Investigating the Current Management of Digestate in the Czech Republic

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Summary

This paper focuses on increasing quantities of digestate which is a final product of anaerobic digestion in biogas stations used as alternative sources of energy or as fermenting facilities which can reduce the quantities of biodegradable wastes on landfills. Digestate is a stabilised material produced by anaerobic digestion in a biogas station in addition to the main product - biogas. Potential use of digestate is limited due to its rather specific physical properties. In particular, individual components in digestate are extremely difficult to separate and its chemical or microbiological composition is special. The quality of digestate is affected mostly by the type of biomass. This paper presents current approaches to digestate and digestate management. It also includes taking and analysing digestate samples, processing of the samples in laboratory centrifuges and assessing the properties of digestate and separation products, i.e. the sludge liquor and separatum.

Keywords: digestate, biogas station, sludge liquor, separatum

Introduction

The current trend in energy recovery lies in renewable sources. Having entered the European Union, the Czech Republic committed itself to duties related to reducing biodegradable municipal waste (BMW). According to Czech Waste Management Plan in Government Regulation 197/2003, Coll., in 2016 only 35% of BMW should be dumped on landfills, as opposed to 1995.

The growing interest in alternative energy sources, along with the requirements for biodegradable waste reduction, has led to building a number of biogas stations able to ferment, besides BMW, also sewage sludge, agricultural crops and waste from agricultural production. Apart from the major product, i.e. biogas, biogas stations also generate fermentation residue, the so-called digestate. The quantity of the digestate grows proportionally to new biogas stations, whose number also increases due to the EU financial support for the technology.

Anaerobic fermentation

Anaerobic fermentation (also anaerobic digestion) is a very complex biochemical, chemical and physical-chemical process of conversion of organics under no access of air (oxygen) into a mixture of gases and undigested, fermented organic residue. The process comprises of four simultaneous phases, namely *hydrolysis*, *acidogenesis*, *acetogenesis and methanogenesis*, where products of one phase serve as a substrate for another; a failure or disruption of activity of one phase may disrupt the dynamics of the overall system. The process is described in detail in Dohányos et al., 1996; Schulz and Eder, 2004; Straka et al., 2003; Kára et al., 2007.

In theory, anaerobic digestion may process almost any organic material with a high content of organics and dry matter below 50%. Based on the dry matter proportion contained in the biomass, there are two types of anaerobic digestion, namely dry and wet, as the dry matter content influences the biomass transport method into the fermentor. Despite the dry operation being less costly (lower heat loss in water heating), wet anaerobic digestion is more common due to an achieved higher biogas production stability (Mužík and Slejška, 2003).

The process of anaerobic fermentation is affected by lack of oxygen, pH (optimum between 6.3 and 7.8), substrate composition and the applied technology. The factors are discussed in detail in Dohányos et al., 1996; Schulz and Eder, 2004; Kasali and Senior, 2007; Dohányos, 2012.

Digestate

Digestate is a stabilized material containing material undigested during digestion and necrotic microorganisms. It may be classified according to various aspects, e.g. dry matter, feedstock or its application method.

Classification according to dry matter

Subject to Regulation 271/2009, on requirements for fertilizers, digestates may be classified according to the dry matter content with a limit of 13% of dry matter, with different limit values of certain elements stated therein.

***Classification according to feedstock, according to** Bulletin of the Ministry of the Environment, 2008; Švec et al., 2010; Marada et al., 2008*

Agricultural – the feedstock is animal substrates, such as semi-liquid manure, manure, dung and other farm fertilizers. Next, the feedstock may be plant substrates. It is advisable to combine the substrates and make use of their different properties. The feedstock may not be wastes or animal by-products.

Sewage treatment – the feedstock is only substrates related to the sludge management within wastewater treatment plants, such as activated sludge and sludge from cesspits and influent waste water. In a biogas station within a wastewater treatment plant, the fermentation residue is labelled as anaerobically stabilized sludge, rather than digestate.

Other – the feedstock is waste specified in Act on Waste 31/2011 and animal by-products according to Regulation of the European Parliament and Council 1069/2009, on health rules for animal by-products and derived products not intended for human consumption.

Classification according to digestate application method

Fertilizer on agricultural land – subject to Regulation 271/2009, on requirements for fertilizers, digestate is a type of an organic fertilizer (type 18.1 e) and, in accordance with Act 9/2009 on fertilizers, it is used for fertilizing agricultural land due to its excellent properties caused by fermentation. However, subject to Act 254/2001, on waters, as amended, digestate belongs among harmful substances and its penetration into surface or ground water must be prevented. In addition, it must not be applied on ameliorated land, wet land, land covered by snow or if frost-bound. (Marada et al., 2008; Mareček et al., 2010; Kužel et al., 2010; Kolář et al., 2011)

Use outside agricultural or forest land – in accordance with Regulation 341/2008, Coll., on details on biodegradable waste management, digestates formed by digestion of biowaste are labelled as remediation digestates. They are classified into 4 groups. According to the individual groups and classes, digestates are, for example, applied on ground surface in sports or recreation facilities, amenity planting, remediation of waste disposal sites, etc.

Other uses – in accordance with Act on Waste 31/2011, digestate must be disposed of if it fails to comply with the requirements set for fertilizers or remediation digestate due to their over-limit values of hazardous elements or foreign substances. There are several disposal options. For example, it may be dumped or used to produce solid alternative fuel when dried and mixed with other types of biomass.

Digestate as an issue

According to the National Technical Platform for Biogas, as of 31 December 2012 there were 481 biogas power plants in the CR with an installed capacity of 363 MW. The number is likely to grow due to the rising redemption price for power from biogas.

Digestate may be perceived from several points of view. First, it is a by-product in biogas generation, applicable as an organomineral or slightly mineral fertilizer. Second, it is waste which may introduce into soils hazardous or even toxic substances which soil microorganisms are not able to degrade. Therefore, they accumulate there, which is not sustainable in the long run.

The current research and available literature deal with the fermentation process itself, its intensification and various types of substrates, i.e. agricultural crops specially grown for the purposes and waste from agriculture. For more information, see Kužel et al., 2010; Hansges el al., 2011; Bühle et al., 2011; Braguglia et al., 2012; Martín et al., 2002; Dewil et al., 2007. Next, research is carried out on the properties of digestate, improving its applicability as fertilizer to enhance the plant growth or enhancement of soil structural properties with respect to aeration. For more information see Kolář et al., 2011; Mareček et al., 2010; Kužel et al., 2010. If the research is carried out by agricultural organizations, they often aim to increase the proportion of dry matter in the digestate or decrease the quantity of the liquid phase, which is more advantageous in terms of the economy of fertilizing. However, the issue of digestate is not dealt with in a complex manner. On one part, the useful components are to be used to maximum and, on the other, the environment should be protected.

Materials and methods

The Institute of Environmental Engineering (IEE), HGF, VŠB-TUO, began a project in 2013 which is co-financed by the Ministry of Agriculture and Severomoravské vodovody a kanalizace Ostrava a.s. It aims to research into processing, use and disposal of waste products from biogas stations. Considering a suitable technology of digestate processing, it is important to separate the solid phase from the liquid one and purify the liquid phase. The objective of the liquid phase purification technology is to obtain another solid phase, which is potentially applicable in agriculture, and water to be handled according to its degree of purification.

Cooperation with a purely agricultural biogas station Stonava Farm was started. The feedstock is pig's semi-liquid manure from their factory farming. It is transported by a system of pumps and reservoirs into the biogas station system. Next, maize silage and crushed maize is used. The maize is also grown in the farm. Biogas generation takes place in two stages at holding time around 80 days. First, the substrate is conducted into a fermentor (in operation since 2011, it has a square floor plan and a paddle stirrer), where the stage of anaerobic digestion occurs. Next, the fermented substrate is pumped into the original fermentors (in operation since 2009, a circular floor plan), where the second stage of biogas generation takes place. Both the stages occur at 45°C. The generated biogas is used to heat and generate power for the whole farm, as well as it is distributed into the power system. The produced digestate is stored in reservoirs to be spread on fields.

Sampling

Samples were drawn by Stonava Biogas Station staff into 10-litre PE cans in March 2013. The sampling was executed from a pumping valve downstream the second-stage fermentors and upstream the storing reservoir for digestate.

Centrifuging the digestate sample

The drawn sample of digestate can be subjectively assessed as a heterogeneous viscous mixture with distinguishable residues of undigested maize silage, of dark brown-green colour due to digested and undigested faeces and silage in the form of scattered sewage. The mixture had a putrid odour. However, when compared to feedstock, i.e. pig's semi-liquid manure and silage, there was a decrease in the typical odour.

Within the experiments the digestate was first filtered through a filter paper KA1-M. However, it was not filterable under atmospheric pressure. Although underpressure was applied, the digestate sample was not filterable. Therefore, a *Thermo electron* Centrifuge, type IEC CL10, was used to separate the solid phase. The digestate was dosed into plastic cuvettes of 50 ml. To achieve effective separation of both phases, centrifuging lasted for 10 minutes at frequency of 4,000 RPM.

Sample analyses were carried out in an accredited laboratory Laboratoř Morava, s.r.o. Dry matter was determined in the samples of digestate, sludge liquor and separatum according to ČSN EN 12879; total phosphorus according to JPP ÚKZÚZ (Uniform procedure of Central Institute for Supervising and Testing in Agriculture), ammoniated nitrogen according to JPP ÚKZÚZ, CODCr according to ČSN ISO 6060, and BOD5 according to ČSN EN 1899-1.

In addition, analyses of digestate and sludge liquor were carried out in the laboratory of the project workplace, and sample density was determined pycnometrically, followed by total phosphorus determination according to ČSN EN ISO 6878, ammoniated nitrogen according to ČSN ISO 7150-1, COD_{Cr} according to TNV 757520, and BOD_5 according to ČSN EN 1899-1.

Results and discussion

Having centrifuged the samples, 2 phases were obtained, i.e. liquid sludge liquor and solid separatum. The liquid phase constituted of about 70% and the separate of about 30% of the original volume. Sludge liquor can be characterized as a viscous liquid of a lighter brown-green colour than the initial feedstock with a lower content of fine sludge. There are no more distinguishable particles of silage. Also, the sensoric properties were much better than in digestate. Separatum is a diggable solid mixture with residues of undigested feedstock and fine sludge. It manifests putrid odour (See Figure 1).

Table 1 shows the results measured in an accredited testing laboratory. However, the final values of COD_{Cr} and BOD_5 in digestate and separatum are not completely objective as this method is applicable for waste water. The samples had to be pre-mixed, homogenized and placed in a solution which was further processed according to the relevant standard. Nevertheless, the data are sufficient for reference.

Considering the testing of the selected procedures and their evaluation in the project workplace, a laboratory of Water Technology, VŠB – TU Ostrava, it was necessary to find out whether the measured results were comparable to the results measured in the accredited laboratory. Therefore, the observed indicators were also determined in the samples of digestate and sludge liquor in the university laboratory. Various sample dilution proportions were also tested. The results from the accredited laboratory are in $mg.kg^{-1}$ of the original sample weight. The results from the university laboratory are in $mg.l^{-1}$. It was also vital to measure the density of the digestate and sludge liquor samples.

The results measured in the project workplace laboratory did not much differ from the results taken in the accredited testing laboratory, even considering different measuring units. The density of digestate and sludge liquor was approximately 1000 $kg.m^{-3}$, and thus the results can be mutually compared even if expressed in $mg.kg^{-1}$ of original weight or in $mg.l^{-1}$ of the sample.

Fig. 1. Separatum, sludge liquor, digestate (left to right)

Rys. 1. Substancja oddzielona, ciecz osadowa, produkt pofermentacyjny

Table 1 Sample analyses results – Laboratoř Morava, s.r.o.

Tabela 1. Wyniki analizy próbki – Laboratorium Morava

Indicator	Unit	*Digestate*	*Sludge liquor*	*Separate*
Total dry matter	%	4.32	2.52	11.3
Phosphorus	$mg.kg^{-1}$ of original wt	688	187	1 320
Ammoniated nitrogen	$mg.kg^{-1}$ of original wt	2 650	2 630	2 430
COD_{Cr}	$mg.kg^{-1}$ of original wt	30 000	25 800	97 000
BOD_5	$mg.kg^{-1}$ of original wt	2 880	3 280	7 900

Table 2 Sample analyses results – laboratory of Water Technology, IEE

Tabela 2. Wyniki analizy próbki – Laboratorium Technologii Wody, IEE

Indicator	Unit	Digestate		Sludge liquor	
		Dilution		Dilution	
P_{total}	$mg.l^{-1}$	1:2000	–[a)]	1:500	–[a)]
		1:2500	712	1:750	158
		1:3000	741	1:1000	166
$N\text{-}NH_4$	$mg.l^{-1}$	1:1000	–[a)]	1:1000	–[a)]
		1:1500	2380	1:1500	2410
		1:2000	2540	1:2000	2490
COD_{Cr}	$mg.l^{-1}$	1:20	29620	1:20	28150
		1:50	31140	1:50	26970
		1:100	30520	1:100	26570
BOD_5	$mg.l^{-1}$	1:500	2650	1:500	2980
		1:750	2800	1:750	3120
		1:1000	2990	1:1000	3190
Density	$kg.m^{-3}$	1020±5		1005±5	

[a)] the value was higher than the calibration curve extent

Contrasting $BOD_5 : COD_{Cr}$ it is possible to gather which component of organic pollution is biodegradable. If the proportion of BOD_5 and COD_{Cr} is lower or equal to 0.2, it is the case of substances difficult to biodegrade; if the proportion of the values is over 0.5, there are easily biodegradable organics (Chudoba et al., 1991). The results in Tables 1 and 2 imply that in the digestate and sludge liquor there are organic substances difficult to biodegrade as the proportion of the indicators was always below 0.2, which confirmed the original assumption.

Conclusion

High quantities of digestate are produced due to the growing number of biogas stations. The most widespread application of digestate is a fertilizer in agriculture. However, the above mentioned information implies that the physical-chemical properties of digestate are problematic and its application in the form of a fertilizer is questionable. The paper is a primary study dealing with the current state of digestate management, properties of digestate and separation products. The digestate was sampled in an agricultural biogas station in Stonava. It was subjectively assessed for its organoleptic characteristics, such as odour and colour, and the following were determined, dry matter, total phosphorus, ammoniated nitrogen and organics by means of COD_{Cr} and BOD_5, in an accredited testing laboratory as well as in the laboratory of the project workplace. The acquired results did not differ much. Extremely high concentrations were measured in all the indicators. The composition and consistence of separate is useful for fertilizing. Despite being heavily polluted, the sludge liquor still contains important elements applicable in fertilizing. The future laboratory activity shall focus on testing flocculation and coagulation agents for more effective separation of the solid phase from the liquid one. The agents will be tested prior to digestate centrifuging as well as during separation of the solid phase from the sludge liquor.

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Badania nad stanem procesów fermentacji w Republice Czeskiej

Niniejszy referat koncentruje się na zwiększaniu ilości produktu pofermentacyjnego, który jest finalnym produktem fermentacji beztlenowej w stacjach biogazu używanych jako alternatywne źródło energii lub jako zakłady fermentacyjne, które mogą redukować ilości odpadów biodegradowalnych na składowiskach. Produkt pofermentacyjny jest materiałem powstałym w fermentacji beztlenowej w stacji biogazu będący dodatkiem do produktu głównego – biogazu. Potencjalne zastosowanie tego produktu jest ograniczone ze względu na jego specyficzne właściwości fizyczne. W szczególności jego pojedyncze składniki są niezwykle trudne do oddzielenia a jego skład chemiczny bądź mikrobiologiczny jest unikalny. Na jakość produktu pofermentacyjnego wpływa głównie rodzaj biomasy z której powstaje. Referat przedstawia aktualne podejście do gospodarki produktem pofermentacyjnym. Zawiera również sposób pobierania i analizy produktu pofermentacyjnego, przetwarzanie próbek w laboratoryjnych wirówkach oraz ocenę właściwości i oddzielenie produktów, tj. cieczy osadowej i substancji oddzielonej.

Słowa kluczowe: fermentacja, stacja biogazu, faza ciekła z osadu, separacja