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POSSIBILITIES OF TECHNOLOGICAL UTILISATION OF BDMW FROM MUNICIPALITIES WITH RURAL BUILDING DEVELOPMENT

MOŽNOSTI TECHNOLOGICKÉHO VYUŽITÍ BRKO Z OBCÍ S VESNICKOU ZÁSTAVBOU

Abstract

The article deals with research into BDMW from biowaste landfilled in a municipality with rural building development from the point of view of its technological treatment and subsequent application of output from technologies. Analyses of biowaste were concentrated on parameters of importance to incineration, anaerobic digestion and composting. The text is also concerned with final outputs, i.e. with the quality of compost in view of content of hazardous elements in the case of composting and with the yield of biogas in the case of anaerobic digestion.

Abstrakt

Článek se zabývá výzkumem BRKO z bioodpadů sládkovaných v obci s vesnickou zástavbou z hlediska možností jejich technologického zpracování a následného uplatnění výstupu z technologií. Analýzy bioodpadů byly zaměřeny na parametry významné pro spalování, anaerobní digesci a kompostování. Hodnoceny jsou také konečné výstupy technologií, a to v případě kompostování kvalitou kompostu z hlediska obsahu rizikových prvků a v případě anaerobní digesce výtěžností bioplynu.

1 INTRODUCTION

According to Council Directive 1999/31/EC on the landfill of waste, the Czech Republic (henceforth referred to as CR) is to reduce the amount of biodegradable municipal waste (BDMW) deposited in landfills to 75%, 50% and 35% of the 1995 amount by the year 2010, 2013 and 2020, respectively [1]. The CR incorporated the main requirements and principles of this Directive into Act 185/2001 Coll., on waste, Executive Decree 341/2008 Coll., on details on the treatment of biodegradable waste and Decree 197/2003 Coll., on waste management plan.

In spite of this the CR exhibits an ever-increasing BDMW growth, which is a trend reverse to that expected in the Waste Management Plan of CR, and a wholly realistic assumption exists that in the year 2010 an EU binding indicator – a drop in BDMW deposited in landfills in comparison with the year 1995 will not be met [2].

This state is influenced, among other matters, by a lack of available capacities for BDW treatment [3]. In the course of forming new capacities, not only the amount but also the qualitative characteristics of biowaste are to be taken into account. Biowaste properties influence technological treatment capabilities and subsequent utilisation of end products.

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The article deals with research into BDMW from biowaste landfilled in a municipality with rural building development from the point of view of its technological treatment and subsequent application of output from technologies.

2 METHODS USED

Sampling was carried out according to the Guideline of Ministry of the Environment on waste sampling, Věstník MŽP (Bulletin of Ministry of the Environment) No. 5/2001 and a Czech standard ČSN EN 14899 Characterization of waste - Sampling of waste materials - Framework for the preparation and application of a Sampling Plan.

Samples were taken directly in a landfill. After tipping municipal waste from collection vehicles, a representative sample of the weight of about 10 kg was taken. Immediately after taking the sample, moisture was determined. The sample was transferred to a chemical laboratory where it was dried at the temperature of 105 $^{\circ}$C. After drying, a part of the sample was homogenized to observe chosen chemical indicators (0.5 kg) and a substantial part of the weight of about 5 kg was manually separated into individual components. The separation itself was performed differently in the case of a sample taken in August 2009; it was carried out directly in the landfill, the weight of the sample was about 200 kg, and to the laboratory merely a representative sample of biomass was transferred to be subject to the analysis. Chemical analyses of BDMW were made according to the following methodologies:

ČSN P CEN/TS 15440:2007 Solid recovered fuels – Method for the determination of biomass content.

ČSN EN 15170:2009 Characterization of sludges – Determination of calorific value.

ČSN P CEN/TS 15403:2007 Solid recovered fuels – Methods for the determination of ash content.

ČSN P CEN/TS 15414-2:2007 Solid recovered fuels - Determination of moisture content using the oven dry method - Part 2: Determination of total moisture by a simplified method.

ČSN P CEN/TS 15407:2007 Solid recovered fuels - Method for the determination of carbon (C), hydrogen (H) and nitrogen (N) content.

ČSN EN 15309:2007 Characterization of waste and soil - Determination of elemental composition by X-ray fluorescence.

3 ANALYSIS OF BDMW GENERATED IN A MUNICIPALITY WITH RURAL BUILDING DEVELOPMENT

For the purpose of finding a suitable technology for the treatment of BDMW generated in municipalities with rural building development, the analysis of biowaste in mixed municipal waste (MMW) produced in the municipality of Fryčovice was carried out. Sampling was performed from August 2008 to July 2009 (with the exception of November to February and May).

The municipality of Fryčovice is situated in the Moravian-Silesian Region, Frýdek-Místek District. The prevailing part of the municipality is composed of houses with gardens (561 family houses, 4 multi-dwelling houses). On the whole, it is a case of original housing development. The gas is supplied to almost 85% of buildings [4], of which (according to the estimate of the municipality chairman) 30% of houses are only gas-heated, i.e. they are not equipped with any solid fuel boiler. According to the Czech Statistical Office, the number of inhabitants as of December 31, 2007 was 2302 [4].

The waste management fee in the municipality amounts to CZK 400/inhabitant/year. Sorted collection: plastic (doorstep collection, bags), glass (collection points, containers), paper (local basic school); bulk waste is collected twice a year. In the municipality of Fryčovice, 744.4 t of mixed municipal waste, i.e. 323.4 kg/head/year was generated in the year 2008.

4 PROCEDURES FOR A POSSIBLE REDUCTION OF BDMW PROPORTION IN MMW

The EU countries that divert from BDMW landfilling use a combination of separate collection, thermal treatment, centralized composting and material recycling. To reduce a proportion of biodegradable waste (BDW), Váňa [5] proposes measures orientated towards the areas of BDW collection and utilisation. Thermal treatment, prevailingly waste incineration, is used largely for mixed waste. Composting and recycling are used for separated components, namely paper and paperboard, textiles, wood, garden waste and kitchen waste [6]. Under existing economic conditions, for small municipalities, the treatment of biological waste by composting at central composting facilities seems to be most suitable. If biowaste production is high, namely more than 10000 ton/year [7], then the utilisation of a biogas station (henceforth referred to as BGS) is reasonable. The realization of this variant is money consuming; it is suitable rather for groups of municipalities [1].

5 TECHNOLOGICAL REQUIREMENTS FOR BDW TREATMENT AT COMPOSTING FACILITIES AND IN BGS'S

Technological requirements are generally valid (Tab.1); in the case of composting, aerobic conversion of waste to a stabilized end product – compost must be ensured, and in the case of biogas stations – production of biogas and stabilized digestate. Factors decisive of the selection of aerobic and anaerobic treatment technologies are the content of organic dry matter and the ratio of carbon to nitrogen [8]. Results of observed parameters of a manually separated off fraction BDMW from Fryčovice are given in Tab.2.

Tab. 1 Required parameters for BDW treatment technologies

	Anaerobic digestion	Composting
Content of organic dry matter	22 – 25% of solid waste [9]	40 – 60%
Content of inorganic component (%)	minimal	
pH	7 – 7.8	
C:N	20:1 – 40:1	30 – 35:1 [10]
CHCO:C:N [11]	300:6.7:1 – 500:6.7:1	
State of matter	Liquid, solid	solid
Moisture		
CHCO – of dry matter	Min. 1.5 g/g	
Content of lignin	> 17% [12]	

Tab. 2 Chosen properties of manually separated off fraction BDMW from Fryčovice

	2008			**2009**				Average
Month of sampling	**08**	**09**	**10**	**03**	**04**	**06**	**07**	
Org. dry matter (%)	57.42	51.36	48.47	32.30	47.52	40.84	18.46	42.33
Biomass content* (%)	28.87	21.94	13.84	9.00	14.48	18.90	17.59	17.80
Calorific value (kJ/kg)	7695	7329	7095	4179	7950	7766	2704	6388
C/N	15.72	14.25	14.93	23.2	21.6	13.3	14.8	16.82
C	20.13	19.53	19.72	16.14	23.74	20.39	9.20	18.40
N	1.28	1.37	1.32	0.70	1.10	1.53	0.62	1.31
H	3.13	2.19	2.28	1.25	3.08	3.53	1.80	2.46
S	0.17	0.01	0.06	0.23	0.15	0.14	< 0.10	0.12
CHCO (g/g)	0.80	0.97	0.53	0.27	0.82	0.47	0.22	0.66

Note * - Determination of biomass content by the selective method of dissolving according to ČSN P CEN/TS15440

Almost all the samples show roughly a half of the required amount of carbon; merely March and April values are higher. Nevertheless, they do not satisfy the requirement for the optimum C/N ratio either. Carbon can be supplied by means of materials with a higher carbon proportion, e.g. wood chips, bark, wood dust, straw, dry leaves, etc. Unfavourable properties for anaerobic digestion are influenced by a high content of mineral admixture of mixed municipal waste, the removal of which in the course of sampling was not feasible. It is probable that by the separate collection of biomass, the ash content will be lower (for more information see Chapter 8 Incineration). The higher content of inorganic component can be positive in the process of composting, in which it acts, on the contrary, as a material suitable for aeration (if building debris is not included).

From the values of chemical consumption of oxygen (henceforth referred to as CHCO), the theoretical production of methane from separated off BDW was calculated according to equations [13]. The actual production of methane was verified in a laboratory fermenter of the company B-BRAUN (vessel volume of 10 l) by co-fermenting with raw sludge from a sewage treatment plant (Central Sewerage Treatment Plant ÚČOV Ostrava). The material was left in the bioreactor for 34 days. The production of methane was, in comparison with the theoretical calculation, very low. This can be a result of a high content of lignin (comparison between data from 2008 and 2009) and a low content of saccharides and also substances that may cause inhibition (heavy metals). The comparison between the theoretical and the actual methane production is given in Tab. 3.

Tab. 3 Comparison between the theoretical and the actual production of methane in BDMW from Fryčovice (dm^3 of CH_4/g of dry matter of separated off BDW)

	2008			2009			
	08	09	10	03	04	06	07
Theoretical methane production	0.288	0.340	0.185	0.287	0.164	0.077	0.231
Actual methane production	0.021	0.026	0.017	0.189	0.128	0.056	0.168
Lignin content (%)	21.04	23.52	28.24	16.78	15.98	12.56	14.98

6 LEGISLATIVE CONDITIONS FOR BDW UTILISATION AT COMPOSTING FACILITIES AND IN BGS'S

Legislative conditions for biowaste utilisation are given above all by Act 185/2001 Coll., on waste, Decree 341/2008 Coll., on details on the treatment of biodegradable waste, and Regulation (EC) No. 1774/2002 of the European Parliament and the Council laying down health rules concerning animal by-products not intended for human consumption. Requirements for the plants (premises, facility, etc.), in which biodegradable waste is to be treated, are based especially on the character of accepted waste and the possibility of utilisation of output products (compost, digestate).

According to this criterion the municipality can utilise the following items for BDW treatment:

1. Community composting (in the sense of Act 185/2001 Coll., on waste in the form of municipal composting facility)
2. *A small plant* treats utilisable biodegradable waste for one windrow in the amount not exceeding 10 ton of this waste; the annual amount of biowaste treated by the small plant must not exceed 150 t. In the small plant, only materials of plant origin, defined in List B of Appendix No.1 to Decree No. 341/2008 Coll., on details on the treatment of biodegradable waste, and other raw materials and waste of plant origin and/or materials that improve demonstrably the quality of composting process and the quality of resultant compost (e.g. non-contaminated soil, pH modifying agents, and others) can be treated.
3. Composting facilities and BGS's

4. Composting facilities and BGS's subject to Regulation (EC) No. 1774/2002. From the point of view of the municipality, the waste (subject to Regulation (EC) No. 1774/2002), which is designated as catering waste (it means originating from business, restaurants and catering facilities) as well as the biowaste from households, in which remains of milk and/or meat are included, is the most significant. Such waste must fulfil special requirements, among others, the crushing of waste to less than 12 mm and the hygienization of waste at the temperature of 70 °C for 60 minutes [14], which is fulfilled by composting merely in bioreactors equipped with automatic temperature measurement and by digestion merely in biogas stations with a hygienization stage [15].

It applies to all four possibilities that the use of compost and digestate for agricultural and/or forest soils must fulfil conditions following from Act 156/1998 Coll., on fertilizers, as amended. The same is true for putting compost and digestate as fertilizers on the market. In the other cases, Act 185/2001 Coll., on waste and also Decree 341/2008 Coll., are decisive.

According to Decree 341/2008 Coll., it is possible to classify outputs from the plants for BDW (compost, digestate) treatment into Category 1 or Category 2.

Category 1 – organic fertilizer
Outputs are subject to Act 156/1998 Coll., on fertilizers. Such compost or digestate can be put into circulation and used for agriculture and/or forest soils. The output must be registered at the Central Institute for Supervising and Testing in Agriculture.

Category 2 – reclamation and restoration compost and digestate
Outputs are subject to Decree 341/2008 Coll., and on the basis of real properties, composition and applications they subdivide into three classes (class 1 – greenery for sports and recreation facilities, class 2 – urban greenery, class 3 – landfill reclamation and restoration). Into this category, municipal composting facilities in the regime of community composting according to Act 185/2001 Coll., cannot classify their outputs.

7 EVALUATION OF UTILISABILITY OF BDMW FROM FRYČOVICE BY MEANS OF COMPOSTING ACCORDING TO LEGISLATIVE CONDITIONS

Values of analyses of BDMW from Fryčovice were compared with limit values for composts laid down in legislation for the utilisation of outputs from biowaste treatment plants. When BDMW from Fryčovice is used as basic input raw material for compost production, without addition of another type of biomass not even quality features of reclamation and restoration compost could be fulfilled, i.e. the C/N ratio (minimally 20 – maximally 30), which will even decrease in the course of composting. During the composting process, a decrease in organic component and organic carbon in the range of 6 – 32% (Goyal S. et al., 2005, Atkinson et al. 1996) occurs. A higher amount of TOC (30 - 60%) biodegraded in the course of composting is reported (Iannotti et al., 1994, Francou et al., 2005, Rekha P., et al. 2005). The contents of hazardous elements in BDMW dry matter for Category 1 and Category 2 are stated in Tabs. 4 and 5. From the tables it is evident that Hg and Zn, the contents of which are increased in the majority of samples studied, represent the biggest problem. After decreasing the content of organic component in the course of composting (by about 25%), the concentrations of hazardous elements will still grow. The estimates of contents of hazardous elements are there in Tabs. 4 and 5.

Tab. 4 Contents of hazardous elements in BDMW dry matter (Fryčovice) and estimates of the contents in produced compost for organic fertilizer

Category 1		BDMW from Fryčovice							compost
Indicator	**Org.fertilizer**	**08/08**	**09/08**	**10/08**	**03/09**	**04/09**	**06/09**	**07/09**	**average**
	(mg/kg of dry matter)								
As	20	< 0.7	< 0.6	1.3	1.2	1.7	0.9	1.1	1.20
Cd	2	0.7	0.9	1.5	2.4	1.1	0.9	0.8	1.33
Cr	100	46.8	**101**	68.7	**132.8**	81.4	84.4	**102.1**	98.61
Cu	150	53.7	139	61.1	122.4	75.6	74.3	59.8	93.61
Hg	1	**1.7**	**6.1**	**2.7**	**1.6**	**1.4**	**1.2**	**1.1**	**2.52**
Mo	20	below detection limit							x
Ni	50	12.9	**64.9**	29.7	**90.9**	35.3	26.3	40.6	48.03
Pb	100	83.4	43.5	43.4	38.3	**315.8**	-	23.3	87.51
Zn	600	**1290**	**1570**	**1890**	**2963**	**993.8**	320.3	334.8	**1495.76**

Note: - below detection limit

Tab. 5 Contents of hazardous elements in BDMW dry matter (Fryčovice) and estimates of the contents in produced compost for reclamation and restoration compost

Indica-tor	Category 2	BDMW from Fryčovice							com-post
	Classes I/II/III	**08/08**	**09/08**	**10/08**	**03/09**	**04/09**	**06/09**	**07/09**	**average**
	(mg/kg of dry matter)								
As	10/20/30	< 0.7	< 0.6	1.3	1.2	1.7	0.9	1.1	1.20
Cd	2/3/4	0.7	0.9	1.5	**2.4**	1.1	0.9	0.8	1.33
Cr	100/250/300	46.8	101	68.7	**132.8**	81.4	84.4	**102.1**	98.61
Cu	170/400/500	53.7	139	61.1	122.4	75.6	74.3	59.8	93.61
Hg	1/1.5/2	**1.7**	**6.1**	**2.7**	**1.6**	**1.4**	**1.2**	**1.1**	**2.52**
Ni	65/100/120	12.9	64.9	29.7	**90.9**	35.3	26.3	40.6	48.03
Pb	200/300/400	83.4	43.5	43.4	38.3	**315.8**	-	23.3	87.51
Zn	500/1200/1500	**1290**	**1570**	**1890**	**2963**	**993.8**	320.3	334.8	**1495.76**

When considering the contamination of BDMW from Fryčovice with heavy metals, it seems that a cause of contamination could be the origin of samples and/or the separation of it from mixed municipal waste. Faviono [21] states that by composting the biodegradable fraction mechanically separated off from mixed municipal waste, used abroad in the past years, an increased risk of soil contamination with heavy metals and other pollutants occurred.

The content of heavy metals in composts from biowaste from various sources has been observed by several authors; comparison with CR legislation is provided in Tab. 6. It is composts from domestic composting that exhibit the best results. They do not exceed the strictest limits determined for Category 1 of outputs, i.e. organic fertilizer. On the contrary, composts from MMV are the least suitable owing to the high values of Cd, Cu, Hg, Pb and Zn. They could be used merely for landfill restoration and reclamation.

Tab. 6: Comparison of composts produced from various sources of BDW from the point of view of CR legislation

indi-cator	Input biowaste								Outputs according to CR legislation	
	Source sorted collection				MMW	Domestic composting			Category 2 classes I/II/III	Category 1
++	[22]	[23] **	[23] ***	[23] +	[22]	[22]	[24] *	[23]		
Cd	0.1-1	0.65	0.74	0.69	4	0.5	0.5	0.79	2/3/4	2
Cr	25-60	31.27	34.87	24.63	70	40	36	28	100/250/300	100
Cu	30-50	71.18	108.87	52.88	270	30	37	68.13	170/400/500	150
Hg	0.1-0.5	0.2	0.25	0.2	2.5	0.2	0.3	0.25	1/1.5/2	1
Ni	10-30	28.36	37.13	22.38	50	20	21	25.75	65/100/120	50
Pb	50-100	68	89.47	54.75	400	100	40	59.63	200/300/400	100
Zn	150-350	245.91	279.33	210.5	1300	250	223	263.75	500/1200/1500	600

Note: * mean, ** towns, *** villages, + towns and villages, ++ data from references

The association Ekodomov was concerned with the observation of the basic characteristics in composts from domestic composting in the CR [25]. It analysed 29 samples from various households. As for the content of heavy metals, for Category 1 the limit value of 600 mg/kg for Zn was not reached in one sampl. For Category 2, all composts are acceptable for class I but 3 samples that are not acceptable owing to the Zn content.

8 INCINERATION

A possibility of waste incineration is given especially by the calorific value and further by the water, ash and combustible contents. The limit for waste incineration without the addition of a support fuel is the minimum calorific value of 5 – 6 MJ/kg. Incineration conditions are the maximum water content of 50%, the maximum ash content of 50% and the minimum combustible content of 25%. Tab. 7 given below states energy parameters of analysed samples from Fryčovice together with parameters of an "ideal" fuel.

Tab. 7 Comparison of energy parameters of BDMW separated off

Incineration conditions	**Ideal fuel**	**08/08**	**09/08**	**10/08**	**03/09**	**04/09**	**06/09**	**07/09**
Calorific value MJ/kg (in state supplied)	min. 5 - 6	6.41	6.03	5.78	**0.94**	**3.26**	**3.53**	**0.41**
Moisture content % (in state supplied)	less than 50%	27.79	36.74	35.64	47.86	42.16	37.56	41.54
Ash content % (in dry matter)	less than 50%	42.62	48.71	**51.61**	**73.29**	**53.42**	**59.9**	**79.53**
Combustible content % (in dry matter)	more than 25%	57.38	51.29	48.39	26.71	46.58	40.1	**20.47**

In samples supplied merely the moisture and the combustible content are acceptable (but sample 07/09). The amount of inorganic component is very high, which causes a low calorific value. Samples of BDMW cannot be recommended for the process of direct incineration. What testifies against incineration is also the fact that the method of reducing the proportion of biowaste in MMW by means of incineration is very money consuming [26]. However, in contrast to the values of

Fryčovice samples, the ash content in biomass is generally low and moves in the range of 0.6 – 1.6% [27]. As mentioned in Chapter 5, a cause of the high content of mineral admixtures was probably the separation of BDW from mixed municipal waste, when the removal of inorganic particles in the course of sampling was not feasible. From the results of X-ray diffraction analysis it follows that the majority part of inorganic components are composed of quartz, feldspars, clay minerals and carbonates that are represented in BDMW by soil particles and/or remains of building debris. It is probable that by the separate collection of biomass, the ash proportion will be decreased. The work (Chudárek et. al., 2009), dealing with the content of mineral admixtures in the separate collection of garden BDMW in the locality of Tišnov, indicates this; the average proportion amounted to 0.01% (expressed including moisture).

9 CONCLUSION

According to the made analyses, the material seems to be non-acceptable for incineration and anaerobic digestion. The biowaste from Fryčovice has a high proportion of inorganic component. For anaerobic digestion, BDMW is non-acceptable owing to a high content of lignin, a low value of CHCO of dry matter of the input material, a high proportion of inorganic component and a content of hazardous elements that may act as inhibitors on microorganisms (especially Hg). BDMW could be further utilised merely as an additive for fermentation (co-fermentation).

To composting, the maintenance of the optimum C:N ratio is of largest importance. In spite of the fact that this ratio was not optimal in the case of analysed samples, from this point of view the material can be recommended for composting - C:N can be simply modified by adding raw materials needed, e.g. wood chips, straw, bark, etc. It is increased contents of heavy metals, especially of Hg and Zn in input BDMW that are a problem; the contents exceed permitted concentrations for compost utilisation. In the course of composting, the contents of them will still increase as a result of biodegradation of organic component. The increased content of hazardous elements could be caused by contamination of samples when taking samples from MMW as indicated by the analyses of composts produced from various biowaste sources. The taking of samples from MMW was also probably a cause of the high proportion of inorganic particles. In the case of application of system of sorted collection, the content of undesirable heavy metals and/or mineral admixtures could be thus acceptable.

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