ANAEROBIC DIGESTION OF SEWAGE SLUDGE

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Abstract. Utilization of sewage sludge causes environmental problems in Latvia, therefore anaerobic digestion of sludge was investigated as the treatment method. Sludge from the wastewater plant „Jurmala" was processed at temperature 38 ˚C ± 1.0˚C in laboratory bioreactors operating in batch mode. The investigated differences between total solids and organic solids contents were 2.0 % for fresh sludge, 2.1 % for old sludge, 3.6 % for sludge stored for a long period and 4.2 % for sludge from a ditch overgrown with vegetation in the wastewater treatment plant „Jurmala". The average biogas yield obtained from the sludge samples was varying from 233 $l \cdot kg_{VSd}^{-1}$ for sludge from the ditch overgrown by vegetation to 397 $l \cdot kg_{VSd}^{-1}$ for fresh sludge. The average methane yield from fresh sludge was 233 $l \cdot kg_{VSd}^{-1}$ and average methane yield from long time stored sludge was 122 $l \cdot kg_{VSd}^{-1}$. The investigated average methane content was 59.0 % in biogas from fresh sludge, and the methane content was 46.1 % in biogas from sludge located for a long storage period. Co-digestion of sludge stored for years with fresh sludge or with agricultural biomass is recommended to increase the methane content in biogas.

Keywords: anaerobic digestion, biogas, sludge, methane.

Introduction

There are problems with environmentally safe utilization of sewage sludge in Latvia. Sewage sludge is colloidal sediment resulting from the treating of municipal, domestic and industrial sewage in treatment plants, as well as depositions from septic tanks and other similar plants for sewage treatment. Wastewater sludge produced 23 258 tons dry matter (DM) [1] in more than 900 wastewater treatment plants (WTP) in Latvia in 2007. Approximately 42 % of sludge produced was utilized for agricultural purposes, 12 % for composting, greenery and recovery, 2 % was landfilled and 44 % was left in WTPs, causing environmental problems. Sludge, that is not utilized, is stored in WTP, and its anaerobic degradation process is still ongoing slowly, releasing greenhouse gases (e.g. carbon dioxide, methane), odours and increasing the risk of pollution of groundwater. According to the Latvia legislation sewage sludge should be treated before its utilization in agriculture. An energy-efficient method for treatment can be sludge anaerobic digestion. Utilization of biogas from sludge can help to attain the target share 42 % of renewable energy in gross energy consumption for Latvia in year 2020 [2]. Sewage sludge anaerobic treatment is allowed by legislation, and can be realized in mesophilic (35 ± 3 ˚C, 21 ± 5 days) or in thermophilic (55 ± 5 ˚C, 5 days) process [3]. Experience in anaerobic digestion of sewage sludge is obtained in the largest wastewater treatment plant in Latvia WTP "Daugavgrīva", located near the city Riga. In WTP "Daugavgrīva" 6648 t DM sludge was produced in 2007. The anaerobic treatment process in WTP "Daugavgrīva" is ongoing at temperature 37 ˚C and the retention period exceeds 21 days. The obtained biogas is utilized for heat and electricity production. There is rising interest for feasibility studies for evaluation of biogas potential obtainable in different WTP in Latvia. The sludge digestion process and biogas output can vary in different WTPs, due to greatly varying characteristics of wastewater, due to different pretreatment methods and different periods of sludge storage. The purpose of this investigation is evaluation of the quality and quantity of biogas released in the anaerobic digestion process of sludge produced in WTP „Jurmala".

Materials and methods

Four different types of sludge from WTP „Jurmala" were investigated, including fresh sludge from decanter, old sludge from storage, partly degraded sludge from long time storage and sludge from the ditch covered with vegetation. The anaerobic digestion process was performed in 8 laboratory digesters of volume 5 l. Each digester was equipped with heating devices for automated regulation of temperature 38 ˚C ± 1.0 ˚C inside of digesters. The digesters were equipped also with sensors for automated recording of temperature, pH value and gas volume data in computer. Fermented cow manure was added in the amount of 15 % of substrate weight in all digesters to provide microbial inoculum for successful anaerobic fermentation process.

The substrates were analyzed for organic matter, total solids, organic solids and moisture content before filling in and after extracting out of digesters. The accuracy of the measurement was ±0.02 for pH value, ±0.0025 l for gas volume and ±0.5 ˚C for temperature. The anaerobic fermentation was provided during 1-2 month period, and was finished after biogas production ceases from mixtures. The anaerobic digestion process was provided in batch mode, i.e. without mixing of substrates or recirculation of leached liquids.

Results and discussion

Results of anaerobic fermentation of sludge biomass samples from WTP „Jurmala" are shown in Table 1.

Table 1

Substrate and biogas parameters

Parameter	Unit	D1	D2	D3	D4	D5	D6	D7	D8
Substrate composition	%	25 Ls 15 In 60 W	25 Ls 15 In 60 W	25 Ds 15 In 60 W	25 Ds 15 In 60 W	25 Fs 15 In 60 W	25 Fs 15 In 60 W	25 Os 15 In 60 W	25 Os 15 In 60 W
Total substrate	kg	4.524	4.518	4.143	4.140	4.521	4.528	4.613	4.608
Raw material total solids	%	18.4	18.5	19.3	19.2	13.7	13.9	12.8	13.1
Raw material org. solids	%	14.8	14.9	15.1	15.0	11.7	11.9	10.8	11.0
Biogas yield	$l \cdot kg_{VSd}^{-1}$	272	25	235	231	403	390	363	360
Average methane content	%	46.8	45.3	44.8	43.2	59.4	58.5	56.5	55.9
Methane yield	$l \cdot kg_{VSd}^{-1}$	127	116	105	99	239	227	205	201

Remarks: Fs - fresh sludge (from decanter); Os – old sludge (from storage); Ls – sludge from long time storage (partly degraded); Ds – sludge from ditch with vegetation; w - water; in- inoculum (fermented cow manure).

The average content of total solids and organic solids in raw material is varying within sludge samples. The investigated differences between the total solid and organic solid contents were 2.0 % for fresh sludge, 2.1 % for old sludge, 3.6 % for sludge stored for a long period and 4.2 % for sludge from the ditch overgrown with vegetation in the wastewater treatment plant "Jurmala". The older the sludge was, the larger the difference between total solids and organic solids was (Figure 1). Such an evidence can be explained by partial biodegradation of sludge located for a long storage period (D1, D2) or sludge from the ditch overgrown by vegetation (D3, D4). The average biogas yield obtained from the sludge samples is varying from 233 $l \cdot kg_{VSd}^{-1}$ for sludge from the ditch overgrown to 397 $l \cdot kg_{VSd}^{-1}$ for fresh sludge (Figure 2). The average methane yield of biogas obtained from the sludge samples is varying from 233 $l \cdot kg_{VSd}^{-1}$ for sludge from the ditch overgrown to 397 $l \cdot kg_{VSd}^{-1}$ for fresh sludge. The average methane yield 233 or 203 $l \cdot kg_{VSd}^{-1}$ was obtained from fresh sludge (D5, D6) and old sludge (D7, D8) samples. The average methane yield from long time stored sludge (D1, D2) was approximately 2 times lower compared to that obtained from fresh sludge (see Figure 2). It can be concluded, that for maximal biomethane production sludge should be treated as soon as possible after its origination in the wastewater pretreatment process, e.g., after dewatering of wastewater sediments in decanter.

The methane content in biogas from different types of sludge is presented in Figure 3. The methane content 59.0 % or 56.2 % was investigated in biogas obtained from fresh sludge or from old sludge respectively. Biogas has methane content sufficient for heat and electricity production in cogeneration units after removal of sulphurous substances. The investigated average methane content was low 46.1 % or 44 % in biogas from sludge located for a long storage period or from the ditch overgrown by vegetation sludge respectively.

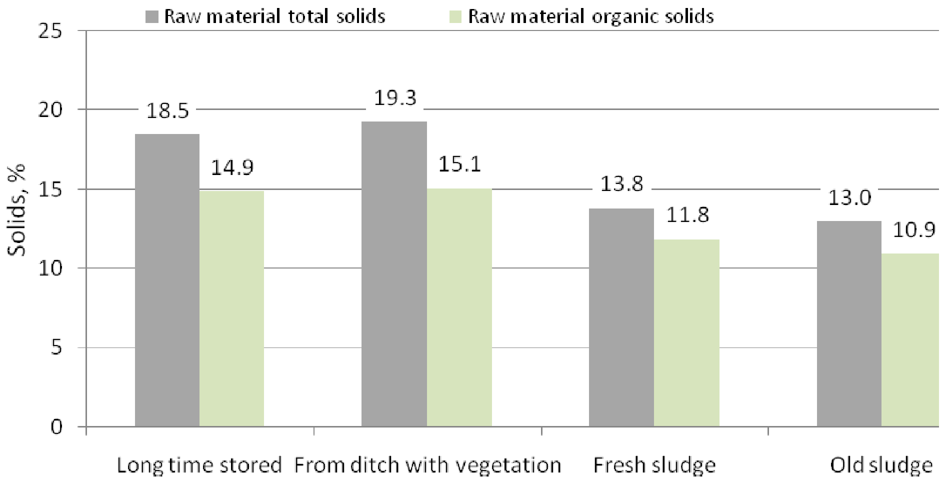

Fig. 1. **Total solid and organic solid content in different samples of sludge**

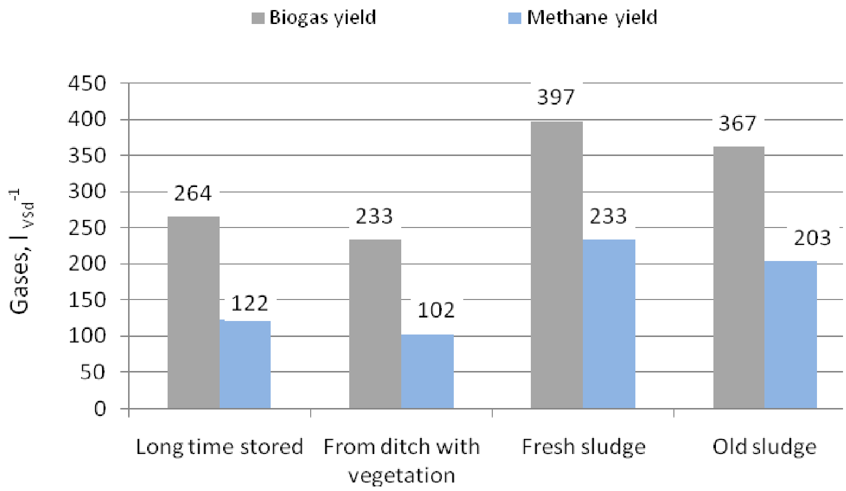

Fig. 2. **Average biogas and methane yields obtained from different samples of sludge**

Sludge stored during a long time period (several years) should be digested together with fresh sludge or co-digested with biomass producing methane-rich biogas, e.g., green biomass, byproducts from food or feed industry or livestock manure, to ensure increased methane content in biogas for more efficient biogas utilization. If biogas is envisaged to use as transport fuel or as natural gas substitute, further treatment, including removal of carbon dioxide and sulphurous substances, should be necessary.

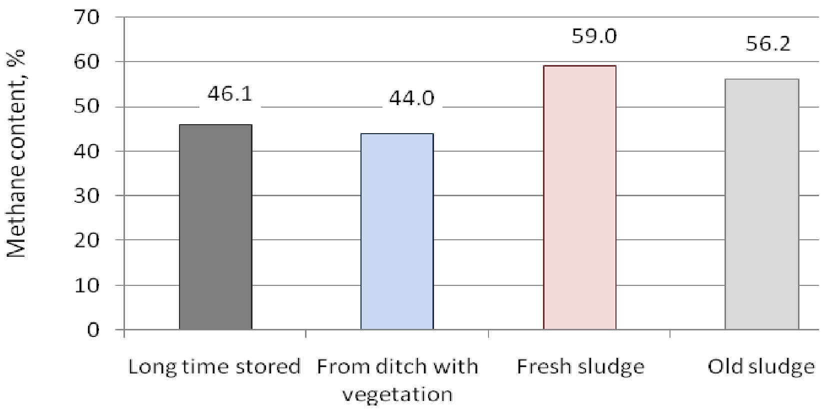

Fig. 3. **Average methane content in biogas produced from different type of sludge**

Utilization of fresh sludge and/or old sludge stored in WTPs for production of biogas can provide cogeneration plants with uninterrupted flow of raw biomass as well as to ensure minimization of the amount of sludge to be transported for agricultural application.

Conclusions

1. The investigated differences between total solid and organic solid contents were 2.0 % for fresh sludge, 2.1 % for old sludge, 3.6 % for sludge stored for a long period and 4.2 % for sludge from the ditch overgrown with vegetation in the wastewater treatment plant „Jurmala”.
2. The average biogas yield obtained from the sludge samples was varying from 233 $l \cdot kg_{VSd}^{-1}$ for sludge from the ditch overgrown by vegetation to 397 $l \cdot kg_{VSd}^{-1}$ for fresh sludge.
3. The average methane yield from fresh sludge was 233 $l \cdot kg_{VSd}^{-1}$ and the average methane yield from long time stored sludge was 122 $l \cdot kg_{VSd}^{-1}$, or around 2 times lower compared to the methane yield from fresh sludge.
4. The investigated average methane content was 59.0 % in biogas from fresh sludge, and the methane content was 46.1 % in biogas from sludge located for a long storage period.
5. Co-digestion of sludge stored for years with fresh sludge or with agricultural biomass is recommended to increase the methane content in biogas.

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References

1. Pārskats par biologiski noārdāmiem atkritumiem un materiāliem 2007.g. (Review on biologically degradable waste and materials, year 2007), LVĢMA, 2008, 6 p. (In Latvian). [online] [15.03.2010]. Available at: http://www.meteo.lv/upload_file/parskati/slodzes/Parsk_par_biol_noard_atkr_2007.pdf
2. Directive 2009/28/EC “on the promotion of the use of energy from renewable sources and amending and subsequently repealing Directives 2001/77/EC and 2003/30/EC”, Official Journal of the European Union, L 140, vol. 52, 2009, p. 148.
3. MK noteikumi Nr. 362, “Noteikumi par notekūdeņu dūņu un to komposta izmantošanu, monitoringu un kontroli” (“Regulations Regarding Utilisation, Monitoring and Control of Sewage Sludge and the Compost thereof”). Latvijas vēstnesis, 73 (3441), 11.05.2006, 30 p. (In Latvian).