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ANAEROBIC DIGESTION OF EXCESS SLUDGE THICKENED IN ULTRAFILTRATION PROCESS

The paper deals with anaerobic digestion of excess sludge followed by ultrafiltration process. Ultrafiltration experiment was carried out with cross flow using polysulfone asymmetric membranes. The fermentation experiments were performed in a laboratory plant consisting of two stirred tank fermenters operating in parallel at 35 °C. As a control one anaerobic fermenter was operated with waste sludge thickened at Czestochowa Waste Water Treatment Plant using classical thickener. The results show a significant improvement in the removal rates of substrates and the enhancement of methane production in fermenter operated with the sludge thickened by means of ultrafiltration process. Although the concentrations of volatile solids in both reactors were on the same level, in the reactor operated with sludge, after ultrafiltration thickening the volatile solid destruction of 40 % was achieved.

1. INTRODUCTION

Anaerobic digestion is most commonly applied process in stabilization of waste activated sludge (WAS) [1], [2]. The volume reduction of the waste sludge with relatively low solid matter content encountered during wastewater treatment is a requirement for the economical stabilization of the sludge. Therefore new methods that allow mechanical pre-thickening of the excess sludge are increasingly applied. Typical sludge thickening methods required construction of the WAS conditioning system including a polymer feed system.

The excess activated sludge is a dilute suspension of microbial cells and cell debris. Because the potential substrates are "membrane-enclosed" within viable cells, excess activated sludge becomes more difficult to degrade compared with primary sludge. Therefore, the pretreatment of excess sludge by chemical, mechanical and thermal disintegration improves a subsequent anaerobic digestion.

The purpose of this study was to compare the performance of mesophilic digestion following by ultrafiltration thickening with the performance of anaerobic digestion

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following a conventional thickening process. The specific objectives of the research were to determine the reduction of volatile solids and biogas production.

2. METHODS

The experiments were done with waste activated sludge (WAS) obtained from the municipal full-scale treatment plant of Częstochowa. The experimental device used for thickening process (figure 1) included four membrane modules, each having surface area of 0.025 m^2. The thickening process was carried out at room temperature, at the flow velocity of the filtered medium of 3.5 m/s over the membrane surface and at a constant transmembrane pressure of $2.5 \cdot 10^5$ Pa.

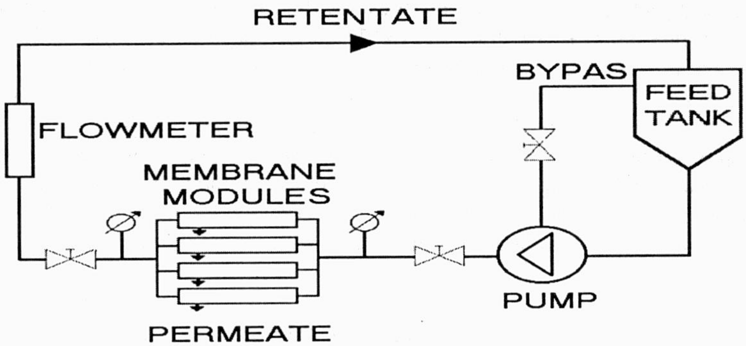

Fig. 1. Experimental set-up

A mesophilic anaerobic digestion was studied using two 5 dm^3 stirred glass digesters, placed in a temperature-controlled chamber at 35 °C. The system operated in bath mode. The first reactor was feed with excess sludge thickened in ultrafiltration process. As a control, the second anaerobic fermenter was operated with the sludge thickened in mechanical thickener at wastewater treatment plant. Both reactors were seeded initially (10% of the reactor working volume) with digested sludge from the mesophilic anaerobic digester from the same wastewater treatment plant. The produced biogas was collected in calibrated glass cylinder. The biogas composition was determined once a week using Orsat apparatus with CO_2 absorption bulb.

The destruction of volatile solids (*VS*) was calculated by means of the following formula:

$$VS_{\text{destruction}} = \frac{VS_{\text{influent}} - VS_{\text{effluent}}}{VS_{\text{influent}}} \times 100\% .$$

The concentration of volatile fatty acids (VFAs) was determined using the method of distillation with water vapour. The changes of the sludge filtration properties were determined using the capillary suction time (CST) test [3].

The concentration of voltaic solids (VS) and volatile fatty acids (VFA) were determined at the beginning and the end of experiment. In order to determine the volatile solids, the samples were first dried at 105 °C for 24 h to obtain the concentration of dry solids. Next, the dry solids were incinerated at 550 °C for 2.5 h. The residues after incineration represent the inorganic dry solids. The difference between the dry solids and inorganic dry solids represents the volatile solids.

For the analysis of chemical oxygen demand in the sludge supernatants, the particulate sludge material was removed by centrifugation followed by filtration through 0.45 μm pore-size membrane filters. COD was determined by oxidation of the organic compounds with $K_2Cr_2O_7$. The Cr^{3+} produced thus was analyzed colorimetrically using the tests and the photometer of the HACH firm.

3. RESULTS

In order to determine the influence of the ultrafiltration thickening process on the anaerobic digestion of the thickened sludge, a mesophilic anaerobic digestion was studied. The table presents characteristics of the substrate being fed into reactors (waste activated sludge thickened by ultrafiltration process and WAS thickened by classical method) and summaries the results obtained during digestion process.

Table

The data and results of the experiments with thickened waste activated sludge

Parameter	Dimension	Before digestion process		After digestion process	
		WAS thickened in UF process	WAS thickened by classical method	WAS thickened in UF process	WAS thickened by classical method
Total solids	g/dm^3	20.0	20.3	16.4	18.7
Volatile solids	%	68.0	66.0	50.3	51.3
	g/dm^3	13.6	13.4	8.3	9.6
Volatile solids destruction	%	–	–	39.2	28.4
pH		6.7	6.8	7.3	7.2
CST	s	95	52	129	66
COD	mg/dm^3 O_2	200	147	–	–
Total biogas production	dm^3	–	–	12.1	6.5
Biogas production/VS degraded	dm^3/g			0.46	0.34

The concentration of volatile solids was by 2% higher in WAS thickened in membrane process. In this case, COD in a liquid phase was by 36% higher. After digestion process a reduction of total solids reached 18% for sludge thickened in UF process and 8% for the second sludge tested, respectively. The VS reduction in the fermenter operating with sludge thickened using ultrafiltration membranes was 40%. In the second reactor, volatile solid destruction was by 28% lower. The measurement of the filtration properties of the digested sludge, carried out using the capillary time test, testified to an increase in CST.

Figure 2 shows biogas production during the digestion process. In the reactor, where the sludge was thickened as a result of ultrafiltration process, the total biogas production was almost by 70% higher than in the reactor, where the sludge was thickened by classical method. In this case, the highest biogas production was observed on the sixth day of fermentation, while in the second reactor biogas production started several days later, and its culmination was observed on the sixteenth day.

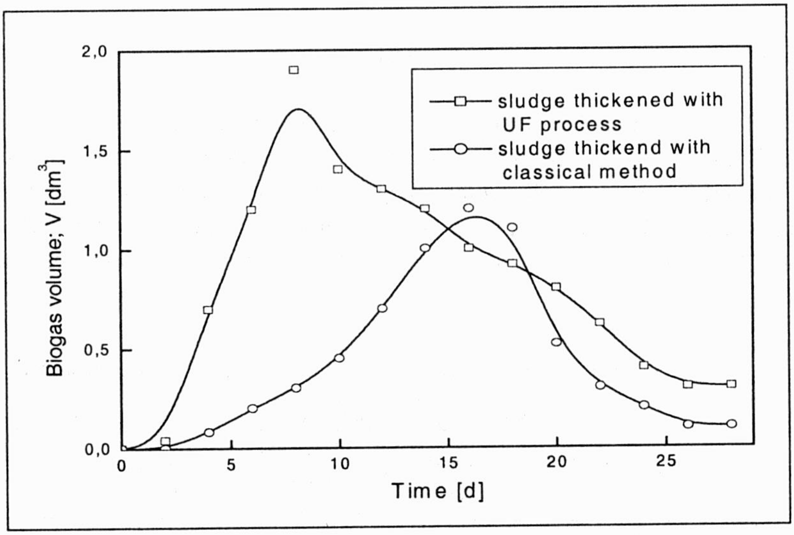

Fig. 2. Production of biogas during fermentation

The composition of biogas produced in both reactors did not substantially differ. The lowest CO_2 concentration in biogas was observed on the fourth week of digestion process and it approached 15%.

4. DISCUSSION AND CONCLUSION

It was found that during digestion of the WAS which was thickened using membrane process, the volatile solid destruction was higher than during anaerobic stabilization of the second sludge thickened with classical method. Although the concentration of volatile solids in both reactors was on the same level, in the reactor operating with sludge after ultrafiltration thickening, the volatile solid destruction of 40% was achieved. In the liquid above the sludge being thickened by means of UF membranes, a higher COD was observed. This phenomenon shows that organic substances occur in higher concentration as dissolved form which is better assimilated by microorganisms responsible for biochemical degradation of organic matter [4]. The high cross-flow velocity in UF process (3.5 m/s) causes partially mechanical destruction of cell membranes of microorganisms and hence released from them dissolved organic substances which accelerate the process of biochemical destruction. In aerobic membrane bioreactors with activated sludge where lower values of cross-flow velocity and transmembrane pressure ($u = 2$ m/s, $\Delta P = 2\cdot10^5$ Pa) were applied, a dispersion of the sludge was observed after a few minutes [5]–[9]. The influence of ultrafiltration thickening process on the sludge structure is similar to the effect of mechanical disintegration of the sludge using special systems for mechanical disintegration of the sludge (mills, homogenizers) [10], [11]. Using the membrane process for WAS thickening shortens the hydrolysis stage as well as displaces and intensifies the next stages of digestion process. The third step of fermentation (methanogenesis) started earlier and a total biogas production was by almost 70% higher in comparison to such a production in the second stabilized sludge.

The VS reduction in the fermenter operating with sludge thickened by classical method was 28.4%. This can be explained by the fact that waste activated sludge comprises facultative anaerobic microorganisms that are not active in an anaerobic digestion process. Because the potential substrates are "membrane-closed" within viable cells, excess activated sludge becomes more difficult to degrade compared with primary sludge.

Our experiment demonstrates that ultrafiltration thickening process has a positive impact on anaerobic stabilization of the excess activated sludge. Therefore ultrafiltration pre-thickening seems to be a promising method to enhance fermentation rate and to reduce the volume of sludge digester.

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FERMENTACJA METANOWA NADMIERNEGO OSADU CZYNNEGO ZAGĘSZCZONEGO ULTRAFILTRACYJNIE

Badano fermentację metanową nadmiernego osadu czynnego zagęszczonego w wyniku procesu ultrafiltracji. Zagęszczanie prowadzono w przepływie krzyżowym, wykorzystując asymetryczne membrany z polisulfonu. Porównanie efektywności procesu fermentacji osadu zagęszczonego z użyciem membran ultrafiltracyjnych i osadu zagęszczonego w zagęszczaczu mechanicznym w Częstochowskiej Oczyszczalni Ścieków prowadzono w układzie statycznym w warunkach mezofilowych. Zaobserwowano wyższy stopień przefermentowania oraz intensywniejszą produkcję biogazu w przypadku osadu zagęszczonego w procesie membranowym. Stopień przefermentowania osadu zagęszczonego ultrafiltracyjnie był wysoki i wyniósł prawie 40%. W przypadku osadu zagęszczonego klasyczną metodą redukcja stężenia związków organicznych była o prawie 28% niższa.