Research Paper

Volume : 3 | Issue : 7 | July 2014 • ISSN No 2277 - 8179

# Fluoride Removal from Aqueous Solution using Industrial Grade Alum

Engineering

**KEYWORDS :** Industrial grade Alum; Adsorption; Chemical composition; Fluoride; removal.

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## ABSTRACT

*The ability of Industrial grade alum to remove Fluoride from aqueous solution has been investigated. The studies were carried out as functions of contact time, concentration and pH. The data indicate that Industrial grade alum surface sites are heterogeneous in nature and that Fits into a heterogeneous site binding model. The optimum pH for complete removal of Fluoride from aqueous solution was found to be 6. The rate of fluoride removal was rapid during the initial 20 minutes, and equilibrium was attained within 50 minutes.*

## 1. Introduction

Fluoride pollution in the environment occurs through two different channels: natural sources and anthropogenic sources. Fluoride is frequently encountered in minerals and in geochemical deposits. Because of the erosion and weathering of Fluoride-bearing minerals it becomes a surface species.

**Table: 1. Fluoride bearing minerals**

| Mineral | Chemical formula | % fluorine |
|---|---|---|
| Sellaite | $MgF_2$ | 61% |
| Villianmite | NaF | 55% |
| Fluorite (Fluorspar) | $CaF_2$ | 49% |
| Cryolite | $Na_3AlF_6$ | 45% |
| Bastnaesite | $(Ce,La)(CO_3)F$ | 9% |
| Fluorapatite | $Ca_3(PO_4)_3F$ | 3-4 % |

On the other hand, Fluorine compounds are industrially important and are extensively used in semiconductors, fertilizers, aluminum industries, and nuclear applications. Toxic wastes containing Fluorine/Fluoride are generated in all industries using Fluorine or its compounds as a raw material. Prominent among these is the aluminum smelter where Fluorine gas is released into the atmosphere or treated as per the plant design specifications. The contamination resulting from spent pot liners is a major problem and mostly is not properly taken care of. Although small scale units treat the wastes by lime, large-scale industries must use elaborate treatment techniques before discharging the effluent.

Fluoride in drinking water may be either beneficial or detrimental to health, particularly to infants and young children, depending on its concentration. No other naturally occurring inorganic constituent in drinking water has been given so wide importance as compared to Fluoride. In excess of 1.5 to 2.0 mg/L Fluoride is known to cause permanent gray or black mottling of teeth enamel and the long-term intake of 3 to 10 mg/L may result in abnormal bone growth in both humans and animals (1).

**Table 2: Concentrations of fluorides and biological effects**

| Concentration of fluoride, ppm* | Medium | Effect |
|---|---|---|
| 0.002 | Air | Injury to vegetation |
| 1 | Water | Dental caries reduction |
| 2 or more | Water | Mottled enamel |
| 8 | Water | 10% osteosclerosis |
| 50 | Food and water | Thyroid changes |
| 100 | Food and water | Growth retardation |
| 120 | Food and water | Kidney changes |
| *In water- medium, ppm can be taken as equivalent to mg/L | | |

On the other hand, Fluoride is recognized as an essential constituent in the human diet. Skeletal and dental problems can be prevented by maintaining Fluoride concentration of about 1ppm in the dietary intake.

Several methods were tried for defluoridation of water, namely, adsorption, ion exchange, electrolysis, and precipitation. The different materials used for defluoridation include activated carbon, bone charcoal, tricalcium phosphate, synthetic ion exchangers, activated alumina, alum, and lime (2). In recent years, considerable attention has been devoted to the study of different types of low-cost materials such as tree bark, wood charcoal, saw dust, weeds, and other waste materials for adsorption of some toxic elements (3-7). Alum is generated from bauxite by the sulphuric acid process. The Industrial grade alum mainly consists of oxides of aluminium and titanium with small amounts of undecomposed silicates (8). Each of these oxides is known to possess adsorption and ion exchange properties (9). Raw alum sludge is highly acidic and is a pollutant. At present, economically viable methods for disposal or reuse are not known. In this context, we examined its use as an adsorbent for the removal of Fluoride from polluted waters. The present studies are carried out with synthetic Fluoride solutions with the objective of establishing process parameters. A few experiments were carried out with additional anions to simulate industrial waste waters.

## 2. Material and Methods

Even though alum has widespread industrial and domestic applications, the waste produced from alum plants has caused serious concern to the society as well as environmentalists.

Industrial grade Alum primarily contains $Al_2O_3$, $SiO_2$, $Fe_2O_3$, $TiO_2$, and $SO_4^{2-}$ . In the absence of viable processes for utilization, these metal values are being discarded as waste. Use of industrial waste material as an adsorbent for the removal of toxic elements may not appear attractive, but Industrial grade alum with its high metal

**Table: 3 Chemical Analysis of Dried Industrial Grade Alum (Wt %)**

| | |
|---|---|
| $Fe_2O_3$ | 7.18 |
| $Al_2O_3$ | 47.2 |
| $TiO_2$ | 20.65 |
| $SiO_2$ | 1.6 |
| $SO_4^{2-}$ | 3.2 |
| LOI | 19 |

Composition could be a reasonable substitute for more conventional expensive adsorbents. The Industrial grade alum sample used in this study was collected from the Visakhapatnam (India) Alum plant. The Industrial grade alum was dried at 110°C for 24 h and crushed to yield a powder. The sample thus was further sieved to 100 mm particle size and stored in airtight containers until further use.

The chemical composition of the Industrial Grade Alum is given in Table 1, shows that the major components are alumina and titanium oxides.

### 2.1 Methodology:

Tests were carried out with Industrial Grade alum. Synthetic Fluoride solutions were used for the adsorption experiments. Standard 0.01 M sodium Fluoride was prepared in deionized water and diluted to exactly 8 mg/L. A known amount of Industrial grade alum and Fluoride solution were taken in a 100-mL stopper conical Flask. the Final volume was made up to 50mL with deionized water. The Flask was agitated at constant speed in a thermostatic water bath at the designated temperature over a period of time and Filtered on a Whatman No. 42 Filter paper (10). The concentration of Fluoride in the Filtrate was determined by SPADNS (11) method and the percentage of Fluoride removed was calculated from the ratio of Fluoride taken and that remaining in the solution. All chemicals used are of analytical grade. All spectrophotometric measurements were made on Chemito 2500UV-Visible Spectropho-tometer using 10-mm matched quartz cells. The pH of the solutions at the beginning and end of the experiments were measured, and the average values are reported. All pH measurements were made by an Elico Digital pH meter (model L1 120) using a combined glass electrode (model CL 51). The pH meter was calibrated with Orian Standard buffers before any measurement.

The experimental parameters studied are Dosage of Industrial grade Alum, Concentration of Fluoride and pH.

## 3. Results and Discussion:

Removal of fluoride as a function of dosage (Industrial grade alum) is shown below. It is evident that for the quantitative removal of 8 mg/L of fluoride, data clearly show that as the concentration of alum increases the fluoride removal was increased gradually.

### 3.1 Effect of Dosage and time:

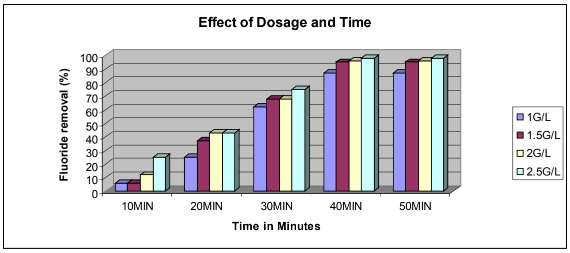

Fig.1: Effect of Alum dosage and Time on Fluoride removal

The variation of fluoride removal percentage with time is shown in Fig. 1. It was observed that with a fixed amount of Industrial grade alum, the amount of fluoride decreases with time. The loading capacity (i.e., the amount of fluoride adsorbed per gram of alum) increased with time and concentration and then attained a constant value after 40minutes. The time to reach equilibrium conditions appears to be independent of initial fluoride concentrations (12). Increase in the dosage from 1g/L to 2.5g/L the percentage of fluoride concentration in the solution gradually decreases with respective time.

### 3.2 Effect of pH:

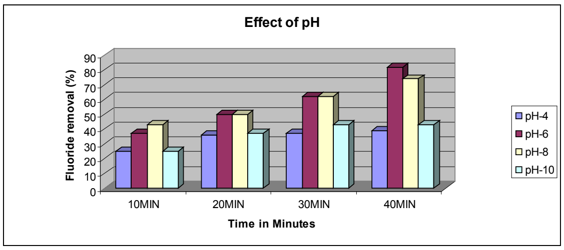

Fig.2: Effect of pH on Fluoride removal

The extent of adsorption of anions is strongly governed by the pH of the solution (13). Because anion adsorption is coupled with a release of $OH^-$ ions, the adsorption is favored by low pH values (14). Hence, the removal of fluoride by Industrial grade alum was studied at different pH values ranging from 4 to 10. The results are presented in Fig.2, which reveals that the Removal of fluoride was maximum at pH 6.

### 3.3 Effect of concentration:

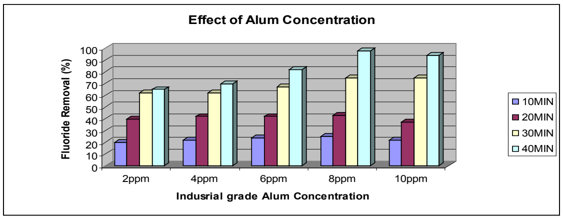

Fig.3: Effect of Industrial grade alum concentration on Fluoride removal

The influence of varying concentrations of industrial grade alum on removal of fluoride at a particular pH is shown in Fig.3 The concentration of surface hydroxyl groups is related to Industrial grade Alum concentration through surface site density (15). Therefore percent of fluoride removal increased with industrial grade alum dose, whereas loading capacity decreased.

## 4.Conclusion:

In the present work a simple, fast, and promising method for the treatment of fluoride from contaminated water is suggested. The Industrial grade alum, containing different metal oxides with a heterogeneous surface, has shown a superior adsorption capability for fluoride ion. Removal method is favored by the appropriate addition of industrial grade alum to fluoride-containing waste water at normal temperature (30°C). The optimum pH for fluoride removal was found to be 6. Studies on the influence showed that an increase of alum from 2 to 10 mg/L has least effect on defluoridation.

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