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국산 DAF 펌프가 적용된 연속 DAF 공정의 운전 조건

Operation Conditions for Continuous DAF Process with Domestic DAF Pump

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Abstract

Dissolved air flotation (DAF) is an effective solid/liquid separation process for low density particles, such as algal flocs, humus materials and clay particles produced from low turbidity water. The fraction of humic substances for natural organic matters (NOMs) are considered problematic in water because it can readily react with chlorine to form harmful by-products (trihalomethanes) and can be exposed to undesirable color, tastes and odors in drinking water. A broad class of NOMs includes fulvic acid, humic acid and humin. This paper will discuss the results from a study that performed with a DAF pump process using synthetic wastewater contained humic substance. Batch jar tests were performed to evaluate coagulant dose and recycle ratio on flotation efficiency.

Key words: DAF, DAF pump, dissolved air flotation, humic acid
주제어: DAF, DAF펌프, 용존공기부상, 휴믹산

1. INTRODUCTION

Dissolved air flotation (DAF) is an effective solid/liquid separation process for low density floc particles, such as algal floc, humus materials and clay particles produced from low turbidity water. It is a proven drinking water treatment technology in many European countries(Longhurst et al, 1987). The fraction of humic substances for natural organic matter (NOM) of low turbidity water is considered problematic in drinking water because it can readily react with chlorine to form harmful by-products (trihalomethanes) and can be exposed to undesirable color, tastes, and odors in drinking water(Kam, et al., 2001).

In general, humic substance solubilities are classified as follows. Fulvic acids are soluble in natural water with high or low pH. Their highest average molecular weight (Mw)

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is about 5kDa; hymatomelanic acids differ from humic acid by being soluble in simple alcohols. Their Mw range from 5 to 11kDa; humic acids precipitate from aqueous alkaline solutions on reducing the pH to 1. They are insoluble in simple alcohols and in water below pH 8. Their lowest Mw is about 12 kDa; humin is insoluble in water at any pH and Mw is at least 70kDa. Humin is further along the progress toward peats, coal and graphite(Jansen et al., 1996). Humic substances have properties typical of weak anionic polyeletrolytes; they have carried weakly acidic functional groups such as carboxylic and phenolic groups(O'Melia et al., 1999).

To DAF process, we introduced a new bubble generation method that applied a DAF pump in place of a saturation tank and a compressor, in order to maintain bubble quality and reduce the operation costs. DAF pump was specially designed to dissolve air into water by using the mechanical high pressure mixing of a centrifugal pump. It has an innovative impeller designed to create a sub-atmospheric pressure region in the seal chamber. Air is aspirated into the seal chamber, then mixed with water and compressed into microbubbles. The microbubbles are then dissolved into water and moved through the discharge of the pump and out to the flotation tank. In this paper, the performance of DAF pump for operating conditions is discussed. We try to find the optimal operation conditions of DAF pump. Bubbles generated from DAF pump were tested in their size and distribution by image analyzer and particle analyzer. Efficiency of DAF pump is tested with gas holdup and removal efficiency of turbidity. As the results were compared with saturator type, we found that DAF pump process was a more efficient system than the saturator type.

The DAF facilities are composed of the following four steps: (1) coagulation and flocculation prior to flotation, (2) bubble generation, (3) bubble-floc collision and attachment in a mixing zone, (4) rising of bubble-floc agglomerates in a flotation tank. This paper will discuss the results of a study that was performed using a batch experiment (DAF jar tester), which involved step (1), and a continuous DAF pump process (DAFPP), which involved steps (2), (3), and (4), both using synthetic low turbidity wastewater containing humic substance.

2. MATERIALS AND METHODS

2.1. Chemical reagents

Humic acid was obtained from the commercial humic acid (Sigma, USA) with composition C: 51.37%, H: 4.19%, N: 0.75%, as indicated by Marzet(Edwards etal., 1985). Humic acid concentrations were used from 8.12mg TOC/L to 18.52mg TOC/L. The coagulant used, $Al_2(SO_4)_3 \cdot 18H_2O$, was pure or analytical grade. Stock solutions of the coagulant were prepared in deionized water. The coagulant solutions were prepared a day before from stock solutions, to avoid ageing phenomena and improve reproducibility. The coagulant concentrations were from 100mg Al_2O_3/L to 1200mg Al_2O_3/L.

2.2. Analytical methods

Aqueous carbon concentrations were measured with TOC analyzer (Shimadzu 5000A). TOC samples were prepared by acidifying to pH 2 with phosphoric acid and stripping with N2 gas to remove inorganic carbon prior to injection. TOC samples were filtered through pre-rinsed glass filter units (GF/C) prior to acidification, stripping, and analysis. UV absorbance was measured from 400nm to 800nm using a spectrophotometer (Lambda 20, Perkin-Elmer Co.) and matched 1 cm quartz cuvettes.

2.3. Bubble Generation

Air was pressurized and dissolved into water under 5kgf/cm^2 in a saturation tank. In order to reduce the effect of particles within the water, distilled and deionized water was used. In DAF pump (DAF 40, Sin Sin Pump Ltd., Korea), we tried to keep 5kgf/cm^2 on discharge pressure. Although particles smaller than 10μm can be detected by the particle counter, only those larger than 10μm were regarded as bubbles. Only a small volume of bubbles was generated to avoid the possibility that a high concentration might decrease the accuracy of the particle

Table 1. Specification of domestic DAF pump

Flow rate	0.2m³/min
Head	45m
Moter power	7.5HP
Impeller	ϕ165 mm
Back vane	ϕ250 mm

counters and increase bubble coalescence.

2.4. DAF jar tester

A DAF jar tester (EC engineering) was used which had the facility to pre-set the stirring intensity and time. The paddle size of the tester was 3.0~5.0cm^2. The coagulation and flocculation conditions involved rapid mixing at 300rpm (G value: 182.6s^{-1}) for 60s followed by slow mixing at 40rpm (21.1s^{-1}) for 20min. Recycle flow was 20%.

2.5. Dissolved air flotation pump process (DAFPP)

The experiments were carried out using a DAFPP, schematically shown in **Fig. 1**. It is comprised of coagulation unit, flocculation unit, flotation unit, and DAF pump. The properties of DAF pump are shown in **Table 1**. The coagulation and flocculation unit have 1 liter and 15 liters useful volume, respectively. The flotation unit has 100mm internal diameter, 800mm height, and useful volume of 8 liters. Operation

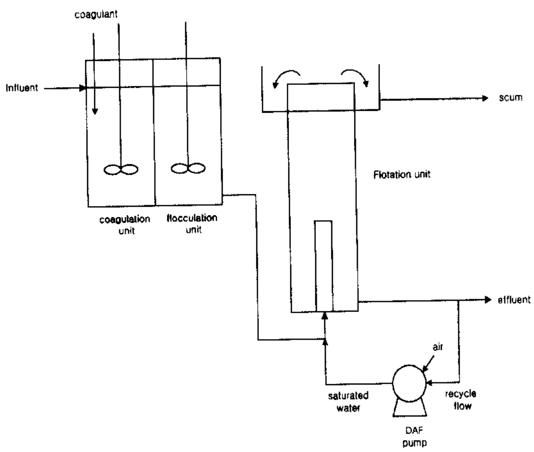

Fig. 1. Systematic diagram of DAF pump process (DAFPP).

conditions of influent were flow rate of 0.2L/min and intial concentration (TOC) of 13.24mg/L. In the coagulation and flocculation unit the speed of paddles could be varied and thereby also the velocity gradient, G(s^{-1}). The G value for optimum efficiency was 182.6 s^{-1} in the coagulation and 21.1 s^{-1} in the flocculation unit. Recycle flow to the DAF pump varied between 20 to 50%.

3. RESULTS AND DISCUSSION

3.1. Batch experiments using the DAF jar tester

A DAF jar tester was used with alum to coagulate humic acid at pH 6.4. The results presented in **Fig. 2** indicate that the required dosages for the alum were determined by the content of residual TOC. Optimum coagulant dosages are determined by the various TOC concentrations. This result clearly indicated that the optimal dosages for TOC concentration of 8.12, 10.93, 13.24 and 18.52mg/L were about 2.52, 3.36, 5.03 and 8.39mg Alum/L respectively, which corresponded to about 60-70% removal. The relations of optimum alum dosages and TOC concentration were followed by the equation of [Alum] = 1.42 × [TOC] + 3.70, R2 = 0.9713; [Alum] is optimum alum dosage (mg/L); [TOC] is humic acid concentration (mg/L).

The results of Chun et al. (1987) by coagulation and sedimentation experiments showed that coagulant dose is more than the results by coagulation and flotation. The difference in alum dosages between flotation (DAF) and sedimentation was amplified because coagulated floc size, which was necessary for successful TOC removal in flotation, was smaller than in sedimentation. The finding that removal of humic substance after coagulation and flocculation was dependent of optimum coagulant dosages was consistent with results presented by several researchers (Kam, 2001; Chun et al., 1987; O'Melia et al., 1999). The coagulation of humic substances by hydrolysing metal salts was described as co-precipitation, charge neutralization and/or adsorption mechanisms, depending on the coagulant dosage and humic substance

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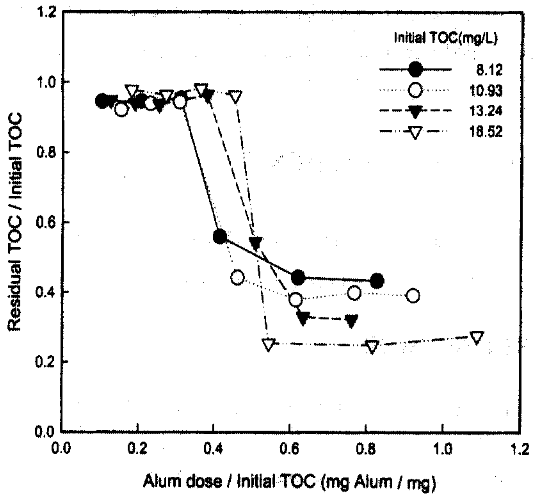

Fig. 2. Influence of coagulant dose on TOC at pH 6.4.

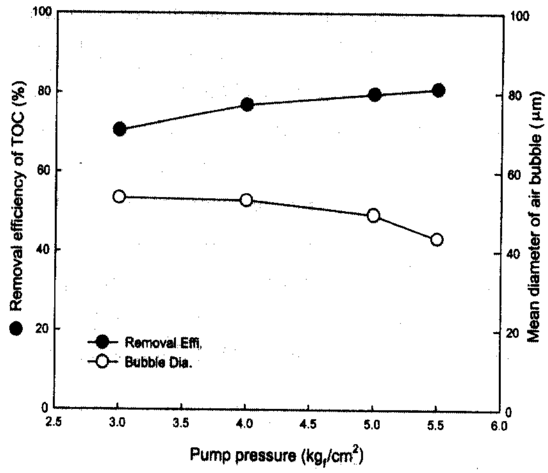

Fig. 3. Effects of pump pressure on removal efficiencies of TOC.

concentration(Duan et al., 2002a). The coagulation reaction of humic acid at pH 6.4 corresponded to the positively charged monomers ($Al(OH)_2^+$ or $Al(OH)_2^+$) or solid amorphous aluminum hydroxide($Al(OH)^3$) (Duan et al., 2002b). Here aluminum species hydrated represented negatively charged carboxyl group or phenolic OH group of humic acid.

3.2. Removal efficiencies of humic acid using a continuous DAFPP

The coagulant dosages in a continuous DAFPP experiment were optimized based on preliminary DAF jar tests, and coagulant dosing rate was 1.8mg alum/min. The removal efficiencies of humic acid were tasted using a lab-scale unit designed by a continuous DAFPP. **Fig. 3** shows the effect of removal efficiencies of TOC on pump pressure. To produce water floated (removed humic acid) removal efficiency of 80% or more, a recycle of 40% was needed. The data show poor treatment with less than $4kgf/cm^2$, but good treatment efficiency is achieved with $5kgf/cm^2$ and above. Released bubble size decreased as the pump pressure increased. It appeared from this result that the removal efficiencies of humic acid increased because of bubblefloc attachment efficiency. Sander E.R. et al.(1994) described that the bubble size decreased with an

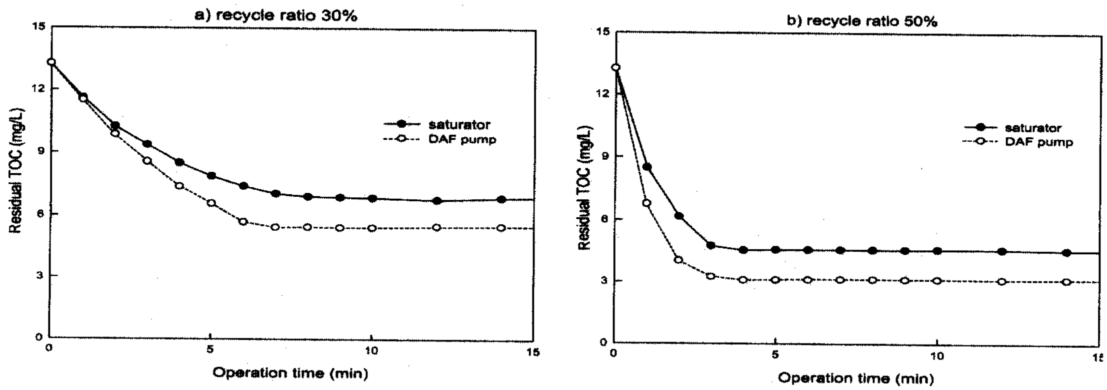

Fig. 4. Comparison between saturator type DAF and DAF pump process.

increase in the saturation pressure, and the adhesion of air bubble and floc depended on the size of the bubbles, floc size and the nature of agglomerated flocs.

Fig. 4 shows that the performance of saturator type DAF and DAFPP are examined by comparing TOC. TOC of treated effluents decreased with increasing recycle ratio, although recycle ratio was 30% and higher. The difference in performance of two systems is amplified because released bubble size, which is mean diameter of about 50μm at 5.0 kgf/cm^2, in DAFPP was smaller than saturator type.

4. CONCLUSIONS

The results obtained in this research permit us to conclude that the preliminary batch experiment (DAF jar tester) can be effectively performed using a continuous DAFPP. The optimal coagulation and flocculation conditions for humic acid was an aluminum concentration, which is described by the equation of [Alum] = 1.42 $\times$ [TOC] + 3.70, corresponding to sweep coagulation for supersaturation. Effect of pump pressure in DAFPP on the removal efficiencies of humic acid is achieved with 5kgf/cm^2 and above. Released bubble size decreases as the pump pressure increases. Finally, studies of continuous experiment indicated that DAFPP produced significantly higher removal efficiencies than saturator type DAF.

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REFERENCES

C.R. O'Melia et al. (1999). *Water Science Technology*, **40**, pp. 47-54.

Chihpin Huang and Hueiling Shiu. (1996). *Colloids & Surfaces*, **113**, pp. 155-163.

Chihpin Jinmin Duan et al. (2002a). *Desalination*, **150**, pp. 1-14.

Chihpin Jinmin Duan et al. (2002b). *Colloids & Surfaces*, **113**, pp. 155-163.

G.A. Edwards and A. Amirtharajah. (1985). *AWWA.*, **77**, pp.50-53.

Hee Dong Chun and Moon Deuk Lee. (1987). *J. of KICHE*, **25**, pp. 303-311.

Longhurst S. J. and Graham, N.J.D. (1987). *Public Health Engineer*, **14**, pp. 71-76.

S. Jansen et al. (1996). *Materials Sci. & Eng.*, **4**, pp. 181-187.

San E.R. et al. (1994). *Water Research*, **28**, pp. 465-473.

Sang-Kyu Kam and John Gregory. (2001). *Water Research*, **35**, pp. 3557-3566.