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Full-scale demonstration of improvement of sludge treatment performance

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ABSTRACT

High water content (73.2%) of dewatered sludge from the "D" water treatment plant (DWTP) rendered its disposal into landfill difficult, which initiated a study to find a solution to decrease its water content. This study involved the use of the thermal dehydrator, which is a filter press augmented by thermal process. A full-scale experiment has been conducted to evaluate the performance of the thermal dehydrator at DWTP since January 2006. The thermal dehydrator successfully reduced the water content of dewatered sludge (49.5%). The use of the thermal dehydrator was also a more economical option than that of the existing belt press. When the operating costs of these two types of equipment were compared, 142,744 won were necessary for the thermal dehydrator based on treatment of 1 ton of solid. On the other hand, 233,493 won was the cost of the existing belt press. The disadvantage of the thermal dehydrator was high energy consumption. Nonethless, it reduced the amount of sludge disposed of at landfill. It also eliminated the use of polymer, which is essential for the operation of the belt press.

Keywords: Thermal dehydrator; Dewatered; Water content

1. Introduction

Since most drinking water treatment plants generate a large amount of sludge, sludge treatment and disposal are important for water treatment. Sludge was usually disposed of through ocean dumping in Korea. However, ocean dumping was recently banned, which caused a concern for drinking water treatment plant managers. They need to find another option for disposal of sludge such as land application and reuse. Reduction of the water content in sludge is important for operation because it is closely related to the transportation cost. The sludge dewaterability is affected not only by specific resistance to filtration (SRF), precipitation velocity and parameter of total solid concentration but also by physical properties such as particle size distribution, density and so on. There are many studies available in the scientific literature to describe cake formation and propose theoretical modeling of solid–liquid separation [1–6], but an effort was still lacking to explain how to use this theoretical approach to scale-up filtration operation.

Sludge dewatering is used to remove as much water as possible from sludge to produce a highly concentrated cake. Historically, there have been many dewatering

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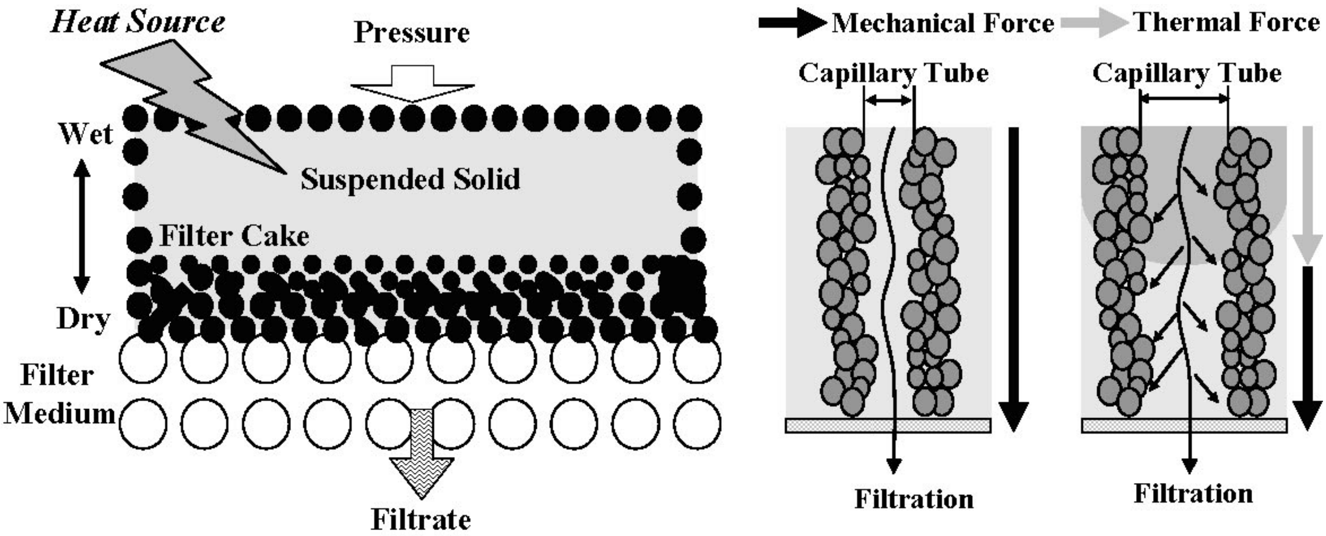

Fig. 1. Mechanism of the thermal dehydrator.

techniques and systems utilized for solid–liquid separation. A few of the various types of systems include belt press, centrifuges, rotary drum vacuum filters, tube filters, rotary screw presses, sand filters, automatic vertical presses, and horizontal or vertical plate filter presses. These various types of system can be further divided into continuous or batch type processes. The solid–liquid separation of these mechanical devices is done by mechanical-physical forces: for example, pressurization, compression, vacuum and so on. Addition of thermal force might improve their dewatering efficiency because the thermal force could induce increase of filtration velocity and decrease of viscosity, surface tension and SRF. In this work, the performance of a full-scale thermal dehydrator (TDH) has been evaluated at DWTP since January 2006 (Fig. 1).

2. Materials and methods

Fig. 2 shows the photograph of TDH. The filter plate was in 1,200 mm (W) × 1,200 (L) mm, and total filter area was 206.8 m^2. The heating plate was installed between the membrane plates so as to conduct heat to sludge layer. Each filter plate, mainly fitted with a polypropylene woven cloth, has a fixed chamber depth and filtration area in providing a fixed volume capacity. The dewatering process consists of sludge feeding, squeezing, blowing, and decaking. The steam as heat source was supplied at each heating plate at approximately 1.2 kgf/cm^2. The sludge is fed into the chambers allowing the suspended solids to form on the filter cloth and continue to cake up until a solid cake thickness is formed in the chamber. The filtrate flows through the cake/cloth and is discharged through the discharge outlet. Then, the sludge feeding step is completed and the diaphragms are pressurized to squeeze additional liquid from the filter cake. When squeezing the filter cake, the porosity of the filter cake decreases so that additional dewatering occurs. Sludge was fed to the center of filter plate at 5 kgf/cm^2 and the squeezing pressure was 15 kgf/cm^2. The total operating time was 2 h per 1 cycle.

Polymer was not used for the evaluation of the TDH performance. Particle size distribution and size of sludge were evaluated using a Master sizer (Malvern, Hydro-2000S) and SEM (Jeo, JSM-5400).

3. Results and discussion

3.1. Sludge characteristics

Fig. 3 shows the SEM photograph of sludges collected both in the summer season (a) and winter season (b) from DWTP. There are many inorganic particles noted from the summer sludge, while organic particles from the winter sludge. Fig. 4 shows the monthly variation of total solid concentration (TS) and volatile solid concentration (VS) of the sludge. The TS concentration increased in the summer season due to increasing rainfall. The VS concentration increased considerably in the winter season. Fig. 5(a) shows the monthly variation of the mean particle size and SiO_2/Al_2O_3 ratio of the sludge. According to Fig. 5(a), the mean particle size decreased comparatively in the summer season, while the SiO_2/Al_2O_3 ratio increased. The majority of the particle size ranged from 40 μm to 70 μm. In the summer season, the size range beside the mean size also decreased.

Sludge dewatering was closely related to the mean particle size and the ratio of SiO_2/Al_2O_3. Fig. 5(b) shows the variation of the cake water content in accordance with

Fig. 2. Photograph of the full-scale thermal dehydrator.

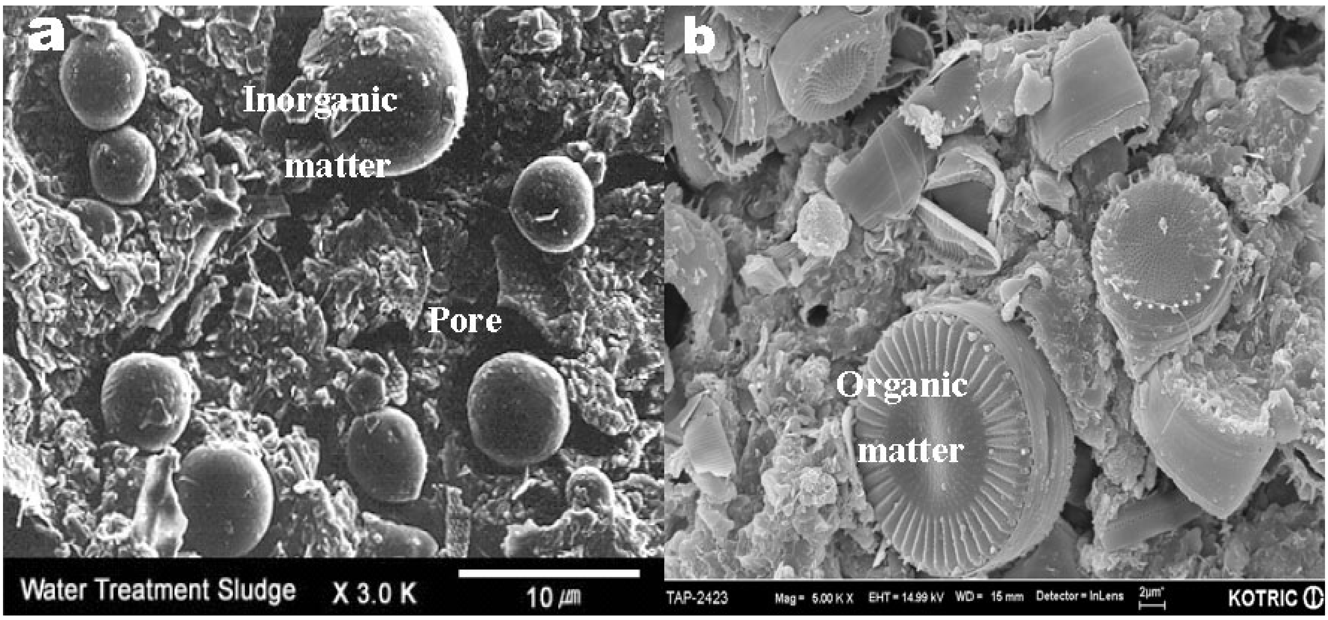

Fig. 3. SEM photograph of DWTP sludge.

the mean particle size and the ratio of SiO_2/Al_2O_3. As the ratio of SiO_2/Al_2O_3 increased, the cake water content decreased. The cake water content was reduced to 38% when the ratio of SiO_2/Al_2O_3 increased to 2.1. This result indicates that the sludge dewaterability could improve with an increase in the ratio of SiO_2/Al_2O_3. The cake water content was also affected by the particle size distribution as well as the mean size. Low water content was obtained when the mean particle size of the sludge was below 40 μm. The cake water content was also low when the

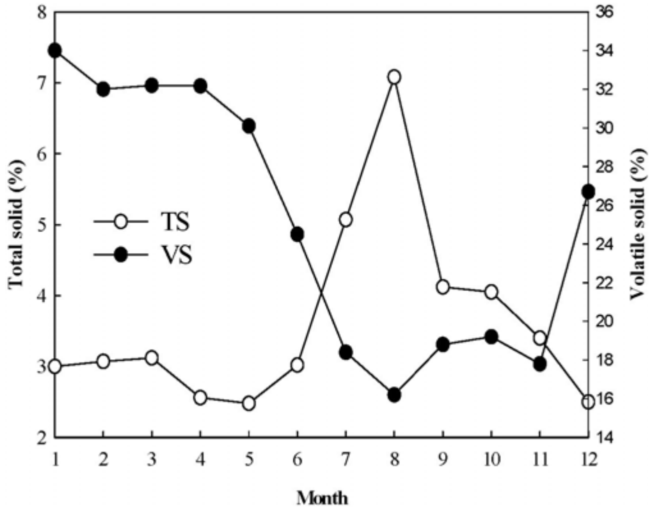

Fig. 4. Monthly variation of TS and VS of DWTP sludge.

standard deviation of the particle size distribution was narrow, which suggests that decreasing the particle size range can improve the sludge dewaterability.

3.2. Evaluation of TDH performance

The filtration velocity was calculated based on the wet cake water content produced from TDH. Fig. 6 shows its relationship with the TS and VS. The higher the filtration velocity was, the more sludge was treated and the lower the wet cake water content was during the same operating time. According to Fig. 6, the filtration velocity had a clear relationship with TS and VS of the sludge. As TS increased and VS decreased, higher filtration velocity was obtained. The filtration velocity was increased up to 1.5 DS-kg/m^2 h when TS was approximately 7% and VS was approximately 15%. However, the filtration velocity was reduced

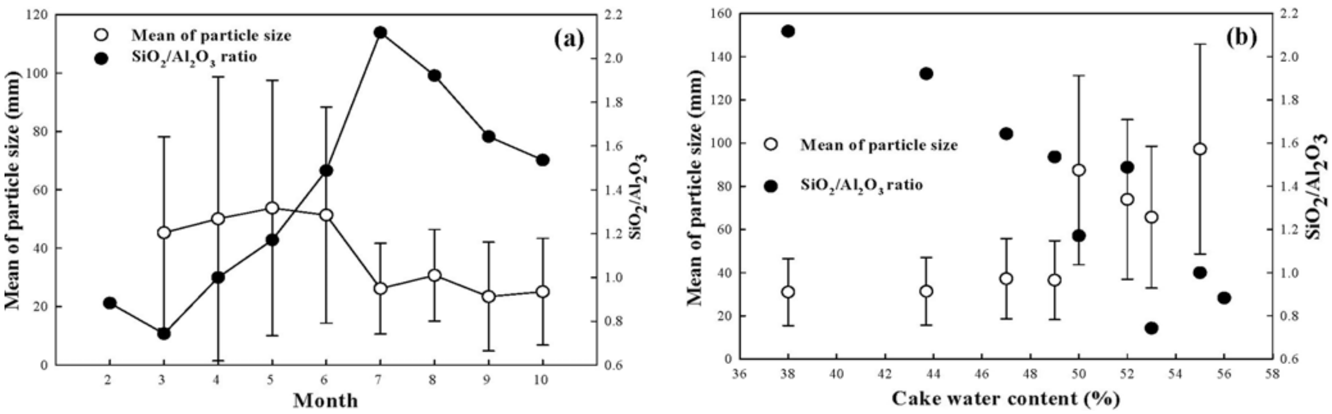

Fig. 5.Monthly variation of the mean particle size and the ratio of SiO_2/Al_2O_3 (a) and relationship of the cake water content with these characteristics (b).

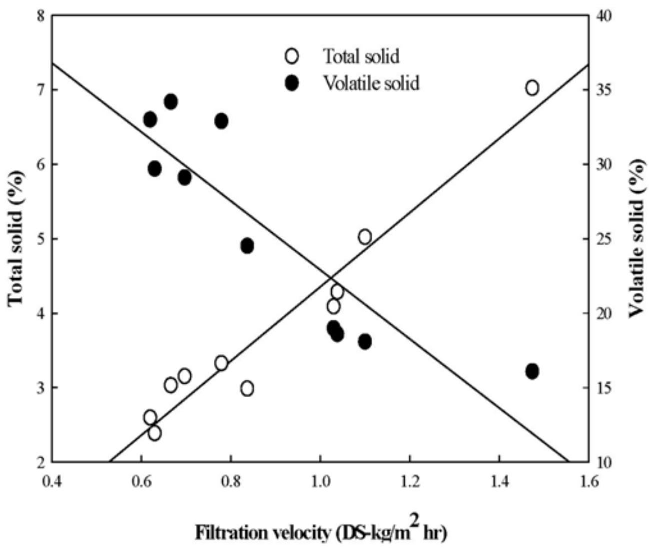

Fig. 6. Relationship of the filtration velocity with TS and VS of the sludge.

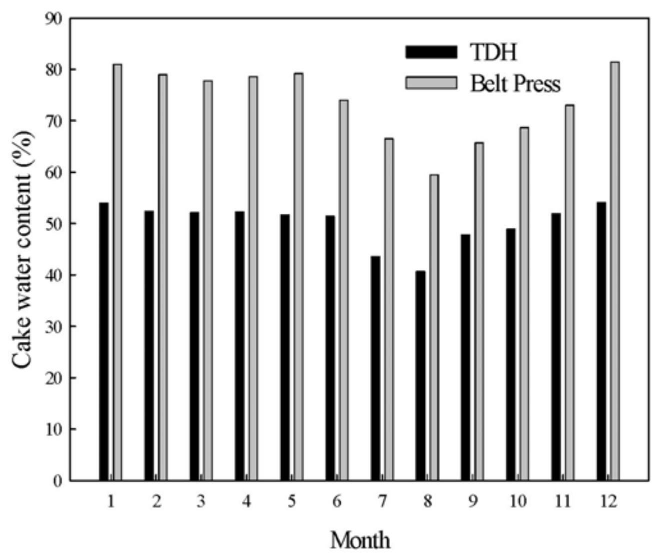

Fig. 7. Comparison of cake water content between TDH and the existing belt press.

Table 1
Economic evaluation of TDH and the existing belt press

Description	Calculation		Unit cost (won)		Operation cost	
	TDH	B/P	TDH	B/P	TDH	B/P
Cost of cake disposal, t	1.98	3.73	55,000	55,000	108,900	205,150
Electric power usage, kWh	528	116.75	63	63	33,264	7,355.2
Water usage, m^3	5	43	116	116	580	4,988
Polymer usage, kg	—	4	—	4,000	—	16,000
Total					142,744	233,493.2
Estimation index, %					100	163.57

to 1.0 DS-kg/m^2 h or below when TS was less than 4% and VS was higher than 20%. Since increasing the filtration velocity led to reduction of the cake water content, sludge dewaterability was also dependent on TS and VS.

The performance of TDH was compared to that of the existing belt press for one year. Their performances were monitored while they were treating the same raw sludge. The monitoring results were summarized in Fig. 7, which shows their cake water contents. According to Fig. 7, the yearly average water content was 49.5% and 73.2% for TDH and the existing belt press, respectively. This clearly indicates that TDH was superior to the existing belt press in sludge dewatering.

Based on the performance comparison between TDH and the existing belt press, an economic evaluation was conducted, as shown in Table 1. Assuming that 1 ton of total solids was treated, the average amount of the cake disposal was 1.98 ton for TDH, while it was 3.73 ton for the existing belt press. TDH required more electric power usage than the existing belt press. Nonetheless, TDH was more economical than the existing belt press. Replacing the existing belt press by TDH could reduce the operating costs by more than 60%.

4. Conclusions

The performance of TDH as a sludge dewatering device was evaluated in this study. For this purpose, the full plant-scale TDH has been operated at DWTP since January 2006, and its performance was compared to that of the existing belt press. According to the results of this study, the seasonal variation of the sludge characteristics was observed. TS increased during the summer season due to heavy rain, while VS increased during the winter season and the early spring season due to algae. Subsequently, the ratio of SiO_2/Al_2O_3 increased and the mean particle size decreased during the summer season. The ratio of SiO_2/Al_2O_3 and the particle size were closely related to the cake water content. As the ratio of SiO_2/Al_2O_3 increased, lower water content was obtained. The water content was low when the mean particle size was small and the size range was narrow. The filtration velocity increased as TS increased and VS decreased. Subsequently, the water content was low, and the sludge dewaterability improved during the summer season. The opposite results were obtained during the winter season.

When the performances of TDH and the existing belt press were compared based on a one-year operation, TDH produced the cake with much lower water content (49.5%) than the existing belt press (73.2%). It produced the dewatered sludge of which the average water content was 49.5%. Although TDH required higher energy consumption than the existing belt press, it reduced the amount of the cake disposed of at landfill. It also eliminated the use of polymer, which is essential for the operation of the belt press. Overall, replacing the existing belt press by TDH could reduce the operating cost by more than 60%. These results clearly suggest that the use of thermal dewatering technology could be feasible to handle the sludge pro-environmentally and economically.

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