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Development of High Rate Dissolved Air Flotation (DAF) Process in Korea Water Treatment Plant

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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.hr. This research evaluated dissolved air flotation as a separation method for algae and organic compounds from water treatment plants. During the service period of 2016.5. to 2017.6., DAF pilot plants(500 m^3 /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). As a result of analyzing the algae cell counts in the influent source, it was expressed at 100-120 cells/mL. In DAF treated water, the removal efficiency of algae cell was found to be up to 90%. The stable turbidity and algae removal were confirmed by operating the high rate DAF process under the condition of the surface loading rate of 30 m^3/m^2.hr.

1. INTRODUCTION

In removal algae and suspended solid occurring at summer and winter season, various pre-treatment, improved precipitation and filter media change have been used but, these processes have been restrictively applied because there is the possibility of side effects such as secondary contamination. (Jung and Kim, 2017; Ministry of Environment, 2012) It is also possible to use dissolved air flotation at detention pond of Intermediate booster station but, needs to expand related facilities. Using dual media(anthracite/sand) and active carbon as filter media is expected to improve algae treatment efficiency. At most water treatment plant, raw water is normally low turbidity but, In rainy season or summer season, raw water has high turbidity because of algae and turbidity matters (Ministry of Environment, 2017). As a alternative coping with raw water quality deterioration, Dissolved air flotation process, raising matters of low density to water surface has been suggested (Filhop et al, 2016) and apply to real process of water treatment plant in Scandinavia, US and Europe. (Haarhoff and Van Vuuren, 1993; Chu et al, 2011) In Korea, although dissolved air flotation is applied to some water treatment process, process optimization depending on raw water properties should be

more developed. Janssens(1993) set up to what extent each process can treat turbidity and chlorophyll-a. According to Janssen, if the turbidity of raw water is more than 20 NTU and chlorophyll-a concentration is low, precipitation process is easier because high density matters(ex, kaolin clay density: 2.6g/cm^3) are relatively more contained than low density algae(general algae density: 1.01~1.18 g/cm^3). But, if chlorophyll-a concentration is more than 10 ㎍/ℓ and turbidity is less than 20 NTU, the flocs are more likely to overflow at sedimentation basin because low density flocs are made by algae.
In winter season, if floc size is 100 ㎛ and water temperature is 4 ℃, the efficiency of sedimentation basin is sharply dropped because the density of alum floc is at most 1.01 g/cm^3. In this case, DAF process is effective. In Korea, water treatment plant using dam water as a source of water supply have a difficulty by algae rather than turbidity. Viitasaari(1995) represented the capacity of floc removal process with surface loading rate. According to Viitasaari, surface loading rate of sedimentation basin is max. 2.5 m^3/m^2·hr while DAF and rapid filtration is 10 times higher than sedimentation basin. This difference of surface loading rate is decrease with increase of SS(Suspended Solid) concentration but, considering low SS concentration of water treatment plant inflow water, the surface loading rate difference of sedimentation and DAF process is not small. Therefore, if the sedimentation process is properly replaced with DAF process, it is possible to increase surface loading rate and save footprint.

In this research, DAF operating conditions such as coagulant injection amount, pressure and water level change in saturation tank are considered and examine the performance of DAF process with removal efficiency of turbidity and algae

2. METHODS

2.1 High Rate DAF pilot plant design

Pilot plant was designed to treat 500 m^3/day. It consists of pretreatment part, bubble generating part, flotation separation part and post treatment part(Fig.1). Pretreatment part include chemical mixture and coagulation. Saturator tank and Recycle pump are included in bubble generating part. Especially, In order to achieve high rate surface loading, flotation tank height is built 4000 mm, which is higher than general tank height. A higher height make bubble retention time longer and improve removal efficiency. Flotation tank weir height can be changed to properly hand floated scum over weir. Bubble injection nozzle consists of two line to adjust bubble flow rate. At the bottom of flotation tank, perforated plate is installed to induce flow change and make bubble retention time longer.

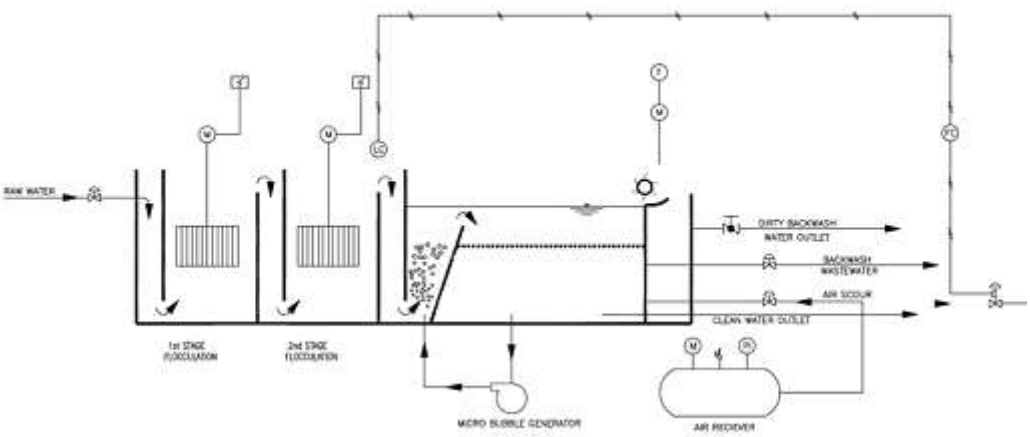


Fig. 1 Schematic Diagram of high rate DAF pilot plant

2.2 High Rate DAF pilot plant operation

Pilot plant was installed at Y water treatment plant in Korea, max. inflow rate is 27 ㎥/hr. Coagulation process consists of two step. Each step has 10 min. HRT(Hydraulic Retention Time). HRT of flotation tank was designed to be 20min. Skimmer has screw shaped blade that can remove floated sludge effectively. Coagulant injection amount was based on the condition result from jar-test and determined depending on raw water turbidity condition. Another consideration was real injection amounts which Y water treatment plant have used. Y water treatment plant have used PAC 10%(Al_2O_3) as a coagulant, 10~30 mg/L has been applied.

3. RESULTS AND DISCUSSION

3.1 Coagulant Injection Optimization for High Rate DAF

The jar-test was conducted to look for the optimal injection amount. Coagulant was PAC 10%, applied concentration range was 0~25 mg/L. For each applied injection concentration, floc condition and treated water quality was observed. In 10~25 mg/L, removal efficiency of turbidity was 56~62%, Considering operating cost, 10 mg/L was optimal injection concentration(Fig. 2). Since this jar-test, as a coagulant injection concentration, 10 mg/L has been applied to DAF pilot plant.

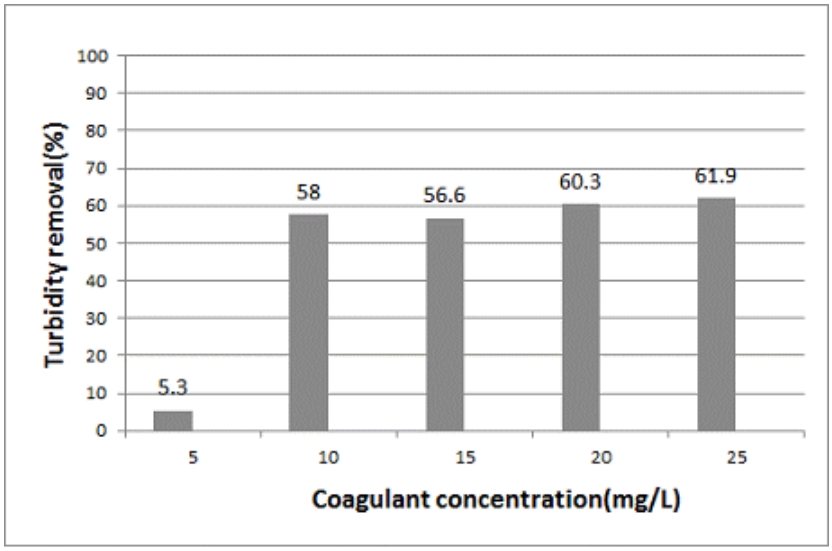
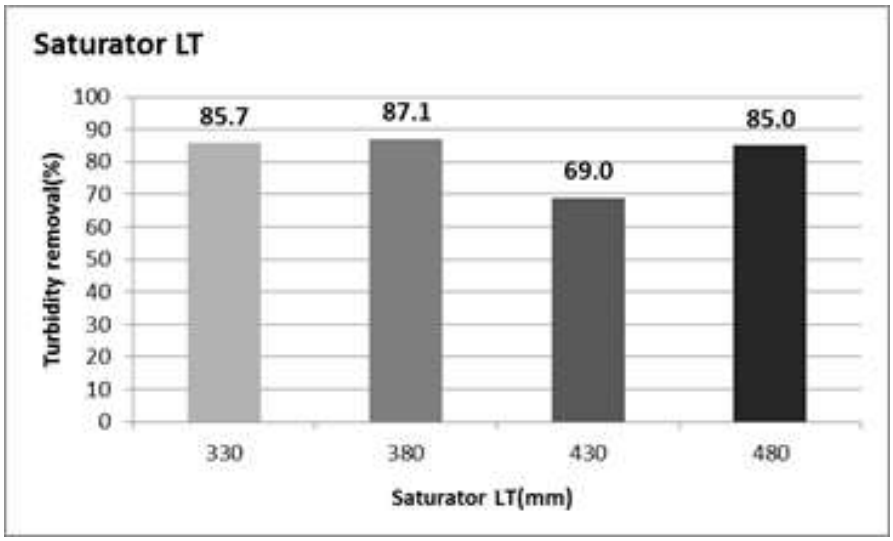


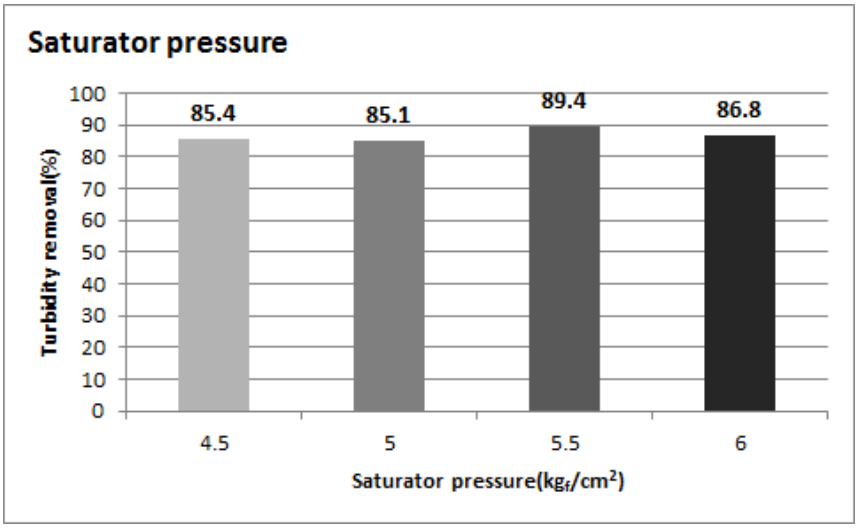
Fig. 2 Turbidity Removal Rate for Each Coagulant Concentration

3.2 Operating Efficiency Depending on Pressure and Water level Change in Saturation Tank

The removal efficiency of turbidity can be influenced by change of pressure and water level in saturation tank. Controlling pressure and water level by automatic control, turbidity removal test was conducted. Water level range in saturator tank was 33~48 mm and pressure range 4.5~6.0 kgf/cm^2 .In the condition of surface loading rate, 30 m^3/m^2·hr, water level 38 mm, pressure 5.5 kgf/ cm^2 was the most effective conditions (Fig.3).



(a)



(b)

Fig. 3 Turbidity Removal Rate for Each Saturator Water Level(a) and Saturator Pressure(b)

3.3 Turbidity Removal Efficiency

DAF pilot plant has been continuously operated from May 22. 2016 to May 24. 2017. Average inflow rate was 27 m^3/hr, surface loading rate 30 $m^3/m^2 \cdot h$ and recycle rate was 10~15% of treated water flow. Turbidity value of raw water has a wide range of variation depending on season and weather. Since June 2016, turbidity removal efficiency was decreased slightly because of high turbidity inflow, but treated water turbidity was maintained under 1.0 NTU. Overall, turbidity result was raw water 1.0~6.0 NTU, treated water 0.48~1.0 NTU(Fig.4).

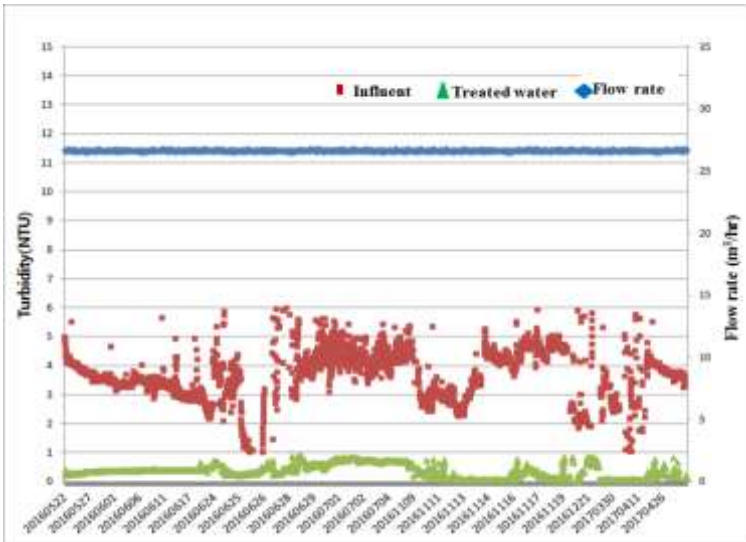


Fig. 4 Variation of Flow Rate and Turbidity in the Raw and Treated Water

3.4 Algal Removal Efficiency

According to the analysis result of algae population in Y water treatment plant from Aug. 2015 to May 2017, In March and April, diatoms was appeared, in June and July, green algae and in Aug. to Nov., blue-green algae. With DAF pilot plant, algae removal test was conducted. In winter and spring season, 100~120 cells/mL of algae was flowing into DAF pilot and detected under 100 cells/mL in treated water(Fig.5). Especially, On April. 13. 2017, inflow algae population was 257cell/mL, in treated water, 27 cells/mL, 90% removal efficiency. Overall, algae removal result was under 100 cells/mL in treated water, which show DAF process is effective in removal of algae.

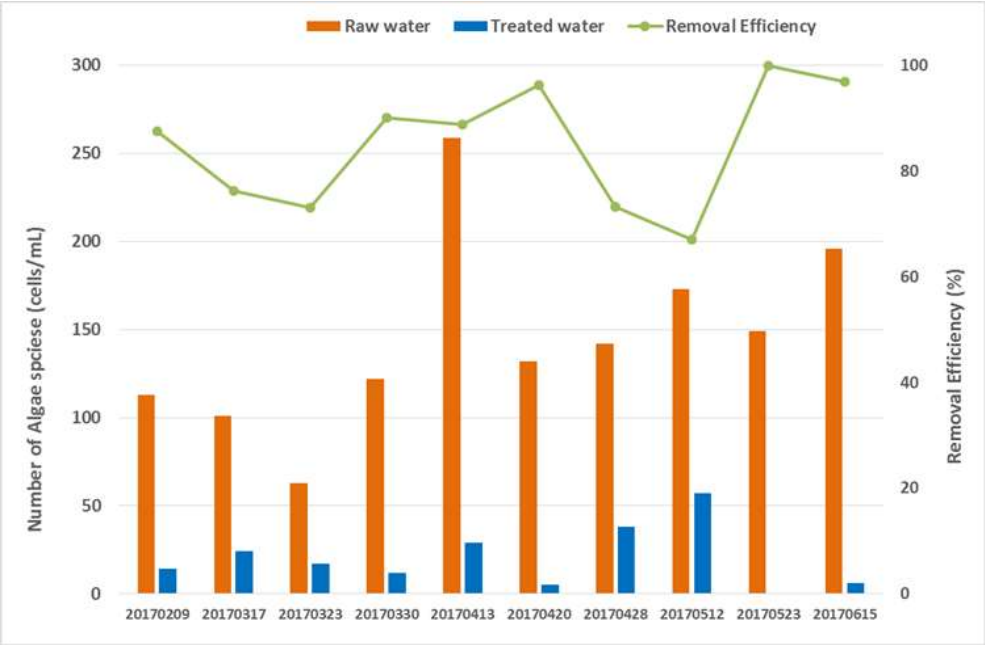


Fig. 5 Evaluation of Algae Population

4. CONCLUSION

The result of DAF pilot plant operation in Y water treatment plant show that the optimal injection amount of coagulant was 10mg/L, but further test and study about various raw water properties is needed. In the condition of surface loading rate, 30 $m^3/m^2 \cdot hr$, water level 38 mm, pressure 5.5 kgf/cm^2 was the most effective conditions. Additionally, the inside design study of saturator tank should be followed for high rate DAF process. DAF pilot plant has been continuously operated from May 22. 2016 to May 24. 2017. Average inflow rate was 27 m^3/hr, surface loading rate 30 $m^3/m^2 \cdot h$ and recycle rate was 10~15% of treated water flow. Turbidity result was raw water 1.0~6.0 NTU, treated water 0.48~1.0 NTU. algae removal result was under 100 cells/mL in treated water.

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