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Comparative Study on Coagulation Process for Vellore Municipal Drinking Water Using Various Coagulants

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Abstract:

The present study is focused to optimize the coagulation process for treatment of water sourced from the Palar River Basin and supplied to the Vellore Municipality. The research was progressed to evaluate the water treatment efficacy of natural coagulant i.e. *moringaoleifera*seed, available locally in abundance, as well as conventional coagulants *viz.* alum and ferric chloride. Primly the basic operational parameters- pH and coagulant dosages were optimized. Further the treatment efficiency was evaluated on the basis of turbidity, total dissolved solids (TDS), organic content in terms of UV absorbance at 254 nm and microbial contamination (MPN for total coliform) for all three coagulants. Best removal efficiency was achieved near neutral pH with dosages of 45mg/L and 25mg/L for alum and ferric chloride, respectively.However, the *Moringaoleifera*could not found effective in removing targeted contaminants.

Keywords: Coagulation, alum, ferric chloride*, Moringaoleifera*, turbidity, total dissolved solids, organic matter, MPN.

1. Introduction:

Water is being used for several purposes by humans but the level of purity of water being consumed is very crucial since it has a direct effect on health. Solution to this global problem is aimed to develop simple, effective, low-cost and easy to use technologies able to reduce organic, inorganic and microbiological water contamination. Coagulation represents a feasible and effective treatment due to its capacity to remove suspended particles of the water through the addition of certain chemicals known as coagulants. The most common ones are alum and ferric chloride. In spite of the effectiveness of these chemicals as coagulants are well-recognized, its application is not possible in poor areas of developing countries due to high cost and low availability of these products. For these reasons, it is desirable to make a progressive replacement of these chemical coagulants with alternative natural coagulant like *moringaoleifera*(drumstick) seeds.

Chemical coagulation followed by separation (sedimentation and filtration) are two basic water treatment processes in which the physical or chemical properties of colloidal or suspended particles are altered such that agglomeration is enhanced to an extent that these solids will settle out of solution by gravity or will be removed by filtration (Zouboulis*et al.,* 2007; Jacangelo *et al.,* 1995; Tomaszewska *et al.,* 2004; Yan *et al.,*2008)]. During the coagulation and flocculation processes, the use of coagulants can change the surface charge properties of solids to promote agglomeration and/or enmeshment of smaller particles into larger flocs. Coagulants are widely used in surface water treatment to enhance the removal of particulate, colloidal, and dissolved substances (Zhao *et al.,* 2008; Gao*et al.,* 2005; Sharp *et al.,* 2006; Gao and Yue*,* 2005).

In drinking water treatment, aluminum coagulants are used to destabilize suspended particles and to react with dissolved natural organic matter (NOM) in the raw water. Proper coagulation is essential for good clarification and filtration performance and for disinfection byproduct (DBP) control. Improper coagulation can cause high aluminum residuals in the treated water and the post-treatment precipitation of particles causing turbidity, deposition and coating of pipes in the water distribution system (Edzwald and Benschoten*,* 1990; Edzwald*,* 1993; Nordstrom and May, 1996). When alum is added to the rapid mix tank, Al^{3+} rapidly undergoes hydrolysis reactions to form other dissolved Al species or Al-hydroxide precipitates (Nordstrom and May, 1996).Ferric chloride is used as a coagulant in drinking water treatment not only for the removal of turbidity but additionally for the removal of color, natural organic materials and arsenic from raw waters. Ferric chloride reacts in water with hydroxide alkalinity to form various hydrolysis products that incorporate Fe $(OH)_3$. These compounds possess high cationic charge which allows them to neutralize the electrostatic charges found on colloidal compounds and also to bind to negatively charged particles, including the ferric hydroxide itself. This ability to bind to itself is the mechanism for the formation of floc aggregates and the basis for ferric chloride's flocculation abilities (California water Technologies).

Moringaoleifera(drumstick*)* is a multipurpose tree native to Northern India that now grows widely throughout the tropics (Fuglie, 2001). Many parts of the tree are used as traditional medicines, the seeds contain up to 40% by weight of quality edible oil (greater than 80% unsaturated fatty acid content (Mohammed *et al.,* 2003)) and the seeds (and oil free presscake) yield proteins capable of acting as effective coagulants in water and wastewater treatment. In terms of water treatment applications, *M. oleifera*seed in diverse extracted and purified forms has proved to be effective at removing suspended material (Broin*et al.,*2002; Ghebremicheal*et al.,* 2005; Ndabigengesere and Narasaih, 1998; Folkard*et al.,* 1996; Folkard and Sutherland 2002; Jahn, 1988; Muyibi and Evison, 1995; Ndabigengesere*et al.,*1995), generate reduced sludge volumes in comparison to alum, soften hard waters (Okudu*et al.,* 2001) and act as effective adsorbent of cadmium (Raghuwanshi*et al.,* 2001). These applications have been, and continue to be, fertile areas for researchers working primarily at laboratory level although some successful pilot and full scale water treatment trials have been reported (Muyibi and Evison, 1995; Sharma *et al.,*2006)[27,28]. However, this technology has not yet been adopted on any treatment plant at any scale: thus far, research activity has not led to sustained use. The major concern in the use of seed extracts for water treatment applications is the residual organic seed material that will be present in the finished water.

The objective of this paper is to evaluate the performance of the chemical (alum, ferric chloride) and natural (*moringaoleifera*seed extract) coagulants to find their optimum dosage for the maximum removal of turbidity, total dissolved solids, UV254 and total coliform (MPN) at their optimum pH. And to find an ideal coagulant for the treatment of drinking water of Vellore area.

2. Materials and Methods:

2.1 Water Sampling:

Six sample locations were selected with the aerial view of the water distribution in Vellore area. Samples from each of the locations were analyzed for all the physico-chemical parameters viz. pH, acidity, alkalinity, turbidity, temperature, hardness, total dissolved solids, dissolved oxygen,MPN, fluoride, sulphate, chloride, phosphates, nitrates and nitrites. Out of all the samples, water sample from Sathuvachari location was found to have values higher than the desirable limits. So this water was taken for further analysis. Sampling was done under sterile conditions.

Fig. 1: View of water sampling location

2.2 Preparation of Reagent:

Alum stock solution (1000mg/l) was prepared by dissolving 23.36 g of Aluminium sulphate ($Al_2(SO_4)_3.16H_2O$) obtained from Thomas Baker in 1000ml of distilled water. Ferric chloride stock solution (1000mg/l) was prepared by dissolving 2.9 g of $FeCl_3$ anhydrous obtained from Thomas Baker in 1000ml of distilled water. *Moringaoleifera*seed extract stock solution (1000mg/l) was prepared by dissolving 50 g of dried seed powder in 1000ml of distilled water. The seeds of *moringaoleifera*was dried and ground to a fine powder of approximately 600µm size. A 5% (w/v) suspension was prepared out of it. The mixture was shaken vigorously in a magnetic stirrer for 30 minutes, to promote water extraction of the coagulant proteins. It is then filtered through a Whatman no 42 filter paper and refrigerated. The mixture is shaken vigorously before use.

2.3 Jar Test

Jar test was conducted on the water samples using the standard six paddle jar test apparatus with varying doses of coagulants in the pH range of 6.5 to 8.5. They were coagulated at 100 rpm for 1 min, 30 rpm for 20 min and then were settled for 30 min. Alum dosage – 35 mg/l to 55mg/l, $FeCl_3$ dosage – 15 mg/l to 35 mg/l and moringa seed extract dosage – 35 mg/l to 55 mg/l was chosen.

The pH was measured using Digital pH meter MK VI. The apparatus was standardized each time before use with 4.0, 7.0 and 9.2 buffer solutions. The pH of raw and coagulated water samples was subsequently measured. The turbidity of the raw and coagulated water samples were measured using Elico CL 52D Nephelometer. The apparatus was standardized with 40 NTU formazin solutions. UV254 was measured at 254 nm with a UV spectrophotometer using 1cm quartz cuvette.

Total dissolved solids in the raw and coagulated water samples were determined adopting the standard procedures. The water samples were filtered using Whatman no 1 filter papers. Empty weights of the crucibles were measured. 10 ml of the filtered samples was taken in each of the crucibles and kept in a hot air oven for 3 hours. Then the final weights of the crucibles were measured and thus the concentration of total dissolved solids was found out.

2.4 MPN Test

Most probable number test was performed in raw and treated water samples to determine the total number of coliforms that is present. McConkeybroth at single and double strength concentrations were used for the purpose. Single and double strength concentration was prepared by dissolving 40.0 grams and 80.0 grams of MacConkey broth in 1000ml distilled water respectively. 5 ml from each of single strength and double strength broth was taken and equally distributed in 10 and 5 sets of test tubes respectively. The samples were serially diluted to give concentrations of 10^{-1}, 10^{-2} and 10^{-3}. The 10^{-1} diluted sample was inoculated in double strength broth while 10^{-2} and 10^{-3} diluted samples were inoculated in single strength broth. The test tubes were further incubated at 37^{o}c for 48 hours and checked for any contamination. The probable number of microbes was determined using the MPN table.

3. Results and Discussion

3.1 Effect of pH:

A set of jar test experiments were carried out for different coagulants- alum, FeCl3 and *moringaoleifera*seed extract by varying the pH in the range of 6.5 to 8.5 at a constant coagulant dosage. Fig 2 depicts the optimum PH for maximum turbidity removal for each of the coagulant. The optimum pH for alum and moringa extract was 7.5 and for $FeCl_3$ it was found to be 7.0. Further experiments were carried out at this pH for each coagulant.

3.2 Effect of Coagulant Dosage

3.2.1 Turbidity

Turbidity is the measure of the degree to which the water loses its transparency due to the presence of suspended particulates. Turbidity measurement could also be used to provide an estimation of the TSS (Total Suspended Solids) concentration. It is essential to eliminate the turbidity of water in order to effectively disinfect it for drinking purposes. Jar test experiments were performed by varying the coagulant dosage to find the optimum dosage for maximum turbidity removal at their optimum pH.

From Figure 3, the optimum dosage of alum for maximum turbidity removal was found to be 45mg/L with a removal efficiency of 74.28%, for FeCl3 it was 25 mg/L with a removal efficiency of 79.41% and for moringa seed extract the optimum dosage was found to be 55mg/L with a removal efficiency of 73.91%.

Experimental details: Alum (35mg/L to 55mg/L), FeCl3 (15mg/L to 35mg/L), moringa seed extract (35mg/L to 55mg/L) at their optimum pH

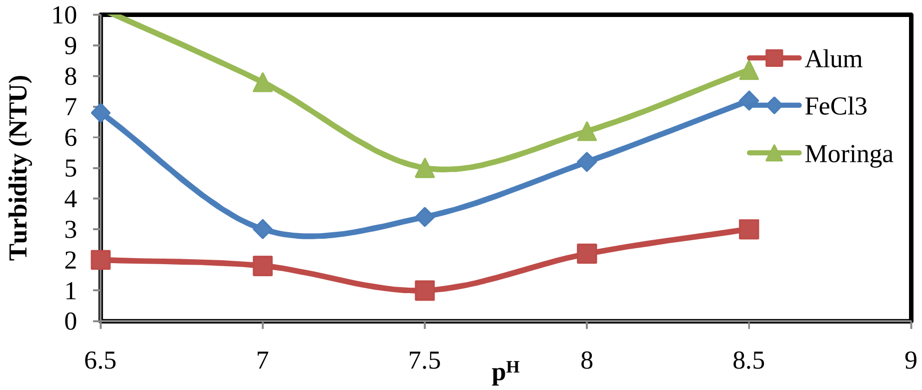

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Fig. 2: Effect of varying the pH on Turbidity removal of the three coagulants-alum (45mg/L), FeCl3 (25mg/L), moringa seed extract (45mg/L).

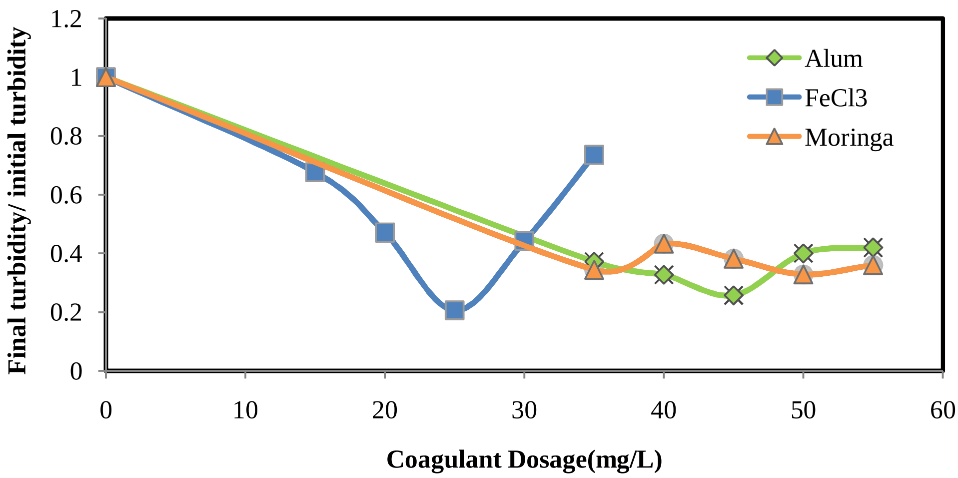

Fig. 3: Effect of varying the coagulant dosage on turbidity removal of the three coagulants.

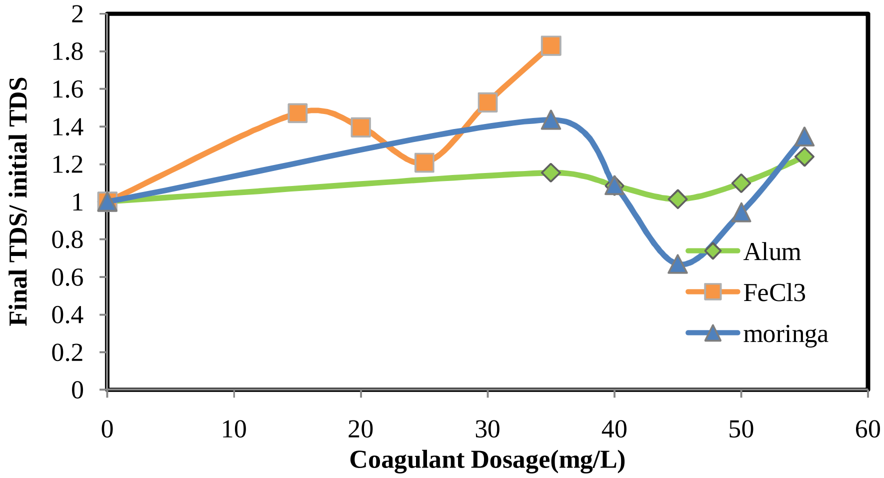

Fig. 4: Effect of varying the coagulant dosage on organic carbon removal of the two coagulants.

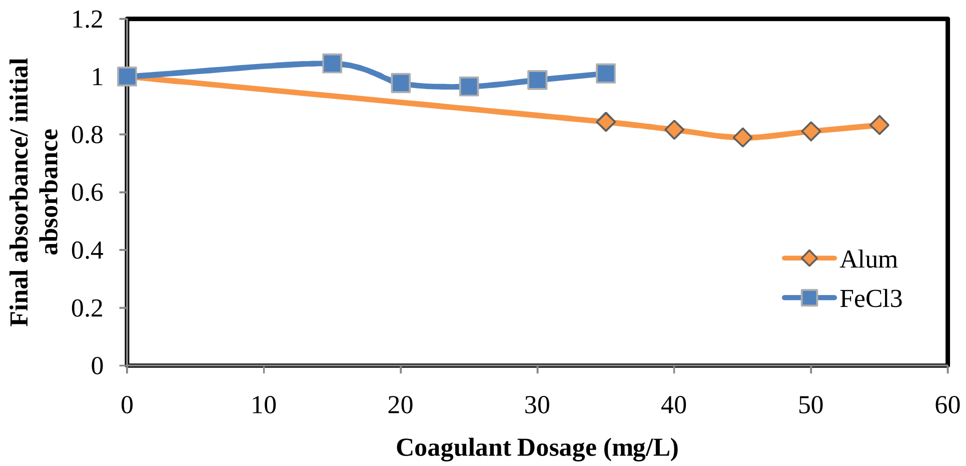

Fig. 5: Effect of varying the coagulant dosage on turbidity removal of the two coagulants

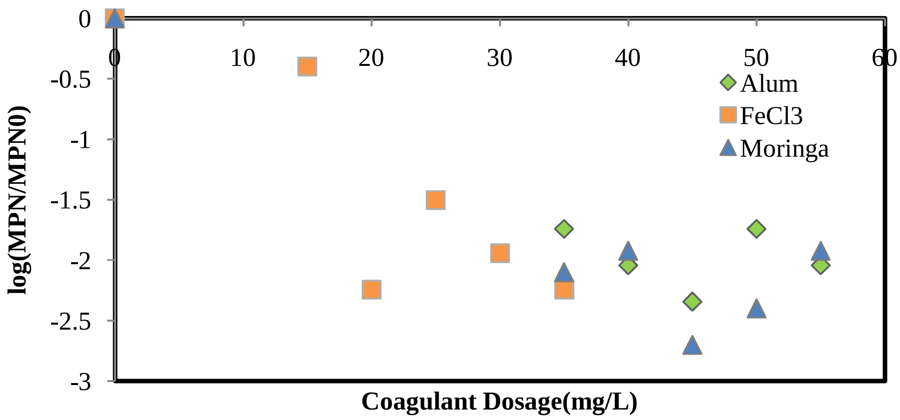

Fig. 6: Effect of varying the coagulant dosage on MPN (total coliform) removal of the three coagulants

3.2.2 Organic Carbon Content:

UV Absorbance is the measure of how much of UV is absorbed by the particles in water sample. UV254 provides an indication of how much organic carbon is present in water. This is due to the strong absorption properties of most dissolved organics at 254nm. Thus UV254 is an indirect measure of organic carbon content in water. Jar tests were performed by varying the coagulant dosage to find the optimum dosage for maximum removal of UV254 absorbance at their optimum pH.From Figure 4, the optimum dosage of alum for maximum organic carbon removal was found to be 45mg/L, for FeCl3 it was found to be 25mg/L and for moringa seed extract the optimum dosage was found to be 35mg/L.

3.2.3 Total Dissolved Solids:

Total Dissolved Solids is the total amount of mobile charged ions, including minerals, salts or metals dissolved in a given volume of water, expressed in units of mg per unit volume of water (mg/L). TDS is directly related to the purity of water and the quality of water purification systems. This includes anything present in water other than the pure water molecule and suspended solids. Experimental jar tests were performed by varying the coagulant dosage to find the optimum dosage for maximum removal of total dissolved solids (TDS) at their optimum pH.From Fig 5, the optimum dosage of alum for maximum removal of total dissolved solids (TDS) was found to be 45mg/L, for FeCl3 it was found to be 25mg/L and for *moringa*seed extract extract the optimum dosage was found to be 35mg/L.

3.2.4 Microbial Removal Efficiency:

The presence of coliforms, fecal coliforms and aerogenic E. coli in water may be determined by means of the MPN procedure. The MPN procedure involves a multiple tube fermentation technique where three or more decimal dilutions of the sample are inoculated into tubes of broth medium and incubated at a specific temperature and for a specific time. Based on the number of tubes indicating the presence / absence of the three groups of organisms, the most probable number present can be estimated from a standard statistical MPN table. Jar tests were performed by varying the coagulant dosage to find the optimum dosage for maximum removal of most probable number (MPN) at their optimum pH.From Figure 6, the optimum dosage of alum for maximum removal of total coliform was found to be 45mg/L with 2 log removal efficiency, for $FeCl_3$ it was found to be 25mg/L with 2.6 log removal efficiency and for *moringa*seed extract the optimum dosage was found to be 50 mg/L with 1.9 log removal efficiency.

4. Conclusion:

We infer alum works best at pH 7.5 with an optimum dosage of 45mg/L for the efficient removal of turbidity, total dissolve solids,organic carbon and total coliform and $FeCl_3$ at a relatively lower pH 7 at 25mg/L dosage with better removal efficiency than alum. M*oringa oleifera* seed extract does not prove to be an effective coagulant in terms of TDS, organic carbon and total coliform.

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