Application of the flotation process to thicken the sludge from a DAF plant

S. Dockko*, S.C. Park, S.B. Kwon*** and M.Y. Han****

*Dankook University, Dept. of Civil and Environmental Eng., Chungnam, Korea
(E-mail: *dockko@dankook.ac.kr*)

**School of Civil, Urban & Geosystem School of Civil, Urban and Geosystem Engineering 38-206, Seoul National University, 56-1, Shinrim-dong, Gwanak-gu, Seoul, 151-742, Korea (E-mail: *myhan@snu.ac.kr*; *avrac96@waterfirst.snu.ac.kr*)

***Korea Water Resources Corporation, 462-1, Jeonmin-dong, Yoosung-gu, Deajeon, Korea
(E-mail: *chester@kowaco.or.kr*)

Water Science & Technology **Vol 53 No 7 pp 159–165**

Abstract Dissolved air flotation (DAF) was evaluated for thickening of the sludges from a water treatment plant which uses DAF. Solid flux theory for gravity thickening was applied to the solid flux of DAF sludge. The higher the polymer dosage, at fixed solid concentration, the greater the rising velocity becomes. When applied with solid flux equations, a similar relationship to that of gravity thickening has been found. However, the values were much higher than in gravity thickening, because both the inflow solid concentration and the floating velocity were higher than for settled sludge. With this result, the proper dosage of polymer could be derived from the relationship between total solid flux and withdrawal velocity of DAF sludge.

Keywords Air/solid ratio; dissolved air flotation; polymer dosage; sludge thickening; solid flux

Introduction

The primary objective of thickening is to increase the concentration of solids in sludge. Thickening has generally been applied to settled activated sludge and/or sludges from treatment of drinking water, and much research has been focused on thickening of such sludges (Bratby and Ambrose, 1995; Chung and Kim, 1995). However, the sludge released from a dissolved air flotation plant settles poorly in the conventional gravity thickening tank and so less interest has been given to thickening of these sludges (Arora *et al.*, 1995; Edzwald, 1995). In this experiment, dissolved air flotation (DAF) was adopted to thicken the sludge released from a DAF plant. The characteristics of gravity thickening and flotation thickening plants are summarised in Table 1 (Korea Water Resources Corporation, 2001).

Generally, the solids flux index has become an important criterion in thickener design. The theory gives us a practical method to express sludge settling and compaction in a gravity thickening tank. According to the theory, the solids flux varies both with gravity and with downward velocity resulting from sludge removal. The solids flux can be calculated and expressed as sludge weight per square metre per day (AWWA, 1991).

The theory of solid flux is applicable to flotation thickening. The purpose of this research is as follows: (1) to ascertain the thickening efficiency, using DAF on sludge collected from a dissolved air flotation plant, as a function of added polymer, and (2) to optimise the solid flux using floating velocity data of sludge during thickening.

doi: 10.2166/wst.2006.220

Table 1 Characteristics of gravity thickening and flotation thickening

Process	Hydraulic retention time (h)	Solids loading rate (kg/m^2.day)	Thickened sludge total solids (%)
Gravity thickening	24–48	25–70	1–2
Flotation thickening	2	80–150	2–3

Table 2 Characteristics of sludge from the W DAF plant (South Korea)

Moisture content (%)	VS/TS (%)	pH	Alkalinity (mg/L as $CaCO_3$)	Turbidity (NTU)	Zeta potential (mV)	Bubble volume (mL/mL)	Temperature (°C)
97.46	41.73	6.69	1,100	3,600–4,000	−4.69– −7.61	0.034	15–17

Methods

A sample of sludge was taken from the W drinking water treatment plant, which is newly constructed and uses the dissolved air flotation process. Table 2 lists some characteristics of the sludge.

Subsamples were weighed into 500 mL beakers and diluted to concentrations of 2.54, 5.08, 7.62, 10.16, 12.70, 15.24, 17.78, 20.32, 22.86 and 25.40 kg/m^3 with tap water. Table 3 shows the pH, zeta potential and aluminium concentration of these samples. The zeta potential of the sludge was measured with a zeta meter (Zetaphoremeter II, France). To measure aluminium concentration, 1 N H_2SO_4 was added to each sample and the mixture was blended for 1 h at pH 2. The supernatant was sampled, filtered through GF/C and analysed by ICP-AES (Shimadzu ICPS-1000IV, Japan).

Anionic polymer was used for coagulation prior to flotation. The characteristics of the anionic polymer used are shown in Table 4. The dosage of polymer was sufficient to give concentrations of 10, 20, 50, 70 and 100 mg/L in five subsamples of sludge from the 25.40 kg/m^3 sludge sample. The zeta potential was measured at the same time. The results are shown in Figure 1.

The reactor for flotation thickening was made of acrylic and was 50 cm high with an inner diameter of 6.1 cm, as illustrated in Figure 2. The pressurised mixture of water and air was injected into the reactor from the bottom, through a nozzle. The sampling valve was set at 3.5 cm above the bottom of the reactor. As a pretreatment, anionic polymer, concentration 50 mg/L, was added to the sludge (concentration 15.24 kg/m^3). The saturation pressure was varied over the range 3, 4, 5 and 6 atm. The total solids (TS), residual

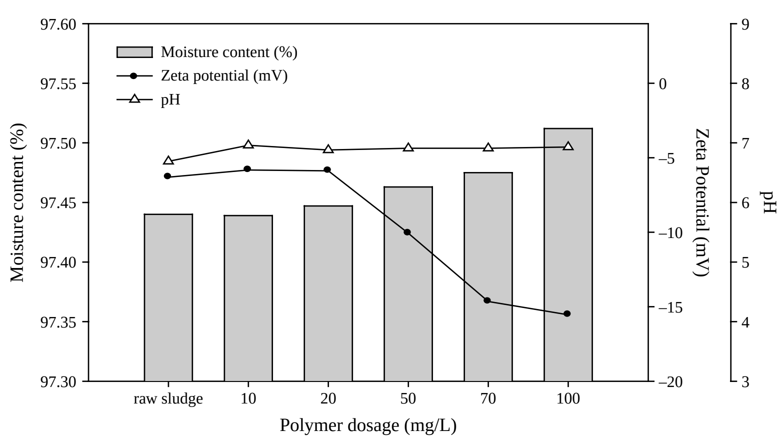

Figure 1 Solid concentration and zeta potential with different polymer dosage

Table 3 Sludge concentration, pH, zeta potential and Al concentration

Solid conc. (kg/m^3)	2.54	5.08	7.62	10.16	12.70	15.24	17.78	20.32	22.86	25.40
pH	7.22	7.16	7.13	6.94	6.80	6.81	6.87	6.72	6.70	6.69
Zeta potential (mV)	−11.36	−11.85	−9.96	−9.02	−7.56	−8.06	−7.13	−7.36	−6.72	−6.30
Aluminium conc. (mg/L)	116.79	362.26	554.93	838.04	1,178.77	1,348.04	1,570.37	1,815.84	2,011.69	2,276.17

Table 4 Characteristics of the anionic polymer used the experiments

Product name	Appearance	Principal ingredient	Type/electric density	Specific density (25 °C)	Viscosity			pH at 0.2%	Effective range of pH	Freezing point (°C)
					0.2%	0.5%	Raw			
A-1883RS	Emulsion with lacteous	Polyacryl-amide	Anionic/strong	1.00 ± 0.04	300	650	1,500	6–8	4–10	−18

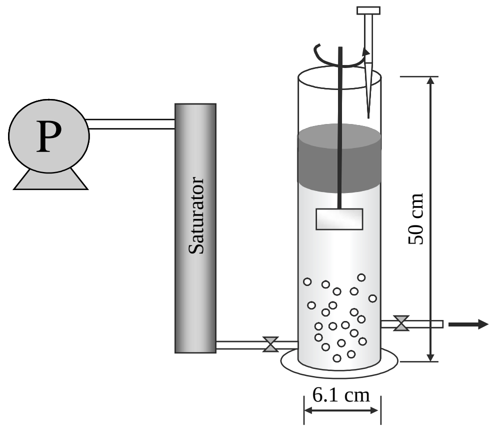

Figure 2 Thickening reactor by DAF

turbidity and height of the sludge level were measured when the recycling ratio was set to 50, 75 and 100%.

The results show that the thickening efficiency increases at high A/S ratio as shown in Figure 3. Note that the operating pressure was fixed at 6 atm and the recycling ratio at 100% during these experiments.

Solids concentration and residual turbidity were monitored 10 min after release of pressure. Ten different samples of diluted sludge were tested to allow measurement of thickening efficiency in terms of solid concentration and turbidity. The height of sludge in the reactor was measured to yield the flotation velocity every hour.

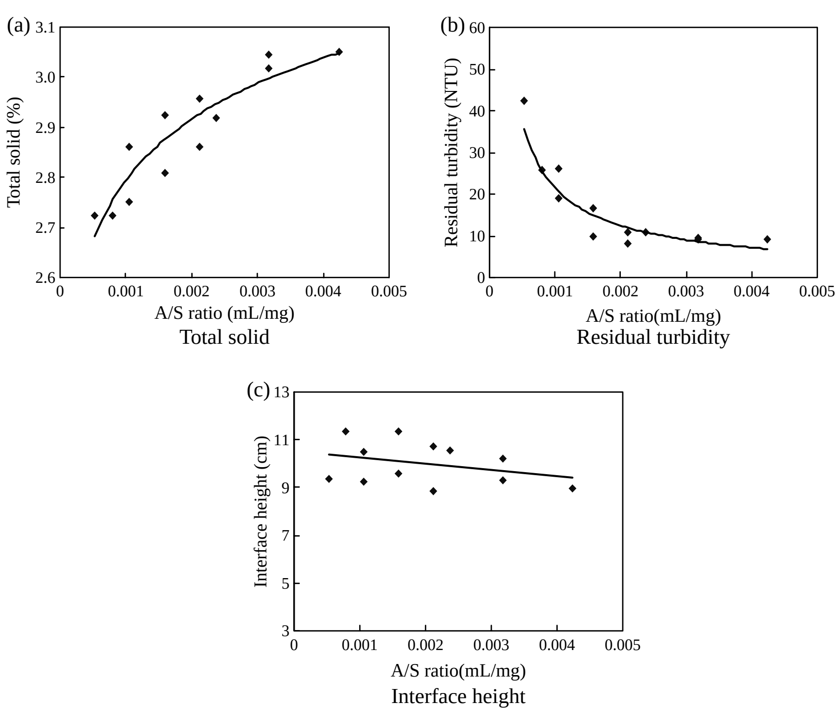

Figure 3 The effect of A/S ratio

Results

Optimum dosage of polymer and efficiency for thickening

The thickening rate and residual turbidity were varied along with the air/solid ratio at different dosages of polymer, as shown in Figure 4. The sludge thickening rate increases with a higher dosage of polymer, as we expected, although the difference is only slight. However, the residual turbidity has the lowest value, under 5 NTU, at a polymer dosage around 50 mg/L, while it exceeds 10 NTU at polymer dosages of less than 20 mg/L or more than 70 mg/L (Figure 4(b)). This is because the sludge floc is still weak and unstable at polymer dosages of less than 10 to 20 mg/L and break apart as the A/S ratio increases. Though the floc size increases at more than 70 mg/L, the upward streamline originated by a microbubble breaks the large flocs into smaller particles. From this result, it is inferred that the optimum dosage of polymer is around 50 mg/L.

Application of solid flux theory to DAF thickening

Rising velocity of sludge. Rising velocity plays an important role in estimation of the solid flux; it can be calculated from the relationship between rising length and lap time to surface, namely, after 10 min:

$$V_{\text{floating}} = Z_{1/2}/T_{1/2} \tag{1}$$

$Z_{1/2}$ is half of total rising length; $T_{1/2}$ means the time to reach $Z_{1/2}$.

The relationship between solid concentration and rising velocity of sludge at a different polymer dosage is shown in Figure 5.

This relationship between solid concentration and rising velocity is exponential. At constant solids concentration, the higher the polymer dosage, the greater is the rising velocity. However, it becomes harder to float the sludge upward as the polymer dosage increases, so that the rising velocity is unchanged at a solid concentration over 20 mg/L.

Application of solid flux theory

Solid flux theory for flotation thickening can be applied from the equation of gravity thickening as follows:

$$F_i = F_u + F_b = v_u \cdot C_i + v_i \cdot C_i \tag{2}$$

where F_i = continuous solids flux (kg/m m^3 day); F_u = withdrawal solid flux (kg/m^3 day); F_b = batch solid flux (kg/m^3 day); C_i = solids concentration (kg/m^3);

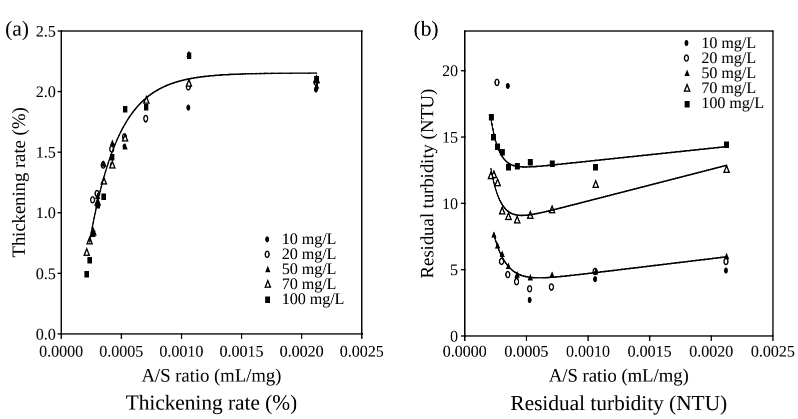

Figure 4 The efficiency of thickening by DAF

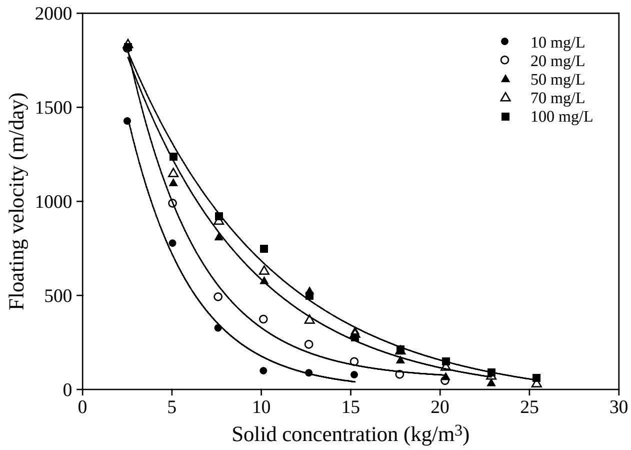

Figure 5 Floating velocity vs. solid concentration

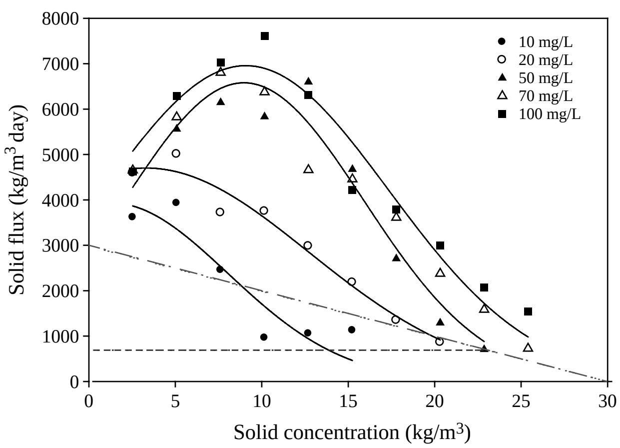

Figure 6 Solid flux by flotation

v_u = withdrawal velocity of floating sludge due to scraper (m/day); and v_i = floating velocity at solid concentration of C_i (m/day).

Solid flux theory for flotation (F_b) has two important parameters: floating velocity (v_i) at solid concentration of C_i and solids concentration (C_i). Operation of the scraper to withdraw floating sludge is critical in deciding the solid flux (F_u).

From the above equations and batch experiments, continuous solid flux (F_i) can be derived as shown in Figure 6. The result is similar to gravity thickening but higher values of solid flux are possible. The solid flux at polymer dosages of 50, 70 and 100 mg/L is higher than at 10 to 20 mg/L. The total solid flux is variable depending on the amount withdrawn by the scraper.

In this study, the limiting flux is 750 kg/m^2/day, calculated by fitting the curve of total solid flux, 3,000 kg/m^2/day, when the polymer is dosed over 50 mg/L. Then, solid concentration can reach approximately 30 kg/m^3 at a withdrawal velocity of 98.43 m/day by operation of the scraper.

Conclusion

Gravity thickeners have been used to thicken sludges at water treatment and wastewater treatment plants. DAF gives good results when used for sludge thickening at wastewater treatment plants. However, there has been almost no application of flotation thickening to DAF sludges at water treatment plants. Currently, the use of DAF plants increases year by year in Korea. Since it is hard to settle sludges from DAF in a gravity thickening tank because the sludge is tightly combined with microbubbles, DAF can be applied again to thicken sludges after an initial DAF process.

Solid flux theory for gravity thickening was applied to estimate the solid flux. This relationship, along with solid concentration and rising velocity, varies exponentially. At similar solid concentrations, the higher the polymer dosage, the greater the rising velocity becomes. However, it becomes hard to float the sludge upward as the polymer dosage increases.

When applied with solid flux equations, a similar relationship to gravity thickening has been obtained. However, the values of solid flux are much higher than in gravity thickening, because the input solid concentration and floating velocity were higher than for settled sludge. With this result, it is considered that total solid flux and withdrawal velocity could be derived theoretically for DAF sludge.

References

American Water Works Association (1999). *Water Quality and Treatment*, 5th edn, McGraw-Hill, New York, pp. 16.16–16-24.

Arora, H., DeWolfe, J.R., Lee, R.G. and Grubb, T.P. (1995). Evaluation of dissolved air flotation process for water clarification and sludge thickening. *Wat. Sci. Tech.*, **31**(3–4), 137–147.

Bratby, J.R. and Ambrose, W.A. (1995). Design and control of flotation thickeners. *Wat. Sci. Tech.*, **31**(3–4), 247–261.

Chung, T.H. and Kim, D.Y. (1995). Significance of pressure and recirculation in sludge thickening by dissolved air flotation. *Wat. Sci. Tech.*, **36**(12), 223–230.

Edzwald, J.K. (1995). Principles and applications of dissolved air flotation. *Wat. Sci. Tech.*, **31**(3–4), 1–23.

Korea Water Resources Corporation (2001). *Water Treatment Technology in Korea*.