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TIMECOURSE STUDY OF COAGULATION-FLOCCULATION PROCESS USING ALUMINUM SULFATE

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ABSTRACT

In conformity with drinking water standards, water purification units must remove colloid impurities in water which shelters microorganisms such as bacteria and viruses, and natural organic matter (NOM) using the sequence of treatment processes including coagulation-flocculation, sedimentation or filtration and disinfection. The coagulation-flocculation process consists of rapid mixing, followed by slow mixing and settling at room temperature. Efficiency of coagulation-flocculation process depends on process parameters. Optimization of significant parameters such as initial pH, coagulant and flocculant dosage, settling time, mixing parameters and the effective temperature for coagulation-flocculation performance is crucial. In this study, time course study of coagulation-flocculation as well as the effects of coagulant dosage and pH in the synthetic wastewater produced by kaolin was investigated. Coagulant dosage and pH optimization is necessary to achieve optimal efficiency. Appropriate coagulant dosage, pH and settling time were 70 mg/L, 6.5 and 45 minutes, respectively and resulted in 99.72% turbidity removal.

1. INTRODUCTION

In conformity with drinking water standards, water purification units must remove colloid impurities in water which shelters microorganisms such as bacteria and viruses, and Natural Organic Matter (NOM) using the sequence of treatment processes including coagulation - flocculation, sedimentation or filtration and disinfection[1]. For example in a study by Martin et al., [2] coagulation/precipitation, flocculation, sedimentation and filtration have been used for the removal process of organic micro-pollutants.

Coagulation-flocculation is one of the methods used for the treatment of industrial and municipal wastewater[3]. This process aims to improve particle separation like filtration and sedimentation. The early application of coagulation has been to remove turbidity from drinking water [4].

Turbidity is one of the indicator parameters for recognition chemical and biological water quality[5] but recently it has been used for many other contaminants removal such as metals, toxic organic matter, viruses, and radionuclides[4].

Coagulation is the process for enhancement tendency of small particles to connect each other in an aqueous suspension. In this process, the target particles have a size range between 0.001 and 1 μm leading to very small ratio of mass to surface area. Because of this small ratio in colloidal suspension, gravitational effects are insignificant while surface phenomena prevail [6]. The repulsive forces of electrical charges are more than attractive body forces due to the size of colloidal particles[3]. Colloids pass through common filters such as paper and sand, however they are relatively large in comparison with ions to cross the membrane. Although ultrafiltration can easily remove colloidal particles, coagulation is required for removal by conventional filtration[4].

Coagulation process consists of two different steps: 1) rapid mixing for coagulant dispersion into water/wastewater with severe agitation 2) slow mixing to convert small particles into clear flocs[3]. The purpose of the coagulation is instability of the suspension, which causes agglomeration, while flocculation is to form larger agglomerates. After flocs settling and its elimination as sludge, supernatant wastewater is moved to next treatment processes or discharged into a watercourse[3]. Coagulation causes particles unstable by four mechanisms: compression of electrical double layer, adsorption and neutralization of electrical charge, entrapment of particles in precipitate and adsorption, and particles bridging[6].

From 1500 BC, aluminum sulfate has been used by Egyptians for settling particles in water. Although the early Romans knew alum, aluminum sulfate usage as a coagulant in water treatment was noted after 77 AD [3]. In high-rate filtration plants, coagulation has been an important unit since the 1880s. From the beginning, alum and iron (III) salts have been used as coagulant chemicals, with the most widespread use of alum. In the 1930s, activated silica was used as a "coagulant aid", and then artificial organic polymers and cationic polymers were recommended in the 1960s. Natural starches were used before the artificial compounds[6]. The color caused by natural organic matter was eliminated by aluminum sulfate and ferric iron for a long time. All surface waters and many groundwaters have organic substances and its removal should be considered[6].

1.1 Effective parameters on coagulation-flocculation process

Coagulation-flocculation yield strongly depends on the process parameters. Optimization of important parameters, such as initial pH, coagulant or flocculant dosage, settling time, mixing parameters, and temperature are required for efficient coagulation-flocculation. Initial contaminant concentration is also one of the process parameters[3].

1.2 Initial pH effect

Effluent pH is a very effective factor in the efficiency of conventional coagulants. Optimization of the pH is necessary for each coagulant. The type of wastewater determines specific pH range and coagulant type for better performance[3]. But in some cases, such as the polymer used for direct flocculation can be used in a wide pH range [7]. It is important to note that the treatment systems without pH adjustment present easiness and low cost [8].

1.3 Coagulant or flocculant dosage effect

Coagulant dosage that depends on the TSS or colloid content in the wastewater, is an significant parameter during coagulation–flocculation[9]. Basically, if the dose is inadequate or too high, it will cause low efficiency in flocculation. Therefore, determination of the optimum dosage for reducing the cost and sludge formation and also obtaining the good performance in treatment is important[10]. Destabilization mechanism impresses the coagulant dosage effect on destabilization[11].

1.4 Settling time effect

In water treatment plant that have coagulation-flocculation unit, flocculation time is an utilizable parameter which must be considered[10]. The overall yield of coagulation process is under the under the influence of strength and settling velocity of flocs formed during this process[3]. The flocs size increase approves the flocs settling speed, so reduces the settling time of the flocs formed [12]. It has been

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reported that using rice starch as coagulant in the coagulation-flocculation process, produced more resistant flocs to shear force, resulting in a significant reduction in settling time [13].

The type of coagulant or/and flocculant used in treatment and also, the type of wastewater are factors that are very effective in settling of flocs produced after the coagulation–flocculation process[3].

1.5 Mixing effect

The rapid-mixing time affects the colloid destabilization and the aggregation of particles[14]. It has been found that coagulation process is affected by mixing conditions and, the rapid mix time had a significant effect on ultimate coagulation yield. Short period of rapid mixing perform better than long rapid mixing on turbidity removal[15]. If the mixing time is short, it will result in the growth of larger flocs (except for flocs with lower shear strength)[3].

1.6 Temperature effect

Temperature is an effective parameter in coagulation reactions and metal coagulant chemistry[11]. Poor performance of coagulation-flocculation process may be the result of doing coagulation at low temperatures or producing fragile flocs that physical forces break them [16]. For example, with decreasing water temperature, the minimum solubility of aluminum hydroxide species shift to higher pH, and the “optimum” operating pH also shifts to higher pH [11]. With the decay of coagulation effect at low temperatures, significant increase of flocculant dosage occurs[17]. However, at low temperature water treatment bio flocculants indicates desirable flocculating performance[18]. Reaction temperature effects on the iron and aluminum oxides conversion in a special time is in accordance with reaction rate theory, which keeps that the rate of a chemical reaction increases with temperature. Furthermore, temperature has distinct effects on the conversion of $Fe3+$ and $Al3+$[19]. Additionally, temperature will impress on the effectiveness of each type of coagulant or flocculant. It was reported that temperature could also affect the raw water turbidity. For example, the temperature increasing during summer results in high turbidity in raw water due to fast algae growth which may need intensive coagulation-flocculation treatment compared to treatment during other seasons[3].

2. METHODS AND MATERIAL

Jar test device was from SCI FINETECH Co. model (FTJT-106). Experiments were performed to investigate variables such as pH, coagulant dose dosage and settling time in the coagulation process using aluminum sulfate (from ACROS). In order to study these variables, turbidity was created artificially using kaolin (DUKSAN, extra pure grade). To prepare artificial wastewater, certain amount of kaolin was added into deionized water without any dispersing agent and the mixture was stirred for half an hour and was settled for 30 minutes. After settling, supernatant soup was separated to adjust pH and examine coagulation process. Adjusting pH was done with HCl 0.1 M and NaOH 0.1M. After pH adjusting, 400 ml of synthetic wastewater was moved into six beakers in jar test device and the effects of other variables, such as coagulant dosage and settling time were investigated. The coagulation-flocculation process involves two steps of rapid mixing and slow stirring which rapid mixing takes place in a shorter time (3 minutes) and slow stirring longer time (15 min) and then the sedimentation stage is performed to precipitate dense masses. The jar test speed and time of mixing are shown in Table.1. After jar-tests performing, samples for turbidity measurement were withdrawn from 2 cm below the liquid level every 15 minutes for timecourse study of the process. Samples turbidity was measured by turbidimeter (HACH, 2100AN). All experiments were carried out at room temperature.

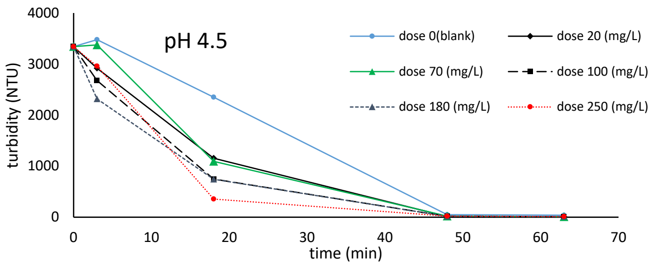
Table 1: speed and time of jar test

Coagulation-flocculation stages	Time (min)	Speed (rpm)
Rapid mixing	3	180
Slow mixing	15	40
Settling	45	-

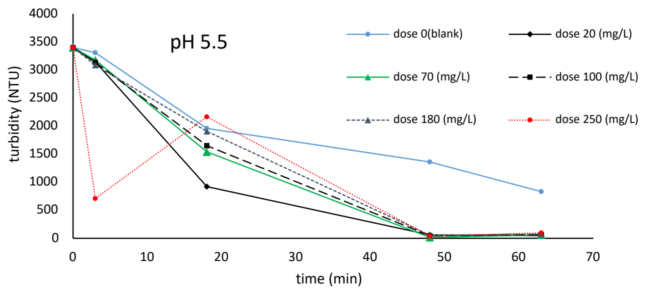
3. RESULTS AND DISCUSSION

In this study, coagulation process in synthetic wastewater with almost equal turbidity but different pH and aluminum sulfate dosage was investigated. As mentioned earlier, pH has an important effect on coagulation process. As shown in Figure 1a, in pH 4.5 with a settling time of 45 minutes, there is no significant difference between blank sample turbidity (without coagulant) and turbidity of samples with different coagulant (aluminum sulfate) dosage. The reason of this observation may be effect of kaolin isoelectric point which is between 4 and 5[20]. Isoelectric point means that the particle has neither positive nor negative charge [6].

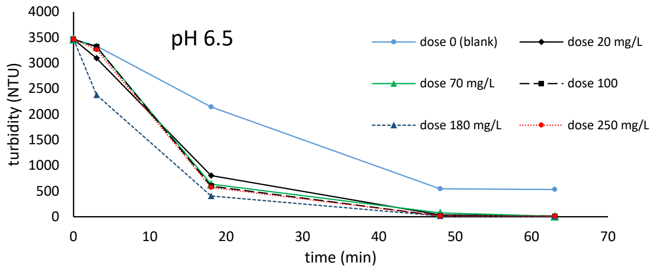
As a result, repulsive force of like charges is gone, suspension loses its stability and eventually precipitates. Consequently, turbidity is significantly removed without the use of coagulants and only by adjusting the pH at this point. At pH 5.5 (Figure 1.b) with 250 mg/L aluminum sulfate dose, turbidity increases after slow mixing that indicates overdosing on alum. The use of low pH due to corrosion is not recommended in wastewater treatment, so using pH 6.5 (Figure 1.c) is better than other investigated pH because of the proximity to the natural pH and 99.72% turbidity removal at 70 mg/L alum. Also, by increasing the settling time, the turbidity is reduced up to 45 minutes with a dose of 70 mg / l alum and pH 6.5 with initial turbidity of 3500 NTU, there is significant difference between 30 and 45 minutes settling times so 45 minutes settling is suitable in this study. However, time course study showed that more than 70% of turbidity removal was done after slow mixing at the pH 6.5, supporting fast removal of turbidity in comparison with other pHs.



(a



(b)



(c)

Figure 1: Evaluation of turbidity at different alum doses and pH over time. (a) pH 4.5, (b) pH 5.5 and (c) pH 6.5. (3 minutes rapid mixing, 15 min slow mixing and 45 min settling. turbidity has been read after each quarter at the time of settling.

4. CONCLUSION

According to this study, important factors should be considered and optimized to achieve optimal efficiency in coagulation-flocculation process. Optimum amount of each parameter including pH, coagulant dosage and settling time varies for each coagulant and it must be earned by conducting experiments. At pH 6.5 with an aluminum sulfate dosage of 70 mg/L and 45 min settling time, the most effective and efficient turbidity removal of 99.72% was observed. Also, more than 70% turbidity removal was occurred after slow mixing where the pH was 6.5.

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