CO-FLOCCULATING MECHANISM AND ITS EXPERIMENT RESEARCH

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Abstract

This paper proposes the physical model of Coagu-flocculation mechanism. In this model we define the course of Coagu-flocculation as three steps, which are mix, coagulation and flocculation. In spite of non strict disguishion of practical course of Coagu-flocculation, but test verify that: first, the mix and coagulation of organic flocculant nearly finish at the same step, and need much stronger mix intensity; while inorganic flocculant need much weaker mix intensity; second, as to ensure forming much bigger floccules, it need weakness mix of certain time.

Keywords: Coagu-flocculation, mix coagulation, flocculation inorganic flocculant, organic floculan, physical model, experiment installation

Introduction

Coagu-flocculation is a unit purification process with the formation of floccules as its central step. The effect of Coagu-flocculation is determined by the chemical action of co-coagulant and the fluid dynamics effects of the facility. Though high efficient and economic co-coagulant are essential, meanwhile fine hydraulic condition should be offered to the facility so as to form Coagu-flocculation particles with nice density and make the later processes of sediment and filtration carried out efficiently. Due to the interaction, Coagu-flocculation becomes a very hard problem. Former studies usually only focused on a specific variable but did not consider other variables. Till now, there hasn't been any entire study about the relationship between different variables. The effect of Coagu-flocculation depends on such factors as PH value , temperature and density, but mainly depends on following two factors[1]: (1) compressed double electric layer mechanism produced after the hydrolysis of co-coagulant adsorption neutralization mechanism and the linking ability of macromolecule complex compound forming the adsorption bridging---these are determined by the character of co-coagulant; (2) The collision rate of small particles and how to control collision properly and efficiently. There are five main ways for collision of particles in water [2]: (1) Brownian Motion of particles (2) differences of settling velocity of particles (3) laminar shear (4) inertia collision of turbulence. The later three are contributed to the hydraulic effect of fluid.

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The collision velocity of particles caused by Brownian Motion is proportional to the temperature of water and the square of density of particles, while has nothing to do with the size of particles. In fact, only small particles have Brownian Motion, with the expansion of size, Brownian Motion becomes weaker gradually, when diameter is more than 1 μ m, Brownian Motion almost disappear [3]. For a common Coagu-flocculation pool, the diameter of particles usually increases from micron level into millimeter level, so the collision caused by Brownian Motion can be ignored. For the collision caused by the differences of settle velocity, it has a certain effect in the settling pool, while in the reacting pool, due to the strong turbulence, relatively; the effect of differences of settle velocity is very small. Especially at the initial step of Coagu-flocculation, the particle is thin, and settles velocity is slow; differences of settle velocity of different particles are even smaller. So for the collision caused by differences of settle velocity usually can be ignored in the reacting pool; while in the industrial Coagu-flocculation process, turbulent area is dominant, so the effect of laminar shear is not so apparent. Based on the above analysis, we can confirm that: the turbulent dynamic effect of fluid is dominant in accelerating Coagu-flocculation of particles.

Mathematic Expression For Collision Between Particles in Coagu-Flocculation

(1) Vortex shear Coagu-flocculation

Motion rule of eddy in the turbulent movement is expressed [7]

$$u = \frac{k}{R^m} \tag{1}$$

where k constant; *m* index, generally, m =0.5-0.9; *u* velocity of calculated point at a tangent; *R* the distance between the calculated point and origin (eddy radius).

Then at radius R the velocity gradient (plastic deformation) is

$$s_R = \frac{\partial u}{\partial R} - \frac{u}{R} = -(m+1)\frac{k}{R^{m+1}} = -(m+1)\frac{u}{R} \tag{2}$$

Heisenbery pointed out [8] that the turbulence also can be studied as average flow, for instance, when the seawater flows, though its velocity, position vary with time, it can be considered as turbulence when observed in a long time, while in the short time, average flow. This is identical with the idea of Cross that turbulent motion can be taken for a model of the combination of some complex compound laminar motion [9]. Using the Coagu-flocculation formula by Camp, the collision frequency N_{ij} between i and j particles, which is caused by velocity gradient of eddy in the unit time and unit volume, can be described

$$N_{ij} = \frac{4}{3} n_i n_j (r_i + r_j)^3 \times |s_R| = \frac{4}{3}(m+1) n_i n_j (r_i + r_j)^3 \frac{u}{R} \tag{3}$$

where n_i density of particle I, n_j density of particle j, r_i radius of particle i; r_j radius of particle j. The rest symbols are the same as above.

(2) Coagu-flocculation of vortex inertial centrifuge

In vortex velocity field, the Coagu-flocculation particles take vortex movement with flow. The collision times N_{ij} between i particles and j particles (vortex radius is R, particles radius is r, density is ρ_s), which is caused by the radial velocity differences in the unit time and the unit volume, is expressed

$$N'_{ij} = \pi n_i n_j (V_{0i} - V_{0j})(r_i + r_j)^2 \frac{u}{\sqrt{gR}} \qquad r_i > r_j \tag{4}$$

where V_{0i} settling velocity of particle i; V_{0j} settling velocity of particle j. The rest symbols are the same as above.

The collision frequency caused by radial inertial centrifugal not only increase along with particle's extension, but also depends on the radius differences, For those particles with the same radius ,in spite of high velocity, there is no collision, therefore inertial centrifugal Coagu-flocculation has a remarkable effect on collecting small particles and making their radius tend to be average. From this, we conclude that: vortex shear force and inertial centrifugal force under the turbulence are the main dynamic causes to accelerate particles to collide, while cortex shear force is the dominant power.

We should point out that till now, there are still no Coagu-flocculation dynamic models which perfectly describe the real situation in water treatment field, for (1) Smoluchowski formula is a model describing the frequency of particle collision under laminar condition, it is not suitable for the case in which turbulence is dominant in the Coagu-flocculation facility [7]. (2) Camp and Stein formula calculates velocity gradient by bringing in energy factors, there is no doubt that it is in favor of promoting the development of water treatment technology, but its weak point is apparent that the calculated results gained from the formula is not the velocity gradient in Coagu-flocculation pool. According to this formula, the bigger the velocity gradient, the better the effect of Coagu-flocculation. But at a certain distance from the back of net grid in the net grid Coagu-flocculation facility used at present, turbulence can be considered approximately as average ones with the same characters in all directions, that is to say the statistical feature value of motion parameter of space point are the same in all directions, so the average velocity gradient at present is zero. While its reacting effect of Coagu-flocculation is far superior to all the other current used Coagu-flocculation facility. This case fully conveyed the limitation of Camp and Stein formula [8]. (3) Levich formula is derived from other technical fields, and accepted only in the turbulent viscosity area [7].

The Drug Dispersion and Its Collision Effect with Grains in Coagu-flocculation

The Coagu-flocculation mechanism for drug dispersion and its interaction with particles include: double electric layer compression, electric neutralization, adsorption bridging. After adding electrolyte, the anti-ion formed by electrolyte in the solution causes the double electric layer compressed, electric potential of colloid ζ reduced (hydrate membrane at the colloid particles' surface disappears or becomes weaker)and finally colloid out of balance; Adding coagulant with opposite electric charge colloid can neutralize the electriferous colloid in water, the absolute value of ζ electric potential descend and colloid is out of balance, while adding excessive coagulant can get the colloids electriferous and regain its balance, as in Figure 1.

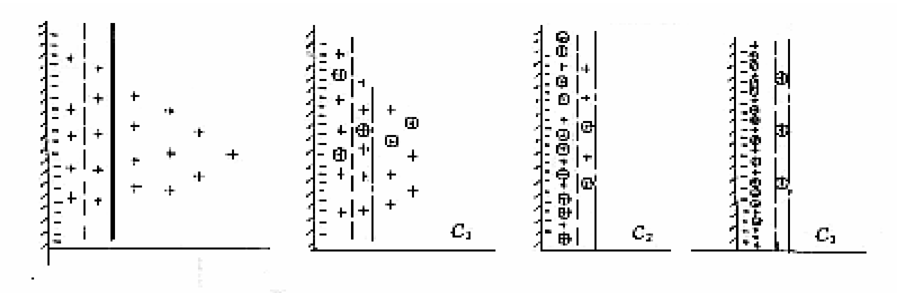

Figure 1: the sketch of ζ electric potential variable at the collide particles surface

But after adding electrolyte, the process of drug dispersion and its interaction with grains becomes rather complicated. Many factors are related with this process, while the drug character PH value colloid character and the hydraulic condition are the most important.

The mechanism of drug dispersion and its interaction with particles and its physical model in-coflocculation

The process of Coagu-flocculation can be classified into three stages [9] (a) drug dispersion and its interaction with particles (defined as mixing effect); (b) coagulation effect; (c) flocculation, as in Figure 2 and Figure 3.

full dispersion of drug and complete contact with colloid particles	→	formation of micro- floccules <5μm	→	formation of macro- floccules <1mm
1. mixing stage	→	2. coagulation stage	→	3. flocculation stage

Figure 2: Coagu-flocculation process

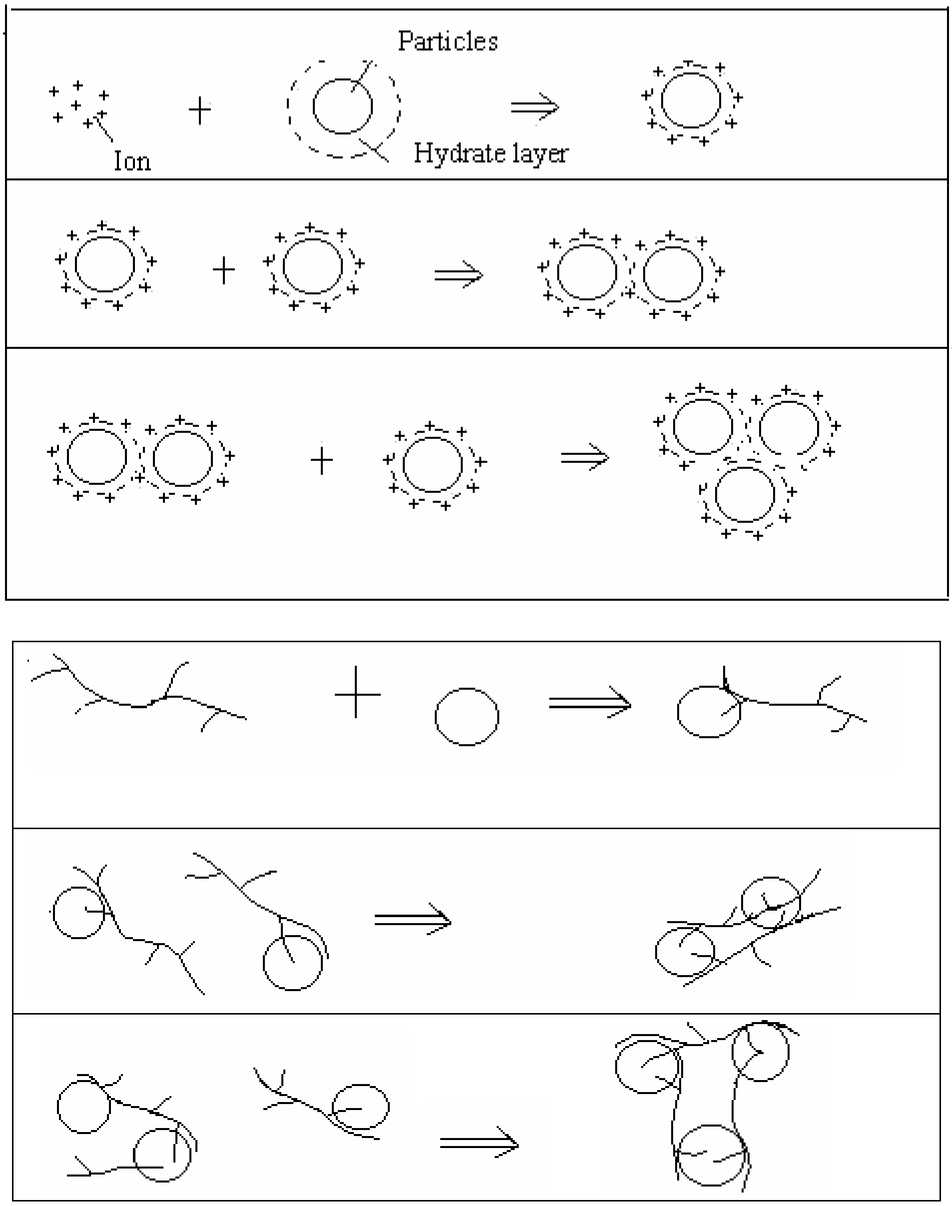

Figure 3: physical models of Coagu-flocculation process

Coagu-flocculation consists of coagulation and flocculation process. In the process of coagulation, the added co-coagulant reacting with colloid particles in water quickly to cause electric neutralization and imbalance of double electric layer compression, then the imbalanced particles coagulate with each other to form primary micro-floccules. While the flocculation process promotes the micro-floccules to continue increasing to form settling floccules with large size and density. In fact, the internal between coagulation and flocculation is very instant, almost occurring at the same time.

The proper distribution of alum size in energy consumption Coagu-flocculation process depends on the correlative relation between the linking ability of adsorption bridging and turbulence shear [10].Turbulence shear mainly depends on vortex size and intensity. The less the vortex size and the larger vortex intensity are, the stronger the effect on alum. In Coagu-flocculation process, proper classification and the way of increasing the capacity of flocculation room step by step should be adopted to meet the objective requirement –with the extension of alum, the input energy rate needs to be reduced correspondingly and bigger alums' continuing concentrating needs a long time. Engineers unified the knowledge of flocculation process on the whole. The control of hydraulic condition in this process is also easy to be achieved Therefore, the writer believes that only when the colloid particles completely contact with the well dispersed drug, it is possible to form micro-floccules, and further completely or high efficiently (if time is short) form big floccules. That is to say only when mixing is well developed, there will be coagulation with high quality and then flocculation with high efficiency. For instance, if a colloid particle dose not contact with drug to emerge (physical) chemical effect, the possibility for the colloid particle to coagulate (flocculate) is rather small, only at the flocculation stage, it may be caught by net or settled by differential sedimentation. The more such particles are, the worse the effect of Coagu-flocculation and settlement. Therefore (1) drug dispersion and its reaction with particles are the most important; (2) consequently occurred hydraulic condition is also the most important content for study.

Experimental Research of Coagu-Flocculation

Experimental installation and condition

Experimental installation, Figure 4: the size of blade is fixed in experiment; the stirring intensity is variable with rotating times (shown by voltage value).

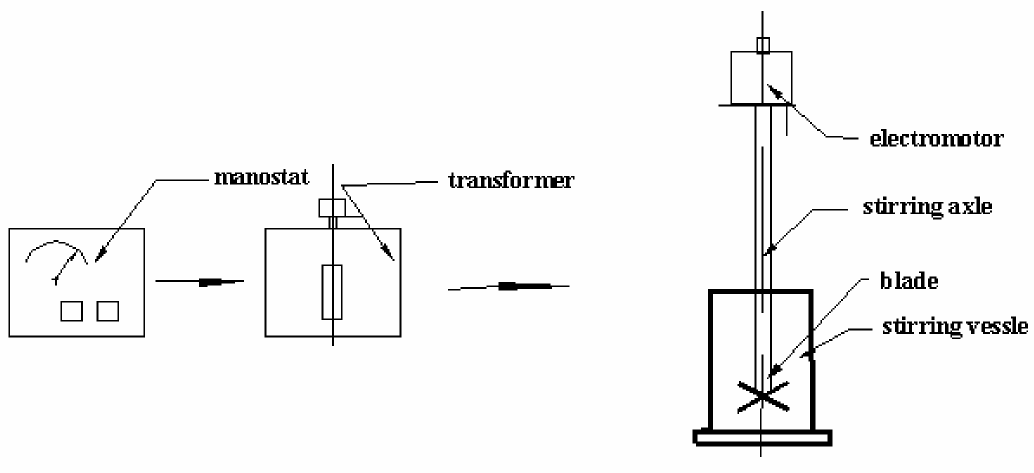

Figure 4 Experimental installation

1. Determination of the best turbulent value in mixing stage

Table 1 shows that in the earlier stage of Coagu-flocculation process, neither stirring time nor stirring intensity affects the Coagu-flocculation effect excessively.

Table 1: The influence of stirring intensity and time on mixing effect (Inorganic drug)

Time (min) \ Condition / No.	Stirring Intensity (Voltage V)			Original Turbidity (NUT)	Purified Turbidity (NUT)	Remarks
	50	70	40			
1	1		3	185	70	1. Suspension : clay 2. PH=6.5 3. Drug volume 10mg/l 4. Drug $AICI_3$
2	3		3	185	69	
3	5		3	185	71	
4		3	3	185	85	
5		5	3	185	98	

Table 2: The influence of stirring intensity and time on mixing effect (Organic flocculant)

Time (min) \ Condition / No.	Stirring Intensity (Voltage V)			Original Turbidity (NUT)	Purified Turbidity (NUT)	Remarks
	50	70	50			
1	1	2	3	185	70	1. Suspension : clay 2. PH=6.5 3. Drug volume 0.1mg/l 4. Drug PAM
2	3	2	3	185	69	
3	5	2	3	185	71	
4	5	3	3	185	55	
5	5	5	3	185	58	

2. The determination of the best turbulence value in coagulating stage

Figure 3 shows that from the view of theory the strong stir makes the collision between particles increase, but it is not in favor of the formation of micro-floccules.

Table 3: The influence of stirring intensity and time on coagulation effect (Inorganic drug)

Time (min) \ Condition / No.	Stirring Intensity (Voltage V)			Original Turbidity ((NUT)	Purified Turbidity (NUT)	Remarks
	50	100	40			
1	1	1	3	190	90	1 . Suspension : clay 2. PH=6.5 3. Drug volume: 10mg/l 4. Drug: $AICI_3$
2	1	2	3	190	118	
3	1	3	3	190	135	
4	1	4	3	190	170	
5	1	5	3	190	175	

Table 4 shows that stronger stirring is more helpful to coagulation effect, making more micro particles coagulate and the formation of big floccules.

Table 4: The influence of stirring intensity and time on coagulation effect (Organic flocculant)

Time (min) / Condition / No.	Stirring Intensity (Voltage V)			Original Turbidity (NUT)	Purified Turbidity (NUT)	Remarks
	50	100	50			
1	1	1	3	190	80	1. Suspension clay 2. PH=6.5 3. Drug volume 0.1mg/l 4. Drug PAM
2	1	2	3	190	78	
3	1	3	3	190	35	
4	1	4	3	190	25	
5	1	5	3	190	31	

3. The determination of the best turbulent value in flocculating stag

Figure 5 shows that forming more big floccules need a certain time in the flocculating step.

Table 5: The influence of stirring intensity and time on coagulation effect (Inorganic flocculant)

Time (min) / Condition / No.	Stirring Intensity (Voltage V)			Original Turbidity (NUT)	Purified Turbidity (NUT)	Remarks
	50	100	40			
1	1		1	188	86	1. Suspension : clay 2. PH=6.5 3. Drug volume 10mg/l 4. Drug $ALCL_3$
2	1		2	188	79	
3	1		3	188	75	
4	1		4	188	25	
5	1		5	188	23	

Table 6 shows that flocculation stage needs a certain time to form more big floccules, but if the stirring time were too long, it would destroy the balance between floccules and breakage.

Table 6: The influence of stirring intensity and time on flocculation effect (Organic flocculant)

Time (min) / Condition / No.	Stirring Intensity Voltage V			Original Turbidity (NUT)	Purified Turbidity (NUT)	Remarks
	50	100	50			
1	1	3	1	188	46	1. Suspension : clay 2. PH=6.5 3. Drug volume 0.1mg/l 4. Drug PAM
2	1	3	2	188	39	
3	1	3	3	188	35	
4	1	3	4	188	25	
5	1	3	5	188	30	

4. Analysis for experiment results

Generally, Coagu-flocculation process is defined to be mixing stage, coagulation stage and flocculation stage. Though there is no strict distinction of Coagu-flocculation process in practice, experiments have proved that (1) mixing of organic flocculant and coagulation are accomplished at the same stage and need stronger stirring intensity; while the mixing and coagulating of inorganic floccules are accomplished almost at the same stage but need weaker stirring intensity. (2) In order to form bigger floccules, the weaker stirring is needed for a certain time.

Conclusions

1. The earlier stage study of Coagu-flocculation mechanism laid particular stress on collision mechanism and velocity gradient theory, but did not coincide with grid Coagu-flocculation in practical application.
2. The correctness and guidance of above definition and physical model have been proved by experiments. Definition of Coagu-flocculation process from microscopic view and the proposition of physical model are more helpful to detail study of Coagu-flocculation mechanism in future.
3. Mixing and coagulation of organic flocculant are accomplished at the same stage and need stronger stirring intensity.
4. The mixing and coagulating of inorganic floccules are accomplished almost at the same stage but need weaker stirring intensity.
5. In order to form bigger floccules, the weaker stirring is needed for a certain time.

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