mg F⁻/l.

Keywords: Fluoride, Low cost adsorbent, Dental Fluorosis, Skeletal Fluorosis, defluoridation.

I. Introduction

Water is the major medium of fluoride intake by humans [1]. Fluoride in drinking water can be either beneficial or detrimental to health, depending on its concentration [2]. Ground water is the major source of freshwater on the earth. Groundwater containing dissolved ions beyond the permissible limit is harmful and not suitable for domestic use. Fluoride beyond desirable amounts (0.6 to 1.5mg/l) in groundwater is a major problem in many parts of the world [3]. The fluorides belong to the halogen group of minerals

and are natural constituents of the environment. Fluorides are mainly found in ground water when derived by the solvent action of water on the rocks and the soil of the earth's crust. Fluoride is the most electronegative of all chemical elements and is never encountered in nature in the elemental form. It is seventeenth in the order of frequency of occurrence of the elements and represents about 0.06% to 0.09% of the earth's crust [4]. Many workers and reviewers used the word 'Fluoride' to denote the ionized, physiologically available form of the element [5]. The chemical activity of the fluoride ion ($E^0 = -2.8$ Volts) makes it physiologically more active than another elemental ion. Therefore, fluoride ions play an important role in human physiology [6]. Its presence in low concentration may either inhibit or stimulates enzymatic process and its interaction with other organic and inorganic body components may cause disruption in normal physiological functions of human body [7]. The popular technologies for the removal of fluoride from water include: coagulation followed by precipitation, membrane processes, ion exchange and adsorption [8-9]. In coagulation, trace amounts of fluoride ions tend to remain in solution due to solubility restriction. Other shortcomings include the resulting high pH of the treated water and the generation of large amount of wet bulky sludge [10-11]. The Nalgonda technique, based on precipitation processes, is also a common defluoridation technique.

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The limitations of the process are: daily addition of chemicals, large amount of sludge production, and low effectiveness for water having high total dissolved solids and hardness. Further, increase in residual aluminum in the treated water has been reported [12]. This may endanger human health as concentrations of aluminum, a neurotoxin, as low as 8.0×10^{-2} mg/l in drinking water have been associated with Alzheimer's disease [13]. Membrane processes, though effective in fluoride removal, demineralise water completely, besides the high initial and maintenance costs. Ion exchange methods are efficient for fluoride removal, but a tedious and difficult process of preparation of resins as well as the high cost necessitates a search for an alternative technique. Adsorption techniques have been quite popular in recent years due to their simplicity, as well as the availability of wide range of adsorbents.

II. Materials and Methods

All the reagents used were of AR grade. Fluoride stock solution was prepared by dissolving 221 mg anhydrous sodium fluoride in 1000 ml distilled water in volumetric flask. Fluoride standard solution was prepared by diluting 100 ml stock solution to 1000 ml distilled water in volumetric flask. This 1 ml solution has 0.1 mg of fluoride.

1. Equipment

Fluoride ion was estimated by Orion ion meter as per standard methods. PH meter, and Remi shaking machine for agitating the samples for the required period at a speed of 200 strokes/minute were used. The surface area of the adsorbent particle, porosity and density were measured by using surface area analyzer, mercury porosimetry and specific gravity bottles, respectively.

2. Material development

Fresh leaves chosen based on their crude fiber content and tress were obtained from neem (*Azadirachta indica*) trees. The fresh leaves were sun-dried for 3–4 days, put in a cotton jute bag

and crushed manually. (This process can save the energy expended in hot air oven drying and mechanical crushing.) The powder was sieved to get various particle sizes, viz. 600, 710, and 850 m, 1 mm, and 1.4 mm. Leaf powder biomass was further digested by chemical methods.

3. Alkali treatment

Leaf biomass powder sample (40 gm) and 400 ml 0.5 N NaOH was taken in 1000-ml conical flask. Then mixture was gently heated on burner for 20 min after boiling started. Using distilled water, the treated biomass was washed which continued until maximum colour was removed and clear water obtained.

III. Results and Discussion

Successful application of the adsorption technique demands innovation of cheap, nontoxic, easily and locally available material. Bio adsorbents meet these requirements. Knowledge of the optimal conditions would herald a better design and modeling process. Thus, the effect of some major parameters like pH, contact time, and particle size of adsorbent and materials was investigated from kinetic viewpoint. Adsorption studies were performed by batch technique to obtain the rate and equilibrium data. Experiments were carried out by shaking 10 g/l of adsorbent dose with 100 ml of aqueous solution containing known concentration of fluoride ions and by agitating the samples on Remi shaking machine at a speed of 200 strokes/min. Samples containing fluoride ions were maintained at a desired pH by adding 0.5 N HNO₃. All the experiments were conducted at room temperature (27 ± 0.5 °C).

A. Effect of contact time

It is found that the removal of fluoride ions increases with increase in contact time to some extent. Further increase in contact time does not increase the uptake due to deposition of fluoride ions on the available adsorption sites on adsorbent material. Preliminary

investigations on the uptake of fluoride ions on the adsorbent material at their optimum pH values indicate that the processes are quite rapid.

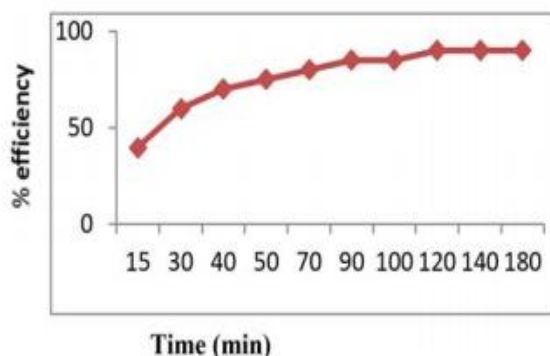


FIG 1: Effect of agitation time on the removal of fluoride ion. Adsorbent dose: 10 g/l, adsorbent size: mixed, volume of sample: 100 ml, temp.: 27°C, initial adsorbate conc.: 10 mg/l, pH: 2.

Typically, 80% of the adsorption occurs within the first hour of the contact for fluoride ions with an initial concentration and adsorbent dose of 10 mg/l for treated biosorbents (Fig.1). This initial rapid adsorption subsequently gives way to a very slow approach to equilibrium and saturation is reached in 1.5 to 3 h. For further optimization of other parameters, this contact time was considered as the equilibrium time. 3.2. Effect of pH. The pH of the aqueous solution is a controlling factor in the adsorption process. Thus, the role of hydrogen ion concentration was examined at pH values of 2, 4, 6, 8. The pH of the aqueous solution is a controlling factor in the adsorption process. Thus, the role of hydrogen ion concentration was examined at pH values of 2, 4, 6, 8, and 10. This was adjusted by adding 0.5N HNO₃ with 100 ml of standard solution of 10 mg/l of fluoride for a contact time of 60 min with a dose of 10 g/l of treated bioadsorbent. The influence of pH on the sorption rate is shown in Fig2.

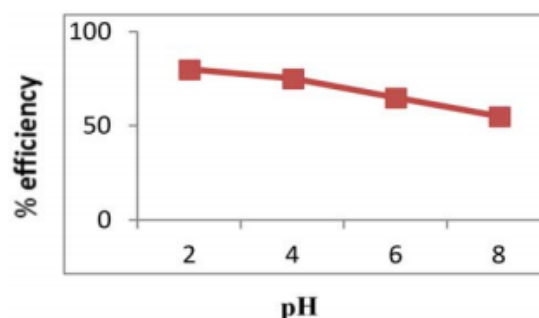


FIG 2: Effect of pH on the percentage removal of fluoride ion. Adsorbent dose: 10 g/l, adsorbent size: mixed, volume of sample: 100 ml, temp.: 27 °C, initial adsorbate conc.: 10 mg/l, time of contact: 60 min.

We have observed decrease in the extent of removal of fluoride ions with increase in the pH of the solution. This was investigated as 80% at pH 2 and 75% in the case of pH 4. Hence further studies were conducted within these pH values. In the case of treated biosorbents, the percentage of adsorption increased almost linearly between 2.0 and 8.0, attaining a maximum removal at pH 2.0 in 60 min of contact time. In this case, the result may be due to neutralization of the negative charges at the surface of the treated biosorbents by greater hydrogen ion concentration at lower pH values. This reduces hindrance to diffusion of the negatively charged fluoride ions on to the increased active surface of treated biosorbents.

B. Disposal of exhausted adsorbent materials

It is necessary to separate fluoride ion before its disposal. The exhausted adsorbent materials need to be dried and burned. The resultant product can be used in the manufacturing of bricks. Using various chemicals such as H₂SO₄, HCL, HNO₃, NaOH, EDTA, etc. desorption is possible.

C. Advantage of low-cost adsorbents over conventional adsorbents

The efficiencies of removal of fluoride ions of various nonconventional adsorbents vary between 50 and 90% depending upon the characteristics

and particle size of adsorbent(s). A combination of adsorbents can also be used effectively in defluoridation treatment.

- Nonconventional adsorbents are relatively cheaper compared to conventional ones and are easily available resulting in savings in cost.
- Nonconventional adsorbents require simple alkali or acid treatment for the removal of lignin before their application and to increase efficiency.
- Since the cost of these adsorbents is relatively low they can be used once and discarded.
- Nonconventional adsorbents require less maintenance and supervision. Separation is possible to segregate the nonconventional adsorbents from the effluents before their disposal.
- These nonconventional adsorbents can be disposed of easily and safely. Used adsorbents can be reused as a filler material in low-lying areas and hence their disposal does not pose any serious problem.

IV. Conclusions

Results show that these low-cost bio adsorbents could be fruitfully used for the removal of fluoride over a wide range of concentrations. Treated bio adsorbents were observed to be efficient for the uptake of fluoride ions between 2.0 and 8.0 pH. Fluoride removal for a given bio adsorbent size increased with time attaining equilibrium within 1.5 h. The percentage of fluoride removal was found to be a function of adsorbent particle size and time at a given initial solute concentration. It increased with time, and higher initial solute concentration decreased with time. The adsorption capacity of treated biosorbents was studied by varying the particle size. With the largest particle

size of 1.4 mm, the amount of fluoride ions adsorbed was found to be 50%. With smallest particle size of 600 μ for an initial fluoride ion concentration of 10 mg/l, 90% adsorption was observed. Small particle size provides more active surface area and hence such results. Treated biosorbents can be disposed of safely by burning after use. Treated biosorbents are locally available and hence involve no expenditure on transportation and have a very low cost for pretreatment. There is no need to regenerate the exhausted treated biosorbents as they are available abundantly, easily, cheaply and locally. Our future work deals with the evaluation and performance of various biomasses for the removal of fluoride.

References

- [1] Geneva, Environmental Health Criteria for Fluorine and Fluorides, 1984, 1-136.
- [2] Murutu C, Onyango MS, Ochieng A, Otieno FA. Fluoride removal performance of phosphoric acid treated lime: Breakthrough analysis and point-of-use system performance, Water SA 2012; 38(2):279-286.
- [3] Brindha K, Rajesh R, Murugan R, Elango L. Fluoride contamination in groundwater in parts of Nalgonda District, Andhra Pradesh, India. Environ Monit Assess, 2010. DOI 10.1007/s 10661-010-1348-0.
- [4] Wedepohl KH. Hand book of geochemistry. Springer-Verlag Berlin. (Ed.: Heidelberg). New York 1974; 2(9):1. ~ 112 ~ International Journal of Chemical Studies
- [5] Bhatnagar A, Kumar E, Sillanpaa M. Fluoride removal from water by adsorption – A review., Chem. Eng. J. 2011; 171:811-840.
- [6] Huo Y, Ding W, Huang X, Xu J, Zhao M. Fluoride removal by lanthanum alginate

- bead: Adsorbent characterization and adsorption mechanism, Chin. J Chem. Eng. 2011; 19(3):365-370.
- [7] Meenakshi RC, Maheshwari. Fluoride in drinking water and its removal, J Hazardous Mater. 2006; 137:456-463.
- [8] Ndiaye PI, Moulin P, Dominguez L, Millet JC, Charbit F. Removal of fluoride from electronic industrial effluent by RO membrane separation., Desalination 2005; 173:25-32.
- [9] Mohapatra M, Anand S, Mishra BK, Giles DE, Singh P. Review of fluoride removal from drinking water, J Environ. Manage. 2009; 91:67-77.
- [10] Gong W, Qu J, Liu R, Lan H. Effect of aluminum fluoride complexation on fluoride removal by coagulation., Colloids Surf. A 2012; 395:88-93.
- [11] Pinon-Miramontes M, Bautista-Margulis RG, PerezHernandez A. Removal of arsenic and fluoride from drinking water with cake alum and a polymeric anionic flocculent., Fluoride 2003; 36:122-128. 12. Gupta SK. A Process for defluoridation of water by a filter bed using indigenous material, Indian J Environ. Sci. 1997; 1(2):149-156.
- [12] Simate GS, Iyuke SE, Ndlovu S, Heydenrych M, Walubita LF. Human health effects of residual carbon nanotubes and traditional water treatment chemicals in drinking water., Environ. Int 2012; 39:38-49.
- [13] Yadav AK, Kaushik CP, Haritash AK, Kansal A, Rani N. Defluoridation of groundwater using brick powder as an adsorbent, J Hazardous Mater. 2006; 128:289-293.