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Studies on removal of fluoride from drinking water by using brick powder adsorbent

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Abstract
Fluoride in ground water naturally present in various minerals of earth. The presence of fluoride causes many health problems to human beings. Low cost brick powder as an adsorbent used to reduce fluoride contamination from ground water. The investigation was carried out on the adsorption of fluoride ion to analyze effect of various parameters like pH, contact time, adsorbent dose and initial concentration. Batch adsorption study was conducted to analyze the adsorption of fluoride in ground water. The experiment studies shows that maximum removal of fluoride in ground water by using brick powder adsorbent is 56 % at optimum conditions.

Keywords: Fluoride, Drinking water, Adsorbent, Adsorption, Parameters.

1. Introduction

Fluorine is a naturally occurring element found in various minerals. However, release into groundwater from volcanic activity and weathering processes can cause elevated levels of fluoride in drinking water. Fluoride, although beneficial for the mineralization of hard tissues in the human body, can be toxic to humans with chronic exposure to elevated concentrations (Khichar and Kumbhat, 2015) [3]. The principal sources of fluorine were drinking water and food such as sea fish, cheese and tea. Small quantity of fluoride is an essential component for normal mineralization of bones and formation of dental enamel. However, excess concentration may result in slow, progressive scourge known as fluorosis (Kumar A and Kumar V, 2015) [1]. Fluorosis is an important public health problem in 24 countries, including India, which lies in the geographical fluoride belt that extends from Turkey to China and Japan through Iraq, Iran and Afghanistan (Arlappa N *et al.*, 2013) [5]. In India, around 20 million people were severely affected by fluorosis and around 40 millions are exposed to its risk. The number of people getting affected, the number of villages, blocks, districts and states endemic for fluorosis have been steadily increasing ever since the disease was discovered in India during 1930s. The reason for the increase in the disease incidence and the sizeable number of locations being identified as endemic zones for fluorosis is due to overgrowth of population, necessitating more and more water, indiscriminate digging of tube wells, resorting to the use of hand pump water, unawareness regarding the importance of checking water quality, specially for fluoride and due to water shortage (Tewari *et al.*, 2012) [10]. Table 1 Shows that the effect of fluoride in water on human health. On the other hand, several fluoride containing compounds have industrial applications, are extensively used in industries such as semiconductors, fertilizers, and electrolysis of alumina, and contribute to fluoride pollution (PaliShahjee *et al.*, 2013) [6]. An optimum concentration can reduce the incidence of dental caries. However ingestion of excessive fluorides, mainly through drinking water causes dental and skeletal fluorosis. Long- term ingestion of excessive fluoride has a chronic effect on the kidneys as well. According to the WHO, the maximum acceptable concentration of fluoride ions in drinking water is 1.5 mg/l to prevent tooth and bone problems (Manjunath *et al.*, 2014) [4]. Concerned with the magnitude of health problems due to excess concentration of fluoride in drinking water several method of defluoridation of drinking water has been developed. The ion-exchange, adsorption, reverse osmosis and precipitation are the usual means of defluoridation. However, in India precipitation and adsorption methods are most preferred. The adsorption method involves the contact of the fluoride contain water with a suitable adsorbant. Precipitation process is based on the addition of chemicals and removal of insoluble compounds as precipitates (Rani *et al.*, 2012) [8]. Ion exchange is a reliable and simple way to remove fluoride from water while its selective up-taking for fluoride is usually not so satisfactory for water because of the coexisting anions such as sulphate, carbonate, phosphate and hydroxide in the drinking water. These anions may impede the effective stabilization of fluoride onto the resins. As for other methods, such as reverse osmosis, electrodialysis, and nanofiltration, they exhibit excellent purification capacity for fluoride removal, but expensive operation cost also limits their extensive application, especially for the wide countryside areas (Kanaujia *et al.*, 2015) [2]. Adsorption methods are effective on both terms i.e. fluoride removal and cost for removal. Hence the need to find locally available defluoridation media for less expensive and technically feasible in rural community level is desirable (Rani *et al.*, 2012) [8]. Biomaterials that are available in large quantities in agricultural fields may have potential to be used as low cost adsorbents, because they represent unused resources that are widely available and environmentally safe. In recent years, the search for low-cost adsorbents that have good ion binding capacities has intensified. Low cost and non-conventional adsorbents include agricultural by-products such as nut shells, wood, bone, peat, and coconut shells processed into activated carbons (Singanan, 2013) [9].

Table 1: Effects of fluoride in water on human health (Patni *et al.*, 2013) [7].

Fluoride concentration (mg/L)	Effects
<1.0	Safe limit
1.0–3.0	Dental fluorosis (discoloration, mottling and pitting of teeth)
3.0–4.0	Stiffened and brittle bones and joints
4.0–6.0 and above	Deformities in knee and hip bones and finally paralysis making the person unable to walk or stand in straight posture, crippling fluorosis

2. Materials and Methods

2.1. Adsorbate

221 mg anhydrous sodium fluoride dissolves in 1000 ml distilled water in volumetric flask for preparation of fluoride stock solution and from this stock solution test solution of 10 mg/L F ion concentration is prepared. Diluting 100 ml stock solution to 1000 ml distilled water in volumetric flask for the preparation of fluoride standard solution.

2.2. Sorbent Preparation (Brick powder)

Bricks were collected from local area. These bricks were washed with distilled water, dried and ground properly to obtain fine powder. The brick powder was washed several times with distilled water till clear water was obtained and was dried in oven at 105 ◦C for 12 h. The dried material was sieved to separate less than 600 micro meter size of particles for the present study (Rani *et. al.*, 2012) [8].

2.3. Batch mode adsorption studies

Batch technique was studied in adsorption of fluoride ion at different known concentration 10, 20, 50 and 100 ppm. Adsorbent was added in 100 ml of the fluoride solution of known concentration 10, 20, 50 and 100ppm in each flask. The absorbent suspensions in 100 ml test solution were taken in each conical flask at different time interval 30 to 180 min. The adsorption of fluoride observed in different time interval from 30 to 180 min and also determines various parameters like pH, adsorbent dose, initial concentration of fluoride etc. After that the sample filtered by using Whatmann filter paper no. 42 and the remaining concentration of fluoride was measured by UV spectrophotometer. The effect of several parameters during experiments, such as pH, concentrations, contact time and adsorbent dose on the adsorption were studied. The pH of test solution was maintained at 0.1 N HCL and 0.1 N NaOH on fixed quantity of adsorbent.

Heavy metal removal percentage was determined using following Equation:

Percentage of heavy metal removal (%) = $[(C_o - C_e) / C_o] \times 100$

Here, C_o- initial heavy metal ion concentration of test solution, mg/l;

C_e was equilibrium final concentration of test solution mg/l.

3. Result and Discussion

The removal of fluoride from drinking water by using brick powder was determined by various parameters such as contact time, pH, adsorbent dose, initial concentration etc. which was graphically shown in figure below:

3.1. Effect of contact time

Adsorption of fluoride ion by using brick powder at different contact times 30, 60, 90, 120, 150, 180 are graphically presented in fig. 3.1. It is found that during experiment the removal of fluoride ion percentage increased with contact time up to 120 minutes after that it reached at constant value. Result shows maximum percentage removal of fluoride ion occurs at 120 min contact time and 10 ppm initial concentration.

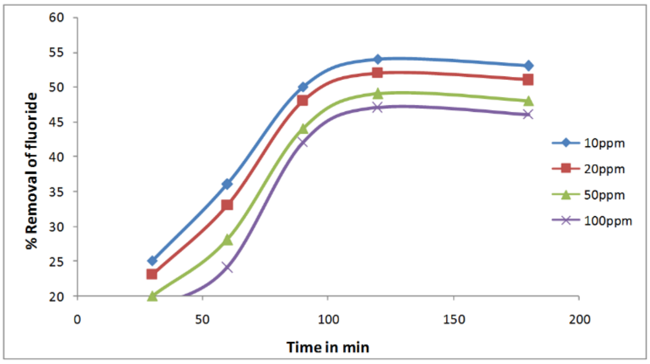

Fig 3.1: Effect of contact time on percentage removal of fluoride ion by brick powder.

3.2. Effect of pH

Fig. 3.2 shows that the effect of pH on percentage removal of fluoride ion by brick powder. In aqueous solution pH is a controlling factor of adsorption process. It affects the fluoride removal efficiency of adsorbents. pH was varying in between 1 to 10. It is adjusted using 0.1 N HCL and 0.1 N NAOH solutions. The experiments were conducted at an initial fluoride ion concentration of 10 to 50ppm in 100ml solution, and constant adsorbent dose 0.5g for fluoride ions. Studies shows that the maximum 56 percentage adsorption occurs at 6pH and then it decreases with further increase in pH.

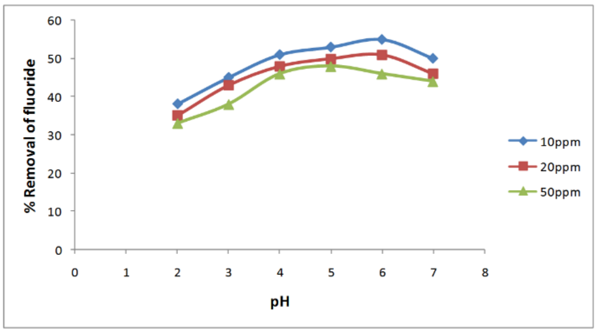

Fig 3.2: Effect of pH on percentage removal of fluoride ion by brick powder.

3.3. Effect of adsorbent dose

The results for adsorptive removal of fluoride ion with respect to adsorbent dose are shown in Fig 3.3. Studies on effect of adsorbent doses are conducted by varying adsorbent doses between 0.2 g to 1 g/100 mL. The pH is maintained at 1 to 10, while initial fluoride ion concentration is fixed at 10ppm and contact time is kept as 120 minutes. Increase the adsorbent dose the removal efficiency will also increase due to increase in surface area, there is more active sites are available for the adsorption of fluoride. Studies shows maximum 56 percentage removal of fluoride ion occurs at 10 ppm concentration, 6 pH and 0.6 gm/100 ml solution.

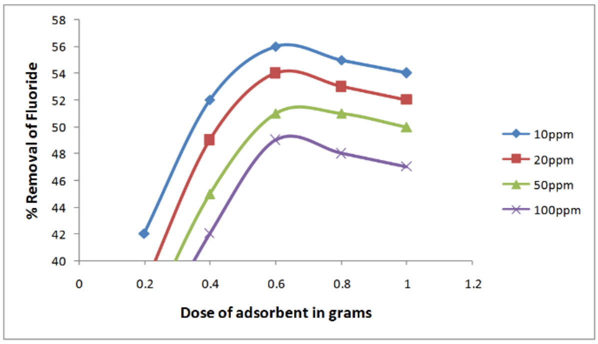

Fig 3.3: Effect of adsorbent dose on percentage removal of fluoride ion by brick powder.

3.4. Effect of initial concentration: Fig 3.4 represents the effect of initial concentration on percentage removal of fluoride ion by brick powder at 0.5g/100ml adsorbent dose, 6pH and 120 min contact time. Result shows that the percentage removal decreases with the increase in initial fluoride concentration. Maximum 56 percentage removal is achieved at 10 ppm of initial concentration. It indicate that solute adsorption capacity reduce due to active sites on the adsorption surface.

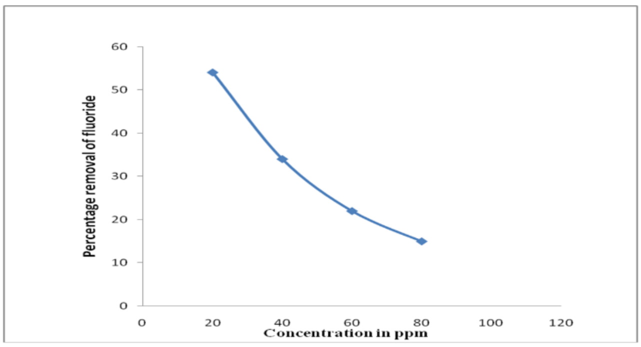

Fig 3.4: Effect of concentration on % removal of metal ions by brick powder.

4. Conclusion: The results demonstrate that brick powder has economical and effective adsorbents in removing fluoride from water to acceptable levels. The study indicate that the optimum condition for removal of fluoride are found to be 120 minutes contact time, 0.6 gm adsorbent dose, 6 pH and 10ppm initial concentration. Maximum 56 % removal of fluoride was found at initial 10 ppm concentration. The experimental investigations by using low cost adsorbents for defluoridation would be useful in developing countries and also useful in rular areas for domestic purpose.

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