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Research Article

CHARACTERISTICS OF MUNICIPAL WASTE BIODEGRADABLE FRACTION AND EVALUATION OF ITS PROCESSING

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ABSTRACT
A growing interest in Renewable Energy Sources initiated the use of biogas as an energy generating material. Biodegradable waste coming from different streams is an important resource for biogas production. The studies were conducted on 20–80 mm fraction of municipal waste separated by rotary screen in the technological process of The Waste Recovery and Storage Plant in Leśno Górne. Morphological composition of the examined waste and their parameters determining their usefulness for composting and fermentation were analysed. On the basis of organic carbon content, the amount of biogas that may be produced from 1 kg of waste was estimated. An approximate amount of biogas which can be obtained in the process of methane fermentation from energy piles, formed from 10 000 Mg of waste was also calculated. Depending on the temperature it was from. 2.8 to 3.8 mln m^3.

Keywords: municipal waste, biodegradable waste, methane fermentation, composting, biogas.

INTRODUCTION

Recently there has been a growing interest in using energy from renewable sources and the EU policy promotes generating electricity from these sources [Kałużyński et al. 2007]. Under EU Directive [Directive 2001/77/EC of the European Parlament]·, EU Member States have the obligation to disseminate the methods of energy production from alternative sources.

Mixed municipal waste, and particularly biodegradable waste, accounting for 54.65% of total urban waste produced in Poland in 2008 [Dz. U. 2010, No 217, item 1183], has been an important, unutilised source of biogas. Biogas production as a result of anaerobic stabilisation of biodegradable waste, may be an alternative to composting, which in the case of mixed municipal waste not always produces the material of good quality [Castaldi et. al. 2006, Jędrczak and Haziak 2005, Sądej and Namiotko 2010]. Anaerobic waste digestion is a stage process, occurring in an appropriate temperature regime [Zawieja et al. 2010], whose final product is biogas, made up predominantly of CH_4 (35–60%) and CO_2 (35–55%). Its fuel value (22 $MJ·m^3$, on average) depends on the percentage share of methane [Sądej and Namiotko 2010]. The utilisation of biodegradable components of mixed municipal waste for biogas production and its use as a source of energy is fully justified [Lapćík and Lapćíkova 2008]. One of the advantages of this process, is meeting the requirements of EU directives by increasing the share of renewable energy sources, reducing the amount of biodegradable waste deposited in landfills and greenhouse gas emissions.

The aim of this paper was to determine morphological composition and physicochemical properties of 20–80 mm fraction separated from municipal waste in the Waste Recovery and Storage Plant in Leśno Górne, and estimate an approximate biogas output from energy piles made from the examined fraction.

MATERIALS AND METHODS

The experiment was conducted on municipal waste fraction of 20–80 mm in diameter, separated by rotary screen in the technological process used in the Waste Recovery and Storage Plant in Leśno Górne. The studies were repeated 9 times from October 2008 to April 2009. During the analysis of morphological composition the following components were separated: organic waste of plant and animal origin, glass, plastics, metals, minerals, fraction < 10 mm.

Selected, dried and shredded organic waste was subjected to laboratory studies. Reaction was determined in H_2O and KCl, moisture by oven-drying method at the temperature 105 °C, loss on ignition by burning the material in a muffle furnace at the temperature 550 °C. The content of carbon and total nitrogen were obtained by means of an elemental analyser. The amounts of total forms of macro- (P, K, Mg, Ca, Na,) and microelements (Cu, Zn, Mn, Ni, Fe, Cd, Pb, Co) were determined after mineralisation in the mixture of HNO_3+$HClO_4$ using atomic absorption spectophotometer, phosphorus -colorimetrically. The level of macro (P, K, Mg, Ca, Na,) and microelements (Cu, Zn, Mn, Ni, Fe, Cd, Pb, Co) soluble in HCl at the concentration 0.5 $mol \cdot dm^{-3}$ was analysed using atomic absorption spectrophotometer , and phosphorus colorimetrically.

In order to estimate the amount of biogas generated from one kilogram of 20–80 mm waste fraction in the process of methane fermentation, in energy piles, the following formula [Rolland and Scheibengraf 2003, Wandrasz and Landrat 2002] was used: $Ge = 1{,}868 \cdot Co\,(0{,}014T + 0{,}28)$ were: Ge [$m^3 \cdot kg^{-1}$] – biogas amount, 1,868 – amount of biogas composed of CO_2 and CH_4, generated from 1 kg of organic carbon ($m^3 \cdot kg^{-1}$ Corg.), Co – total amount of organic carbon in substrate (kg $C \cdot kg^{-1}$), T – temperature (°C). The weight of waste undergoing biodegradation was calculated on the basis of percentage content of organic waste, paper and cardboard in the total weight of 20–80 mm fraction, designated for biological digestion.

DISCUSSION AND RESULTS

Processing municipal solid waste in the form in which it is produced in households in Poland is not possible. At least initial, mechanical pre-treatment is necessary [Meller et al. 2007] and such a technology was used in the Municipal Waste Recovery and Storage Plant in Leśno Górne. The waste in this plant is separated by rotary screen into three fractions: < 20 mm, from 20 to 80 mm and above 80 mm. The fraction from 20 to 80 mm made up about 28% of total weight waste and was characterised by different content of particular components (Figure 1). Percentage share of particular components changed, depending on the season of year In this fraction, organic waste represented the highest mean share – 45%. Similar value for mixed municipal waste was given by [Kulczycka and Kowalski 2008]. The percentages of other components were as follows: small fraction <10 mm – 18.4%, glass – 13.7%, paper and cardboard – 11.3%, plastics – 5.0%, debris

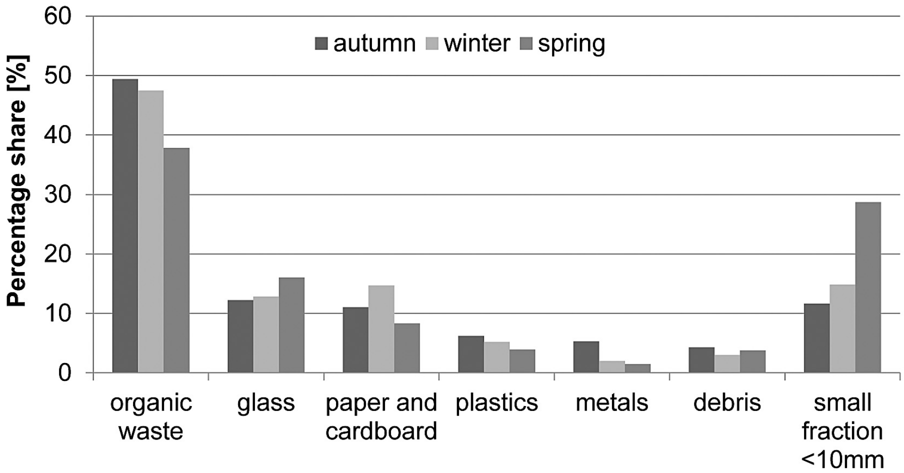

Figure 1. Morphological composition of 20–80 mm fraction of municipal waste separated in Municipal Waste Recovery and Storage Plant in Leśno Górne from November 2008 to April 2009

– 3.7%, metals – 2,4%. The pH analysis of examined waste fraction (Table 1) in terms of appropriate values for the process of fermentation confirmed that the obtained results allow for using this fraction as an energy pile material.

Taking into consideration the process of composting, the obtained pH values are slightly too low since it is assumed that the optimum value for this process is 6.5 [Den Boer et al. 2011]. The share of organic matter, measured as a loss on ignition was 72.47%. Such a high organic matter content in the analysed waste fraction proves its great usefulness both for the process of methane fermentation and composting [Den Boer et al. 2011, Szpadt and Jędrczak 2008]. Rolland and Scheibengraf [2003] report that the municipal waste produced in Germany contain from 170 to 220 g·kg^{-1} of organic carbon but separated paper and cardboard 370, and kitchen waste even 430 g·kg^{-1} of organic carbon. The content of organic carbon in the studied fraction ranged from. 320.3 to 367.8 g·kg^{-1}. The mean moisture of waste amounted to 63.20% and should be regarded as optimal for the process of fermentation. The wastes under study are characterised by too narrow C/N ratio in relation to recommendations for composting and too wide C/P ratio [Den Boer et al. 2011] .

However, narrow C/N ration does not rule out the application of fermentation for the utilisation of these wastes. N content (1.8%), P (converted to P_2O_5 – 0.65%) and K (converted to K_2O – 2.08%) qualify the analysed organic waste as useful for composting, whose final product will have the appropriate level of the above mentioned elements [Szpadt and Jędrczak 2008]. The content of macroelements, soluble in HCl at the concentration 0.5 mol·dm^{-3} (Table 4), regarded as an available form, makes up from 42.7% (calcium) to 83.8% (potassium) of their total amount, which indicates the good fertiliser properties of the end product of composting. The total content of heavy metals in organic waste varied.

Maximum total content of Ni and Pb exceed the admissible values for organic solid fertilisers [Dz. U. 2008, No 119, item 765]. However, their mean concentration in organic waste, even if we assume 1.5–2.0-fold concentration of Ni and Pb

Table 1. Reaction, loss on ignition, dry matter, moisture and total content of organic carbon, nitrogen and sulphur in samples of 20 – 80 mm waste fraction

Value	pH		Loss on ignition	Dry matter	Moisture	C_{org}	N_{og}	S	C:N	C:S
	H_2O	KCl	(%)			(g·kg^{-1})				
min.	5.45	5.80	50.05	33.19	55.72	320.3	12.56	2.64	16.2	45.9
max.	6.14	6.20	85.71	44.28	69.96	367.8	22.75	7.74	26.2	129.9
mean	–	–	72.47	36.80	63.20	342.9	18.11	3.95	19.4	96.3
S	–	–	10.42	4.35	4.35	14.2	14.20	1.60	3.6	28.1

Table 2. Content of macroelements soluble in mixture of concentrated HNO_3 + $HClO_4$ in samples of 20 – 80 mm waste fraction

Value	P	K	Ca	Mg	Na
	(g·kg^{-1})				
min.	2.33	10.30	33.79	1.83	3.41
max.	4.31	23.08	163.10	3.41	5.42
mean	2.85	17.31	71.47	2.41	4.20
S	0.63	4.77	39.72	0.50	0.64

Table 3. Content of trace elements soluble in HNO_3 + $HClO_4$ in samples of 20 – 80 mm waste fraction

Value	Fe	Zn	Mn	Cu	Ni	Pb	Co	Cd
	(mg·kg^{-1} d.m.)							
min.	2302	317	77.6	17.6	15.8	16.1	1.82	0.404
max.	9660	1320	238.7	126.8	80.6	383.1	4.99	1.919
mean	4543	596	157.2	46.8	29.98	74.61	3.05	0.940
S	2856	330	6.1	33.0	20.27	117.30	1.00	0.468

Table 4. Content of macroelements soluble in HCl at concentration 0.5 mol·dm^{-3} in samples of 20–80 mm waste fraction

Value	P	K	Ca	Mg	Na
	(g·kg^{-1})				
min.	1.13	9.09	14.42	1.45	1.91
max.	2.11	17.80	77.42	2.52	4.61
mean	1.50	14.27	30.93	1.83	2.95
S	0.33	3.88	19.17	0.39	0.88

Table 5. Content of trace elements soluble in HCl at concentration 0.5 mol·dm^{-3} in samples of 20-80 mm waste fraction

Value	Fe	Zn	Mn	Cu	Ni	Pb	Co	Cd
	(mg·kg^{-1} d.m.)							
min.	610	266	64.6	8.4	8.2	11.4	0.32	0.247
max.	2868	824	194.4	66.1	20.6	282.3	1.55	1.148
mean	1160	423	108.8	23.9	17.4	55.1	0.68	0.536
S	786	169	44.6	17.7	7.1	86.6	0.38	0.284

in the product [Szpadt and Jędrczak 2008], shows that the limit values will not be exceeded.

The total Cd content of investigated substrate does not exceed the permissible concentration for solid organic fertilisers, whereas the content of macroelements soluble in HCl at the concentration 0.5 mol·dm^{-3} (Table 5) and percentages of Zn, Pb, Mn, Ni and Cd (76.9–60.0%) in their total content, may mean their elevated concentration in the plants fertilised with produced compost.

In order to estimate an approximate biogas output resulting from the fermentation process of 20–80 mm waste fraction (mean share of organic matter – 56.3%) the pile of total weight 10 000 Mg was chosen. Taking into consideration the amount of processed mixed municipal waste in Leśno Górne (30 000 Mg) and the percentage (27.8%) of 20–80 mm fraction separated from this waste [Meller and Rogalska 2008], it can be stated that the formation of energy pile will last about. 13.5 month and the mass of organic waste will reach 5630 Mg. The determined level of organic carbon, in examined organic waste was on average 0.343 kg C·kg^{-1} of waste fraction. On the basis of the above presented formula, it was found that the estimated biogas output from the pile with the above given parameters may reach from 2 761 996 m^3 for mesophillic process to 3 766 359 m^3 for thermophillic process. On the assumption that CH_4 content will amount to 65%, it is possible to obtain about 1.8 and 2.5 mln m^3 of methane, respectively.

CONCLUSIONS

1. In morphological composition of separated 20–80 mm fraction, 56.3% of biodegradable waste was found..
2. Narrow C:N (19.4:1) in the examined waste and slightly acid reaction are optimal for the process of methane fermentation but are not favourable for composting.
3. Both organic matter content of the analysed waste fraction (72.47%), and its moisture (63.20%) prove that it is an excellent material for biological processing.
4. The analysis of separated fraction, shows that there is no exceedance in the mean amount of cadmium, lead and nickel, in relation to the guidelines for the waste designated for biological digestion.
5. Estimated amount of biogas obtained as a result of methane fermentation from energy piles of 10 000 Mg of 20–80 mm waste fraction may reach from about 2.8 to 3.8 mln m^3, depending on temperature.

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