Ultrasonic Alkaline Pretreatment of Biological Activated Sludge from Wastewater Treatment Plants

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Ultrasonic treatment has become a modern method for removal of micropollutants and refractory compounds from water/wastewater and to improve biodegradation efficiency of biological activated sludge from wastewater treatment plants, in order to produce biogas. This paper is referring to the ultrasonic pretreatment of biological activated sludge, before anaerobic fermentation phase, to increase the amount of biogas generation. The pretreatment of biological sludge is based on two steps: alkaline digestion and ultrasonication. Ten minutes of alkaline condition (pH 9.5 - 10.5) followed by 10 minutes ultrasonication (20 kHz frequency) were the general operating condition of sludge pretreatment phase. Parallel tests (with and without ultrasonic pretreatment step) were performed in order to assess the effect of ultrasonic pretreatment on biogas generation. Ultrasonication in alkaline condition of biological sludge heave led to doubling the amount of biogas generated in anaerobic fermentation phase.

Keywords: ultrasonic, wastewater treatment plant, biological activated sludge, anaerobic, biogas

The municipal wastewater treatment plants of medium and high size have a specific flow of sludge treatment and conditioning. The biological excess sludge must be treated both for biogas generation and to reduce the volume (dewatering step) [1-2]. Some wastewater treatment plants have facilities of compost producing for agricultural purposes. Biogas generation take place in methane-tanks which are anaerobically fermentation bioreactors [3-5].

Ultrasonic field has an important effect to biological activated sludge because of two important phenomena: mechanical action due of ultrasonic shock waves and sonolysis based on cavitation effect. Both of them increase the solubility level of organic matter (COD, BOD) which lead to a higher amount of biogas generation in anaerobically digestion phase [6].

Ultrasonication and alkaline digestion has proved to be together very efficient for biological sludge pretreatment. Previously experimental data were use in this paper work as optimal conditions for alkaline - ultrasonication pretreatment phase [5,7,8].

This ultrasonic pretreatment method can be adapted to be used in present wastewater treatment plants or could be include in the new designed WWTP [1, 4, 9]. A synthetic flow treatment scheme of the biological sludge will be presented in the experimental conclusions part.

Experimental part

SONICS VIBRACELL 500 ultrasound source was used for experimental tests. The ultrasonic frequency was 20 kHz. There was no need of cooling jacket for reaction vessel because in this case the heating of reaction volume is useful for the next phase of biological sludge treatment - anaerobically digestion.

The pretreatment phase of biological sludge had two steps with the following main experimental conditions:

- *The alkaline digestion* with NaOH 50% (*p*H 9.5 - 10.5), 10 min moderate stirring;
- *Ultrasonication* (20 kHz frequency, 9000 kJ energy, 80% amplitude), 10 min, without cooling system.

Figure 1 shows both phases of ultrasonic pretreatment and anaerobic digestion phase. Anaerobic digestion phase was performed at 37.5 ^{0}C.

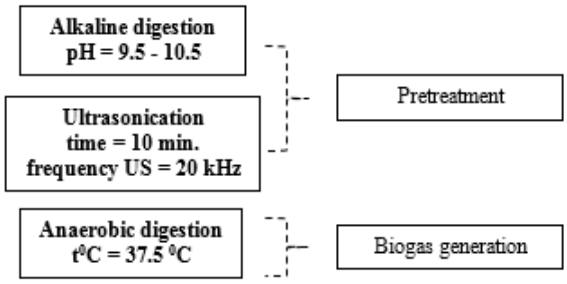

Fig. 1. Biogas generation scheme

In order to compare the performance of biogas generation by anaerobic digestion, two paralel tests were performed:

- bioreactor 1: anaerobic digestion, no ultrasonic pretreatment;
- bioreactor 2: ultrasonic and alkaline pretreatment followed by anaerobic digestion.

The main parameters of process efficiency were: organic load and fatty acids levels during the all experimental period of time (30 days), biogas and methane amount. The initial sludge mixtures of both biological reactors had 2 L of activated biological sludge (treated or untreated with ultrasonic field) and 1 l of fermented sludge from a municipal wastewater treatment plant (to assure the specific bacteria content for anaerobically digestion).

Initial sludge mixture from each bioreactor had the following characteristics:

-bioreactor 1 (control sample): *p*H = 6.1, dry substance (d.s.) = 4.71%, volatile fatty acids (VFA) = 5,520 mg/L, COD = 14,080 mg O_2/L;

-bioreactor 2 (ultrasonic pretreatment): pH = 9.75, dry substance =1.18%, volatile fatty acids = 10,080 mg/L, COD = 22,000 mg O_2/L.

Results and discussions

The analyze of initial composition of both sludge mixtures (before anaerobically digestions) emphasized the main following differences:

-dried substance is four times lower in test bioreactor 2 (1.8%) comparing to test control bioreactor 1 (4.7%);

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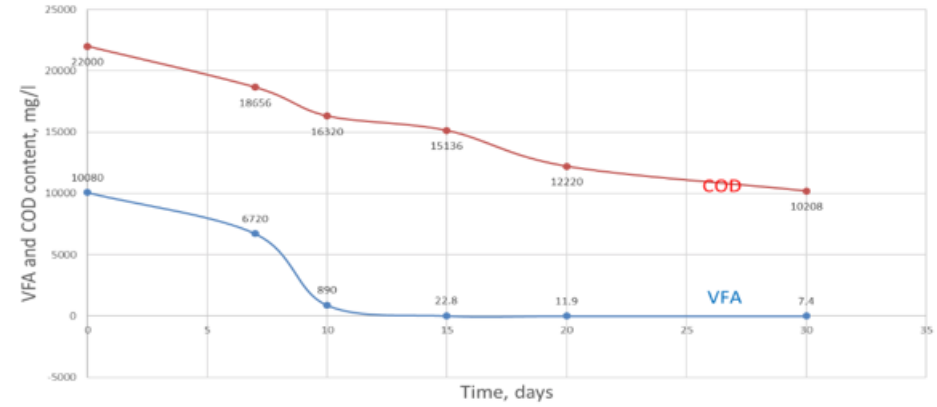

Fig. 2. Test bioreactor 2: COD and VFA evolution during 30 days anaerobically digestion

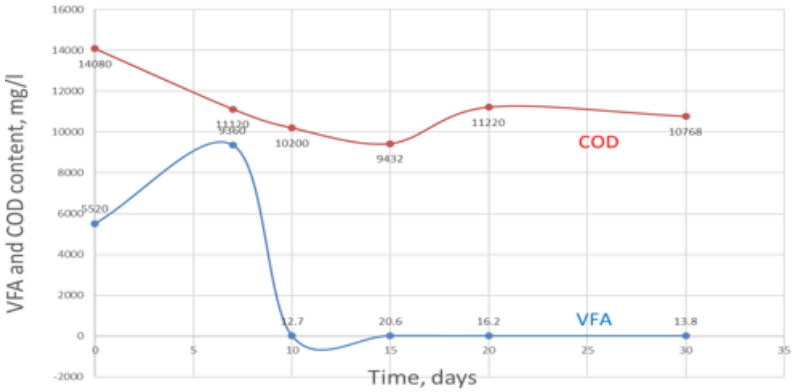

Fig. 3. Control test bioreactor 1: COD and VFA evolution during 30 days anaerobically digestion

-volatile fatty acids concentration is 1.8 times higher (10,080 mg/L) in bioreactor 2 than bioreactor 1 (5,520 mg/L);

-COD level in bioreactor 2 (22,000 mg O_2/L) is 1.6 time higher (14,080 mg O_2/L in bioreactor 1).

The main conclusion is the higher solubilization degree of organic matter because of ultrasonic and alkaline pretreatment, which leads to a different evolution in time in the anaerobic digestion phase of COD, volatile fatty acids, biogas amounts.

Figures 2 and 3 show the evolution in time of COD and VFA.

Bioreactor 2 (test) monitoring observations:

-COD decrease slowly from 22,000 mg O_2/L to 10,000 mg O_2/L;

-VFA decrease slowly from 10,080 mg/L to 7.4 mg/L;

-after 10 days VFA concentration was 890 mg/L and COD was 16,320 mg O_2/L, still having biogas generation potential.

Bioreactor 1 (test control) monitoring observations:

-COD generally decrease from 14,080 mg O_2/L to 10,768 mg O_2/L;

-VFA increase from 5,520 mg/L to 7,936 mg/L in the first week of anaerobically digestion and decrease suddenly in the next three days;

-after 10 days VFA concentration was 12.7 mg/L and COD was 10,200 mg O_2/L.

After 30 days the COD transformation was 54% for test bioreactor 2 (ultrasonic pretreatment) and 23 % in case of test control (bioreactor 1 without ultrasonic pretreatment) respectively.

It seems that is better to have a slowly transformation of COD into biogas and to start the anaerobically digestion having a higher amount of VFA since the beginning, because of ultrasonic alkaline pretreatment.

The evolution of biogas production in both bioreactors is presented in table 1 and figure 4. The plastic bags for biogas were emptied after 7, 10, 15,20 and 30 days. The total biogas amount is the sum of these partial volumes.

The main observations for anaerobically digestion are as followings:

-since the beginning the amount of biogas was higher in test bioreactor 2 (the smallest difference was noted after 10 days: 4 L in bioreactor 1/6 L in bioreactor 2); after 15 days the difference was significant: 2 L in bioreactor 1/8 L in bioreactor 2;

-the methane content of biogas from bioreactor 2 (max. 70% after 15 days) was higher than bioreactor 1 (max.

No.	Time, days	Bioreactor 1 – TEST CONTROL		Bioreactor 2 - TEST	
		Biogas volume, L	CH_4 content, %	Biogas volume, L	CH_4 content, %
1	7	1	35	4	40
2	10	4	50	7	60
3	15	5	65	8	70
4	20	2	40	8	65
5	30	0.2	10	0.5	30
		Total 12.2 L		Total 27.5 L	

Table 1
BIOGAS PRODUCTION IN TEST AND TEST CONTROL BIOREACTORS

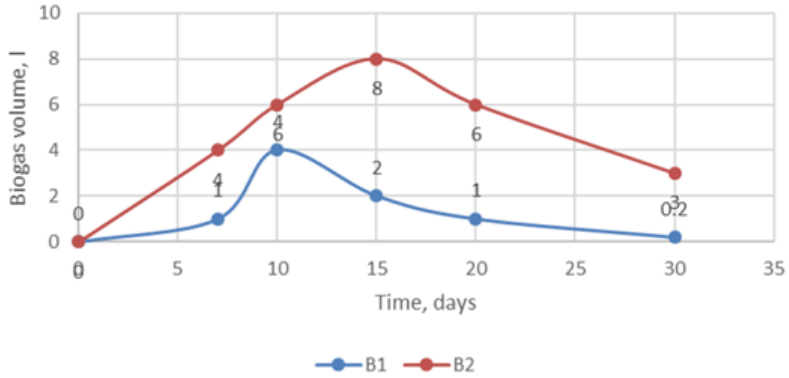

Fig. 4. Biogas generation - 30 days anaerobically digestion

65% after 15 days) during all the testing period of time.

Conclusions

The positive influence of ultrasonic and alkaline digestion to biogas generation in anaerobic digestion has two main causes:

-from the beginning of anaerobic digestion phase, the ultrasonic pretreated sludge from bioreactor 2 has a higher content of organic load (56%) and fat acids (~80%) than bioreactor 1 (no pretreatment); thus, test bioreactor is better prepared for anaerobic digestion having a significant advantage comparing with test control bioreactor (no sludge pretreatment);

-after 30 days, the biogas volume generated in bioreactor 2 was two times higher than bioreactor 1 and the content of methane was 70% comparing with 65% (bioreactor 1).

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