PERFORMANCE EVALUATION OF FLY ASH AS LOW COST ADSORBENT FOR FLUORIDE REMOVAL

Bhavyalekshmi R[1],
G Madhu[2]
[1] Researcher,(M.Tech), [2] Professor, Department of Safety and Fire Engineering, School of Engineering , CUSAT, 682022
E-mail ID: [1]bhavyalekshmi23@gmail.com , [2]profmadhugopal@gmail.com

ABSTRACT: Environmental pollution due to rapid advancements in modern industrial practices is one of the most significant problems of this century. Water resource contamination by different types of pollutants has attracted much serious attention in the last few decades. This is particularly due to their acute, toxic and chronic health effects. The suitability of fly ash (FA) and chemically modified fly ash (CFA) as low-cost adsorbents to effectively treat fluoride-contaminated water through adsorption has been investigated in the present work. Fluoride is beneficial in human body for the calcification of dental enamel and maintenance of healthy bones when present within the permissible limit. But when fluoride is present in excess of 1.5 mg/l, it causes severe health effects on humans. Fluoride contamination in water has been caused by glass industry, chemical industry, metal industry and high tech industry. The effect of various parameters viz. contact time, pH effect (pH 2.5-8.5), adsorbent dose (0.1-0.5 g/l), and initial fluoride concentration (5-25 mg/l) has been investigated to determine the adsorption capacity of both FA and CFA. Adsorption studies also revealed that acid treated fly ash is more efficient than raw fly ash. The efficacy of CFA to remove fluoride from water is found to be 82% at pH 2.5, contact time for 30min, dose of 0.5 g/l, when 5mg/l of fluoride is present in 250 ml of water. Acid treatment of fly ash will enhance adsorption capacity, the results suggest that CFA can be used as effective and economical adsorbent for fluoride removal from water.

Key words: Fluoride, Adsorption, Chemically treated fly ash, Fluoride removal

INTRODUCTION

In India, fluoride is the major inorganic pollutant of natural origin found in groundwater (Meenakshi et al., 2006). Fluoride is beneficial in human body for the calcification of dental enamel and maintenance of healthy bones when present within the permissible limit. But when fluoride is present in excess of 1.5 mg/l, it causes molting of teeth and lesion of endocrine glands, thyroid, liver and other organs. The most common symptoms of chronic fluoride exposures are skeletal fluorosis, which can lead to the permanent bone and joint deformations and dental fluorosis (Tripathy et al., 2006; Mohapatra et al., 2009; Tor et al., 2009). 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. Among various techniques adsorption occupies a prominent place in fluoride removal (Mahramanlioglu et al., 2002 ; Jamode et al., 2004). It is recognized that fly ash is a promising adsorbent for removal of various pollutants. Chemical modifications of fly ash will make conversion of fly ash into a more efficient adsorbent for gas and water cleaning (Wang et al., 2006). The utilization of fly ash as low-cost adsorbent for fluoride removal may shift it from waste material category to resource material category. In this paper, adsorption capacities of fly ash (collected from HNL, Kottayam,Kerala) (FA) and chemically modified fly ash (CFA) for fluoride removal is evaluated, thus to develop a new cost effective, simple and efficient technology for removal of fluoride from water thus by reducing environmental burden and enhance economic benefit.

2.0 MATERIALS AND METHODS

2.1 Preparation of the adsorbent

The experiments were carried out using samples of fly ash (processed from Hindustan Newsprint Limited, Kottayam) and chemically modified fly ash as adsorbents. For obtaining Chemically modified fly ash, some amount of collected fly ash was sieved through 75 micron IS sieve and subjected to pre treatment by mixing 500 g fly ash (FA) with 1000 ml double- deionised water to remove the soluble inorganic matter that are present in order to eliminate pores clogging. The sample was mixed in 1M HCl solution in the ratio of (1g) fly ash to (2ml) of acid, filtered and heat treated at 105ºC for 12 hrs in a conventional oven and also allow to furnace.

2.2 Preparation of adsorbate

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.

2.3 Batch Studies

Batch adsorption tests were conducted by mixing known weight of adsorbents and 250ml of solution of known fluoride concentration. Fluoride concentration used was in the range of (5-25) mg/l. The mixture was shaken well in an incubator shaker and 50ml of samples of solution were withdrawn from the bottles at known time intervals and tested for fluoride concentration using spectrophotometer. Preliminary experiments showed that adsorption is fast and the removal rate is negligible after 40min. Therefore contact time of 40min was used for batch studies. The sample was filtered to remove any fine particles and analyzed for fluoride concentration. Series of experiments were conducted to determine the effect of contact time, adsorbent dose, pH of the solution and initial fluoride concentration. All experiments were conducted at room temperature (31±5˚C).

2.4 Fluoride Analysis

The initial fluoride concentration and concentration of fluoride remaining on the solution were determined using Spectrophotometer. Estimation of fluoride ion concentration was done by SPADNS colorimetric method.

3.0 RESULTS AND DISCUSSIONS

3.1 Effect of Contact Time

The optimum time to attain equilibrium is 40 min. The percentage removal of fluoride was 82% for CFA and 56% for FA with initial concentration 5mg/l and adsorbent dosages of 0.5g each. The sudden rise in removal of fluoride indicates that the adsorption of fluoride probably takes place due to the diffusion taking place into the pores on the adsorbent surface.

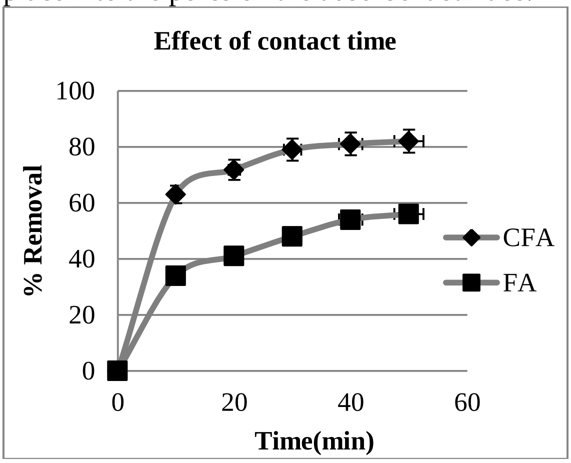

Fig 1: Effect of contact time on fluoride removal

(Initial concentration= 5ppm, Adsorbent dosages= 0.5g/250ml fluoride solution, pH =2.5, Time= 0-50min, at room temperature)

3.2 Effect of Adsorbent Dose

Percentage removal of fluoride ions increases as dosage increases from 0.1 to 0.5 g. Such behavior is obvious because the number of active sites available for fluoride removal would be more as the amount of the adsorbent increases. It may also be observed that initially the removal of fluoride increases as the dose is increased, but beyond 0.5 g, there is no significant increase in removal.

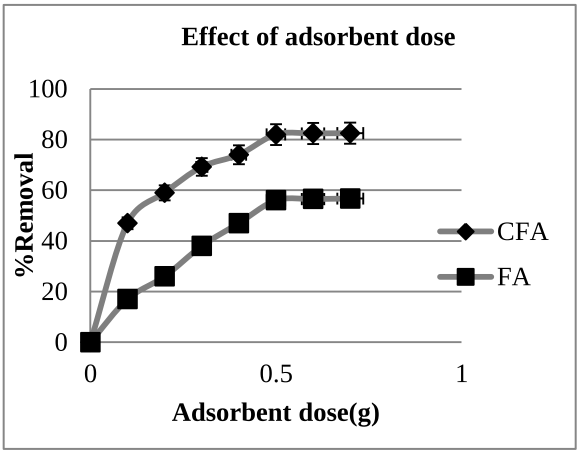

Fig 2: Effect of adsorbent dose on fluoride removal

(Initial concentration= 5ppm, Adsorbent dosages= 0.1-0.7g/250ml fluoride solution, pH =2.5, Time= 40min, at room temperature)

3.3 Effect of Varying Concentration of Fluoride

From the plot it is clear that higher adsorption was found to take place at lower concentrations due to the interaction of all fluoride ions present in the solution with binding sites. At higher concentrations, more fluoride ions are left unadsorbed in solution due to saturation of adsorption sites. When the concentration of fluoride ions became higher, the percentage removal decreased since the sites available for adsorption became less due to saturation of adsorption sites.

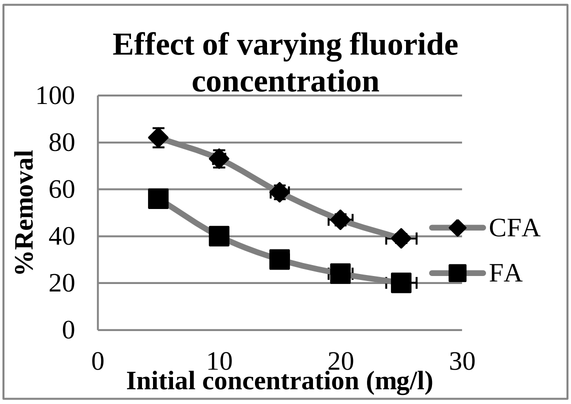

Fig 3: Effect of varying concentration on fluoride removal

(Initial concentration= 5-25ppm, Adsorbent dosages= 0.5g/250ml fluoride solution, pH =2.5, Time= 40min, at room temperature)

3.4 Effect of pH on Fluoride Adsorption

Fluoride removal decreases with increasing pH, and the removal of fluoride is maximum (56% for FA and 82% for CFA) at pH =2.5. Therefore, all the experiments were conducted at pH =2.5. It is known that in highly acidic medium, the adsorbent surface is highly protonated while it is neutralized and tended to have negative charge in alkaline medium.

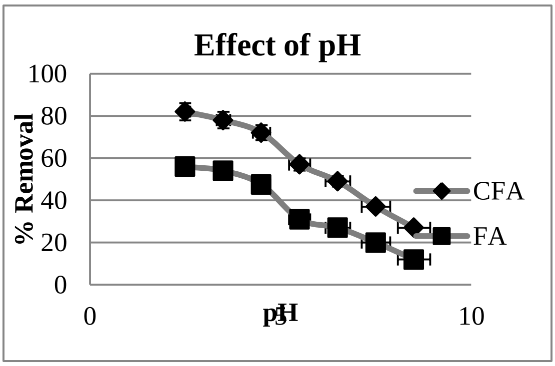

Fig 4: Effect of pH on fluoride removal

(Initial concentration= 5ppm, Adsorbent dosages= 0.5g/250ml fluoride solution, pH =2.5-8.5, Time= 40min, at room temperature

4.0 CONCLUSIONS

The batch study on fluoride removal by adsorption using fly ash and chemically modified fly ash were carried out in batch mode. The major findings of the study are discussed in this section.

- Batch studies on fluoride removal showed significant effects of the variables contact time, adsorbent dose, initial concentration, pH etc.
- The results provide a good indication of the different operating conditions that would be required for efficient removal of fluoride from aqueous solution.
- The efficacy of CFA to remove fluoride from water is found to be 82% at a pH of 2.5, contact time of 40min, adsorbent dose of 0.5 g/l, when 5mg/l of fluoride is present in 250 ml of water and that of FA is 56% for same operating conditions.
- Chemically modified fly ash is more efficient in removing fluoride.

REFERENCES

1. Jamode,A.V. Sapkal,V.S. and Jamode,V.S. (2004)"Defluoridation of water using inexpensive adsorbents", Indian Inst. Sci, J, Vol. 84, pp.163–171.

2. Mahramanlioglu, M. Kizilcikli, I. and Bicer, I.O. (2002) "Adsorption of fluoride from aqueous solution by acid treated spent bleaching earth", Fluorine Chem,J,Vol. 115,pp.41–47.

3. Meenakshi , R.C. and Maheshwari, (2006) "Fluoride in drinking water and its removal", Hazard Mater ,J,Vol.137 ,pp.456–463.

4. Mohapatra, M. Anand,S. Mishra, B.K. Giles,D.E. and Singh,P. (2009) "Review of fluoride removal from drinking water", Environ Manag,J,Vol. 9,pp. 67–77.

5. Tor,A. Danaoglu,N. Arslan,G. and Cengeloglu,Y. (2009) "Removal of fluoride from water by using granular red mud: Batch and column studies", Hazard Mater ,J,Vol.164,pp. 271–278.

6. Tripathy,S.S, Bersillon,J.L. and Gopal,K , (2006) "Removal of fluoride from drinking water by adsorption onto alum-impregnated activated alumina", Separation and Purification Technology Vol.50 pp.310–317.

7. Wang, S. and Wu, H.(2006) "Environmental-benign utilization of fly ash as low-cost adsorbents", Hazard Mater ,J,Vol.136,pp. 482-501.