STUDY AND RESEARCH ON CLEANING PROCEDURES OF ANAEROBIC DIGESTION PRODUCTS

STUDIUM A VÝZKUM POSTUPŮ ČIŠTĚNÍ ANAEROBNÍ DIGESCE

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Abstract

This paper focuses on increasing quantities of digestate, a final product of anaerobic digestion, in biogas stations being built as alternative sources of energy. The potential use of digestate is limited due to its rather specific physical properties. This paper presents current approaches to digestate and digestate management. The objective is to compare the properties of digestate and the products of its separation via centrifuging, i.e. the liquid phase known as digestate liquor, and the solid phase referred to as digestate fibre. Its focus is mainly laid on techniques for dewatering digestate in low-solid anaerobic processes only, which have been tested for the effectiveness of the basic physical and chemical methods including their combinations. The measured results show that the use of coagulants and flocculants for this purpose would be very problematic in practice with regard to their high consumption as well as the need to input other elements into the process.

Abstrakt

Předložený článek se zabývá problematikou narůstajícího množství digestátu jako konečného produktu anaerobní digesce v bioplynových stanicích, budovaných jako alternativní zdroje energie. Digestát má v současné době omezené využití, které je dáno jeho specifickými fyzikálními vlastnostmi, zejména extrémně problematickou separací jednotlivých složek, ale také chemickým a mikrobiologickým složením. Jeho vlastnosti jsou z největší části ovlivněny druhem zpracovávané biomasy. V úvodní části tato studie předkládá současné možnosti nakládání s digestátem. Předmětem experimentální části je popis odběru a analýzy vzorků digestátu včetně jeho zpracování v laboratorních podmínkách použitím odstředění a následné posouzení vlastností digestátu a produktů separace, tj. fugátu a separátu a dále testování koagulačních a flokulačních činidel pro účinnější separaci tuhé fáze z digestátu, resp. fugátu. Použití koagulantů a flokulantů pro tyto účely v praxi by bylo značně problematické s ohledem na jejich vysokou spotřebu a vnos dalších prvků do procesu.

Key words: biogas plant, biogas, whole digestate, digestate liquor, digestate fibre, flocculation and coagulation agents

1 INTRODUCTION

Digestate is produced by biogas plants (BGPs) whose number significantly rises. The growth is caused by the increasing interest in alternative, or renewable energy sources, and the requirements for reducing biodegradable waste. The use of alternative energy sources is also an integral part of the energy policy in the Czech Republic, similarly to the European Union, where biogas shows a growing trend.

The process used in biogas plants is a process of anaerobic digestion (also called fermentation). It is a complex biochemical, chemical and physicochemical process of organic matter conversion in the absence of air (oxygen) to a gas mixture and a fermented undecomposed organic residue. This process consists of four consecutive stages: hydrolysis, acidogenesis, acetogenesis and methanogenesis. The product of one phase serves as a substrate for the second phase, and failure or disruption of one of the activities can break the dynamics of the system. These process steps are subsequent, but in continuous operation they occur simultaneously. The degree of lability and stability within the hydrolysis of organic substances (e.g., the difference between carbohydrate raw materials and sawdust with high lignin content) is an important factor as well. (Dohányos at al., 1998; Schulz, 2004; Straka et al., 2006; Kára et al., 2007)

The process of anaerobic fermentation affects the inaccessibility of air, pH (optimum 6.3 to 7.8), substrate composition (which requires a correct ratio of organic matter, nitrogen and phosphorus, in addition to the presence of micronutrients and vice versa the absence of heavy metals, oxidants, etc.), residence time and applied technology. (Dohányos et al., 1998; Schulz, 2004; Kasali & Senior, 2007; Dohányos, 2014)

Biogas, which is a mixture primarily of methane and carbon dioxide, is the main product of anaerobic digestion besides several other minor compounds, and is used mainly for the production of electricity and heat. In addition to biogas, biogas plants produce a fermentation residue called digestate. The amount of the produced digestate increases proportionally with the increasing number of biogas plants. The growth in the number of BGPs are supported by grants from the EU.

The anaerobic digestion process can be theoretically performed with almost any organic material with high organic content and solid content of less than 50%. Feedstock for BPSs may be biodegradable municipal waste (BMW), sewage sludge, agricultural crops and wastes from livestock production.

It is possible to divide the anaerobic digestion processes into two types according to the solid contained in biomass – dry and wet, which is associated with the way of transporting biomass to a digester. Although the dry running method is cheaper (less heat loss during water heating), the wet anaerobic digestion process is used more frequently as the biogas production thus achieves higher stability. (Mužík and Slejška, 2014)

1.1 Digestate

Digestate is a stabilized material containing material undigested during digestion and necrotic microorganisms. Its properties are mostly affected by the kind of processed biomass and process parameters.

Digestate may be classified according to various aspects, e.g. dry matter, feedstock or methods of its application. Most often, we encounter digestate which is the feedstock from agriculture and is most widely used for fertilization. It should be noted that from a view of farmers, there is a problem consisting in its large amount and the fact that it is too fluid (low dry matter content usually not exceeding 8 wt. %).

Digestate may be perceived from several points of view. First, it is a by-product in biogas generation, applicable as a mineral fertilizer. Second, it is waste which may cause penetration of hazardous or even toxic substances in the soil, which are not degradable by soil microorganisms. Therefore, they accumulate there that is unsustainable in the long run.

On the basis of the previously acquired information and experience, it can be concluded that the composition of digestate is suitable for fertilization, because up to 50% of organic nitrogen, such as ammonium ion, is released in fermentors by plants in the form of mineral uptake. If we assess the amount of nutrient in fertilizer from the whole digestate, especially a mineral and nitrogen fertilizer (in absolute values), it might seem that it contains high amounts of phosphorus and potassium, but in terms of agrochemicals the amounts are relatively low. (Kolář et al., 2010). On the other hand, it contains large amounts of relatively stabilized indigestible organic matter, because almost all biodegradable organic substances were converted during the long process of anaerobic digestion to biogas, and it is not clear whether the organic matter present in the digestate will be well spent by microorganisms in the soil. There is very problematic high water content, however, mainly in that part of the digestate, to which nitrogen in an unstable form is bound, which is well applicable for plants (crops). Dry matter content of the typical digestate is between 2-8%, usually not exceeding 4%.

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 Kolář et al., 2010; Hansges el al., 2011; Bühle et al., 2011; Braguglia et al., 2012; Martín et al., 2002; Dewil et al., 2007. The research has been 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; Kolář 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 has not been studied in its complexity. On the one hand, useful components are to be used to maximum, on the other hand, the environment should be protected.

1.2 Possibilities of whole digestate management

The following diagram shows theoretical possibilities of disposing the whole digestate or cleaning the digestate, and was generated on the basis of available literature sources. (Blumerg, 2014; Chambers, 2011; Chauzy et al., 2010; Fuschs et al., 2010; Nielsen et al., 2005; Degremont. Heliantis™ Solar Sludge Drying, 2012)

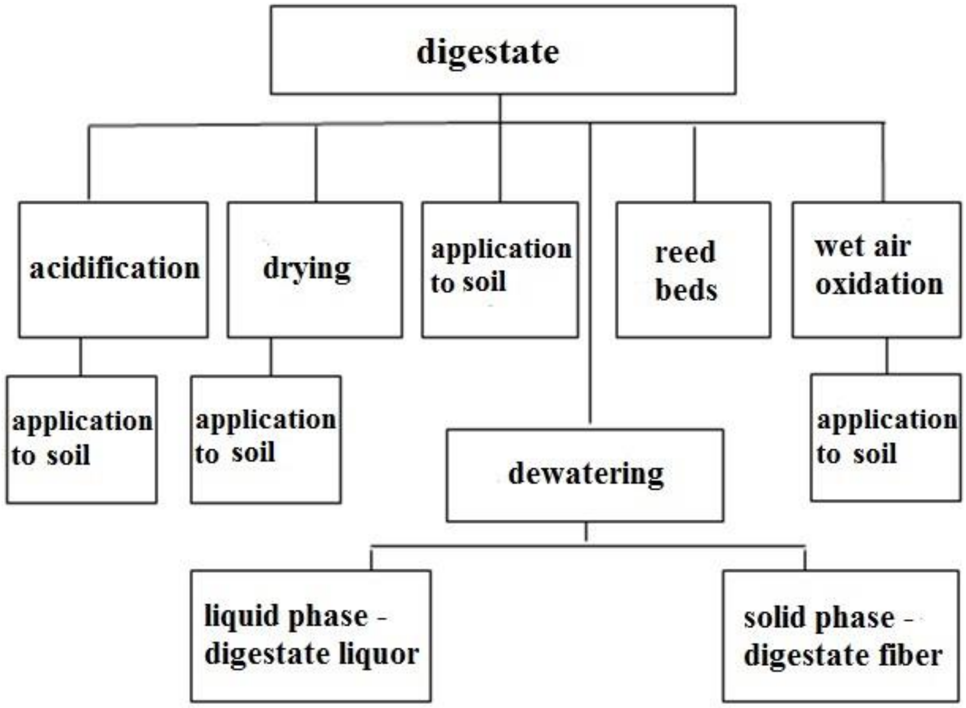

Fig. 1 Variants of digestate management

Digestate can be applied directly to the soil, which is a commonly used procedure. To prevent the release of ammonia, the acidification process can be used; however, it is necessary to take into account that this digestate management method will be connected with soil acidification, which is undesirable for the most types of soils.

By drying, if it is dried, the digestate has got rid of excess water. The dried digestate can be applied to soil as a fertilizer and is much easier to handle. However, in general, the thermal methods are very expensive. Biogas releases from cogeneration units a large amount of heat, but the amount is not able to ensure the drying of the digestate so it is often used only for drying wood biomass. Although the digestate volume is relatively large in a BGP, the drying of digestate is not frequently used in practice. It is also possible to use solar drying. In this case, the digestate is fed into ventilated greenhouses. Nevertheless, there is a disadvantage due to the requirement for a large area, which cannot be ensured for following volumes of digestate, despite the possibility to provide the waste heat from cogeneration units. Each method has its drawbacks, whether the high energy demand or the needed amount of space.

The evaporation, which is able to ensure about 20% dryness of digestate, is a less economically demanding process than drying.

Wet air oxidation is the oxidation of liquid sludge (digestate), under air conditions of increased pressure (4-6 MPa) and temperatures (200-300°C), which represents up to 90% of organic matter transferred in the sludge into the liquid phase in a form of mixtures of short-chain fatty acids and methanol. Even in this case, there are complicated and economically demanding technology requirements, such as high temperature and pressure, and final treatment of resulting gas and waste water.

Reed beds are a good solution for the production of low volume digestate for sites with low volume production of digestate. These are areas below ground level where reeds are planted and the digestate is being cleaned in the root system. Simultaneously, the digestate is thickened by evaporation. Water flowing from such system is useful for example for irrigation. Mineralization of digestate takes up to 10 years. Then it is possible to extract the sludge and apply it as an inorganic fertilizer. This technology is highly dependent on the size of required area.

2 THICKENING AND DEWATERING OF DIGESTATE

As already mentioned, there are problematic properties of digestate, such as low solid content, so thickening and dewatering is the only option and a separate chapter of the digestate management. Requirements for these processes are as follows: gravitational forces, centrifugal forces or pressure.

When thickening the digestate, 5-10 % solid content of sludge can be reached. A horizontal belt filter or centrifuge can be used. The process can be intensified by adding a polymer, which causes flocculation of colloidal particles. However, the required amount of polymers is extremely high (see results below).

When dewatering the digestate, 18% solid content of slurry and more can be achieved. For these purposes, we can use sieve belt presses or centrifuges as well as the process can be intensified in this case by dosing a polymer. The separated solid phase is known as digestate fibre and the separated liquid phase as digestate liquor. The digestate slurry or the solid digestate from high solids "dry" anaerobic digestion often has 18-25% total solid content and some technologies produce even drier digestate. But there are only tens of "dry" biogas plants in Europe.

2.1 Possibilities of digestate fibre management

The following diagram (Fig. 2) summarizes theoretical possibilities of disposing the digestate fibre, and was generated on the basis of available literature sources. (Chambers, 2011; Fuschs et al., 2010; Pyreg, 2011; Pell Frichmann consultans Ltd., 2012; Degremont. Heliantis™ Solar Sludge Drying, 2012)

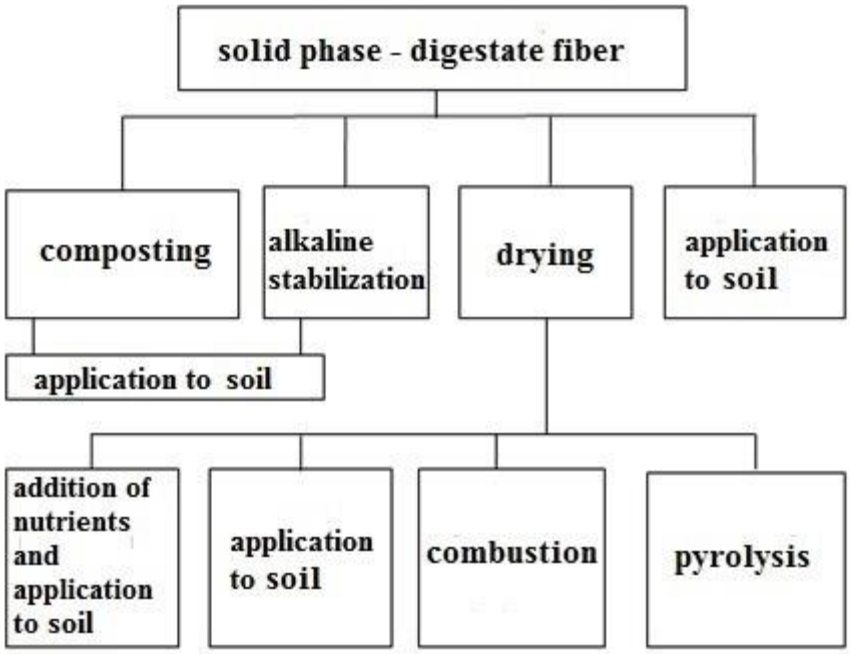

Fig. 2 Selected options for digestate fibre management

The options include the composting of digestate fibre, lime stabilization, which results in the destruction of pathogens, however, an increase in pH, which almost always causes the release of ammonia also included in the digestate fibre (but several years ago, fertilization with ammonia was common so it should not be a problem for farmers). The direct application to the soil is the most frequently used option. Finally, it is also possible to dry the fibre fraction and to enrich it with nutritional elements, and thus, improve its quality as a fertilizer, and apply it into the soil. The fibre fraction of digestate is a good solution to lighten and aerate the soil. The improved access of air to the root system and soil improvement hydrolimits can have a good yield effect, which unfortunately is often mistakenly ascribed only to nutrients. (Vaněk et al., 1998)

The dried digestate fibre may be used as fuel for combustion or fuel production such as pyrolysis and gasification. Adding suitable inert soil to the digestate fibre (or wash it with water), and then use it as a substrate for pot culture is another theoretical option.

2.2 Possibilities of digestate liquor management

The following diagram (Fig. 3) summarizes the options for the management of digestate liquor. (De la Rubia, 2010; Botheju and Bakke, 2010; Driver, 1998; Gao, 2010; Guštin, 2011; Iyovo and Du, 2010; Maurer et al., 2001; Tchobanoglous et al., 2004; Evans, 2009)

Volume LX (2014), No.4
p. 39-50, ISSN 1802-5420

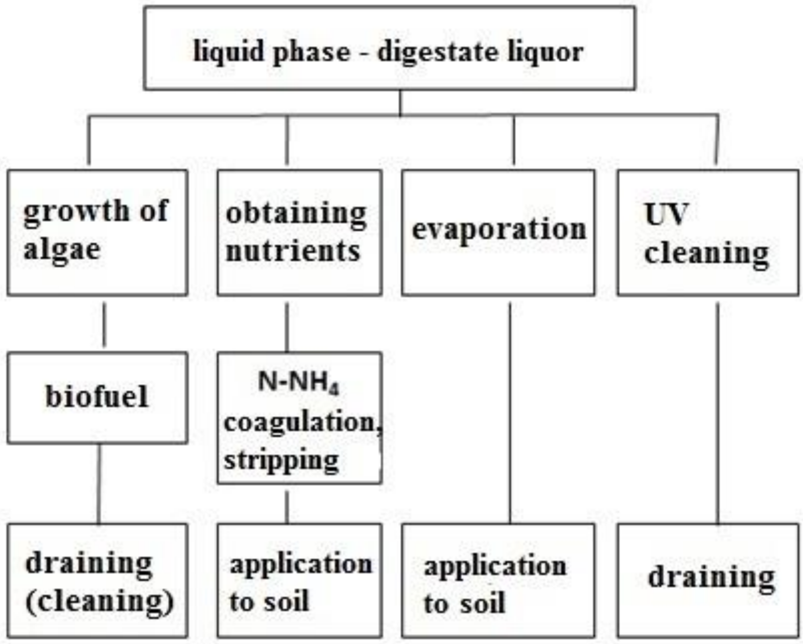

Fig. 3 Selected options of digestate liquor management

The liquid phase can be used for the production of algae as a source for fuel production. In Netherland, digestate liquor is used as a raw material for the growth of algae which is further used for fuel production.

The digestate liquor contains valuable elements. It is especially ammonium nitrogen that is most appropriately directly ploughed into the soil; however, the struvite precipitation is another theoretical option.

Evaporation (wet surface heat exchangers), typically utilised for whole digestate treatment, can be realized with equipment operating on the principle of a heat exchanger. After the evaporation, the material can be re-mixed with digestate fibre and used for fertilization. This system was launched in Scotland and is able to reduce the volume of digestate liquor to 15% of the initial volume, while the waste heat comes from a cogeneration unit.

Cleaning the digestate liquor using ultrafiltration and reverse osmosis – authors in foreign publications refer to the laboratory results of these methods, but their practical application in biogas plants in available resources have not been found. That is why their use is highly questionable with regard to the fouling of membranes, optionally filters, serving as protection against microscopic colloidal particles.

3 EXPERIMENTAL PART

Within the experimental part, all digestate samples were collected from agricultural biogas plants in the Moravian-Silesian and Olomouc Regions; the samples were subjected to tests of separation of the solid phase, and digestate products (digestate liquor and digestate fibre) were analysed and coagulation and flocculation agents were tested for the intensification of the process of separation of the solid phase of whole digestate.

3.1 Sampling and analysis of whole digestate, digestate liquor and digestate fibre

Digestate samples were collected from agriculture biogas plants in two-month intervals. The monitored BGP processed organic waste from pigs, silage from well silage agricultural crops (corn and beet tails), and at the end of summer months, fresh grass or sorghum, and during winter and spring months, silage with high solid content (more than 50% of dry matter) were added. After centrifuging the sample of digestate on laboratory conditions, the digestate liquor and digestate fibre fractions were subjected to a chemical analysis. They were monitored for CODCr, BOD5, total phosphorus and ammonia contents.

The aim was to compare the properties of the whole digestate and the separated products by centrifugation, (liquid phase – digestate liquor and solid phase – digestate fibre). The obtained results were compared. Laboratory tests and cleaning of the whole digestate and digestate liquor were carried out in the laboratory at the Technology and Water Management Department of the Faculty of Mining and Geology at the VSB-Technical University of Ostrava. The analyses of the samples were performed also in an accredited laboratory.

The results that have been obtained from both laboratories are the same (even if every time different units were used). The digestate and digestate liquor density is about 1000 kgm^{-3} so the results can be mutually

Volume LX (2014), No.4
p. 39-50, ISSN 1802-5420

compared even if they are expressed in mg.kg^{-1} of the original weight or in mg.l^{-1} of the sample. The analyses of the samples were carried out in the company Laboratoř MORAVA, s.r.o., an accredited laboratory. In the samples of the whole digestate, digestate liquor and digestate fibre, solids were determined according to EN 12879: total phosphorus by JPP ÚKZÚZ (a uniform workflow of the Central Institute for Supervising and Testing in Agriculture), ammonia nitrogen by JPP ÚKZÚZ, $CHSK_{Cr}$ according to ISO 6060, and BOD_5 according to EN 1899-1.

Further analyses of digestate and fugate were conducted in the university laboratory. The samples density was determined using the pycnometer method, total phosphorus according to EN ISO 6878, ammonia nitrogen according to ISO 7150-1, COD_{Cr} according to TNV 757520, and BOD_5 according to EN 1899-1.

4 RESULTS AND DISCUSSION

According to a subjective assessment of all digestate samples, it can be concluded that the digestate is a heterogeneous viscous mixture of dark brown-green colour with visible unaltered remains (e.g. corn silage) and with the typical putrefactive and ammonia odour.

The measured properties of digestate from various agricultural sources have comparable values. Due to the high concentrations and the need for high dilution of samples, the measurements have a degree of uncertainty; however, understanding the issue is sufficient.

The average value of total phosphorus was P_{total} 800 mg.kg^{-1} of the initial sample weight. The average value of ammonia was $N\text{-}NH_4$ 2.500 mg.kg^{-1} of the initial sample weight. The average value of organic substances, expressed as COD_{Cr} in the whole digestate was 30.000 mg.kg^{-1} of the original sample weight. The average value of biodegradable substances expressed as BOD_5 in the whole digestate was about 3200 mg.kg^{-1} of the original sample weight. BOD_5 values are approximately 10 times lower than the values of $CHSK_{Cr}$.

4.1 Separation of digestate fibre

First the digestate samples were filtered through the KA1-M filter paper, but the digestate was not filterable under atmospheric pressure. The digestate sample was not filterable either in vacuum. For the solid phase separation (digestate fibre), the laboratory centrifuges of the Merci company were used. The digestate was dispensed into plastic tubes of 200 ml and subjected to centrifugation at 4100 rpm for 5 min.

Fig. 4 shows photographs of products separated by centrifugation of the solid digestate which is in the liquid phase – digestate liquor representing around 70-80% of the initial volume of the whole digestate. The digestate liquor shown on the left, can be characterized as a viscous brownish-green liquid lighter than the starting mixture (whole digestate is shown on the right) with a lower content of fine sludge. There is a noticeable residue of silage no longer. Also sensory properties were significantly better than those of the whole digestate.

The further products obtained by the centrifugation were in the solid phase – digestate fibre constituting about 20-30% of the initial volume of the whole digestate. The digestate fibre can be characterized as a solid engravable mixture containing the remains of the undecomposed input substrate and fine sludge with a typical smell.

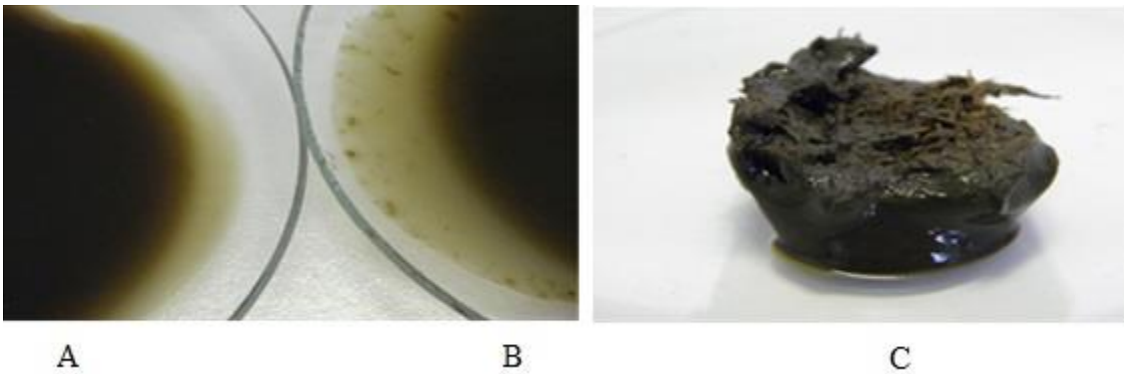

Fig. 4 Samples of digestate liquor (A); whole digestate (B); digestate fibre (C)

The results of compositions of digestate fibre and digestate liquor from individual agriculture biogas plants were also compared.

The average value of total phosphorus was Ptotal 800 mg.kg^{-1} of the initial sample weight. The average value of ammonia was $N\text{-}NH_4$ 2.500 mg.kg^{-1} of the initial sample weight. The average value of organic substances expressed as COD_{Cr} in the whole digestate was 30.000 mg.kg^{-1} of the initial sample weight. The average value of biodegradable substances expressed as BOD_5 in the whole digestate was about 3200 mg.kg^{-1} of the initial sample weight. The BOD_5 values were approximately 10 times lower than the values of $CHSK_{Cr}$.

Using the ratio of BOD_5:COD_{Cr}, it can be concluded that it is a heavily biologically degradable substance. Digestate fibre is mainly applicable in agriculture for soil aeration, although it contains a relatively high proportion of total phosphorus and ammonia; but it is attached to the stabilized organic material and it is almost inaccessible for plants. It had been expected as the instable organic matter in the feed material was decomposed by anaerobic fermentation for about 40 days or more.

With regard to the concentrations of ammonia nitrogen and phosphorus, it is apparent that phosphorus is mainly in the separator, while the distribution of ammonia in the two phases is approximately the same.

Tab. 1 Average values of indicators in samples of whole digestate, digestate liquor and digestate fibre

Indicator	Unit	Whole digestate	Digestate liquor	Digestate fibre
Dry mass	%	4.32	1.52	16.3
P_{celk}	$mg.kg^{-1}$ of orig. weight	800	200	1 600
$N\text{-}NH_4$	$mg.kg^{-1}$ of orig. weight	2 500	2 500	2 500
$CHSK_{Cr}$	$mg.kg^{-1}$ of orig. weight	30 000	26 000	97 000
BSK_5	$mg.kg^{-1}$ of orig. weight	2 800	3 200	8 000

Digestate liquor (liquid phase) is heavily polluted, so cleaning procedures will be tested and analysed. It is important to realize that the digestate liquor contains valuable elements for farmers, therefore the aim, besides the cleaning, will also be to get the solid phase which is also useful for fertilization. It is necessary to consider the effectiveness of digestate liquor cleaning, because in agricultural practice, the application of liquid-suspension fertilizers is quite common.

4.2 Testing coagulating agents

Coagulation and separation is a set of processes that may be used for removing colloidal and macromolecular organic compounds from wastewater. Ferric or aluminium salts are used as coagulating agents.

During the laboratory testing, hydrates of ferric chloride and ferric sulphate were used, containing a comparable amount of ferric ions. If water is too dirty, it is essential to choose an appropriate dose based on the detected contamination. Therefore, it is appropriate to use the basic benefit formula $DZ = 8 * c$, where $c = COD$ (Pitter et al., 1983) for the calculation.

As it is usual in the coagulation tests, series of tests were conducted with multiple basic doses from 0.1 to 1.2 times the calculated base dose. The experiments were conducted with both the digestate liquor and the whole digestate.

The used coagulants caused a decrease in pH, therefore it was necessary to correct the course of coagulation and adjust the pH value to about 5, which was carried out by dosing calcium hydroxide. It was also required to add a certain amount of dilution water that was added in the process of dispensing the solutions of coagulants. The experiments were carried out through the use of 20% solutions of $FeCl_3$ or $Fe(SO_4)_3$. During the experiments, the suspension with lime milk was mixed using the LAVAL magnetic stirrer for 1 min. After that a dose of coagulant was added and the sample was mixed with the magnetic stirrer for 2 minutes at maximum speed and additional 10 minutes at low speed. Subsequently, the pH value was measured and the sample was filtered through the filter paper for quantitative analyses KA-4 at medium speed. The monitored indicators in the filtrate were determined.

4.3 Coagulant $FeCl_3$

It is necessary to add coagulant into the digestate (digestate liquor) to reduce the pH value to about pH 2. The value of pH is modified by the dose of $Ca(OH)_2$ as a 10% suspension. In order to achieve efficient coagulation, the doses of 50 ml of 10% slurry of Ca $(OH)_2$ and 160 ml of 20% $FeCl_3$ solution to 1 litre of digestate (digestate liquor) were used.

After the use of the effective doses of agents, it can be stated that the value of COD_{Cr} was reduced to about 600 mg · l^{-1} (η 99%); $N\text{-}NH_4$ 350 $mg.l^{-1}$ (η 85%); P_{total} 3 $mg.l^{-1}$ (η 99%). Conversely, there were found out

Volume LX (2014), No.4
p. 39-50, ISSN 1802-5420

increased concentrations of Cl^- 9300 mg.l^{-1}; Ca^{2+} 1200 mg.l^{-1}, pH was 4.8. In the analysis of the sludge, N, P, C, Fe and chlorides prevailed. (Vidlářová, 2013)

4.4 Coagulant $Fe_2(SO_4)_3$

It is necessary to add coagulant into the digestate (digestate liquor) to reduce the pH value to about pH 3. The value of pH is modified by the dose of $Ca(OH)_2$ – 10% suspension. To achieve efficient coagulation, the doses of 80 ml of 10% slurry of $Ca(OH)_2$ and 160 ml of 20% solution of $Fe_2(SO_4)_3$ in 1 l of digestate (digestate liquor) were used.

After the use of the effective doses of agents, it can be stated that the value of COD_{Cr} was reduced to about 500 mg · l^{-1} (η 98%); N-NH_4 1000 mg.l^{-1} (η 60%); P_{total} 2 mg.l^{-1} (η 99%); and Ca^{2+} and SO_4^{2-} concentrations increased to 600 mg.l^{-1}; 8000 mg.l $^{-1}$ respectively. The pH value was 5.8. In the analysis of the sludge, N, P, C, Fe and sulphates prevailed. (Vidlářová, 2013)

4.5 Evaluation of the use of coagulants

In order to achieve coagulation, extremely high doses of agents were used. The composition of the filtrate corresponded with the reagent. We achieved a significant reduction of organic compounds in the liquid phase, but there was also a significant increase in sulphate, or chloride and calcium ions. Likewise, in the filter cake, enormously high concentrations of nitrogen, phosphorus, organic matter iron and sulphates, or chlorides were found.

Regarding the usability of coagulants in the separated solid phase, which should primarily be used for fertilization of the soil, the content of nitrogen, phosphorus, calcium and organic substances is generally beneficial for fertilization. Also an iron concentration is beneficial, but the dose of coagulant must be high enough to carry out successful coagulation. Furthermore, the chloride content in fertilizers leads to the acidification of soil so it is preferable to use an organic material containing sulphates which can be commonly found in fertilizers (e.g. in fertilizers used for the cultivation of rape plant).

Coagulant tests use the same procedure for both the whole digestate and the digestate liquor (Fig. 5). It has been discovered that the samples of the digestate are filterable after coagulation when using the same volumes as for the coagulants in testing the digestate liquor, despite the fact that the undiluted digestate has a higher concentration than the undiluted digestate liquor COD_{Cr}, i.e. 30,000 mg.l^{-1} compared to 26,000 mg .l^{-1}. In several cases, foam formation was found. This can be eliminated by adding skimmers; or the flotation process can be tested in the whole digestate management, however, this will be the subject of further research. (Vidlářová, 2013)

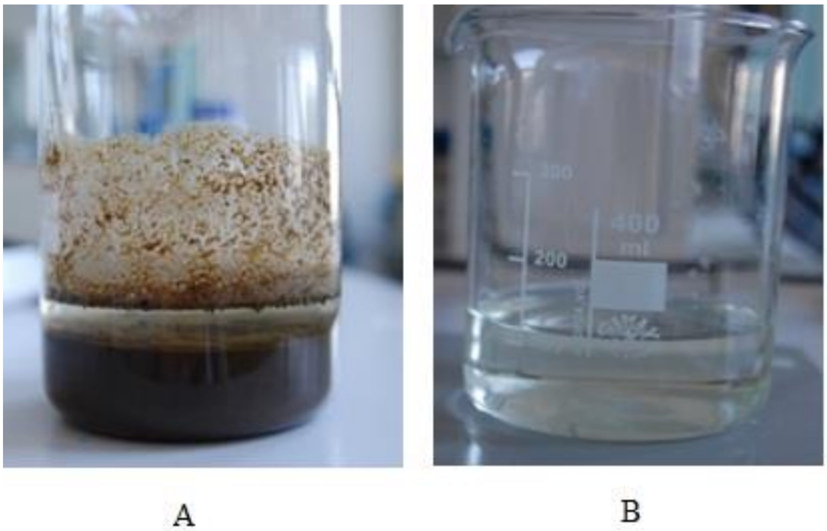

Fig. 5 Sample of whole digestate after using coagulation agents (A); filtrate (B) ($Fe_2(SO_4)_3$)

4.6 Testing flocculation agents

Flocculation with an organic polymeric flocculant is a process of destabilization of polymer colloids (flocculants) and there are two mechanisms. In the first case, it acts as a coagulant neutralizing the negative surface charge of sludge particles to permit subsequent aggregation, and in the other, it serves as a row bridging mechanism to activate the formation of flakes.

Digestate, or digestate liquor, is a system of macroscopic and colloidal particles which consists mostly of negatively charged particles.

Flocculants were tested as 0.1 or 0.05% solutions. For individual experiments, after dispensing the selected dose of flocculants, the suspension was always stirred with a glass rod and left for sedimentation. If the macro flakes were created, the pH value was measured and the suspension was filtered through the filter paper for the quantitative analysis KA-4 at medium speed. The monitored indicators were determined in the filtrate.

Anionic flocculants (SOKOFLOC 12 and 26) were the first test agents, which, as expected, did not cause the system destabilization, and, therefore, were excluded from further experiments. We also tested various types of cationic flocculants (SOKOFLOC 56, SOKOFLOC 61, SOKOFLOC 65, SOKOFLOC 68, SOKOFLOC 109, Superfloc C475 and C496 Superfloc). Good results were achieved, i.e. the destabilization and the formation of macro flakes, when using e.g. SOKOFLOC 61 and 65.

To achieve smooth flocculation when using the flocculants, an additional and large volume of water was required in comparison with the experiments with coagulants. As for the composition of the filtrate, after the application of effective doses of agents, we claim that the $CHSK_{Cr}$ value decreased to about 2000 mg · l^{-1} (η 93%); NH_4-N 360 mg.l^{-1} (η 85%); P_{total} 10 mg.l^{-1} (η 99%). The pH value was around 7. (Souček, 2014)

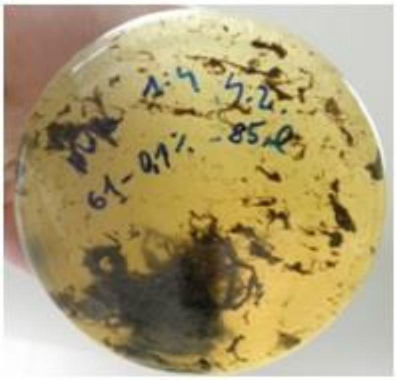

Fig. 6: Sample of whole digestate after flocculation (Sokoflok 61)

5 CONCLUSIONS

Digestate is one of the major environmental problems regarding the growing number and characteristics, especially its low dry matter content. The paper presents various theoretical possibilities for the treatment of whole digestate, digestate liquor and digestate fibre that were found in available literature. It also presents the results of a basic chemical analysis of individual components (whole digestate, digestate fibre and digestate liquor) which clearly shows that the digestate liquor is a very stable material containing elements which are difficult to use for plants. Then the presentation of used methods for the separation and purification of the whole digestate follows. The digestate fibre obtained by centrifugation is available directly to fertilization, and the digestate liquor is the liquid phase of the whole digestate. The digestate liquor is heavily polluted, but also contains important elements useful for the purpose of fertilization. In the research of the purification of the whole digestate and digestate liquor, first the properties of samples from five agriculture BGPs were evaluated. It was determined that the properties are comparable so the cleaning procedures generally applicable to the digestate can be applied. The methods for separation of the solid phase of the digestate – digestate fibre or digestate liquor were tested as well. If flocculants and coagulants are not used, centrifugation may be applied as a separation process. When adding coagulation and flocculation agents to intensify the process, their consumption for effective coagulation and flocculation was enormously high; the solid phase was well-separable by sedimentation and filtration. The use of coagulants and flocculants in practice would be highly questionable and problematic due to their high consumption and the need to input further elements into the process and hence to the product separation.

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RESUMÉ

Předložený článek se zabývá problematikou narůstajícího množství digestátu jako konečného produktu anaerobní digesce v bioplynových stanicích, budovaných jednak jako alternativní zdroje energie a dále jako zařízení schopné fermentovat, a tím snižovat množství ukládaného biodegradabilního odpadu na skládky.

Digestát je stabilizovaný materiál, který vzniká při anaerobní digesci v bioplynové stanici vedle hlavního produktu bioplynu. Producenty digestátu jsou bioplynové stanice, jejichž počet výrazně roste, a to s ohledem na zvyšující se zájem o alternativní resp. obnovitelné zdroje energie spolu s požadavky na redukci biodegradabilních odpadů.

Digestát má v současné době omezené využití, které je dáno jeho specifickými fyzikálními vlastnostmi, zejména extrémně problematickou separací jednotlivých složek, ale také chemickým a mikrobiologickým složením. Jeho vlastnosti jsou z největší části ovlivněny druhem zpracovávané biomasy. Digestát představuje environmentální problém s ohledem na jeho rostoucí množství a vlastnosti, především nízký obsah sušiny.

Odstředěním digestátu získáme separát, a fugát. Mezi možnosti nakládání se separátem se řadí kompostování separátu. Nejvyužívanější možností je přímá aplikace přímo na půdu. V neposlední řadě je také možné separát sušit a dále s ním nakládat, a to obohacením o nutriční prvky a tímto zvýšit jeho kvalitu jako hnojiva a aplikovat na půdu. Vysušený separát je možné také využívat jako palivo při spalování nebo ho využít pro výrobu paliva, a to uplatněním procesů jako jsou pyrolýza a zplyňování.

Kapalná fáze digestátu - fugát, která je silně znečištěná, nicméně obsahuje důležité prvky rovněž využitelné pro účely hnojení. Kapalnou fázi je možné využít pro produkci řas jako zdroje pro výrobu paliva. Z fugátu mohou být získány cenné prvky (týká se to především amoniakálního dusík).

V rámci výzkumu čištění digestátu a fugátu byly nejprve zhodnoceny vlastnosti vzorků digestátu z 5 zemědělských bioplynových stanic. Byly sledovány ukazatele $CHSK_{Cr}$, BSK_5, celkový fosfor a amoniakální dusík. Cílem bylo srovnat vlastnosti digestátu a produktů jeho separace odstředěním, tj. kapalné fáze tzv. fugátu a tuhé fáze, tzv. separátu. Na základě srovnání bylo zjištěno, že vlastnosti digestátů z různých zemědělských zdrojů mají srovnatelné vlastnosti Na základě tohoto zjištění můžeme konstatovat, že lze uplatňovat postupy čištění, které by byly aplikovatelné na digestát obecně.

Dále byly testovány způsoby separace tuhé fáze z digestátu, resp. fugátu. Bez použití flokulačních a koagulačních činidel lze pro separaci uplatnit proces odstřeďování. Co se týče posouzení vhodnosti použití koagulačních činidel, v odseparované tuhé fázi, která by měla být použita především ke hnojení půd, je obsah dusíku, fosforu, vápníku a organických látek za účelem hnojení obecně přínosný. Rovněž určitá koncentrace železa je přínosná, nicméně v dávce koagulantu potřebné k úspěšné koagulaci, je jeho obsah vysoký. V případě použití flokulantů byl pro dobrý průběh flokulace, oproti experimentům při použití koagulantů, nutný přídavek většího objemu ředící vody.

Pro intenzifikaci procesu odstřeďování použitím koagulačních a flokulačních činidel účinné, ale jejich spotřeba pro účinnou koagulaci a flokulaci byla enormně vysoká. Tuhá faze je dobře oddělitelná i sedimentací a filtrací. Použití koagulantů a flokulantů pro tyto účely v praxi by bylo značně diskutabilní a problematické i s ohledem je na jejich vysokou spotřebu a vnos dalších prvků do procesu a tedy do produktů separace.