LIQUIDIZATION OF DEWATERED ORGANIC SLUDGE
AND ANAEROBIC TREATMENT

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ABSTRACT

Dewatered sewage sludge was thermochemically liquidized at 175 °C and the
liquidized sludge was separated by centrifugation to 58% (w/w) supernatant and 42%
precipitate. The amount of proteins in the liquidized sludge slightly decreased through
the liquidization process, however, that of lipids increased. The supernatant separated
from the sludge liquidized with dewatered sewage sludge was successfully
anaerobically digested. Biogas yield from the supernatant from dewatered sewage
sludge at organic loading concentrations of 1.9-2.2 g VS/l during 9 days' incubation
was 440 ml/g-added VS and digestion ratio was 66% (w/w). Biogas yield in the case
of dewatered sewage sludge was 257 ml/g-added VS and digestion ratio was 45%.
Similar results were obtained in the case of the anaerobically digested with sewage
sludge and dewatered sludge. Anaerobic digestion of the supernatants from the
liquidized sludges resulted in high biogas productivity and high digestion ratio
compared with these of the original sludges. Moreover, the precipitates contained
lower moisture, therefore, they can be incinerated easier than the respective original
sludges.

INTRODUCTION

Treatments of sewage sludge and anaerobically digested sludge have been
important environmental issues to resolve. Anaerobic digestion of sewage sludge is
commonly used for treatment of sewage sludge and energy is recovered in the form of
methane (Fannin et al., 1983). A thermal pretreatment system for anaerobic digestion
of concentrated sewage sludge with 2-3% volatile solid (VS) has been studied to
improve anaerobic digestibility and dewatering properties (Haug, 1977; Haug et al.,
sludge for thermal pretreatment is huge, and therefore this process consumes a large
amount of energy.

Dewatered sludges (VS of 12%) are clay like solids and are therefore not suitable
for anaerobic digestion. An attempt at liquidization of dewatered sewage sludge by a
thermochemical process was conducted (Dote et al., 1993; Sawayama et al., 1995).
The volume of dewatered sewage sludge decreased markedly from that of
concentrated sewage sludge (VS of 2-3%), suggesting that heat treatment of
dewatered sewage sludge would require less energy than in the case of concentrated
sewage sludge. As for anaerobically digested sludge, thermochemical liquidization
can possibly improve anaerobic re-digestibility and the dewatering properties.

This paper deals with the thermochemical liquidization of dewatered sewage
sludge and anaerobically digested and dewatered sludge, and the batch anaerobic
digestion of the supernatants separated from the liquidized sludges.

METHODS

Liquidization of sludge

Dewatered sewage sludge, and anaerobically digested and dewatered sludge
used in the experiment were obtained from an aerobic sewage treatment facility for
domestic sewage in Ibaraki prefecture, Japan. The liquidization of the dewatered
sludges were conducted as previously demonstrated (Dote et al., 1993). After purging
with nitrogen gas, the dewatered sludge was heated at 175°C in an electric furnace
and held at 175°C for 1 h in a 1 l autoclave (4 MPa). The liquidized sludge was
separated by centrifugation (1000 g, 10 min) to supernatant and precipitate.

Anaerobic digestion

Seed sludge for batch anaerobic digestion was obtained from the sewage sludge
treatment facility in Ibaraki prefecture, Japan. Two liters of the seed sludge (VS
concentration: approximately 1 %, w/w) was incubated in a 2 l conical flask at 35°C. A
sample was added to the seed sludge at 1.6-2.2 g-VS/l and air in the digester was
purged with nitrogen gas. Samples for anaerobic digestion included the original
sludges (dewatered sewage sludge, and anaerobically digested and dewatered
sludge), liquidized sludges and separated supernatants. The gas production yield
from the digester was monitored by displacement of saturated sodium chloride
solution.
Analyses of sludges and gas

Moisture content was determined by heating the sample at 105°C for 24 h before weighing, and VS and ash content were determined by heating at 600°C for 1 h. Digestion ratio was expressed as the ratio of the amount of VS decrease during 9 or 8 days' digestion to the amount of VS added.

The Kjeldahl-nitrogen method was used for protein analysis. After extraction, a gravimetric method was used for determination of lipids. The Somogyi method was used for carbohydrate analysis.

High heating value (HQ, MJ/kg) for VS of sludges is calculated using Dulong's formula (Selvig & Gibson, 1945):

\[ HQ = 0.3383C + 1.442(H + O - 8) \]

where \( C, H \) and \( O \) are weight percentages of carbon, hydrogen and oxygen, respectively. Low heating value (LO, MJ/kg) is calculated using the following equation:

\[ LO = HQ\times V - 0.0251(9\times H + M) \]

where \( V \) is the ratio of volatile solid and \( M \) is the weight percentage of moisture.

The biogas composition was determined by gas chromatography. The digestion ratio was expressed as the ratio of decreased VS during 9 or 8 days of digestion versus added VS.

RESULTS AND DISCUSSION

Liquidization

Procedures of liquidization and anaerobic treatment for sewage sludge are shown in Fig. 1, and those of liquidization and anaerobic re-treatment for anaerobically digested and dewatered sludge are shown in Fig. 2. Dewatered sewage sludge (moisture, 84%, w/w; VS, 12%, w/w), and anaerobically digested and dewatered sludge (moisture; 84%, w/w; VS; 11%, w/w) were successfully liquidized by thermochemical reaction at 175°C with holding time of 1 h. The protein content (33%) in the sewage sludge was higher than that (28%) in the liquidized sludge. On the other hand, the lipid content (14%) in the liquidized sludge from the sewage sludge was approximately two times higher than that (7%) in the sewage sludge. It was reported that volatile acids would be produced through thermal treatment (170-230 °C) of sewage sludge (Fisher & Swanwick, 1971). These results suggest that proteins were converted to lipids through the liquidization process.

The liquidized sludge from the dewatered sewage sludge was separated by centrifugation to supernatant (58%, w/w) and precipitate (42%, w/w), and that from the anaerobically digested and dewatered sludge was separated to supernatant (46%, w/w) and precipitate (54%, w/w). The moisture content of the precipitates decreased from the both original sludges through centrifugation, therefore, thermal liquidization of organic sludges was considered to be a pretreatment for dewatering.

Anaerobic digestion

The supernatant separated from the sludge liquidized with the dewatered sewage sludge was successfully anaerobically digested. The digestion ratio (66%) of the supernatant was higher than that of the original sewage sludge (45%) after 9 days of incubation. The total biogas yield from the supernatant during 9 days' incubation was 440 ml/g-added VS (Fig. 3) and the total methane yield was 328 ml/g-added VS. The biogas productivity in the anaerobic treatment of the supernatant was improved by thermochemical treatment compared with those of the original sewage sludge and the liquidized sludge. There was no difference in methane contents of biogas (75-77%) among those three anaerobic experiments.

The supernatant from the sludge liquidized with the anaerobically digested and dewatered sludge was separated by centrifugation to supernatant (58%, w/w) and precipitate (42%, w/w), and that from the anaerobically digested and dewatered sludge was separated to supernatant (46%, w/w) and precipitate (54%, w/w). The moisture content of the precipitates decreased from the both original sludges through centrifugation, therefore, thermal liquidization of organic sludges was considered to be a pretreatment for dewatering.

Anaerobic treatment of the thermal treatment liquor (average COD; 6-10 g/l) has been studied (Pugh et al., 1987; Kimata et al., 1993). After this preliminary batch experiment, application of the anaerobic digestion method with granular sludge such as the UASB method could contribute to a faster digestion rate for the supernatant from liquidized sludge.

Low heating values of precipitates
The precipitate separated from the sludge liquidized with the dewatered sewage sludge was composed of 71% moisture, 19% VS and 10% ash. The precipitate obtained by centrifugation of the sludge liquidized with the anaerobically digested and dewatered sludge was composed of 76% moisture, 14% VS and 10% ash. This thermochemical liquidization process improved the dewaterability of the dewatered sludges.

The calculated low heating value of the precipitate separated from the sludge liquidized with the dewatered sewage sludge was 1.2 MJ/kg and that of the original sludge was -1.0 MJ/kg. The calculated low heating value of the precipitate separated from the sludge liquidized with the anaerobically digested and dewatered sludge was -0.4 MJ/kg and that of the original sludge was -1.6 MJ/kg. The precipitates separated from the liquidized sludges have higher heating values compared to those of the original dewatered sludges which means that incineration of the precipitate could save energy by using less fuel. A more suitable dewatering method for liquidized sludges would provide higher low heating values for their solid fractions.

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REFERENCES


Fig. 1. Flow diagram of liquidization and anaerobic treatment of sewage sludge.

Fig. 2. Flow diagram of liquidization and anaerobic re-treatment of anaerobically digested sludge.

Fig. 3. Gas yield from anaerobic treatments from sewage sludge (open circle) and anaerobically digested sludge (open triangle), and supernatant (closed circle) from sewage sludge and supernatant (closed triangle) from anaerobically digested sludge.