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Agricultural use of biogas digestate as a replacement fertilizers

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Abstract

Functioning of an agricultural biogas plant is connected with generating large amounts of post-digestion matter. After considering the physicochemical properties, the basic direction of digestate utilization should be its use as a fertilizer. A possibility of agricultural utilization of digestate as a fertilizer was investigated. Digestate obtained from an agricultural biogas plant was tested for the content of macroelements and heavy metals. The content of macroelements in the soil was also examined before and after digestate application. Digestate was used in alfalfa cultivation. The analysis showed an increase in macroelements content in alfalfa leaves. It was found that digestate can be used as a fertilizer.

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Keywords: digestate; fertilizers; alfalfa; heavy metals.

1. Introduction

The current stage of civilization development is beset with new problems associated with the availability of energy sources. At present, energy requirements are mainly fulfilled by fossil fuels. However, their resources are limited and according to numerous scientific forecasts they may soon be exhausted. Moreover, energy obtained from fossil fuels has a detrimental effect on the condition of natural environment, contributing to its degradation (Biernat et al. 2012, Comparetti et al. 2013).

In view of these fears and dangers there emerges a growing interest in new energy carriers which could constitute energy sources alternative to fossil fuels, and would improve the natural environment. Biodegradable organic waste and

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municipal waste can be the desired energy sources (Biernat et al. 2012).

Implementation of modern technological solutions in industry can also have a beneficial effect on environmental protection, mainly due to the reduction of waste, including hazardous substances (Chaaban 2001).

Many countries are striving after the production of energy from renewable sources. These sources also include the production of energy from anaerobic decomposition of agricultural substrates (Comparetti et al. 2013, Govasmark et al. 2011). In Sweden it has been decided that until 2018 40% of all food waste should be recovered in the form of energy (Chiew et al. 2015).

Fermentation processes are a method of organic waste utilization, widely known all over the world. As a result of the process, there are formed biogas and post-digestion matter which can be used as a fertilizer in agriculture. Substrates for methane fermentation include biological waste from agriculture, food industry or urban greenery maintenance, and also sludge from sewage treatment (Biernat et al. 2012).

Functioning of agricultural biogas plants is connected with producing large amounts of post-digestion matter. Its amount is approximately similar to the mass of substrates used in the fermentation process in a biogas plant. In some biogas plants digestate mass can be smaller if a part of technological liquid is reversed as process water to fermentation chambers (Mystkowski 2015).

Post-digestion liquid from a biogas plant can be used either in a liquid or solid form. In the case of larger installations and, consequently, greater amounts of post-digestion matter create the need for storage. As a rule, separation is used to obtain solid fraction, which is used as a fertilizer, and liquid fraction – leachate, which is returned to a biogas plant (Kowalczyk-Juśko et al. 2015). The generation of large amounts of leachate is one of the most important problems in digestate management. Desiccation (separation) is conducted to reduce the negative features of this product (Kaparaju et al. 2008).

Digestate can be defined as liquid from anaerobic decomposition of animal and plant waste (Mystkowski 2015). It contains considerable amounts of mineral elements (nitrogen, phosphorus, potassium). In terms of rapidity of action (absorption of elements by plants) it resembles mineral fertilizers since N, P and K elements are easily available for plants. Post-digestion pulp also contains a part of organic matter, which has a positive effect on physicochemical properties of fertilized soils (Kouřimská et al. 2012, Kowalczyk-Juśko et al. 2015, Odlare et al. 2008, Rehl et al. 2011).

Post-digestion pulp management is an extremely important issue for each biogas plant in Poland. It should be planned at an early stage of preparation for biogas plant construction. According to the law, digestate from agricultural biogas plants is treated as potentially hazardous waste such as sewage sludge, which seriously complicates the possibility of its management (Kowalczyk-Juśko 2014). Govasmark et al. (2011) as well as Heviánková et al. (2013) emphasize the possibility of occurrence of pathogenic bacteria and heavy metals in digestate. This is why it is important that digestate is safe for use as a fertilizer.

The basic direction of digestate management, after considering its physicochemical properties, should be its utilization as a bio-fertilizer (Kowalczyk-Juśko et al. 2015). Eickenscheidt et al. (2014) and Vázquez-Rowe et al. (2015) also highlight the use of digestate as a fertilizer, in place of mineral fertilizers. A biogas plant located in agricultural areas should collect organic products from local farms. Farmers, on the other hand, in their efforts to ensure soil quality on their farms, should use digestate from local biogas plants as a fertilizer (Comparetti et al. 2013, Garfi et al. 2011, Kowalczyk-Juśko et al. 2015, Tao et al. 2014). Digestate used as a fertilizer improves soil fertility, plants quality and their immunity to biotic and abiotic agents (Kouřimská et al. 2012). Kouřimská et al. (2012) in their studies conclude that the use of digestate improves the quality and yield of vegetables. Chiew et al. (2015) say that the use of digestate as a fertilizer increases the content of macro- and microelements in the soil and plants. Odlare et al. (2008) did not find any negative effects that digestate might have had on the soil.

As a waste product, digestate can be subjected to disposal operations, however, generally it is recommended that digestate should undergo recovery operations. The most frequent way of post-digestion pulp management is recovery by means of R 10 method – 'treatment on the soil surface bringing benefits for agriculture or improving the condition of natural environment' (Czekała et al. 2012). For this reason post-digestion substance can be used as an agent improving soil quality (Kowalczyk-Juśko 2014).

It is important to understand that natural and organic fertilizers are not the same according to the law. In common language these two terms have the same meaning, which leads to many misunderstandings. Natural fertilizer is defined as derived from farm animals (manure, liquid manure), whereas organic fertilizer is produced from an organic substance or a mixture of organic substances. A natural fertilizer must be mixed with soil, but an organic one need not. Similarly, there is a prohibition of using natural fertilizers on soils without vegetation cover when a field slope is more than 10% (Kowalczyk-Juśko 2014).

There are numerous techniques of applying digestate on the soil surface. Their choice depends on the methods of digestate processing, type of fertilized crops, time of fertilization. Liquid manure spreaders or sprinkling machines are used to apply digestate on a field surface. Sprinkling machines can be used for post-digestion sludge with low content of dry matter (below 5%). It is recommended to consider more possibilities of using digestate apart from its direct application on fields, for example as a bio-fertilizer, fertilizer nutrient or energetic material, (Garfi et al. 2011). Solid fraction of post-digestion sludge after separation can be further processed. Second drying and pelletization are often used (Kratzeisen 2010, Kowalczyk-Juśko et al. 2015).

The aim of this investigation is to examine the possibility of agricultural utilization of digestate in place of mineral fertilizers, and also comparing the content of macroelements after fertilization with digestate and mineral fertilizers.

2. Method

Digestate was obtained from the biogas plant in Piaski (Lubelskie Province) and was applied on an experimental field for alfalfa cultivation. For the sake of comparison, alfalfa was also sown on another field and was fertilized with mineral fertilizers. The experimental fields were located in Uchanie Commune, Lubelskie Province. The area of each experimental field was 50 m^2. The soil on the fields is 2nd valuation class. The fields were sown in April, 2015. The first harvest of alfalfa was gathered and examined for the content of macroelements. Digestate was used in the amount of 180 l per 50 m^2 (36000 l/ha). On the field that was fertilized with mineral fertilizers there were used: nitrogen – 20 kg/ha, phosphorus – 60 kg/ha, potassium – 80 kg/ha.

Digestate was also tested for the content of macroelements and heavy metals. Soil samples were examined for the content of macroelements as well. The tests were conducted before and after digestate application.

Laboratory tests were performed at the District Chemical-Agricultural Station in Lublin.

3. Results

The biogas plant (a biogas combined heat and power plant) is located in Piaski Commune, Lubelskie Province. The electric power is 0,99 MW, and the thermal power – 1,1 MW. The annual electricity production – approximately 8 400 MWh. The generated biogas is desulfurized, dewatered, cooled and pumped by means of an underground gas pipeline into a cogeneration engine which generates electricity and heat in a combined process. The following are used as an input into the digestion process: green waste matter, maize silage, beet pulp, stillage, whey.
Prior to its application, digestate was examined for the content of macroelements and heavy metals (Table 1). Digestate pH reaction was 8,73 and is similar to the pH reaction of bovine liquid manure (7,90).

The analysis of the results showed that digestate did not contain any heavy metals. Both digestate and bovine liquid manure contain similar amounts of macroelements. Based on the results of this investigation it has been found that digestate can be used as a fertilizer.

In view of many authors' indications that digestate fertilizes soil and can be used instead of mineral fertilizers, soil samples were examined as well. Those examinations were also aimed at detecting changes in the content of macroelements. They were performed before and after digestate application. The results are presented in Table 2.

The analysis of the tests results revealed an increase in soil pH reaction from 7,56 to 7,63. The small increase in soil pH reaction is of no special importance since this is still a basic reaction, which is favorable to good development of plants. There was also observed increase in the selected macroelements. The content of phosphorus rose by 5,90 mg per 100 g of soil, potassium by 9,20 mg per 100 g of soil and magnesium by 0,4 mg per 100 g of soil.

Potassium is a macroelement which has a fundamental significance for plant nutrition. It plays a key role in plant water balance, activates enzymes, takes part in the process of photosynthesis and transportation of assimilates, and also activates sensitivity to water stress associated with drought. The basic role of magnesium in plants is connected with its presence in chlorophyll particles, thus influencing photosynthesis processes. This element plays a significant role in determining the quality of plant products in terms of their nutritional value for animals and people. Phosphorus deficiency inhibits plant growth, reduces yield and its quality. If soil is rich in macroelements, plants absorb them more easily, and produce a higher yield.

Table 1. Comparison of selected macroelements and heavy metals in digestate and bovine liquid manure

Examined feature	Digestate	Bovine liquid manure
1	*2*	*3*
Phosphorus [g/l]	0,09	2,30
Potassium [g/l]	5,25	3,70
Calcium [g/l]	0,25	0,21
Magnesium [g/l]	0,04	0,09
Cadmium [mg/l]	<0,43	<0,43
Lead [mg/l]	<0,43	<0,43
Nickel [mg/l]	<0,43	<0,43
Chromium [mg/l]	<0,43	<0,43
Copper [mg/l]	0,43	0,49
Zink [mg/l]	2,01	1,90
Manganese [mg/l]	2,20	1,80
Iron [mg/l]	70,70	19,70

Table 2. Tests for pH reaction and macroelements content in the soil.

Examined feature	Before digestate application	After digestate application	Difference (3-2) in %
1	*2*	*3*	*4*
Reaction [pH]	7,56	7,63	0,93
Phosphorus [mg per 100 g of soil]	31,40	37,30	18,79
Potassium [mg per 100 g of soil]	7,20	16,40	127,78
Magnesium [mg per 100g of soil]	13,40	13,80	2,99

In order to detect changes in the content of macroelements in alfalfa cultivated on the soil fertilized with mineral fertilizers and digestate, the alfalfa leaves from the first harvest were tested for the content of macroelements. The results are presented in Table 3.

Table 3. The content of selected macroelements in alfalfa leaves from the first harvest.

Examined feature	Alfalfa sown on the soil fertilized with mineral fertilizers	Alfalfa sown on the soil fertilized with digestate	Difference (3-2)
1	*2*	*3*	*4*
Nitrogen [%]	3,11	3,66	0,55
Phosphorus[%]	0,28	0,30	0,02
Potassium [%]	1,67	1,96	0,29
Calcium [%]	1,85	1,96	0,11
Magnesium[%]	0,37	0,38	0,01

The analysis of the study results showed a percentage increase of particular macroelements in alfalfa leaves. The highest increase was observed in the content of nitrogen and potassium, which rose by 0,55 p. p. (percentage point) and 0,29 p. p., respectively. The relative percent differences for the examined macroelements were as follows: nitrogen – 17,68%, phosphorus – 7,14%, potassium – 17,37%, calcium – 5,95%, magnesium – 2,70%. The increase in the content of macroelements in alfalfa leaves has positive significance, because it is possible to obtain fodder rich in macro- and microelements. Alfalfa is a fodder which is eaten willingly by animals, for this reason it is most often used to feed dairy cattle. In addition, it also makes a good component of fodder for pigs, poultry, sheep and horses. It is a plant which is extremely rich in protein. Its leaves contain mineral salts, especially calcium, phosphorus, potassium, magnesium and a whole range of microelements. In consequence, it is recommended to replace mineral fertilizers with digestate by reason of a higher content of macroelements in alfalfa cultivated on the soil fertilized with digestate, because of which such fodder is more willingly eaten.

4. Summary

The major factors that determine the way of digestate utilization include its quality, local conditions and legal regulations. In Poland the factor which determines the utilization of biogas plant's by-products is legal norms, which do not facilitate digestate management (Czekała et al. 2012).

Fertilizing fields with digestate brings numerous benefits, e.g. reduction of the demand for plant protection products (destruction of weed seeds during fermentation), reduction of odor nuisance, or destruction of possible pathogens (Kowalczyk-Juśko 2015).

The investigation revealed that post-digestion liquid contains similar amounts of macroelements as bovine liquid manure. No heavy metals were found in digestate. An increase in the content of macroelements was observed in the leaves of the alfalfa fertilized with digestate in comparison with the alfalfa fertilized with mineral fertilizers. Consequently, post-fermentation residues from biogas plants can be used as a fertilizer. The only condition is the rational utilization of such residues. Further studies are necessary to confirm that digestate has an effect on plants' yielding.

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