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The Study on the Enhanced Dewaterability of Municipal Wastewater Sludge and Economic Assessment by Ultrasonic Treatment

Seungmin Na[1†], Young Uk Kim[2], Mingcan Cui[3], Younggu Son[1], and Jeehyeong Khim[3]
([1]Dep. of Civil and Env. Eng., Kumoh National Ins. Tech.; [2]Dep.of Civil and Env. Eng., Myongji Univ.; [3]School of Civil and Env. Eng., Korea Univ.)

1. Introduction

A large quantity of sludge is produced in biological wastewater treatment facilities and the dewatering and disposal of this sludge is a major economic factor in facility operation[1)]. Several studies on improving the dewaterability of sludge using ultrasound (US) have been undertaken[2,3)]. This process is not hazardous to the environment, and cause no secondary contamination[4)]. Moreover, owing to recent developments in high power transducers, the treatment of large amounts of sludge has become possible. The ultrasonic process leads to cavitation effects, which is extream condition as like high temperature (> 5000 K) and pressure (> 1000 atm) and highly oxidizing OH radicals due to implosive collapse of the cavitation bubble. This phenomenon of US can be changed to sludge dewatering propety, and reduced total solid (TS) of sludge. Therefore, the objective in this study was observed dewaterability of sluge by US with capillary suction time (CST) and specific resistance to filtration (SRF), as indicator of sluge dewaterbility degree. In addition, to estimate the economic feasibility, the useful energy vlaues of the sludge cake by US process were examed using the method suggested by Reimann[5)].

2. Experimental Method

The sludge samples were collected after the anaerobic digestion tank, from the Jungnang municipal wastewater treatment plant, Seoul, Korea. The initial TS and water content of the sludge were approximately 1.5 and 98-99%, respectively. The pH of the sludge was 7.6. A bath type ultrasonic processor (Chosun, Model CS-1000, 30×30×30 cm, Korea) with 8 unit transducers of 28 kHz was used. The CST and SRF were measured to evaluate the dewaterability of sludge by the US process. The CST was monitored by the procedure reported by Na[6)] and Vesilind[7)]. The SRF test is also known as the Büchner funnel test[8)]. A CST and SRF of the raw sludge samples of approximately 100~110 sec and 2.44×10^{14} m kg^{-1} were chosen to correct the other initial impacting factors. The TS, volatile fatty acid (VFA) and water content of the sludge cake were measured using normalized methods[9)]. The results under each set of test conditions are presented as the volumetric supplied energy term (E_v). The E_v is defined as follows:

$$E_V = {P \times t}/{Vol.} \qquad [1]$$

Where P is the applied US power (kW; 0.1~0.6 kW), $Vol.$ is the total volume of the sludge sample (ℓ; < 0.5 ℓ) and t is the US irradiation time (sec)[10)].

Seungmin76@gmail.com

3. Results and Discussion

To confirm the sludge volume and mass by US treatment, produced sludge cake and a reduction of water content were observed with and without US, as shown in **Fig. 1**.

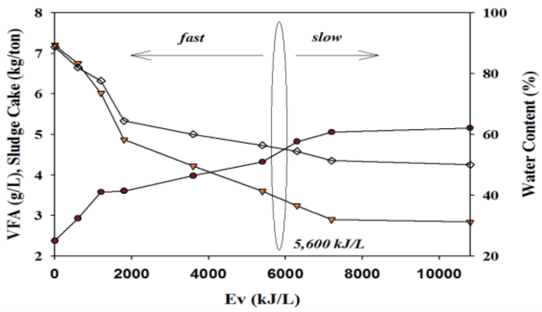

Fig. 1 Water contents (%) in sludge cake, VFA (g/L) concentration in supernatant and sludge cake (kg/ton) with *Ev* after centrifugation (3000 rpm, 1hr) [●: VFA, ▼: Sludge cake, ◊: water content]

At 5,400 kJ L^{-1} condition, the exhausted sludge cake volume was reduced from 5 to 1.3 mL, a reduction in the sludge cake volume of more than 74% (V_2/V_1=0.26). The sludge mass also was reduced by 40% compared with no treatment. The water content in the sludge cake was decreased about 22% at Ev of 5,400 kJ L^{-1}. The VFA concentration in supernatant also increased approximately 2 fold in this condition. The sludge cake and water content reduction below 5,400 kJ L^{-1} were fast decreased than that of above 5,400 kJ L^{-1} of Ev. When sludge is treated ultrasonically, the flocs are separated and disintegrated. The water content in the sludge cake quickly decreased due to the release of some of the water trapped inside the sludge flocs or cells, at initial operation time.

Fig. 2 shows that CST and SRF indicate how fast sludge will release its water were measured in terms of E_v. Decreases in the CST and SRF with increasing *Ev* were clearly observed. Especially, the CST and SRF were decreased from 103 sec and 2.019×10^{14} m kg^{-1} to 43.5 sec and 1.0×10^{14} m kg^{-1} between 5, 400 and 10,800 kJ L^{-1} of applied energy.

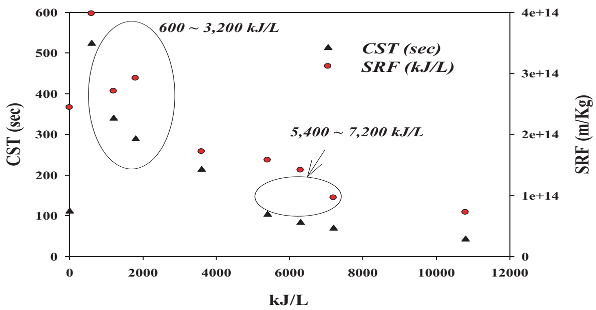

Fig. 2 CST and SRF vs. *Ev* [initial CST value = 110.8 sec, initial SRF value = 2.44 ×10^{14} m/Kg]

The velocity of CST was faster about 58%, and the resistance of SRF was more lower approximately 50%. However, the CST and SRF increased with *Ev* between 600 and 3,200 kJ L^{-1}, which is opposite of the condition for sludge reduction. The reason for more difficult dewatering resulted from the change of the organic form and fraction by US treatment. Chu[11] reported a three step mechanism for sludge treatment due to the application of US. The first stage is a "disruption step" where macromolecule organic matters within the sludge are converted into small molecules by a hydromechanical mechanism. In the second stage, a "solubilization step" small molecule matters become solubilized in relation to the high energy injection. Finally, the treated sludge is disinfected by the intense temperature and pressure in relation to the sonication time. This can be confirmed from the disruption of sludge floc and elution of bound water trapped inside the sludge cell with increase E_v value (**Fig. 3**).

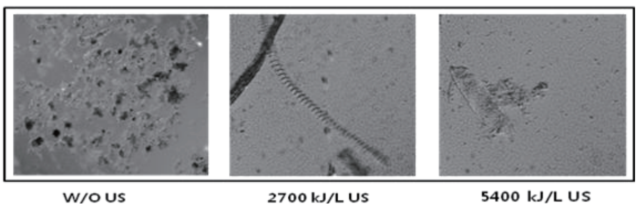

Fig. 3 The disruption of sludge flocs and cell with and without US (10 time dilution ×400 times expansion)

Therefore, increased CST and SRF values between 600 and 3600 kJ L^{-1}, can be caused by inhibition of disrupted suspension solid in the first stage.

If sludge is incinerated, the economic efficiency of ultrasonically treated and untreated sludge can be estimated, as proposed by Reimann[5]. He[5] suggested the estimated values of useful excess energy of sludge cake, according to the water content and DS (VS, dried organic solids in sludge cake), when incinerated. **Table I** shows results of the estimated useful excess energy, when the sludge cake with and without US treatment were incinerated. It illustrates the calorific values of nontreated sludge, dewatered to 59% DS, with an 86% H_2O content and treated sludge cake (5,400 kJ L^{-1}), dewatered to 70% DS, with a 67% H_2O content. To dry sludge cake dewatered to 86 and 67% H_2O, 2,400 and 1,750 kJ kg^{-1}, respectively, would be required. The excess energy required for an untreated sludge cake was calculated to be -150 kJ kg^{-1}, whereas that for treated sludge cake (70 % DS) was estimated to be 2,450 kJ kg^{-1}. Therefore, an untreated sludge cake requires another primary energy source, such as oil or gas.

Table I Useful excess energy for the incineration of sludge cake, before and after ultrasonic treatments

kJ/L	Demand energy for water evaporation (kJ/kg)	Supplied energy from the dry contents (kJ/kg)	A safety factor (TEDS[b] for water evaporation, kJ/kg)	The excess energy (kJ/kg)
0[a]	2,400	1,650	1,000	- 150
5,400	1,750	5,200	1,000	2,450

a : ultrasonically untreated sludge **b**:TESD=Theoretical Energy Demand Stated for water evaporation(control: 86% H_2O, 59% DS, 5400kJ/L: 67% H_2O, 70% DS)

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