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A Case Study of DAF Pilot Plant for Application of Water Treatment Plant (WTP)

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Abstract. In recent years there have been large increases in the hydraulic loading rates used to design dissolved air flotation (DAF) facilities for drinking water applications. High rate DAF processes are now available at loading rates of 20 to 40 $m^3/m^2{\cdot}h$. The objective of the present work is to develop commercialization technology on physical process for algae removal in water treatment plant. During the service period of 2016.05 to 20163 06, DAF pilot plants (500 ton/day) process has shown a constantly sound performance for the treatment of raw water, yielding a significantly low level of turbidity (DAF treated water, 0.21~1.56 NTU). The simultaneous removal of inorganic and algae particles is frequently required during the rainy season in Korea. Although the DAF process has been successfully applied to the treatment of algae-laden water with low turbidity, it has been reported that inorganic particles caused by rainfall could highly affect flotation efficiency. A case study was carried out to evaluate the dissolved air flotation (DAF) pilot plants (500 ton/day) process installed in the YC-WTP. The DAF process revealed a sound performance for the treatment of turbid water (turbidity= 5.8~12.1 NTU) caused by source water (YC Lake) for the YC-WTP. This study evaluated several integration of a DAF combining with granular activated carbon (GAC). In order to select the best position of the GAC process, pilot plants experiments were performed using several water samples, such as raw water, coagulated water and DAF treated water collected from YC-WPT.

Keywords: Algae, dissolved air flotation, GAC, field application

1. Introduction

Cyanobacteria (blue-green algae) have been identified worldwide, posing a significant risk to water supplies when they occur in reservoirs, lakes and rivers used as water sources, due to their ability to produce toxins – as well as taste and odor compounds – as secondary metabolites under particular conditions of growth. The occurrence of cyanobacteria (blue-green algae) in reservoirs, lakes and rivers used as drinking water sources is a worldwide environmental health issue, due to the ability of some cyanobacterial streams to produce toxins, as well as taste and odour compounds, as secondary metabolites under particular conditions of growth. The most commonly occurring group of cyanobacterial hepatotoxins in freshwaters are microcystins and as a result of the increasing concern with their health implications the World Health Organisation [1] has set a provision alguideline-valuein drinking water of 1.0mg/L for microcystin-LR (MC-LR), one of the most toxic and usual microcystin variant. Microcystins are potentially produced by common genera of cyanobacteria, such as Microcystis, Planktothrix and Anabaena [2]. Microcystis are unicellular or colonial while Planktothrix and Anabaena are naturally occurring filamentous cyanobacteria. Algae also cause operational problems such as the blocking of filters, which reduce the using time of filter and increase the consumption of backwash water. Actually, many conventional water treatment plants combined by sedimentation in Korea have undergone serious operational problems due to the scum generated by algae floats [3].

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Therefore, the more advanced and efficient techniques, that is the application of the DAF process (dissolved air flotation), have been introduced into the treatment process for reducing the algal load. Algal-rich waters have difficulties to be treated by sedimentation because of the characteristics of algae which has the tendency to float, its small size, low cell density and negative surface charge [4]. An alternative technique for the clarification of algal-rich waters is dissolved air flotation (DAF) [5]. The principle of sedimentation is based on removal of settleable floc particles by the process of gravity settling, while the principle of DAF is based on the removal of bubble-flocs agglomerates as air bubbles rise and contact with flocs in flotation tank. DAF process was not used in water treatment plants but wastewater treatment plants, so there was not much experience of using DAF for water treatment in Korea. However, it has been successfully applied in Korea to treat the raw water containing algae blooms.

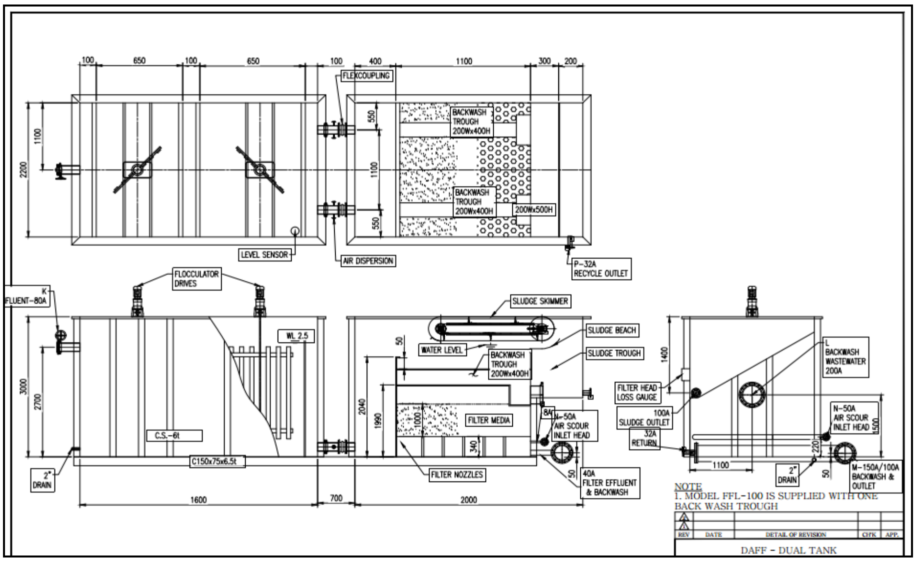

Fig. 1: Schematic design of DAF pilot plant (500m^3/d).

Table I: Summary of the information on the design and operating parameters

Process	Contents	Condition
General	Flow rate	500 m^3/day
	Operating time	24 hr/day
	pH	7.5
	Turbidity	5 NTU
	SS	5 ~ 10 mg/L
Coagulation	Specific surface area	3.6 m^3
	Type	rectangle
	Flow type	weir
	HRT	3.6 x 60 / 20 = 10.8 min
Flotation	SS	5 ~ 10 mg/L
	HRT	15 ~ 25 min
	Loading rate	30 m^3/m^2•hr (499 L/㎡ . min)
	Depth	2.50 ~ 2.60 m
Saturator	Size	0.3 D x 0.95 H
	Area	0.077 m^2

Primary clarification involves either sedimentation or flotation of flocculated water. Conventional drinking water treatment trains include coagulation (C), flocculation (F) and sedimentation (S). However, algal-rich waters especially important during a cyanobacterial bloom occurrence pose problems to sedimentation, due to the algae tendency to float, its small size, low cell density and negative surface charge.

An alternative technique for the clarification of algal-rich waters is dissolved air flotation (DAF) [6]. As far as the DAF operating conditions are concerned, the effectiveness of the pressurized recycle system has been referred as crucial to the success and economy of the DAF process [5], [7]. DAF is generally more effective than sedimentation for treating algal-rich water.

This study evaluated several integration of a DAF combining with granular activated carbon (GAC). In order to select the best position of the GAC process and pilot plants experiments were performed using raw water, coagulated water and DAF treated water collected from YC-WPT

2. Materials and Methods

2.1. Operating Conditions of the Pilot Plant

The overall layout of the DAF pilot plant (500 m^3/d) is illustrated in Fig. 1 and Table I. The operation of the DAF pilot plant (500 m^3/d) consists of three different processes, those of pre-coagulation/flocculation, DAF process, and filtration with granular activated carbon (GAC). In order to optimize the coagulation efficiency, the DAF pilot plant (500 m^3/d) has two pump diffusion units consisting of mixing pump, jet spray nozzle, and chemical diffusers. The jet spray nozzle equipped in the raw water pipeline provides high intensity mixing by discharging between 3 and 5% of the total plant flow through the flash mix against the target plant, resulting in uniform and rapid distribution of coagulants into the raw water stream. Two types of operating modes strategically control these processes, as shown in Fig. 2. These operating modes are 1) Coagulation process, 2) DAF process, 3) GAC filtration. Among the various operating modes, the coagulation and DAF process modes are only used at the low (< 10 NTU) and common level (< 5 NTU) of turbidity in raw water. During the service period of 2015.06.01 to 2015. 06. 31, the DAF pilot plant (500 m^3/d) was operated with only two operating modes (Coagulation process and DAF process) to test the performance of the DAF plant, regardless of the raw water quality. The DAF pilot plant (500 m^3/d) was operated with the coagulation process and DAF process operating mode. Table I summarizes the information on the design and operating parameters of each process installed in the DAF pilot plant (500 m^3/d). The DAF pilot plant (500 m^3/d) has a total capacity of 680 m^3/d.

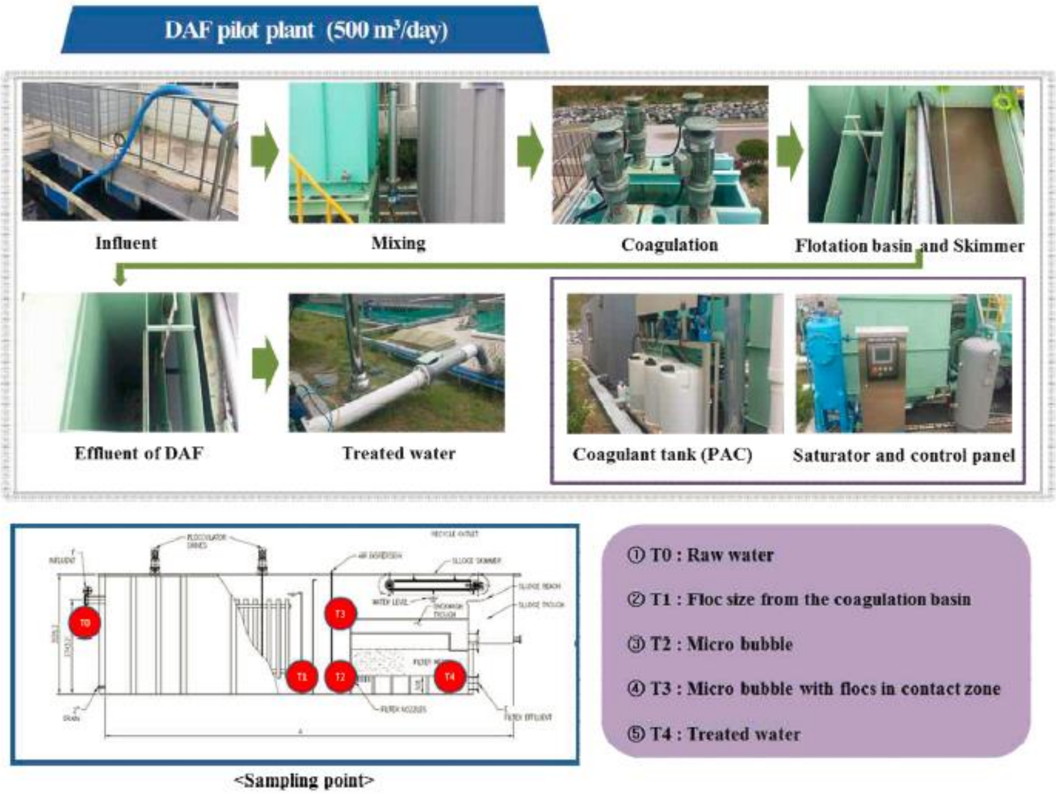

Fig. 2: Schematic design of DAF pilot plant (500 m^3/d).

Flotation basin was made 4,000mm of height in order to implement the high rate (30 $m^3/m^2 \cdot h$) by varying the installation height of the tank was injured optimize the sludge scraper. In addition, a nozzle was constructed in two line due to the control the bubble generation. The lower perforated plate is installed to the occurrence to generate the flow of the bubble is formed the long remained an essential device for the high rate implementation. DAF system is designed to work processing capacity of 500 m^3 according to the design criteria developed by the research process.

2.2. Batch Experiment for Coagulation with Jar Test

Jar tests were conducted on a program-controlled AF-600 Jar Tester. Algae containing test water of 500 mL was transferred into a 1,000mL beaker; under rapid stirring of 130 rpm, predetermined amount of coagulant was added, after 5 min, the stirring was changed to 60 rpm with a duration of 20-30 min; then samples were collected and filtered using 0.45 μm membrane filter for residual turbidity and algae measurement. Turbidity was also measured (Hach, USA) for some tests after 20 min of quiescent settling, samples for turbidity measurement were taken from 2 cm below the surface. The pH of test water was adjusted by adding 0.5 mol l^{-1}, HCl and 0.1 mol l^{-1} NaOH solutions.

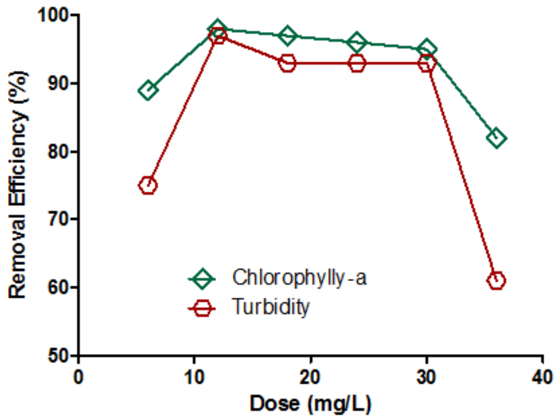

Fig. 3: The removal efficiency of Chlorophyll-a and turbidity using various PAC concentration.

3. Results and Discussion

3.1. General Coagulation Behaviors of YC-WTP Raw Water

The most important quality factor in the matters to be taken into account in determining the coagulant injection rate is the turbidity. Although turbidity is the high cohesive performance excellent, and over-injection, there is a tendency that the negative charge of the impurities have been charged stable to positive charge. In addition, when injected a large amount of coagulant, a large amount of aluminum hydroxide is generated and precipitation through the adsorption or cross-linking action and suspended solid particles. Since the turbidity there is no opportunity to collision of impurity particles with each other as low, to settle it is adsorbed a coagulant to excessive amount injected aluminum hydroxide particles.

In order to investigate the removal rate of the turbidity and algae by coagulation, use the Jar tester, by introducing the sample with a coagulant in a beaker of 1 L (PAC, 17%), after 3 minutes the rapid agitation of 132 rpm, the slow stirring of 60 rpm after 20-32 minutes, were analyzed for turbidity and Chl-a concentration of the supernatant. As the preliminary experiment result using the Jar tester, the removal of Chlorophyll-a and turbidity was 98% and 96.8% at the PAC concentration of 12mg/L and the lowest efficiency was exhibited in the 36 mg/L of PAC concentration (Fig. 3).

3.2. Coagulation Control with Steaming Current Detector (SCD)

The streaming current detector is a charge measuring device. The instrument will indicate the net ionic and surface charge on particles in a stream of liquid. Streaming current is related to the zeta potential but the two values are not numerically equal. In the actual instrument, water flows into the cell where it is drawn into the bore of a piston during the upstroke and expelled on the downstroke. Particles in the water are temporarily fixed on the piston and cylinder surfaces. As the water moves back and forth, the charged particles move past electrodes in the cylinder wall. These moving charges generated a small current which is termed the streaming current value. In the case of coagulation, the positive charges of the coagulant and negative charges of dirt particles in the water begin to neutralise on mixing. The time required to complete the neutralisation to its maximum extent is a function of mixing energy, raw water characteristics, coagulant type and temperature (among others). Untreated water has a naturally occurring negative charge [8].

Based on the results of coagulant proper injection range of the obtained preliminary study through the preceding experiments were carried out the SCD reference value derivation experiment for continuous operation. The changing trend of zeta potential in accordance with the injection amount of the coagulant to target of the water treatment plant (PACs, 10%), shown in Fig. 4. The trend analysis of the zeta potential with various PAC concentration using YC raw water was observed -9.8 mV to -10.3 mV whereas the PAC concentration was 35 ~ 40 mg/L. The appropriate PAC dosage is 35 ~ 40 mg/L in the given experimental conditions. Since the turbidity of raw water Y water treatment plant is the higher is not, appropriate coagulant injection amount was carried out without pH control. Change of seasonal characteristics of the water treatment plant, in particular plans in preparation for the high turbidity that occur during the rainy season, advance the ongoing studies that take advantage of the SCD in order to optimize the coagulant injection amount.

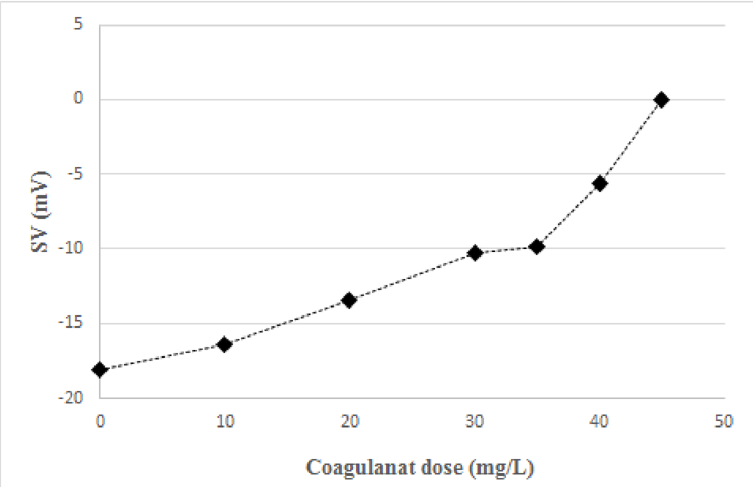

Fig. 4: The variation of zeta potential in coagulation basin using SCD (Streaming Current Detector) with various PAC concentration

3.3. A Case Study of the DAF Pilot Plant

After each step by the stabilization of the DAF pilot plant (500 m^3/day), carry out about one month of continuous operation from May 22, 2016 until June 22, 2016 (Fig. 5) A result of continuous operation, average flow rate of about 27 m3/m2·hr shows the surface loading rate of about 30 m3/m2hr, recycle rate is operated by 14.8%. A case study was carried out to evaluate the dissolved air flotation (DAF) pilot plants (500 m3/day) process installed in the YC-WTP. The changes in turbidity due to the continuous operation, the inflow water, 2.1~6.7 NTU, treated water shows the results of the turbidity of 0.48~1.5 NTU. The DAF process revealed a sound performance for the treatment of turbulent water (turbidity= 5.8~12.1 NTU) caused by source water (YC Lake) for the YC-WTP. As a result of pilot plant experiment, Edzwald (2001) suggested that DAF has high removal efficiency of Cryptosporidium as much as the oocyst log removal of about 2.5 for spring and 1.7 for winter. Furthermore, Edzwald and co-workers found that DAF is very suitable for treating backwash water which may contain pathogenic agents and can be achieved the effluent water turbidity of below 1 NTU when the feed water turbidity was in excess of 50 NTU [9]. Generally, the bubble size should be in the range of 10 to 120 ㎛ to form stable bubble-floc aggregates and its mean diameter is about 40 ㎛. Strong and small size floc particles can be produced by strong flocculation mixing and short flocculation time. Since bubbles and particles need to be attached and particle-bubble agglomerate density should be reduced to less than water, large flocs are not necessary for flotation unlike for sedimentation [10]. Recently, flotation was combined with filtration in one tank in Sweden and other countries [11], [12].

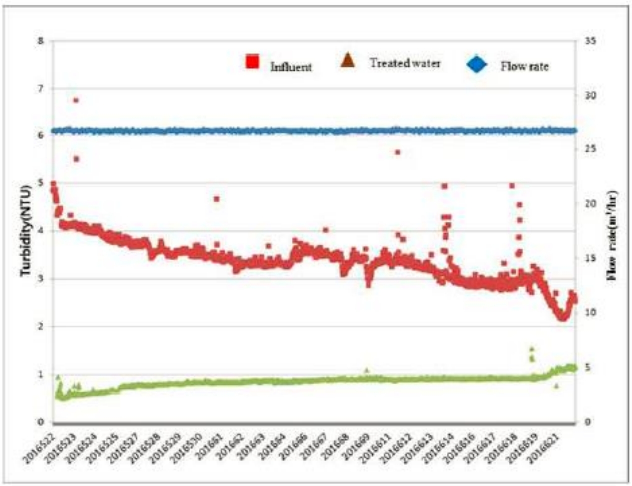

Fig. 5: Variation of flow rate and turbidity in the raw and treated water during the operation of DAF pilot plant (500 m^3/day).

4. Conclusions

As the preliminary experiment result using the Jar tester, the removal of Chlorophyll-a and turbidity was 98% and 96.8% at the PAC concentration of 12mg/L and the lowest efficiency was exhibited in the 36 mg/L of PAC concentration. This study evaluated several integration of a DAF combining with granular activated carbon (GAC). Pilot plant experiments will have to be performed using several water samples such as raw water, coagulated water and DAF treated water collected from YC-WTP in order to determine the best position of the GAC process.

5. Acknowledgements

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