Evaluation of Fractal Growth Characteristic of Flocs for Aluminium Sulphate and Ferric Chloride Using Microscopy Method

P. S. Randive, D. P. Singh, A. G. Bhole, V. P. Varghese, and A. M. Badar

Abstract Coagulation and Flocculation processes are some of the important aspects of water treatment. The properties of flocs, such as size, structure, and strength have a significant effect on the solid and liquid separation process also it affects the basic operations of the industrial unit process. Floc structure is an important factor that influencing the coagulation effect and to identify the post-treatment load. The physical characteristics of the floc are therefore fundamental in determining their removal efficiency. Study of floc generated and its growth characteristics in the flocculation process plays an important role as it decides the removal policies, effect on subsequent processes, and ultimately the quality of water. The present investigation is to study the floc growth for two different aluminium and iron-based coagulants, Aluminium Sulphate and Ferric Chloride, respectively, using the microscopy method. This paper deals with the examination of two different kinds of flocs for strength, breakage, recovery, and floc growth rate.

Keywords Flocculation · Floc · Microscopy method

1 Introduction

In the water treatment plant, coagulation and flocculation is an important process for the removal of turbidity from water. The process of adding certain chemical called coagulants to water which reacts with impurity in order to form insoluble and gelatinous matter called flocs which can be precipitated quickly is known as coagulation. Addition of coagulants culminates in chemically charging collides so as to configurate substantially large molecule by accumulating all particles. In coagulation process, chemical coagulants are added into the water which reacts with alkalinity

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to form gelatinous precipitated which is known as floc. Flocs are characterized as immensely porous, asymmetrical, saggy aggregate made up of smaller colloidal particles. Chowdhury et al. [1] studied the submicron colloid numbers, fluxes, and removals in two conventional water treatment plants. Also obtained the comprehensive study of supramicron (>1 p.m) particles and its behaviour. Concluded that removals of submicron colloids and supramicron particles ranged from 57 to 99% and 91 to 99%, respectively, considering two water sources from two conventional water treatment plants. The properties of flocs, such as size, structure, and strength have a significant effect on the solid and liquid separation process. The size, shape, and formation are the fundamental things that to be considered for the operation of industrial unit process. Dense flocs settle down easily. Therefore, knowing the physical characteristics of flocs subsequently increases its removal efficiency and results in low turbid treated water during settlement. To contemplate the necessity of floc structure and its behaviour in the flocculation process it is essential to analyze the floc structure, formation, and breakage in detail. There are various methods to measure floc size this is microscopy, light scattering, photography and image analysis, transmitted light, individual particle sensor, etc. Hurst [2] built an experimental apparatus to develop and understand floc blanket physics. In his study, he used visual insights floc blanket mechanics. Considered 1.3 cm thick section of floc blanket through which light intensity is transmitted. Experimental results show remarkable enhancement in particle removal efficiency and may drop operation and maintenance costs. Microscopy method is used to determine the floc parameter. For the determination of floc sizes microscopy is a widely used method. There are some limitations of microscopy method like it takes more time for sample preparation also required large sample size. Besides that, it is simple to perform, understand, and gives adequate information about the floc structure. This experimentation work aims to evaluate the characterize growth and regrowth ability of flocs with additional coagulant dosage strategy to explore the floc formation mechanism and floc characteristics using microscopy method. Ghanem et al. [3] studied ballasted flocculation processes to evaluate microscopic observations, Bench scale observations, density tests, and centrifugal settling tests. It gives information about the controlling mechanisms, interconnection between ballasting agent and coagulants for floc built up. Chakraborti et al. [4] used (DLA) mechanism and discussed the characteristics of flocs in flocculation process based on diffusion-limited aggregations. Microscopy is one of the commonly used floc sizing methods and carried out by precisely locating a selected sample particle from the suspension onto a microscope.

The floc strength factor is a measure of floc strength by exposing the floc to single level of increased shear rate within the carrying vessel and comparing the floc size before and after breakage. The floc recovery factor is an indication of the extent to which the floc size recovers during regrowth phase after breakage.

In the present study, two easily available and easily soluble coagulants are considered for experimentation and its sizes are measured for further calculations using microscopy method. General categorization of metal coagulants is aluminium-based and iron-based. For experimentation one from each category Aluminium Sulphate and Ferric Chloride coagulant is considered and floc strength, breakage, recovery factor as well as floc growth rate is determined and compared.

2 Experimental

2.1 Sample Preparation

Experimentation was conducted on artificial turbid water. Digital Nephelo Turbidity meter was used to measure the turbidity for each sample. After some trials, the required turbidity of 100 NTU was achieved by addition of 0.11 g/lit of kaolin clay in the water sample. Turbidity of 100 NTU was maintained throughout the experimentation for both the coagulants. Jar Test apparatus was used for determining the optimum coagulant doses for both Aluminium Sulphate and Ferric Chloride coagulant. Using pipette flocs formed during the jar test apparatus, procedure was collected steadily and observed under microscope. Diameter $d1$, $d2$, $d3$ of the above-collected sample is determined by placing them on glass slides and observing under a microscope.

2.2 Microscopy Method

Amongst various methods, microscopy refers to the most extensively used technique since long as a method for floc counting and sizing. [5, 6]. Pipette is widely used for collecting flocs from the treated sample. In this experimentation, the flocculated suspension was prepared in which a hollow glass tube was immersed and sealed at the top and then removed. The floc carried through the tube was slightly placed below the microscope for analysis. This method provides a good representative sample of the flocs without many ruptures. Microscopy method is the simplest method, at high magnification able to view the individual particles, examine, investigate and analyze it. This method is used to analyze floc shape and irregularity. Most popularly used method in many applications. Notable method in finding porosity and shape factor of flocs. Besides, microscopy is a comparatively inexpensive method to determine floc shape characteristics.

2.3 Coagulant Used

Aluminium Sulphate. Aluminium Sulphate is the most common coagulants used in waterworks. It chemical composition is $Al_2(SO_4)_3 . 18(H_2O)$. It requires the presence of alkalinity in water to form floc. Aluminium Sulphate (alum) added in water reacts

Table 1 Floc growth size of Aluminium Sulphate

Size 1 (*d*1) μm	Size 1 (d2) μm	Size 3 (*d*3) μm
200	120	173
266	133	186.2
293	146.3	213
Average = 253	Average = 133.1	Average = 191

with alkalinity present in it and leads to the formation of gelatinous precipitated of aluminium hydroxide which attracts fine suspended impurities over its surface does grow in size and easily get settled. It works on the pH range 6–8.5. Alum is widely used coagulant as it is more effective when pH of water ranges between 6.5 and 8.5. Its doses depend upon turbidity, colour, taste, pH value and temperature of water.

Ferric chloride. Ferric chloride is an inexpensive inorganic coagulant, as it is generated as waste material from steelmaking operations. However, it's by far the most corrosive and hazardous inorganic coagulant, and its use is limited to facilities equipped to handle it safely. pH sensitivity is somewhat less than alum. It works over a wide pH range 5–7. It is suitable for usage in the lime-softening process (pH 9).

Jar test apparatus is used for formation of flocs and also dosages were calculated considering 100 NTU turbidity for both the coagulants separately. After the experimental procedure of floc formation for both the coagulants diameter $d1$, $d2$, $d3$ is determined by using the microscopy method which is the simplest and accurate method of determining floc sizes. Details of diameter for Aluminium Sulphate are shown in Table 1 and images of flocs before, after breakage and recovery is shown in Fig. 1a–c.

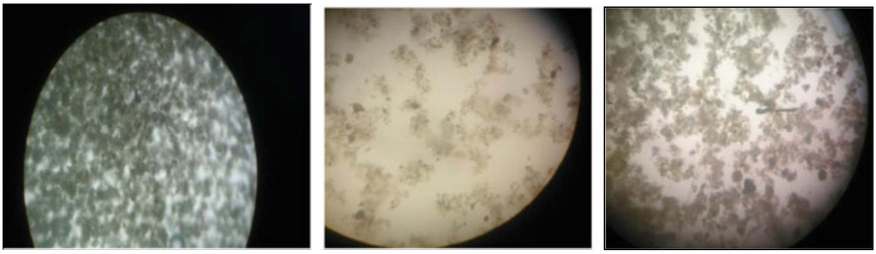
Details of diameters for the coagulant Ferric chloride is shown in Table 2 and images of flocs before, after breakage and recovery is shown in Fig. 2a–c.

a.) Floc before breakage(d1) b) Floc after breakage (d2) c) Floc recovery (d3)

Fig. 1 Images of flocs of Aluminium Sulphate

Table 2 Floc growth size of ferric chloride

Size 1 ($d1$) µm	Size 2 ($d2$) µm	Size 3 ($d3$) µm
479	213	293
505.4	239.4	266
532	266	319.2
Average = 505.47	Average = 239.5	Average = 292.73



a) Floc before breakage(d1) b) Floc after breakage (d2) c) Floc recovery (d3)

Fig. 2 Images of flocs of ferric chloride

3 Results

3.1 Floc Strength Factor

The floc strength factor is a measure of floc strength by exposing the floc to single level of increased shear rate within the containing vessel and comparing the floc size before and after breakage. It is compared in Fig. 3.

From Fig. 3, it is clear that Aluminium Sulphate floc is more resistant to hydrodynamic shear force than that of ferric chloride flocs. As floc strength for Aluminium Sulphate floc is more than ferric chloride floc.

Fig. 3 Floc strength factor

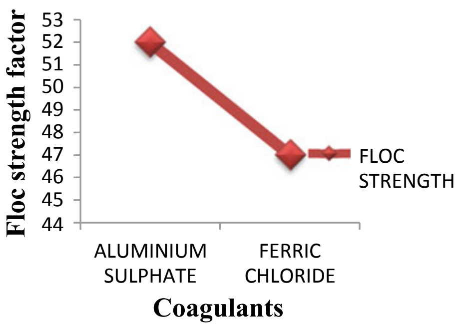
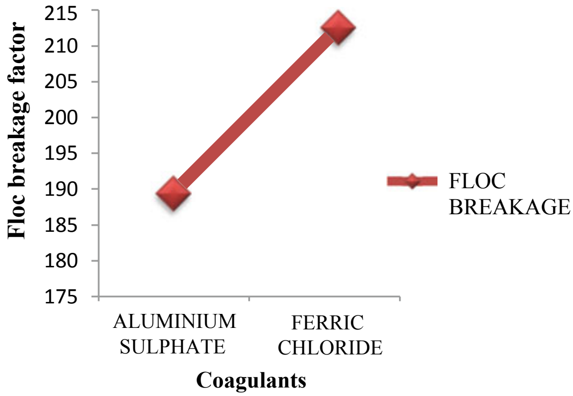


Fig. 4 Floc breakage factor



3.2 Floc Breakage Factor

Strength property of floc depends on the stability of floc in suspension and the number of bonds holding by the floc particles intogether. The floc breakage factor is compared in Fig. 4.

In the flocculation process, floc breakage plays a crucial role, the equilibrium of formation and breakage of floc results in the substantially stable floc size and structure. From Fig. 4, it is clear that ferric chloride flocs break more easily than Aluminium Sulphate flocs. As floc breakage factor is more for ferric chloride floc.

3.3 Floc Recovery Factor

The floc recovery factor is an indication of the extent to which the floc size recovers during the regrowth phase after breakage.

From above Fig. 5, it is clear that rate of recovery after breakage is more for Aluminium Sulphate flocs.

3.4 Floc Growth Rate

Floc growth rate is compared for both the coagulants as shown in Fig. 6.

From Fig. 6, it is clear that ferric chloride gives bigger and heavier floc than Aluminium Sulphate, hence the rate of settling will be more for ferric chloride flocs. It also shows that the rate of growth for floc is more for Aluminium Sulphate than ferric chloride floc. It also shows that floc growth time for ferric chloride is more than that of Aluminium Sulphate.

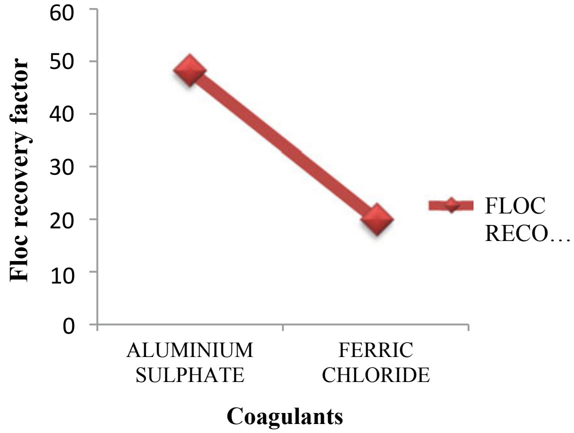


Fig. 5 Floc recovery factor

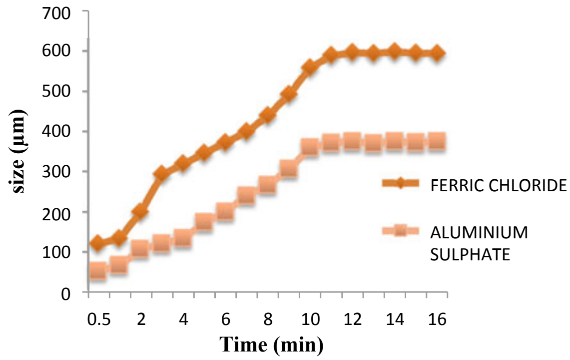


Fig. 6 Floc growth rate

4 Conclusion

Floc formation, breakage, and reformation were studied in detail which can give important indications for floc removal mechanisms. Experimental results were obtained from the microscopy method and they are compared considering both the coagulants Aluminium Sulphate and Ferric Chloride. The following conclusions were made.

1. The floc size for Ferric Chloride is more than Aluminium Sulphate floc. Therefore, the settling time for ferric chloride will be less than the Aluminium Sulphate floc. It will increase the efficiency of water treatment by reduction in settling time.
2. The floc strength and recovery is more for Aluminium Sulphate than Ferric Chloride coagulant. Hence Aluminium Sulphate flocs will be more resistant to hydraulic shear forces. Stability is more for Aluminium Sulphate floc.

3. The growth rate and growth time for Ferric Chloride are less than the Aluminium Sulphate. Hence Aluminium Sulphate floc requires less time for flocculation than ferric chloride, therefore, increase the efficiency for water treatment.
4. Cost of Aluminium Sulphate is less than that of Ferric Chloride. So Aluminium Sulphate is cost-efficient.
5. From the above results we can conclude that for floc removal, Aluminium Sulphate coagulant is more efficient than that of Ferric Chloride.

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