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Single and combined chemical coagulants for *Oscillatoria sp.* removal in raw water for water treatment plant

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Abstract

Chemical coagulation for *Oscillatoria sp.* removal using coagulants of Alum, Polyaluminum chloride (PACl), combined PACl/Alum and combined PACl/Ferric chloride ($FeCl_3$) are evaluated by the jar test method to optimize the coagulant type and dosage. The synthetic water at 15 million cells/L of the concentration of algae cells is used as the raw water. The experiments conduct on a single coagulant and combined coagulant in terms of the turbidity and chlorophyll A removal performances. The results can be concluded that the maximum removal of turbidity (97.14%) and chlorophyll A (99.67%) is achieved from the combined PACl/Alum dosage (ratio 3:1 or 60:20 mg/L). The combined coagulant provides the best *Oscillatoria sp*. removal in comparison to its single coagulant counterpart.

Keywords: *Oscillatoria sp.*, Coagulant, Coagulation, Algae removal, Chlorophyll A

1. Introduction

Eutrophication is one of the most widespread environmental problems of surface water [1]. Furthermore, the eutrophication contains an unnatural enrichment of plant nutrients. The result of increasing plant nutrients in water sources encourages the algae growth, which forms a bloom over the water surface. The algae bloom in water sources can cause many problems in any water treatment process, such as causing a short filter operation, increasing a coagulant demand, creating an odor and taste and creating a chlorinated DBP (Disinfection by product) problem.

The first industrial estate in the southern of Thailand is SRIE (Southern Region Industrial Estate) in Songkhla Province. The water supply in SRIE from the water treatment plant comes from a reservoir in the estate area. The algae bloom problem occurred last year in the reservoir with *Oscillatoria sp*. (95%) as the majority specie of algae. Later, it caused the odor problem. Thus, the water supply for factories in SRIE had an odor similar to the fishy smell while the quality of water supply still met the water supply standard.

Chemical coagulation is the most commonly used in the water treatment processes when a water source contains large amount of suspended matters such as algae, silt or mud [2]. The performance of coagulation depends on the various factors such as coagulant type, pH value and coagulant dosage. When a chemical coagulant is added to water, colloidal material will join together into flocs. Flocculation is a slow mixing of the water to encourage the flocs to form and grow to a bigger size which they can be easily to settle out. The treated water is separated from the floc. The combined coagulants have not been found much in the literature reviews. This study evaluated the coagulation performance of Alum, PACl, combined Alum and PACl, combined PACl and $FeCl_3$. The ratios of combined coagulant are 100/20, 60/20, 40/20, 40/40, 20/60 and 20/100 by weight.

2. Materials and methods

2.1 Raw water

In order to control the *Oscillatoria sp.* concentration, in this study the synthetic water is used. The distilled water (DI water) is diluted with the high concentration of *Oscillatoria sp.* The DI water is used as pure water without any contamination of chlorine and other algae species. The concentration of algae is approximately 15 million cells/L in this study. The *Oscillatoria sp.* cells are cultured using BG11 medium at 28-32^{o}C in the laboratory. After 30-day culturing, the algae are harvested. The raw water characterizations are shown in Table 1.

Table 1 Characteristics of raw water

***Oscillatoria sp.* concentration (million cells/L)**	**pH**	**Turbidity (NTU)**	**Chlorophyll A (mg/m^3)**
15	7	8.5-11	225-250

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2.2 Procedure for jar test

The method of jar test is conducted following the standard practice for coagulation-flocculation testing to evaluate the chemical dosages and pH in order to achieve the optimum result [3]. Raw water was filled in six beakers of 1L each (Figure 1). The various coagulants are added and then followed by a 1-min rapid stirring at 100 rpm (Coagulation process) and a 30-min slow stirring at 30 rpm (Flocculation process) and a 30-min settling (Sedimentation process). For combined coagulant process, after 1-min rapid mixing time of the first coagulant dosage in the raw water, the second coagulant is added immediately [2].

Figure 1 Jar test

2.3 Analytical methods

The turbidity, pH and Chlorophyll A of the raw water and the treated water are analyzed. The suspended solid analysis is conducted following ASTM. The turbidity and pH are measured using a turbidity meter and a pH meter, respectively. The chlorophyll A concentrations are measured by the spectrophotometry [4].

3. Results and discussion

The coagulation performance is considered in terms of turbidity and chlorophyll A removals. All experiments are conducted in triplicate. The experiments are examined with a dosage range of 40-90 mg of coagulant/L of raw water for Alum, 1-30 mg of coagulant/L of raw water for PACl, combined Alum/PACl and combined PACl/$FeCl_3$ (100/20, 60/20, 40/20, 40/40, 20/60 and 20/100 ratios by weight). For the combined coagulants, the first dosage is PACl then is followed by Alum or $FeCl_3$ dosages, because the PACl is a less pH-dependent coagulant [2] to prevent a dramatic change of the pH value before adding other coagulant. Figure 2 shows the effect of coagulant dosage on the turbidity efficiency removal.

The residual turbidity in the treated water after the jar test is decreased with the increasing Alum dosage. At the increasing dosage, the residual turbidity increased at the first period and then decreased. This can be attributed to the coagulant dosages. The coagulant types have different removal effect on algae because of their various sizes, surface charge and the cell density [5]. The jar test results of the combined PACl/Alum dosage provided the better turbidity removal efficiency (97.14%) than that of the Alum, the PACl and the combined PACl/$FeCl_3$ dosages. The second highest efficiency was the combined PACl/$FeCl_3$ dosage (96.23%). The less efficiency was the Alum dosage (82.30%). Figure 3 shows similar trends. The combined PACl/Alum dosage provided the better Chlorophyll A removal efficiency (99.67%).

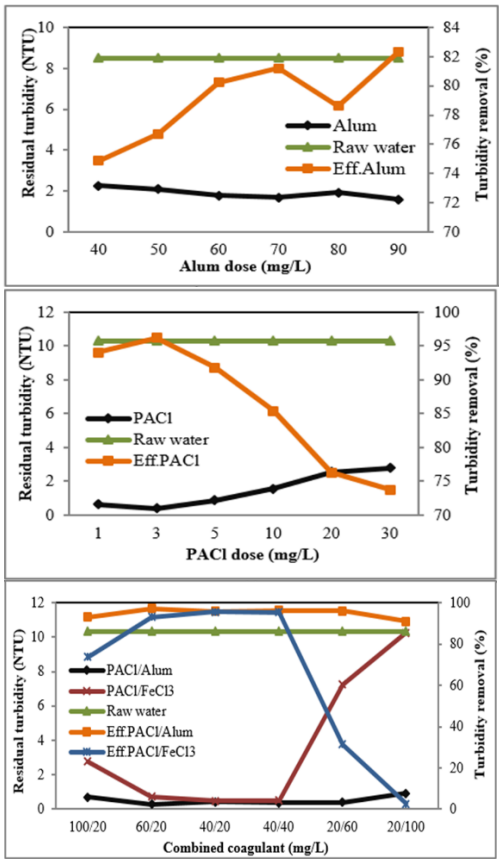

Figure 2 Effect of various coagulant dosages on turbidity removal

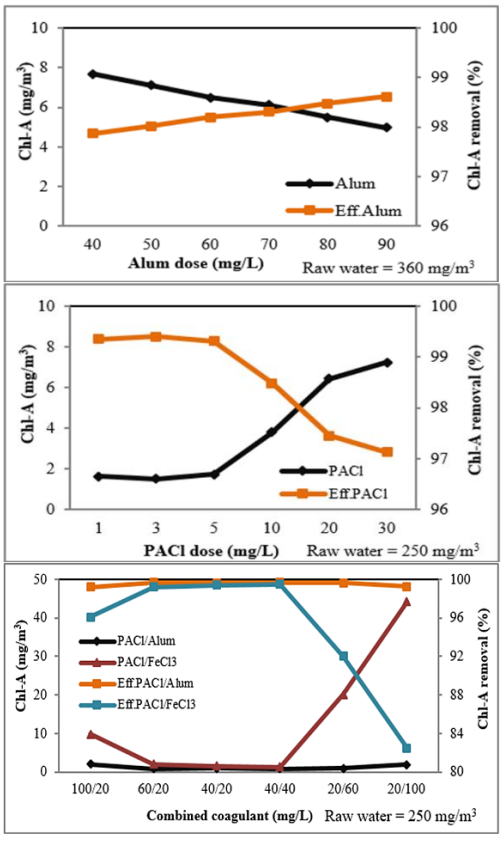

Figure 3 Effect of various coagulant dosages on Chlorophyll A removal

The coagulation-flocculation process using chemical coagulants can be explained through the compression of double layer, charge neutralization, entrapment, adsorption and complexation [6]. The dominant turbidity removal mechanisms using the PACl coagulant were suggested to be the adsorption, entrapment and sweep-flocculation [2]. Alum coagulant is similar to the PACl because they are the aluminum salts. For the $FeCl_3$ coagulant, the mechanisms like to charge neutralization [7-8]. Therefore, the used of combined coagulant will be better than that of any single coagulant because the combined coagulant can enhance the bridging ability of coagulations and floc is relatively large then its settle better[2].

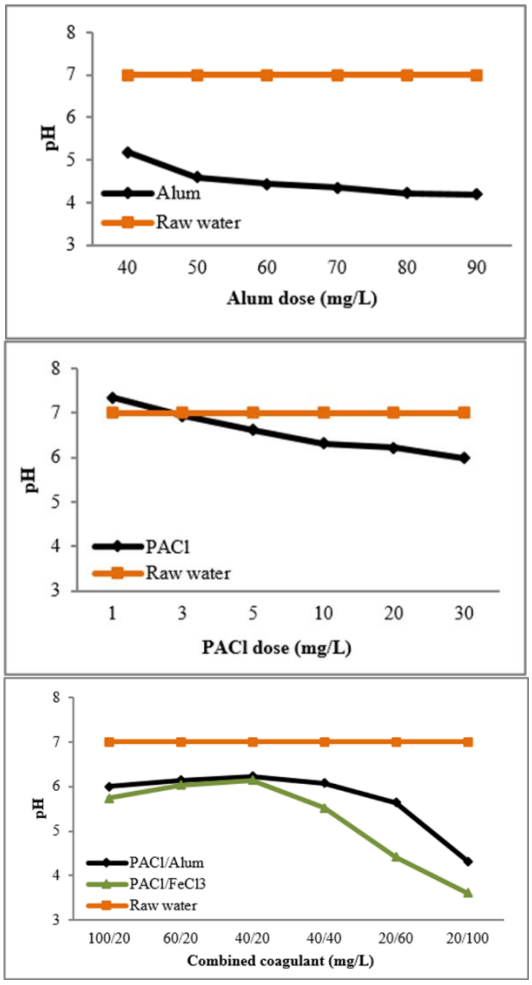

Figure 4 pH values after coagulation process

Figure 4 showed the pH values after coagulation, the initial pH value is about 7 (neutral) because the raw water is the synthetic water which is prepared from the distilled water. It has been reported that the pH/alkalinity could affect the chemistry of coagulants, particularly the speciation distribution of coagulants after dosing [2]. When the coagulant dosage was increased, the pH of the treated water decreased. The alkalinity which is related to the pH value is also decreased. The salts from coagulant will be forming aqua metallic ions as soon as the coagulant was added to the water. Thus, the ion is related to the system making the pH value decreased. According to the experimental results, the coagulation is effective because the amount of alkalinity is sufficient.

4. Conclusions

The raw water in this study contains approximately 15 million cells/L of *Oscillatoria sp.* concentration, 225-250 mg/m^3 of initial Chlorophyll A and 8.5-11 NTU of initial turbidity. The results showed the optimum single coagulant dosage of Alum and PACl are 90 and 3 mg of coagulant/L of raw water, respectively. The optimum dosage of combined PACl/Alum and combined PACl/$FeCl_3$ are 3:1 ratio or 60:20 mg of coagulant/L of raw water and 2:1 ratio or 40:20 mg of coagulant/L of raw water, respectively. The quality of treated water (i.e. Chlorophyll A and turbidity) from the combined PACl/Alum coagulant is better than that of Alum, PACl and combined PACl/$FeCl_3$ coagulants.

5. References

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