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# POLYALUMINIUM CHLORIDE – ANALTERNATIVE TO ALUM FOR DEFLUORIDATION

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**ABSTRACT**

*In this paper the fluoride removal efficiency of polyaluminium chloride (PAC) was determined through batch experiments and was compared with the fluoride removal efficiency of alum. The amount of alum and PACl were decided according to the doses of alum recommended in batch Nalgonda defluoridation technique. The results showed that PAC is effective in removing fluoride from water, with a removal efficiency comparable to that of alum. The fluoride removal capacity of PAC was found to be dependent on the initial concentration of fluoride in the raw water to be treated and on the pH maintained during the reaction.*

***Keywords: Polyaluminium Chloride, Fluoride Removal Efficiency, Nalgonda, Defluoridation***

## I. INTRODUCTION

Underground water is generally considered to be agood source of drinking water because of the very low content of organic contaminants.However, there is a high amount of fluoride which must be removed before consumption.Long-term ingestion of high fluoride can result in mottling of teeth, as well as softening of bones and ligaments(Kaseva, 2006) on exposure to fluoride through drinking water above the permissible limit (1.0–1.5 mg/L). It may also manifest in severe dental and skeletal fluorosis (Mondal, 2015). Skeletal Fluorosis can cause pain and stiffnessin joints (Czerwinski et al. 1988) as well as deformitiessuch as crippling, kyphosis, and genu varum (Choubisa, 2001).The World Health Organization (WHO 2004) recommends an upper limit of 1.5 mg/L fluoride in drinking water.About 66 million people are affected by presence of high fluorides (>1.0mg/l) in drinking water (Susheela, 1991) and are confronted with endemic Fluorosis especially in rural and semi-urban areas. More than 20 developed and developing nations have been identified as being endemic for fluoride in water sources (Meenakshi 2006). The high fluoride levels in drinking water and its impacts on human health have increased the importance of defluoridation studies (S. Chidambaram et al., 2003).

The Nalgonda Defluoridation Technique is considered to be the most economical and simple method for bringing the fluoride content to acceptable limit (<1.0 mg/l) in drinking waterand is reported to have high removal efficiency. This technique is widely accepted in the rural areas and villages in India due to the low costs involved,as against the expensive activated alumina processwhich is usually adopted in the towns/ cities. Alternatively, other salts of aluminium are also employed for the purpose. As for instance, polyaluminium chloride (PACl) is used as a coagulant for removal of fluoride from water. PACl is a chloride salt of aluminium as unlike alum, which is a sulphate salt of aluminium. It is increasingly used as a coagulant in water treatment. Against the conventional use of aluminiumsulphate (alum) it is showing distinct advantages.Poly Aluminium

Chloride (PACl)(Muthu et al., 2003) can be an effective coagulantfor the removal of fluoride from water with a higher removal efficiency. It is available in powder and liquid form. Polyaluminium chlorides are synthetic polymers dissolved in water. They react to form insoluble aluminium poly-hydroxides which precipitate in big volumetric flocs.The flocs absorb suspended pollutants in the water which are precipitated with the PACl and can together be easily removed.

## II. THEORY

The Nalgonda process (Nawlakhe et al.,1975) was originally developed on the basis of laboratory tests and field studies at NEERI and uses high dosages of alum varying from 145 to 1600 mg/L (16 to 181 mg/L as Al) for treating raw water fluoride levels of 2 to 10 mg/L at varying alkalinity.The Nalgonda Defluoridation process (Nawlakhe and Bulusu, 1989) involved addition of aluminium salts, lime and bleaching powder into the water and was followed by rapid mixing, flocculation sedimentation, filtration and disinfection. The alum hydrolyses to form aqua-complex aluminium ions which complex immediately with fluoride ions forming dissolved aluminium fluoride and aluminium hydroxyl fluoride complexes. Cotton wool like flocs develop, which have a tendency to settle. Removal of the flocs leads to removal of fluoride along with these flocs. The coagulation process depends on the pH of the reaction mixture, fluoride concentrations and alum dosages. The dosages of alum required to bring the fluoride level to 1 mg/l in water are presented as a function of fluoride concentration and alkalinity of the raw water in a dosage designed table, originally published by Nawlakhe et al. (1975). Dose of lime is decided so as to bring the pH of the reaction to 6.5-8.5, which is assumed to be the pH range for minimum solubility of aluminium.

## III. MATERIALS AND METHODS

### 3.1 Chemicals

All chemicals used for the study, namely, sodium fluoride (NaF), aluminiumsulphate ($Al_2(SO_4)_3.16H_2O$), calcium carbonate ($CaCO_3$) were of analytical grade obtained from Merck. Polyaluminium chloride solution (KANPAC 10 HB) was obtained from Aditya Birla group, with Aluminium content of 10.2% as $Al_2O_3$ as per thespecifications provided by the supplier as shown in Table (http://www.adityabirlachemicals.com/brands/kanpac.html).

Batch defluoridation experiments were performed on a Jar Test Apparatus. Besides the determination of defluoridation capacities of alum and PAC, the effect of variables like pH and concentration of fluoride in raw water was also studied.

Known solutions of different concentrations of fluoride in raw water were prepared in laboratory. Alum and calcium carbonate were added simultaneously to the jars containing the known fluoride concentrations. The doses of the chemicals used were according to those prescribed in the Nalgonda defluoridation table originally given by Nawlakhe et al. The dosage of PAC was kept to be equivalent to alum in terms of aluminium content.

The concentration of fluoride was measured using fluoride ion selective electrode (Orion make). The pH measurements were done on pH sensitive electrode (Hanna make). Bench-top digital TDS meter was used to make the TDS measurements. The concentration of sulphate ion was determined by using UV Visible Spectrophotometer (Schimadzu).

## IV. RESULTS AND DISCUSSION

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### 4.1 Alkalinity

Highly basic PAC was used which had high basicity as compared to alum and hence required lesser dose of lime for maintaining the optimum pH for floc formation. By performing titration experiments the acidity of solutions having equivalent concentrations of alum and PAC in terms of aluminium content was determined. PAC was found to have approximately half acidic strength as compared to alum, and hence was found to require half of the dose of lime to maintain the desired pH for the reaction.

### 4.2 Flocculation pH

The formation of aluminofluoro complexes is basically dependent on the pH of the reaction mixture. The pH range of 6.5-8.5 is found to be optimal for efficient flocculation. The conventional Nalgonda technique prescribes the dose of lime for bringing the pH in the desirable range.

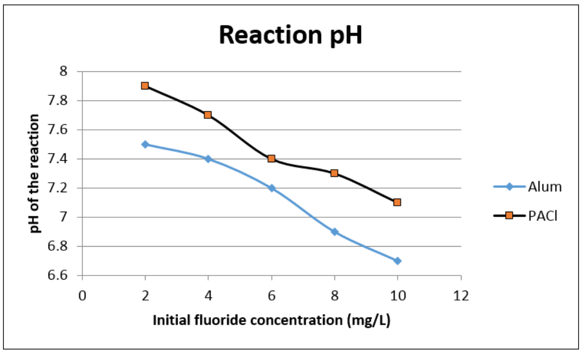


**Fig.1 pH During Flocculation in Batch Reaction of Alum and PACl**

As PACl used was of high basicity, so only half of the dose required for alum, was sufficient to bring the pH to the desirable for PACl. Even with half of the dose of lime, the batches with PAClshowed pH in the range 6.5-8.5.

### 4.3 Defluoridation Capacity

The samples were treated with recommended doses of alum and PACl.

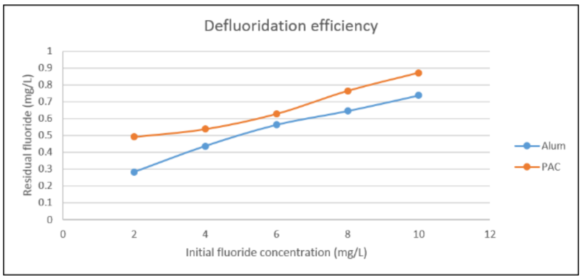


**Fig.2Defluoridation Capacity in Batch Reaction of Alum and PACl**

The residual fluoride content after treatment with PACl was found to be slightly higher than that with alum, but were within the acceptable limit of 1.5 mg/L. The defluoridation capacity of PACl was found to be comparable to that of alum.

### 4.4 Total Dissolved Salts

An upper limit of 500 mg/L is prescribed for drinking water. Both, alum and PACl add to the TDS of the samples. But, as compared to alum, PACl leads to lesser increase in the TDS of the sample, as the amount of lime required to neutralize PACl is half of the amount required for alum.

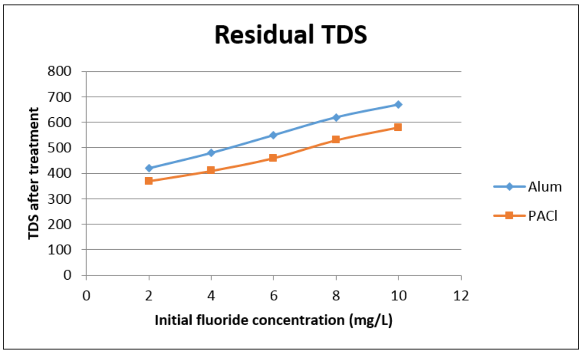


**Fig.3 Residual TDSafter treatment with alum and PACl**

Since PAC requires half of the amount of lime required for alum, hence the residual TDS of water treated with PAC is lower than that treated with alum and falls within the acceptable limits for drinking water for lower doses of raw water fluoride.

### 4.5 Sulphate content

Alum, being a sulphate salt of aluminium, introduces sulphates to the drinking water, which has laxative effect on humans.

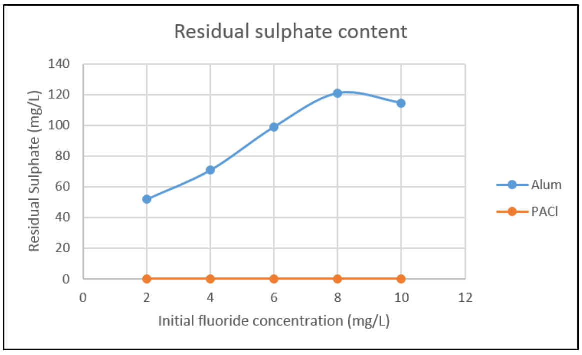


**Fig.4 Residual Sulphate After Treatment with Alum and PACl**

As, PACl is a chloride salt, so it does not add sulphate to the water and hence provides an added advantage over alum.

## V. CONCLUSION

PACl has been shown to have comparable defluoridation capacity to alum, with the added advantage of being highly basic and hence requiring almost half dose of lime, as is required by alum. This results in lesser addition of TDS to the water being treated. Additionally, unlike alum, PACl is a chloride salt, so does not add sulphate to the water being treated. So, PACl can be effectively used as an alternative to alum for fluoride removal.

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