

# Fluoride Removal from Water using *Moringa oleifera* Seed Coagulation and Double Filtration

Ravikumar K, Prof. Sheeja A K

**Abstract**— The best available technologies for fluoride removal from water are generally considered to be activated alumina adsorption and reverse osmosis. These methods are of high cost. Fluoride removal by aluminium coagulation is cost effective. Its secondary pollution badly affects human health. To reduce the fluoride by 1.0 mg/l, a dosage of 10-12 mg/l Al is required. This will increase the residual aluminium concentration in treated drinking water. Aluminum ions will cause anemia, hair loss and adverse neurological effects such as Alzheimer's disease. The drinking water quality standard is 0.1 mg-Al/L in the western developed countries while 0.2 mg-Al/L in many other countries. The important issue urgently to be solved is to develop new environmental coagulants with satisfactory coagulation and little secondary pollution. *Moringa oleifera* seed acts as a natural coagulant, adsorbent and antimicrobial agent. It is believed that the seed is an organic natural polymer. The coagulation mechanism of the *Moringa oleifera* coagulant protein has been described as adsorption, charge neutralization and interparticle bridging. It is mainly characteristic of high molecular weight polyelectrolyte. In this study the advantage of proposing a sequential process using coagulation with *Moringa oleifera* seed and double filtration (Up-flow roughing filtration followed by rapid filtration) for the removal of fluoride from water is analysed.

**Index Terms**— Adsorption, coagulation, double filtration, eco-friendly, fluoride, rapid sand filter, roughing filter, sustainability, turbidity

## 1 INTRODUCTION

THE need for simple, reliable and effective method of water treatment led to the application of plant materials, including seed coagulants of *Moringa oleifera*. The root of *Vetiveria zizanioides* (Vetiver) is an effective adsorbent for the removal of fluoride from aqueous solution up to 80% (1). Leaf powder of *Ocimum sanctum* (Tulsi) is an effective adsorbent for the removal of chromium up to 92% (2).

The *Moringa oleifera* (MO) tree (figure 1) grows in tropical and subtropical regions around the world and its seeds have been used in drinking water treatment in small scale in Sudan and India for generations. The coagulant in the seed is a protein that acts as a cationic polyelectrolyte. The soluble particles in the water attaches to the active agent that binds them together creating large flocs in the water. Previous studies indicate that *Moringa oleifera* is an efficient coagulant for the removal of turbidities in both water and waste water treatment.

The *Moringa oleifera* is one of the natural coagulants that have been tested over the years as an alternative to the use of inorganic and synthetic coagulants. Disadvantages of inorganic and synthetic coagulants are it causes Alzheimer's disease and similar health related problems, reduction of pH, high costs, production of large sludge volume and low efficiency in coagulation of cold water. *Moringa oleifera* has potential in water treatment- as a coagulant, a soften agent and bactericidal agent. Advantages of *Moringa oleifera* as a natural coagulant are its low cost, produces lesser volume of biodegradable sludge, and

it does not affect the pH of the water. *Moringa oleifera* is a sustainable, low cost, locally available, simple, reliable, acceptable, eco-friendly and household level point of use water treatment coagulant/technology most suitable for developing countries where major population use contaminated water for drinking purposes.



Fig.1. *Moringa oleifera*

Literature survey reveals that *Moringa oleifera* plant is the most inexpensive credible alternative for providing good nutrition and to cure and prevent a lot of diseases [3]. Aqueous extract of *Moringa oleifera* showed strong and superior antibacterial activity against bacterial strains such as *Staphylococcus aureus*, *Bacillus subtilis*, *Escherichia coli* and *Pseudomonas aeruginosa* [4]. *Moringa oleifera* is the best natural coagulant that can replace aluminium sulphate (Alum) which is widely used all around the world [5]. Acid extract of natural polyelectrolyte *Moringa oleifera* seed is very effective as a coagulant for removal of fluoride from water [6]. Removal of turbidity and hardness can simultaneously be done by using *Moringa oleifera* seed extract with 1.0M sodium chloride solution (MO-NaCl) [7]. *Moringa oleifera* seed extract against *E. coli* by TVC method reduced >99.9% *E. coli* count [8]. Efficient reduction (80.0% to 99.5%) of

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high turbidity produces an aesthetically clear supernatant, concurrently accompanied by 90.00% to 99.99% bacterial reduction [9].

*Moringa oleifera* seeds are capable of adsorbing the Fluoride and heavy metals from aqueous systems. The removal by *Moringa oleifera* seeds were 88% for fluoride, 90 % for copper, 80 % for lead, 60 % for cadmium and 50 % for zinc and chromium(10). Distilled water extract of *Moringa oleifera* seed powder achieved 90 to 95% sedimentation of the suspended particles in underground and surface water samples(11). Increased dose of *Moringa oleifera* seed powder showed reduction in turbidity, TDS, TS, hardness, chlorides, alkalinity, acidity, MPN and SPC in ground water samples (12). *Moringa oleifera* Lam. as a coagulant agent provided significant results, which justify its use as an alternative coagulant in the process of coagulation/flocculation of produced water (which is the waste that has the highest volume during the production and exploration of oil) (13). Shelled blended *Moringa oleifera* seed as a biosorbent removes C.I. Acid Orange 7 from the aqueous systems (14). The percentage removal by *Moringa oleifera* seeds were 90 % for copper, 80 % for lead, 60 % for cadmium and 50 % for zinc and chromium (15). Coagulation - flocculation process using *Moringa oleifera* seeds after oil extraction as a natural coagulant presents a viable alternative for the treatment of Palm oil mill effluent (16). The efficiency of coagulation-photooxidation processes for removing color from a landfill leachate by using *Moringa oleifera* coagulation as a pre-treatment was effective(17).

Many states of India including Kerala have undesirable concentrations of fluoride in groundwater [18]. Fluoride is considered as a "two edged sword" because deficiency of fluoride intake leads to dental caries while excess consumption leads to dental and skeletal fluorosis. Contamination of drinking water due to fluoride is a severe health hazard problem. Excess of fluoride (>1.5 mg/L) in drinking water is harmful to human health. Different technologies may be applied to diminish these levels in water for consumption. This study was an effort to investigate the water treatment potential of indigenous plant coagulant *Moringa oleifera* seeds with double filtration for removal of fluoride.

## 2 OBJECTIVES

The objectives of the study were

1. To identify a sustainable, low cost, locally available, simple, reliable, acceptable, eco-friendly, household level point of use water treatment technology most suitable for rural population of developing countries.
2. To find a process that allowed efficient removal of fluoride from aqueous systems.
3. To evaluate the up-flow roughing filtration process followed by rapid filtration as a suitable method for the separation of the flocs formed using the *Moringa olifera* seed coagulant.
4. To determine the removal efficiency of various fluoride con-

centrations in water using *Moringa oleifera* coagulation and double filtration.

## 3 MATERIALS AND METHODS

### 3.1 Preparation of MO Seed Powder

Dry MO pods were collected from Varkala, Trivandrum. Pod shells were removed manually; kernels were grounded in a domestic blender and sieved through 600micro meter stainless steel sieve. Figures 2, 3, 4 and 5 shows the MO pods, MO seed, de-husked seed kernel and seed powder.



Fig.2. *Moringa oleifera* pods



Fig.3. *Moringa oleifera* seeds



Fig.4. *Moringa oleifera* de-husked seed kernels

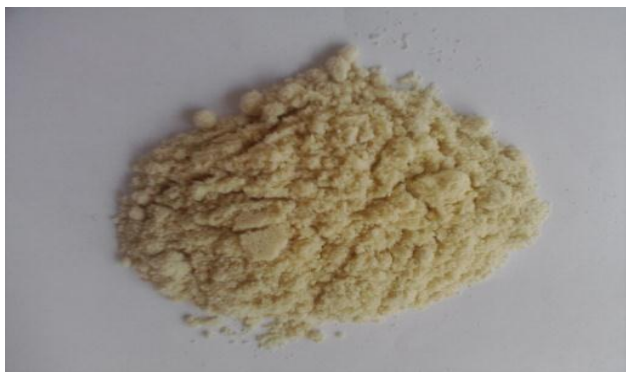


Fig.5. Moringa oleifera seed powder

### 3.2 Aqueous Extract

Aqueous extract was prepared by using 200ml of tap water and 25 g of MO seed powder, mixed by a magnetic stirrer for 60 minutes and settled for 20 minutes. *Moringa oleifera* aqueous extract is finally filtered through 20µm paper filter

### 3.3 Coagulant Activity Test

Jar test was conducted to determine the effective dosage of coagulant to reduce the fluoride of the sample. The standard procedure was 1 min of rapid mixing (120 rpm) followed by 15 minutes of slow mixing (30rpm) for flocculation and 60 minutes of settling. Jar tests were performed in synthetic fluoride water with different initial concentrations of 2,4,6,8 and 10mg/L.

### 3.4 Filtration test with roughing filter

In vertical-flow roughing filters the water to be treated flows in sequence through the three filter compartments filled with coarse, medium and fine filter material. The size of the three distinct filter material fractions were between 25 and 3 mm, and graded in to fractions of 25-16mm, 16-8mm and 8-3mm as shown in figure 6.

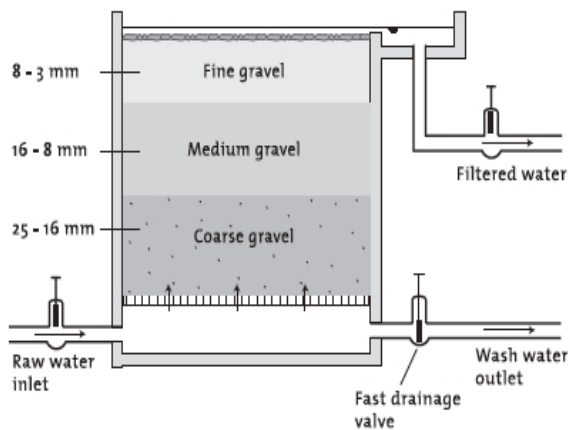


Fig.6: Up flow roughing Filters

### 3.5 Filtration test with rapid sand filter

In rapid sand filters the water to be treated flows in se-

quence through the three filter compartments filled with coarse, medium and fine filter materials. The size of the three distinct filter material fractions were between 50 and 0.5 mm, and graded into fractions of 25-50mm, 13-25mm and 0.5-1mm as shown in figure 7.

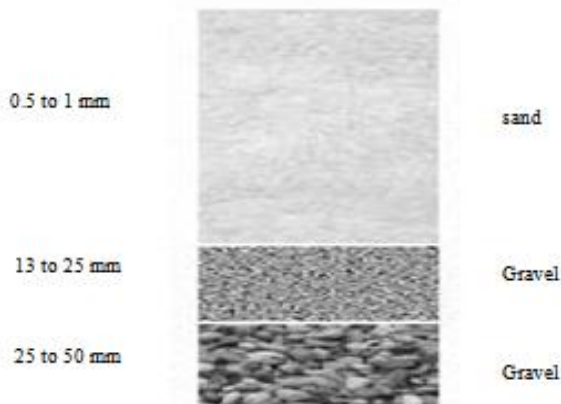


Fig.7: Rapid Sand filter media size

### 3.6 MO seed coagulation and double filtration

Double filtration as shown in figure 8 is an efficient and effective drinking water treatment technique for source water with high turbidity, organic matter, and suspended solids.

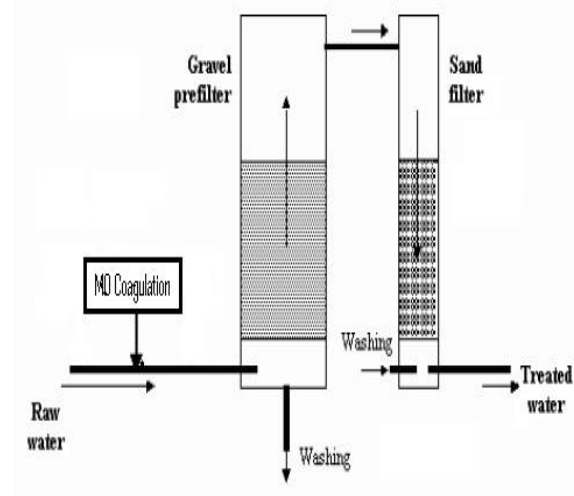


Fig 8: Moringa oleifera Coagulation and Double filtration

Jar tests were performed in synthetic fluoride water with different initial concentrations of 2,4,6,8 and 10mg/L for coagulation flocculation and sedimentation with optimum MO seed coagulant dosage of 2.5g/L. The standard procedure was 1 min of rapid mixing (120 rpm) followed by 15 minutes of slow mixing (30rpm) for flocculation and 60 minutes of settling

Roughing filtration was conducted directly after the coagulation and flocculation processes with MO and separates the

suspended solids. Vertical-flow roughing filter was operated at 0.3 to 1.0 m/h filtration rates. The separated solids, which accumulate mainly in the coarse filter fraction next to the filter bottom, can be easily flushed out with the water stored in the filter. Therefore, the use of upflow roughing filter in layers was used.

Rapid sand filtration was conducted directly after the roughing filtration and separates the last remaining flocs that failed to disappear during roughing filtration. The washing of the roughing filter was carried out through lower drainage, and the washing of the rapid filter was counter current.

## 4 RESULT AND DISCUSSIONS

### 4.1 Coagulation activity test results of synthetic fluoride water sample

Coagulation- flocculation was done using shelled blend-ed, aqueous extract of *Moringa oleifera* seed powder. These co-agulants were extracted by using a standard preparation method. Optimum doses of 2.5g/L coagulants were used for different initial fluoride concentrations of 2,4,6,8 and 10 respectively. The optimum dosage is the minimum dosage of coagulant corresponding to the removal of fluoride within the standard limits. First the optimum dose was determined, which was 2.5g/L. At optimum dosage of 2.5g/L of coagulant dosage the final fluoride concentration reduced below 1mg/L, but the turbidity increases in all five synthetic fluoride water samples as shown in Table 1.

**TABLE 1. TURBIDITY AND FLUORIDE CONCENTRATIONS AFTER COAGULATION TREATMENT WITH DIFFERENT CONCENTRATIONS OF FILTRATED *MORINGA OLEIFERA* COAGULANT**

Dosage of MO 2.5g/L			
Initial fluoride concentration mg/L	Final fluoride concentration mg/L	Fluoride removal efficiency %	Final turbidity NTU
2	0.91	54.50	87
4	0.90	77.50	82
6	0.88	85.33	83
8	0.88	89.00	82
10	0.80	92.00	86

### 4.2 Coagulation activity test results of synthetic fluoride water sample after upflow roughing filtration.

Samples of water collected from the outlet of roughing filter were used for analyzing the turbidity and fluoride. Table 2 presents the results of turbidity removal from fluoridated water with initial fluoride concentrations of 2,4,6,8 and 10 mg/L, after upflow roughing filtration. An up-flow roughing filtration stage was chosen because it is a process with a high efficiency in the removal of light flocs. The bed of the upflow gravel roughing filter was made up of three layers of gravel of different granule measures.

**TABLE 2. TURBIDITY (NTU) AFTER TREATMENT WITH FILTRATED *MORINGA OLEIFERA* COAGULANT AND UPFLOW ROUGHING FILTRATION**

Dosage of MO 2.5g/L			
Initial fluoride concentration mg/L	Final fluoride concentration mg/L	Turbidity after roughing filtration NTU	Turbidity removal efficiency NTU
2	0.91	16	81.60
4	0.90	12	85.36
6	0.88	12	85.54
8	0.88	11	86.58
10	0.80	15	83.52

### 4.3 Coagulation activity test results of synthetic fluoride water sample after upflow roughing filtration and rapid filtration (double filtration)

Samples of water collected from the outlet of rapid filter were used for analyzing the turbidity and fluoride. Table 3 represents the results of turbidity removal from fluoridated water with initial fluoride concentrations of 2,4,6,8 and 10 mg/L, after double filtration.

**TABLE 3. TURBIDITY (NTU) AFTER TREATMENT WITH FILTRATED *MORINGA OLEIFERA* COAGULANT AND DOUBLE FILTRATION**

Dosage of MO 2.5g/L			
Initial fluoride concentration mg/L	Final fluoride concentration mg/L	Turbidity after double filtration NTU	Turbidity removal efficiency NTU
2	0.91	4	95.40
4	0.90	3	96.34
6	0.88	3	96.38
8	0.88	2	97.56
10	0.80	3	96.51

The combined coagulation and double filtration process is an alternative for fluoride removal, since the coagulation process is effective in removing F<sup>-</sup> ions and double filtration complements the process by reducing the turbidity to the limits. In this study, the double filtration step was performed just after coagulation in order to remove colour and turbidity caused by the addition of *Moringa oleifera* coagulant, so as to meet the standards for water potability. Therefore, the utilization of the combined treatment allows for the production of fully treated water. It is known that the filtration process is not efficient for the removal of ions, which indicates that fluoride retention was mainly due to the process of coagulation with the coagulants obtained from *Moringa oleifera*. Thus, it is more

likely that the mechanism of interaction between the *Moringa oleifera* proteins (positively charged) and fluoride (negatively charged) was ion adsorption and charge neutralisation.

## 5. CONCLUSION

*Moringa oleifera* is an environmentally-friendly natural coagulant most suitable for the treatment of water containing undesirable fluoride concentrations. Based on the experimental test results; the following conclusion can be drawn.

1. The best coagulation condition was reached using *Moringa oleifera* coagulant dose of 2.5 g/L with 10 mg/L of fluoride in the water, achieving this way 92% of fluoride reduction in the treated water.
2. The maximum turbidity removal efficiency of roughing filtration and double filtration were 86.58% and 97.56% respectively for de-fluoridated water. The final turbidity obtained was within acceptable limits for drinking water production in all the five de-fluoridated water samples (<5 NTU).
3. The process of up flow roughing filtration followed by rapid filtration is suitable for the separation of the flocs formed using *Moringa oleifera* seed coagulant.
4. The de-fluoridation efficiency increases as the initial fluoride concentration increases and the final concentrations of fluoride in all the five de-fluoridated water samples after coagulation with MO seed coagulant were within the desirable limit (0.6-1mg/L).
5. It is an eco-friendly technology that is economically more advantageous than other treatment alternatives.

In accordance with the above conclusions, it is suggested that tap water extracted *Moringa oleifera* seed powder and treatment with coagulation and flocculation followed by double filtration with roughing filters followed by rapid filtration is considered in the event of expansion or construction of small scale waterworks, presuming that an adequate amount of plantations are established.

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