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EFFECTS ON ANAEROBIC DIGESTION OF SEWAGE SLUDGE PRETREATMENT

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ABSTRACT

This research investigates the effect of sludge pretreatment on the anaerobic digestion of waste-activated sludge (WAS). In the key of this sludge pretreatment process, bacteria in the WAS were ruptured by mechanical jet and smashed under pressurized conditions. The protein concentrations in the sludge varied significantly after pretreatment. Protein concentration increased according to jet times and pressure. In batch experiments, volatile solids (VS) removal efficiencies were 13~50% when the WAS pretreated once under 30 bar was fed into an anaerobic digester with 2~26 day retention time. In the same operating conditions, when intact WAS was fed into the digester, VS removal efficiencies were 2~35%. Therefore, it is recognized that higher digestion efficiencies of the WAS were obtained through a mechanical pretreatment of sludge. © 1997 IAWQ. Published by Elsevier Science Ltd

KEYWORDS

Anaerobic digestion; digestion rate; waste-activated sludge pretreatment; cell rupture; jet and smash.

INTRODUCTION

Municipal sewage treatment plants contain sludges, such as primary and secondary sludge. It has been reported that primary sludge (PS) is defined to be consisted of sand, food-waste, settled material of inorganics and organics including influent raw sewage, while secondary sludge is a settling material produced at the secondary clarifier of the sewage treatment plant after biological treatment.

Up to date, most sewage sludge has been stabilized by anaerobic digestion processes which are consisted of either one or two digesters in Korea. But these processes always have such disadvantages as long-term retention time (RT), low organics removal efficiency, unstable process and so on.

The microbial cell membrane or cell wall of WAS have been considered to have an inhibiting effect on the sludge digestibility in the anaerobic digestion process because WAS, feedstock for anaerobic bacteria, is mainly consisted of aerobic bacteria. Through the mechanical pretreatment process with high pressure jet and smash, the present investigation aims to develop a new sludge pretreatment process foe effective anaerobic digestion. In the present investigation, the WAS was selected as an organic substrate, a methodology to follow sludge pretreatment was developed, and then physicochemical changes of WAS by sludge pretreatment and the effects of pretreatments on the digestion were discussed.

MATERIALS AND METHODS

The key of this investigation is a process that ruptured microorganisms in the WAS by pretreatment at high pressure. Additional motivations to select this process are 1) the requirement of very simple facilities for application to existing plants, 2) no requirement of additional equipment in the pipeline of sludge transport from sludge stock tank to anaerobic digester 3) the improved performance of anaerobic digestion through the temperature increase and the particle size reduction after sludge pretreatment.

Experimental equipment and methods

Figure 1 shows a schematic outline of the sewage sludge pretreatment equipment, which consisted of two acrylic tanks of diameter 200 mm, height 400 mm, and thickness 20 mm. The tanks were designed to be used repeatedly and tolerant to high pressure and smashing. The smash-flat was made of heat treated steel hard enough to tolerate the high pressure jet and smashing. Pretreatment procedure is as follows:

First of all, for sludge to be well passed through the nozzle, the WAS was filtered by a standard testing sieve (NO. 25, sieve size : 710 μm) to remove sands and stored in a storage tank (1). The sludge which was pressured by pressure pump (2) was jetted to the smash-flat after passing through pressure gauge (3), T valve (4), nozzle (5) in turn, which was the first pretreatment, and transferred to storage tank (6).

When the WAS is pretreated, the microorganisms of WAS appear from 5~50 bar to ambient pressure (1 bar) instantly, then they are jetted and smashed against the smash-flat. Velocity and driving force from jet nozzle (ϕD 1.2mm) to smash-flat is theoretically about 30~100 m/sec and 0.11~1.54 kgf, respectively.

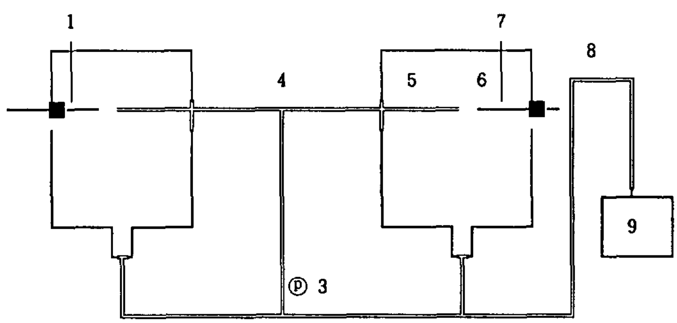

Figure 1. Configuration of the equipment for sludge pretreatment and bioreactor: 1. sludge storage tank; 2. pressure pump; 3. pressure gauge; 4. T valve; 5. nozzle; 6. smash-flat; 7. storage tank; 8. influent; 9. bioreactor.

Cell rupture level for sludge pretreatment was estimated by protein concentration in the WAS according to equation (1) because the cytoplasm of the microorganisms is mainly composed of protein.

$$P^{*} = \frac{\text{Protein conc.}}{\text{Maximum protein conc.}} \times 100 \qquad (1)$$

Operation conditions of anaerobic bioreactor

A batchwise anaerobic bioreactor with 1.2 l capacity has operated continuously for 26 days without any added substrate. For start-up, a mixture of 10% digestion sludge and 90% WAS sample was obtained from a municipal sewage treatment plant in Seoul, Korea, added into the bioreactor and operated batchwise at 35±1°C.

RESULTS AND DISCUSSION

Physicochemical changes of sludge

When WAS was pretreated 5 times under 5, 10, 20, 30, 40, and 50 bar, the protein concentration increased according to jet times and pressure (Fig. 2). Before sludge pretreatment, the protein concentration relative to maximum protein concentration (P^*) for WAS was 14% and increased to 35, 55, 75, 80, and 86% after 5 pretreatments under 5, 10, 20, 30, and 50 bar, respectively. These results indicate that the increment ratios of P^* reduces as the jet pressure increases.

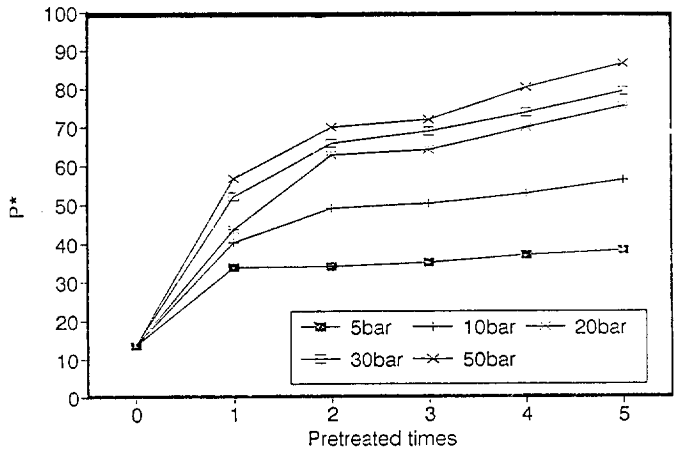

Figure 2. Protein concentration ratio by pretreatment condition changes of waste-activated sludge.

Table 1 show the distributions of particle size in the sludge solids intact sludge and when WAS was pretreated once under 10, 30 and 50 bar. The solid particle size of WAS reduced according to the pretreated pressure. The mean particle size was 69 μm for intact WAS, while those of WAS pretreated once under 10, 30, 50 bar were 37, 22, and 19 μm, respectively.

Table 1. The particles size distribution changes by pretreatment conditions of waste-activated sludge

unit : μm

Pretreated conditions	Mean size±S.D	Particle size distribution		
		<25%	<50%	<75%
(a) unpretreatment	69.1 ± 0.27	47.9	71.8	106.2
(b) once (10bar)	37.0 ± 0.37	21.5	38.9	66.7
(c) once (30bar)	21.6 ± 0.40	12.2	21.0	39.8
(d) once (50bar)	18.7 ± 0.41	10.4	18.4	35.1

** (a) intact; (b) once pretreatment under 10bar; (c) once pretreatment under 30bar; (d) once pretreatment under 50bar

Table 2. Typical concentrations of before and after WAS pretreatment

(unit : mg/l)

Item	Pretreatment(mean)	
	Before	After
SCOD	100~210 (152)	760~1250[a] (990) 910~1530[b] (1,250)
TOC	80~130 (90)	560~920[a] (780) 810~1220[b] (1,010)
Protein	63~85 (75)	250~320[a] (290) 290~380[b] (320)
Alkalinity	225~238 (229)	270~300[a] (280) 310~350[b] (330)
pH	6.3~6.5 (6.4)	6.4~6.7[a] (6.5) 6.5~7.0[b] (6.6)

* Pretreated times : once
Pretreated pressure : a;30bar, b;50bar

Anaerobic digestion in bioreactor

From the three batch experiments with intact and pretreated WAS with the same operating conditions, these experimental results are virtually equal to each other (Table 3).

Table 3. Measured and calculated parameters for intact and pretreated WAS sample during batchwise anaerobic digestion

( ) : Pretreated WAS(30bar)

Incubation time (day)	*SCOD (mg/l)	**Gas as VS[a] (mg)	Cum. Gas as VS (mg)	Removal VS minus a[b] (mg)	Cum. Removal VS minus a (mg)	a/b
0	131 (780)	0 (0)	0(0)	0(0)	0(0)	0.0(0)
1.5	221(1694)	20 (312)	21 (313)	59(248)	59(248)	0.4(1.3)
2	231(1674)	41 (645)	62 (958)	58(314)	117(561)	0.7(2.1)
4	321 (750)	166(2187)	229(3145)	73(192)	190(753)	2.3(11.4)
6	510 (435)	395 (791)	625(3937)	104(55)	295(808)	3.8(14.3)
8	687 (278)	520 (520)	1145(4458)	188(42)	483(850)	2.8(12.4)
10	211 (225)	729 (250)	1875(4708)	128(39)	611(889)	5.7(6.4)
12	165 (211)	1062(166)	2937(4875)	51(35)	661(925)	21.0(4.7)
14	118 (202)	416 (83)	3354(4958)	111(36)	772(960)	3.7(2.3)
26	140 (160)	750(187)	4104(5145)	121(62)	893(1022)	6.2(3.0)

* VS = 1.18 SCOD - 59(R^2 = 0.99)

** Gas as VS : 480 l gas /removal kg VS
(gas productivity after 100-days digestion)

CONCLUSIONS

Sludge pretreatment appears to be the rate-controlling step in the case of anaerobic digestion of WAS. An anaerobic digestion performance for WAS was developed and evaluated. The three major steps in this study are WAS thickening; pretreatment of WAS; anaerobic digestion. Then, we may arrive ate the following conclusions for sludge pretreatment.

(1) When the WAS was pretreated 1~5 times under 5~50 bar, protein concentration increased from 63~85 mg/l to 108~391 mg/l.

(2) VS removal efficiencies were 13~50% when the once pretreated WAS under 30 bar was digested with 2~26-day digestion time while VS removal efficiencies were 2~35% in the digestion of intact WAS.

(3) The digestion rate of the intact WAS and the pretreated WAS followed a first-order reaction kinetics. The digestion rate coefficients were 0.01 day^{-1} and 0.04 day^{-1} respectively. With reduction of particle size of the WAS through destroying cell wall or membrane, the digestability of the WAS can be remarkably improved.

(4) WAS pretreatment increased the anaerobic treatment efficiency and performance of the WAS digestion.