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The Changes of Algae Pretreatment Efficiency in the Coagulation and Electro-Flotation Process

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Abstract

The algae bloom in river has been issued in Korea. In order to alleviate treatment load of water treatment plant and to meet water treatment capacity of the plant, a high-speed algae pretreatment methods connected with water intake pipe are required. In this study, a pilot-scale of pretreatment system was tested. It was consisted of coagulation and electro flotation processes. The algae pretreatment efficiency by the comparisons of chlorophyll-a, nutrients (total nitrogen, total phosphorous), and chemical oxygen demand (COD) concentration was evaluated. As a result, the system showed about 45% of removal efficiency by the only flotation separation without coagulation judged by chlorophyll-a concentration. On the other hand, the removal efficiency was improved with increase of coagulant dosage and electric power. It was improved to about 80% of chlorophyll-a concentration. The system could treat algae containing solution within a few minutes on the basis of residence time of flotation tank. Consequently, this study suggests that the system could be used as an algae pretreatment step in water treatment process.

Keywords*: algae bloom, electro flotation, coagulation, algae pretreatment*

1. Introduction

The algae bloom is a massive increase of harmful algae caused by eutrophication in the stagnated water bodies such as lake and reservoir. Algae not only causes taste and odor in drinking water, but threatens the public health by discharging harmful toxins such as Microcystin-LR [1]. On the other hand, algae bloom in rivers recently has been issued also in Korea as well as the water bodies. This comes from the increase of residence time of river water due to the construction of dams inside river, and from the high rate of dependence of water intake on river water. To reduce the treatment load of water treatment plant (WTP) due to the river algae bloom, it is necessary to develop control methods connected with water intake pipe. Because the pipe was operated with a high water velocity to meet a treatment capacity of a WTP, a more rapid pretreatment method than conventional coagulation and pre-oxidation systems are required.

The electro-coagulation and flotation (ECF) process has been investigated for algae control [2]. This process has advantages of less chemical dosage and no pH adjustment [2-7], however, it needs relatively long electrolysis time. This is because metal ions need time to flow out from the sacrificial electrode, which are required to facilitate a cohesive reaction by maintaining charge neutralization around the algal cells. S. Gao et al. (2010)

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obtained an optimal electrolysis time of 30 minutes on condition of 1 mA/cm^2 of current density. Besides, the same goes for other target compounds as well as algae. A.H. Mahvi et al. (2011) presented the electrolysis time of 20 minutes for ammonia and 40 minutes for phosphate. In addition, M.M. Emamjomeh et al. (2009) suggested 40 minutes of electrolysis time for nitrate reduction [10-15]. Since their experiments were conducted with the sacrificial electrode in the lab-scale electro coagulation (EC) system, it was necessary to secure a sufficient electrolysis time. However, it is not reasonable to apply the EC process as an algae pretreatment process connected with water intake pipe of WTP. It is necessary to consider more rapid pretreatment method.

This study focused on the high-speed algae pretreatment method. To reduce the electrolysis time, a coagulation combined with electro-flotation (EF) process was studied instead of the EC process. A pilot scale of pretreatment system was tested to control the harmful algae in river water.

2. Material and Methods

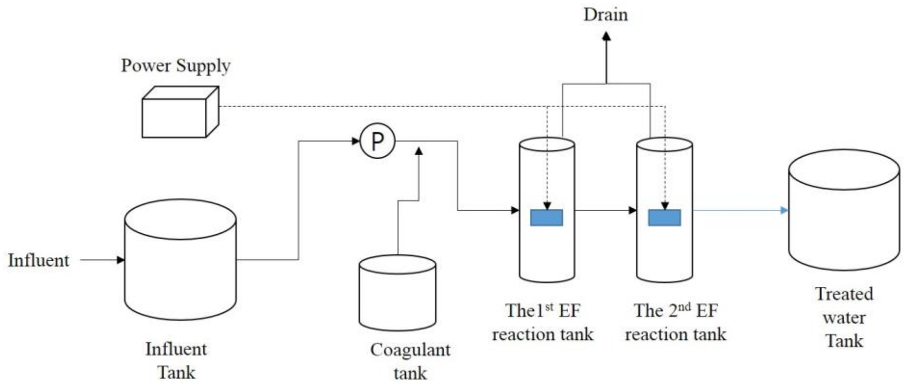
2.1. The High-Speed Algae Pretreatment System

Figure 1 shows the pilot scale of algae pretreatment system, which was composed with coagulation and EF processes. The system was designed to treat 100 m^3/day of raw water, and was installed in a WTP located around the Nak-Dong river basin in Korea. The influent was dosed with a coagulant, and was contacted with micro bubbles created from the EF system.

The EF system has two separated reaction modules. Each reaction module has a set of electrode for the reaction inside of a flotation tank. The electrodes were made of platinum, and the efficient area per electrode was 25 cm^2. The operating condition for current density was 20 mA/cm^2. In addition, each flotation tank has a volume of around 0.08 m^3. The supernatant algae scum was overflowed to the upper drain. Table 1 summarizes the specifications of the electrode.

In this study, the influent was tested with a capacity of 17.5 m^3/day. The EF system was operated in condition of around 4.5 minutes of residence time based on the flotation tanks.

(a)



(b)

Figure 1. The High-Speed Algae Pretreatment System for WTP Influent: (A) A Front View of the EF System, (B) P&ID of the System

Table 1. Specifications of the Flotation Electrode

Item	Specification
Material	Platinum
Efficient area	25 cm^2/ea.
Electrode interval	3 mm
Electrode number	10 electrodes/set
Current density	20 mA/cm^2
Connection method	Bipolar

2.2. Coagulation

As a coagulant to accelerate coagulation between algae cells, 17 % of the powdered potassium aluminum sulfate (alum) was used. The solution of the alum in water was supplied to pipe before EF reaction modules. The coagulant dosage was modulated by regulating the chemical supply pump.

2.3. The Algae Pretreatment Efficiency

The algae pretreatment efficiency of the high-speed EF system was analyzed by the comparisons of chlorophyll-a, total nitrogen (T-N), total phosphorous (T-P), and chemical oxygen demand (COD) concentration between raw water and the treated water. Furthermore, the effect of electric power and coagulant dosage was evaluated by changing the operating conditions. The electric power has a range of 20-280 W, and the coagulant dosage was 0-25 ml/min. The algae pretreatment efficiency was expressed as eq. (1).

$$R_p = \frac{(C_i - C_e)}{C_i} \times 100\ (\%) \tag{1}$$

where, R_p is the algae pretreatment efficiency (%), C_i means influent concentration, and C_e indicates effluent concentration on target compound.

3. Results and Discussions

3.1. The Influence of Electric Power Changes

Figure 2 shows the chlorophyll-a concentration by the changes of electric power. The influent concentration (C_i) was described with raw water concentration. The effluent concentration (C_e) was the treated water of each electric power. The calculation results of the pretreatment efficiency (R_p) for each water quality index was summarized in Table 2. It was observed that the effluent concentration was decreased as the increase of electric power. According the Table 2, the pretreatment efficiency of chlorophyll-a concentration was about 40% in the 20W electric power conditions. With increase of the electric power to 110W, removal efficiency was changed little. And then, it was observed that the efficiency was increased to about 50% in the 190 W electric power condition and about 65% in the 280W electric power condition compared to raw water.

Figure 3 shows the nutrient concentration changes by electric power. The T-N concentration showed little changes in spite of the electric power increase. The overall pretreatment efficiency was below 10% of raw water concentration. On the other hand, the T-P was effectively removed by the increase of electric power. The pretreatment efficiency of T-P concentration was about 47% in 20W electric power conditions. As increase of the power, it was enhanced to 67% in 280W conditions. As T-N compound has lower pretreatment efficiency than T-P compounds, it was supposed that the electric power has little influence on the low coagulation efficiency. As a result, the algae removal could be improved by the increase of micro bubble quantity due to the electric power change. The fast flotation reaction by the bubbles could support the efficient removal of algae aggregates and nutrients.

Figure 4 shows the results of COD changes by electric power. As increase of electric power, the pretreatment efficiency gradually enhanced. The pretreatment efficiency was about 20% in the condition of 55W of electric power. The efficiency was slightly decreased to 11% at 100W condition. And then, it was increased to 26% in 280W condition. The average pretreatment efficiency was about 18%. The results lead the possibility of removal of organic matter as well as algae and nutrients.

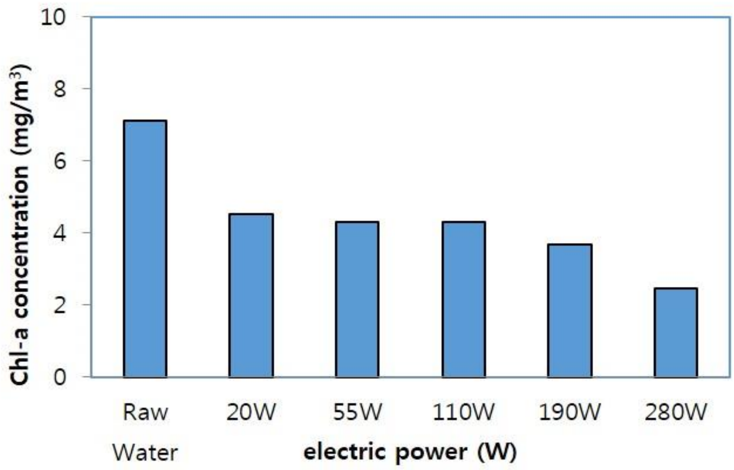
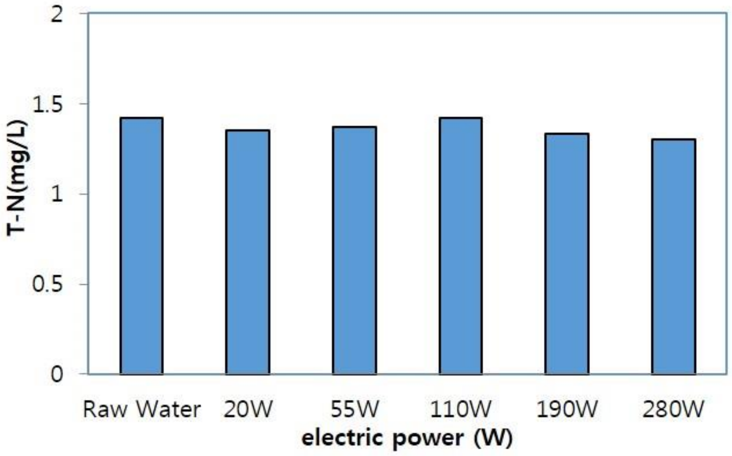


Figure 2. Chlorophyll-a Concentration by the Change of Electric Power



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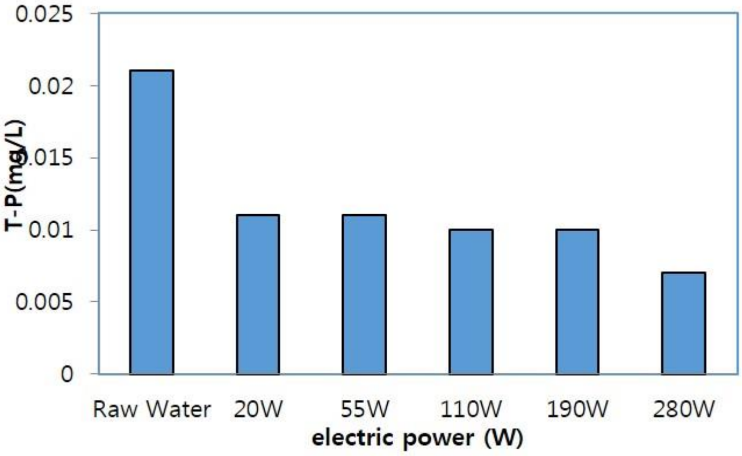

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Figure 3. The Nutrients Concentration by the Change of Electric Power: (A) Total Nitrogen, (B) Total Phosphorous

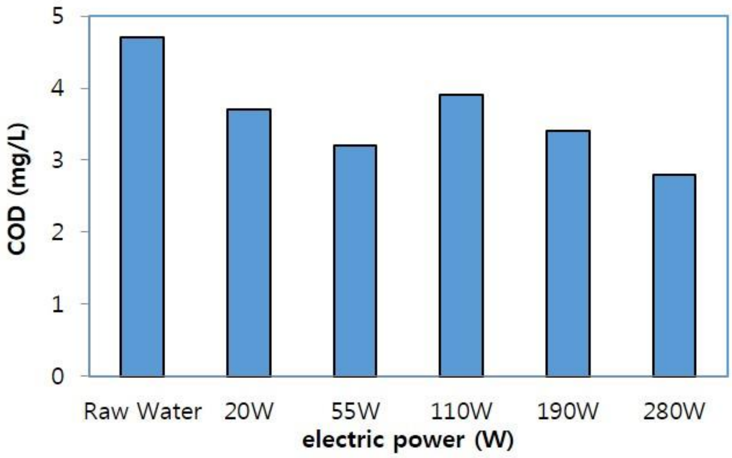


Figure 4. COD Concentration by the Change of Electric Power

Table 2. The Pretreatment Efficiency by Electric Power

Electric power (W)	Chl-a (%)	T-N (%)	T-P (%)	COD (%)
20	36.3	4.9	47.6	14.1
55	39.7	3.5	47.6	21.1
110	39.7	0.0	52.4	11.3
190	48.2	6.3	52.4	18.3
280	65.3	8.5	66.7	26.7
average	45.8	4.6	53.3	18.3

3.2. The Influence of Coagulant Dosage Changes

Figure 5 shows experimental results by the changes of coagulant dosage. The calculated pretreatment efficiency (R_p) by coagulant dosage changes was presented in Table 3. According to the Table, the pretreatment efficiency of chlorophyll-a concentration was about 45% in the 0 ml/min of alum dosage. It means that the removal efficiency was not enough with the only EF system without coagulation. On the other hand, the pretreatment efficiency was improved with coagulation. As alum dosage was increased over 15 ml/min condition, the efficiency was enhanced to about 60%. In addition, the pretreatment efficiency was increased to about 80% compared to raw water condition in the 25 ml/min of coagulant dosage.

Figure 6 shows nutrient concentration changes by coagulant dosage. The T-N concentration showed also little changes by the increase of coagulant dosage. However, the removal efficiency of T-P concentration was increased from 15% (0 ml/min) to 60% (25 ml/min). As a result, it was supposed that a phosphorous ion has more strong cohesion than nitrogen ions due to the chemical composition of the alum.

Figure 7 shows COD concentration by changes of coagulant dosage. The pretreatment efficiency of COD was increased up to 72% in condition of 15 ml/min of coagulant dosage. The efficiency was decreased to 4% in 20 ml/min condition, however, it showed that the average pretreatment efficiency was about 30%. The average efficiency is slightly higher than the average efficiency of COD by electric power (18%).

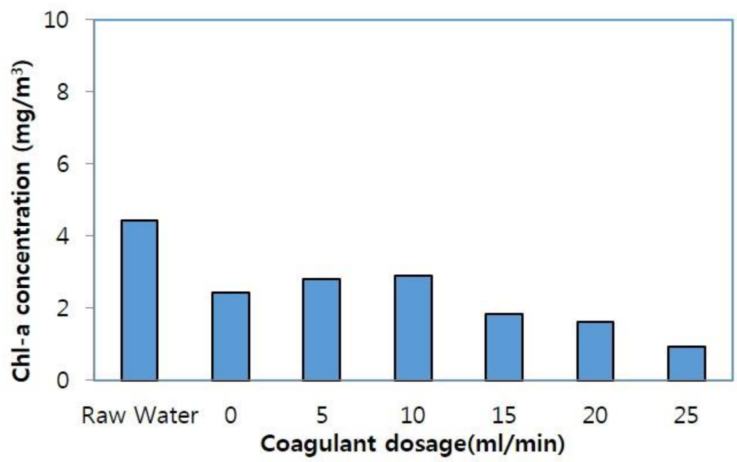
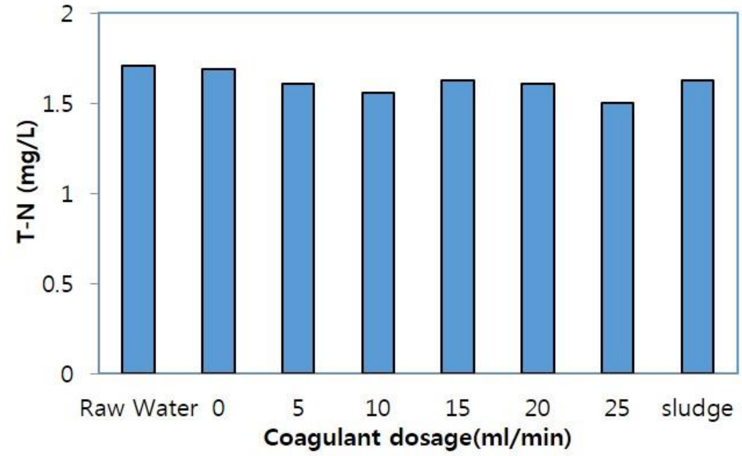


Figure 5. The Chlorophyll-A Concentration by the Changes of Coagulant Dosage



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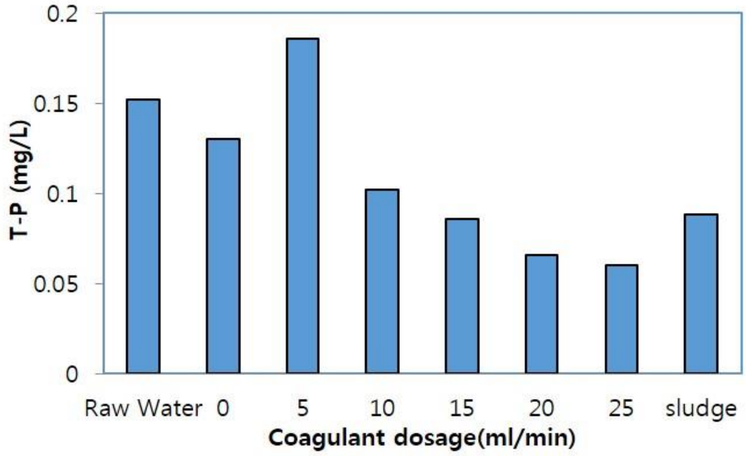

(b)

Figure 6. The Nutrients Concentration by the Changes of Coagulant Dosage: (A) Total Nitrogen, (B) Total Phosphorous

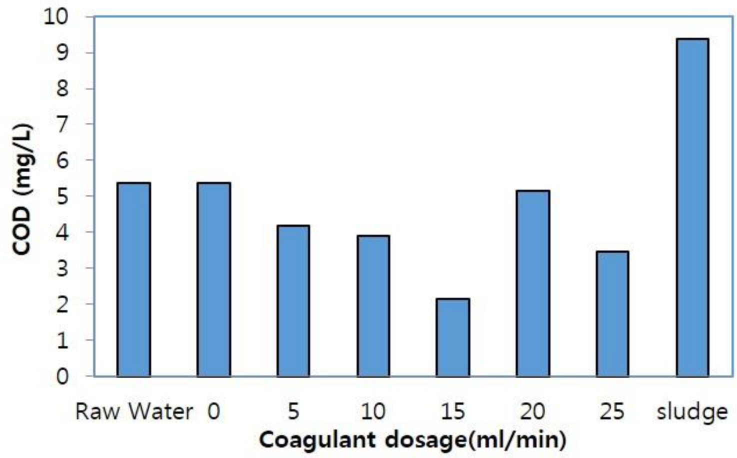

Figure 7. COD Concentration by the Changes of Coagulant Dosage

Table 3. The Pretreatment Efficiency by Coagulant Dosage

Coagulant dosage (ml/min)	Chl-a (%)	T-N (%)	T-P (%)	COD (%)
0	45.3	1.2	14.5	-0.5
5	36.7	5.8	-22.4	26.1
10	34.7	8.8	32.9	32.4
15	59.0	4.7	43.4	72.5
20	63.3	5.8	56.6	5.0
25	79.1	12.3	60.5	42.8
average	53.0	6.4	30.9	29.7

4. Conclusion

It is difficult to remove algae from influent, which have high concentration of it, using traditional water treatment methods. Therefore, a new technology is required to remove algae from highly concentrated influent to the WTP.

This study evaluated algae pretreatment efficiency by the comparisons of chlorophyll-a, nutrients, and COD concentration between raw water and the treated water. As the increase of electric power and coagulant dosage, the removal efficiency was improved to about 80% (Chlorophyll-a) within a few minutes on the basis of a residence time of the flotation tanks. In addition, coagulant dosage changes have more significant effect to the pretreatment efficiency than electric power changes. It means that the efficient coagulation should be prerequisite prior to secure a suitable flotation capacity.

This coagulation combined with EF system could be used as an algae pretreatment process at the previous step of water treatment process of WTP.

Acknowledgments

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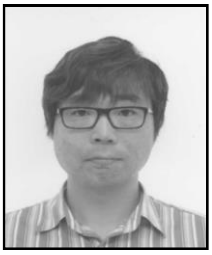

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