Agronomy Research **15**(4), 1559–1570, 2017
https://doi.org/10.15159/AR.17.009

Performance analysis of biodegradable municipal solid waste collection in the Czech Republic

O. Chotovinský* and V. Altmann

Department of Machinery Utilization, Faculty of Engineering, Czech University of Life Sciences in Prague, Kamycká 129, CZ165 21 Prague 6 – Suchdol, Czech Republic
*Correspondence: chotovinsky@tf.czu.cz

Abstract. The article deals with the issues of biodegradable municipal solid waste management system, focusing on its separate collection. The two basic locations are compared – rural area and urban area. The emphasis is put on evaluation of individual biodegradable municipal solid waste collections development from 2012 to 2015. Individual technological performances of collection are also observed and evaluated (e.g. biodegradable municipal solid waste production, development of container quantity and collection frequency). The observed data also verify the efficiency of biodegradable municipal solid waste management compared to relative representation of this waste in rest municipal solid waste, which is produced in both locations. Also referential locations without separate biodegradable municipal solid waste collection are observed for evaluation. There are one locality of an urban area and one rural area too. The decrease of biodegradable municipal solid waste in rest of municipal solid waste at the basic rural researched area indicates that the directive on landfills could be followed with well-chosen technological parameters of separate biodegradable municipal solid waste collection at a given site. A statistically significant impact of separate biodegradable municipal solid waste production on relative amount of the biodegradable part in rest municipal solid waste has been demonstrated at the side of this basic rural area.

Key words: municipal solid waste, rest municipal solid waste, biodegradable municipal solid waste, biodegradable municipal solid waste collection, material analysis.

INTRODUCTION

Biodegradable municipal solid waste (BMSW) or the biodegradable part of rest municipal solid waste (RMSW) is considered a potential source of perennial bioenergy (Greg, 2010). According to the aggregated indicator 'Global human-appropriated biomass', it was estimated that up to one fifth of the total primary production is returned to the global ecosystem as a biodegradable component of municipal solid waste (MSW) (Vitousek et al., 1986; Imhoff et al., 2004). Most of the BMSW is collected and aggregated in population centers with high energy demands. This waste of biological origin produced at a municipal area is quantitatively very important category of waste and the way how it is treated can both positively and negatively influences environmental components. BMSW accumulation affects the anthropogenic greenhouse effect and the climatic change of the planet. The greenhouse gases production during BMSW decay at landfills contributes to global greenhouse gases emissions with approximately

4% (Papageorgiou et al., 2009). Nevertheless, technologies using this type of BMSW are increasing and gradually displacing fossil energy. As a consequence, the formation of methane during storage of BMSW at dump areas can be reduced (Consonni et al., 2005). This may also decrease the need for waste dumps located near urban areas (Porteous, 2005). A directive which has a crucial value from this perspective and which is fully integrated with Czech legislation is called Council Directive on the landfill 1999/31/EC. The directive's requirement determines gradual decrease of BMSW stored at landfill to 2020. In 2010 there could be 75% of the whole BMSW mass produced in 1995 stored at landfill, in 2013 50% of this amount and by the year 2020 only 35% of BMSW from 1995. In the Czech Republic, there were 1,530,000 tons of BMSW produced in 1995 and in 2010 there were 1.5 million tons of BMSW stored at landfill instead of admissible 1.15 million tons. The precautions of the directive should cover material and energetic use of the waste from the perspective of BMSW management system (Vehlow et al., 2007). The most common technological method of material utilizing is composting. Composting is highest form of recycling. Compost can improve soil conditions and plant growth, and reduce the potential for erosion, runoff, and non-source pollutions. Compost is an organic matter resource. Properly produced compost aids humus to soil (Epstein, 1997). The BMSW can also be processed by the anaerobic digestion method that produces biogas and organic fertilizer as well.

Any type of BMSW is capable of aerobic and anaerobic decomposition. This in particular applies to the part of MSW composed of grass clippings, leaves, twigs, branches, and garden refuse. The decomposable part also includes separately collected biodegradable waste from residential areas, commercial establishments (e.g., restaurants) and institutions (e.g., schools), as well as waste paper (paper and paperboard products), wood, natural textiles and clothing made from these (Vrbová & Balner, 2009). Table 1 shows an overview of BMSW types and the biological component ratio in each type of waste (Kotoulová, 2001).

Table 1. Summary of biodegradable municipal solid waste - according to legislation in the Czech Republic

Type no.	Name of the Type of Waste	Ratio
20 01 01	Paper and cardboard with the exception of highly glossing paper and the wallpaper waste	1.00
20 01 08	Cafeteria biodegradable waste	1.00
20 01 10	Clothing	0.60
20 01 11	Textiles	0.50
20 01 38	Wood not included in 20 01 37	1.00
20 02 01	Biodegradable waste	1.00
20 03 01	Rest municipal solid waste	0.54
20 03 02	Marketplace waste	0.80
20 03 07	Bulky waste	0.50

Note: Ratio – the biological component proportion in each type of waste.
Type no. – the code for each type of waste by the Waste Catalogue of the Czech Republic.

Waste collection is probably one of the most conspicuous activities in a waste management system and one that the public comprehend highly. The service of waste collection is defined as a combination of a certain technology and a human labour (Bilitewsky et al., 1997). This action corresponds not only with the waste collection from certain type of source, but includes the transport of this waste to the places where the waste management lorries are loaded (Tchobanoglous et al, 2002). The method of BMSW collection and its organization significantly affect the quality and quantity of the obtained material and have an impact on the technical equipment requirements for collected BMSW treatment during subsequent processing (Tchobanoglous et al., 1993).

1. Kerbside collection using conventional and specially designed collection vehicles.
2. Incidental kerbside collection by charitable organizations.
3. Delivery by residents to drop-off centers.

Waste collection for separating the biodegradable part from municipal solid waste could be analysed according to their performance in terms of costs (Teerioja et al., 2012; Rogge & De Jaeger, 2013), environmental impacts (Powell, 1996; Maimoun et al., 2013; Teixeira et al., 2014; Yildiz-Geyhan et al., 2016), recycling/collection rates (Wilson & Williams, 2007), and public participation and behavior (Oskamp et al., 1996; Wang et al., 1997; Bolaane, 2006; Martin et al., 2006; Shaw et al., 2006).

The goal is put on evaluation of separate BMSW collections, focusing on the issue of their performances which can make BMSW diversion from landfill more effective. The first part of this paper is evaluation of separate BMSW collection at sites A and B (rural and urban areas with separate BMSW collection) in period of time 2012–2015. The work is further based on assessing the effectiveness of separation in terms of relative BMSW representation in RMSW in monitored years of above mentioned areas and the values of relative BMSW representation in RMSW are available for referential sites C and D (without separate BMSW collection). BMSW production of the same period in one researched area with an effective separation is also analysed and compared to its significant impact on relative amount of BMSW in RMSW.

MATERIALS AND METHODS

Basic rural area A and urban area B, biodegradable municipal solid waste production data

The built-up rural area A spans 18 hectares with 19 hectares of gardens. 627 permanent residents live in 233 family houses and 10 blocks of flats. Most houses use gas as the heating energy. Separate collection of BMSW can be considered fully developed, with good access throughout the territory of village. The collection here is applied as combination of drop-off and pick-up systems. Both systems are applied 0.12 m^3 and 0.24 m^3 containers and large volume containers (18 m^3).

The built-up urban area B spans 48 hectares with 53 hectares of gardens. 4,955 permanent residents live in 862 family houses and 52 blocks of flats in this town. Gas is the most common heating medium. Separate collection of BMSW is fully developed in the whole territory. Both drop-off and pick-up systems are applied. 0.77 m^3 containers and 0.24 m^3 containers (previously used), as well as large volume containers (18 m^3) are placed in the municipality.

Table 2 specify, on a month-by-month basis, the BMSW production in rural area A and urban area B in 2012 and 2015 (peripheral input data). These tables summarize also the real number of containers/month, available per collection drive.

Table 2. Biodegradable municipal solid waste production (20 02 01) in the rural area A and the urban area B 2012 –2015

Month	Production [t]		Collected containers [pcs.month^{-1}]			Collections [drives.month^{-1}]		
	C_{BMSW} 0.24 m^3	LSC 18 m^3	C_{BMSW} 0.24 m^3*	C_{BMSW} 0.12 m^3	LSC 18 m^3	C_{BMSW} 0.24 m^3	C_{BMSW} 0.12 m^3	LSC 18 m^3
Area A			**2012**					
April	2.20	9.84	33	5	4	2	2	1
May	1.30	-	33	5	-	2	2	-
June	2.92	13.08	33	5	4	2	2	1
July	4.40	8.98	33	5	4	3	3	1
August	3.14	18.34	33	5	4	2	2	1
September	4.30	-	33	5	-	2	2	-
October	1.89	18.41	33	5	4	2	2	1
November	1.60	-	33	5	-	2	2	-
Area A			**2015**					
April	2.08	15.45	71	5	4	1	1	1
May	5.18	10.67	71	5	4	2	2	1
June	11.11	23.43	81	5	4	3	3	1
July	5.98	2.43	81	5	4	2	2	1
August	10.44	23.49	86	5	4	2	2	1
September	10.72	-	86	5	-	2	2	-
October	9.01	36.56	86	5	4	3	3	1
Area B			**2012**					
April	2.06	-	80	-	-	1	-	-
May	8.69	-	80	-	-	4	-	-
June	7.99	14.24	80	-	1	4	-	3
July	10.77	9.53	80	-	1	5	-	2
August	10.93	4.03	80	-	1	4	-	1
September	8.25	8.02	80	-	1	4	-	2
October	12.66	4.07	80	-	1	5	-	1
Area B			**2015**					
March	7.96	3.57	34		1	3	-	3
April	16.07	3.84	34	-	1	5	-	3
May	13.84	3.59	34	-	1	4	-	2
June	12.44	-	34	-	-	4	-	-
July	16.20	-	34	-	-	4	-	-
August	19.16	-	34	-	-	5	-	-
September	11.62	-	34	-	-	3	-	-
October	3.93	-	34	-	-	1	-	-

**- C_{BMSW} containers (volumes of 0.24 m^3) were changed for C_{BMSW} containers with volumes of 0.77 m^3 in Náměšť nad Oslavou in 2012.*

Source: research ESKO-T s.r.o.

RMSW analysis data – Sites A, B, C, D

The values given in Tables 3–6 were provided by collection company (ESKO-T s.r.o.), which perform regular RMSW (Type no. 20 03 01) analysis at monthly intervals in the region. Substance analysis of RMSW have been performed since 2012. For the purpose of evaluating total amount of BMSW in RMSW data from January to December of each year is used. Values for the amount of individual types of municipal waste are in

2012–2015 and all the sites are listed in merged tables 3–6, where the total amount of each RMSW sample is presented in tons. For all basic and referential sites only BMSW with the specific Type no. 20 02 01 (Biodegradable waste) is listed in merged tables.

Table 3. RMSW analysis of the basic rural area A in 2012 and 2015

Month in	1.	2.	3.	Month in	10.	11.	12.
2012	2.49 [t]	2.56 [t]	2.48 [t]	2015	5.08 [t]	4.82 [t]	5.02 [t]
Type no.	[kg]	[kg]	[kg]	Type no.	[kg]	[kg]	[kg]
…				…			
20 02 01	17.6	7.2	12.8	20 02 01	2.2	0.6	3.6
…	84.4	103.4	94.2	…	80.6	83.6	88.4
Total				Total			

Table 4. RMSW analysis of the basic urban area B in 2012 and 2015

Month in	1.	2.	3.	Month in	10.	11.	12.
2012	8.24 [t]	8.28 [t]	7.26 [t]	2015	9.08 [t]	11.3 [t]	5.71 [t]
Type no.	[kg]	[kg]	[kg]	Type no.	[kg]	[kg]	[kg]
…				…			
20 02 01	2.2	12.6	12.8	20 02 01	12.2	4.2	7
…				…			
Total	93.0	95.6	107.8	Total	101.6	96.0	97.4

Table 5. RMSW analysis of the referential rural area C in 2012 and 2015

Month in	1.	2.	3.	Month in	10.	11.	12.
2012	1.49 [t]	1.28 [t]	1.31 [t]	2015	1.89 [t]	1.42 [t]	2.15 [t]
Type no.	[kg]	[kg]	[kg]	Type no.	[kg]	[kg]	[kg]
…				…			
20 02 01	14.0	0.8	0.4	20 02 01	5.8	2.6	0.8
…				…			
Total	81.4	59.0	72.2	Total	87.0	84.8	82.6

Table 6. RMSW analysis of the referential urban area D in 2012 and 2015

Month in	1.	2.	3.	Month in	10.	11.	12.
2012	7.96 [t]	6.98 [t]	7.26 [t]	2015	7.55 [t]	7.15 [t]	6.45 [t]
Type no.	[kg]	[kg]	[kg]	Type no.	[kg]	[kg]	[kg]
…				…			
20 02 01	7.4	20.4	12.8	20 02 01	8.8	5.8	2.2
…				…			
Total	91.0	129.4	107.8	Total	98.6	99.0	87.8

Determining the average value of the RMSW composition in terms of BMSW distribution - Methodology

The determination of the amount of BMSW in RMSW is based on the results of composition analysis (Tables 3–6). Average values of the content of individual RMSW components are calculated by derived relation (1), where is adjusted formula for arithmetic mean from progressively performed RMSW analysis in 2012 and 2015. For the considered calculations, the methodology also allow for relation (3) determining the relative amount of BMSW in RMSW.

Average relative content of type of waste in RMSW [%]

$$\bar{p}_D = \frac{\sum_{i=1}^{n}(\frac{m_{Di}}{m_{Ci}})}{\mathrm{n}} \cdot 100 \quad (1)$$

where $\bar{p}_D$ – Average relative content of type of waste in RMSW [%]; m_{Di} – content mass of type of waste in one RMSW sample [kg]; m_{Ci} – one whole RMSW sample mass [kg]; *n* – number of performed RMSW analyse [-].

Relative amount of BMSW in RMSW [%]

$$P_{BMSW} = \frac{m_{BMSW}}{m_{sample}} \cdot 100 \quad (2)$$

where p_{BMSW} – Relative amount of BMSW in RMSW [%]; m_{BMSW} – content mass of type of waste in one RMSW sample [kg]; m_{sample} – one whole RMSW sample mass [kg].

Also methodology for descriptive statistics was used to process the RMSW composition results – standard deviation and coefficient of variation.

Standard transformation for correlation, regression model and analysis of variance – Methodology

In order to obtain a more precise interpretation, a standardized transformation has been applied. This model, which is more suitable for handling winter months without BMSW (20 02 01) collection in the municipality, is depicted in Table 7. The program STATISTICA 8 was used to analyse the data and obtain the necessary characteristics of correlation, simple regression and analyse of variance (*F*-test in regression).

Table 7. Standard transformation

Year	Quarter	Relative amount of BMSW in RMSW [%]	Average monthly BMSW production [t]
2012	1Q	$\frac{c_1 + c_2 + c_3}{3}$	$\frac{1}{3}(\sum_{i=1}^{n} x_{i(0.12;\,0.24)} + \sum_{i=1}^{n} x_{i(0.12;\,0.24)} + \sum_{i=1}^{n} x_{i(0.12;\,0,.24)})$
…	…	…	…
2015	4Q	…	…

Note: x_i *= the amount of BMSW in* C_{Bmsw} *containers (0.12 and 0.24 m*^{3}*) per one drive of collection; n = the number of collection (drive of collection);* c_1*,* c_2 *and* c_3 *= monthly relative amount of BMSW in RMSW [%].*

RESULTS AND DISCUSSION

The overall success evaluation of BMSW collection is shown in Fig. 1. Fig. 1. shows that in all the researched areas, with the exception of the site A, the percentage of BMSW in RMSW is steady and it has more likely increasing or an equal tendency. Table 8 show the value of individual calculations of descriptive statistics (standard deviation and coefficient of variation) relating to average checked values of BMSW in RMSW.

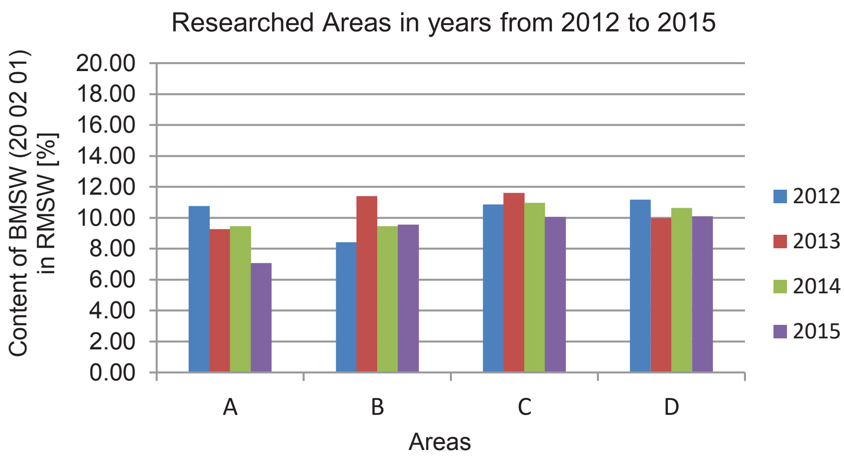

Figure 1. Graphical representation of the relative amount of BMSW in RMSW [%] at the side of all researched areas.

Table 8. Standard deviations (s) and coefficients of variation (V) of the sites A, B, C and D (BMSW values 20 02 01)

Year	A		B		C		D	
	s [-]	*V* [-]	*s* [-]	*V* [-]	*s* [-]	*V* [-]	*s* [-]	*V* [-]
2012	4.93	36.82	3.81	34.99	4.04	41.98	3.02	27.03
2013	2.68	43.15	3.89	34.11	5.40	53.76	3.15	32.52
2014	4.12	45.89	4.15	47.72	4.24	38.14	3.51	33.00
2015	2.59	60.73	4.43	39.49	5.11	56.09	4.70	49.49

The sites with introduced separate collection of BMSW placed four types of BMSW containers in the both built-up area. Their usage is as follows:

- C_{BMSW} containers 0.12 m^3, 0.24 m^3 and 0.77 m^3 – BMSW from residences,
- LSC containers 18 m^3–BMSW from public green areas.

The year-by-year development of the number of BMSW containers and their collection at the sides A and B is presented in Table 9 below.

Table 9. Number of total biodegradable municipal solid waste containers and number of collected containers per month at the areas A and B

Year	C_{BMSW} 0.12 m^3	C_{BMSW} 0.24 m^3	C_{BMSW} 0.77 m^3	LSC 18 m^3
Area A*				
2012	5/11	33/70	-	4/4
2013	5/11	45/88	-	4/4
2014	5/10	86/170	-	4/4
2015	5/11	86/170	-	4/4
Area B*				
2012	-	88/330	-	1/2.7
2013	-	88/310	-	1/3.8
2014	-	-	33/137	1/1.5
2015	-	-	34/123	1/2.3

**-total of containers/collected containers per month (C_{BMSW} – adjusted BMSW containers; LSC -large-sized containers).*

Increasing the number of CBMSW 0.24 m^3 containers (and the associated increase of the number of participating residences) influenced the total volume of collected BMSW between 2012 and 2015 at the side of rural area A with effective separation. This trend, recalculated to average monthly BMSW production by individual drive of collection, is presented in Table 10. Table 10 is also complemented by appropriate values of relative amount of BMSW in RMSW in percent. This table represents the standard data transformation for mentioned statistical methods in the chapter Materials and Methods.

Table 10. Average values from data obtained for individual quarters of the years 2012–2015 (Standard transformation)

	Quarter\year	2012	2013	2014	2015
	1Q	0	0	0	0
	2Q	13.00	5.00	8.00	12.00
	3Q	16.00	11.00	16.00	9.00
	4Q	7.00	9.00	8.00	2.00
	1Q	0	0	0	0
	2Q	2.14	2.38	4.61	6.13
	3Q	3.95	5.49	7.73	9.09
	4Q	1.16	3.36	4.11	3

**-collection of C_{BMSW} containers (0.12 and 0.24 m^3).*

The first of result of the analysis by STATISTICA 8 is focused on determining the correlation coefficient (the Correlations matrices function) in Table 11. The simple regression summary is presented in Table 12. The Coefficient of Determination R^2 can be considered as a percentage of the total variability of the response variable, as explained by the regression model. However, use of the Adjusted Coefficient of Determination R^2 is recommended (Šmilaur, 2007).

'*F* statistics', resulting from the analysis of the variance regression model, was carried out as an intermediate step of the selected regression function (Table 13).

Values of the Mean Squares in Table 10 were used for testing the significance of the regression model, whereas the key value used was the ratio of the model mean square and the residual mean square. In the case of the null hypothesis, the value of this ratio should be relatively close to 1 (i.e., the explained and unexplained variability should be of a similar size). More precisely (for this particular model), it should originate from the F disturbance with a parameter value of 1.14 (for the presented model). Nevertheless, the probability that the true value of this ratio, i.e. the *F* statistic (with a value of 15.01014), originates from this F disturbance is less than 0.000001 or equal to 0^6, as confirmed by the values in the '*p*-level' column. Hence H_0 can be rejected with this probability of a Type I error (at the concerned level of significance).

Table 11. Result of correlation values

	Correlations (Table 10) Marked correlations are significant at $p < 0.05000$ $N = 16$ (Case deletion of missing data)
Variable	[t]
[%]	0.7193
	$p = 0.000$

Table 12. Results of regression for Average The development of biodegradable municipal solid waste production per one collection drive

	Regression summary for Dependent Variable: [%] (Table 10) R = 0.71931223 R^2 = 0.51741008 Adjusted R^2 = 0.48293937 F(1.14)=15.01014 p < 0.00168 Std.Error of estimate: 0.04019					
N = 16	Beta	Std.Err. of Beta	B	Std.Err. of B	t(14)	p-level
Intercept			0.024204	0.015839	1.528144	0.148751
[%]	0.719312	0.185663	0.014296	0.003690	3.874292	0.001685

Note: The R field contains the coefficient of correlation, which is the positive square root of R-square; The R^2 field contains the coefficient of determination, which measures the reduction in the total variation of the dependent variable due to the independent variable;
The Adjusted R^2 is interpreted similarly to the R^2 value except the adjusted R^2 takes into consideration the number of degrees of freedom;
The F-value, df and resulting p-value is used as an overall F-test of the relationship between the dependent variable and the set in independent variables;
The Standard error of estimate measures the dispersion of the observed values about the regression line. The Intercept field contains the intercept value if you selected to include the intercept in the model on the Model Definition - Advanced;
The Std. error field contains the standard error of the intercept;
The t-value with the resulting of p-value are used to test the hypothesis that the intercept is equal to 0; The beta coefficients are the regression coefficients you would have obtained had you first standardized all of your variables to a mean of 0 and a standard deviation of 1;
The N is total number of observations.

Table 13. ANOVA results

	Analysis of Variance; DV: [%] (Table 10)				
N = 16	Sums of Squares	df	Mean Squares	F	p-level
Regress	0.024245	1	0.024245	15.01014	0.001685
Residual	0.022614	14	0.001615		
Total	0.046859				

Note: The N is total number of observations.

We present below a graphical representation of the regression line, (Fig. 2).

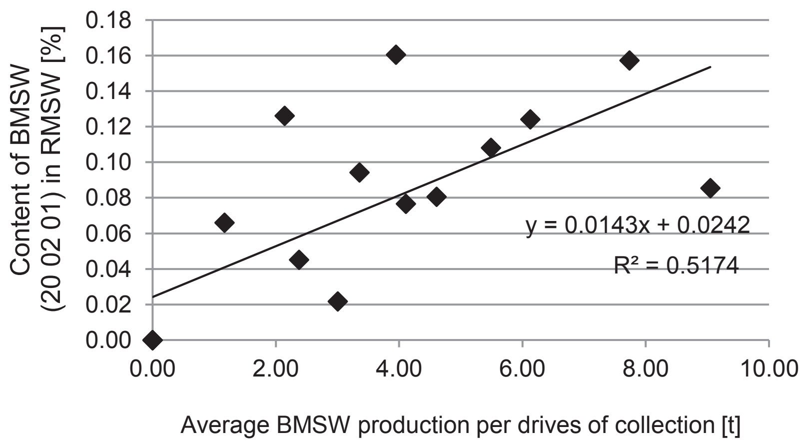

Figure 2. Graphical representation of regression.

According to Fig. 1. in more detail, there is a decrease of relative content of BMSW 20 02 01 in RMSW approximately from 10.77% to 7.08% here in monitored years 2012–2015 and these values remain in the site A. This state is achieved by providing a sufficient number of containers and with probably consequently shortening the delivery distance. On the other hand there was no reflection of separate BMSW collection in RMSW composition at the site B. The representation of BMSW in RMSW still remains about 10% in monitored period. Stable values were also observed at the referential sites C and D and without separate BMSW collection. At the site B, where separate system of BMSW collection has also been introduced, the collection did not have a positive effect, probably there was an increased number of 24 m^3 C_{BMSW} containers in exchange for a decrease in 0.77 m^3 C_{BMSW} container numbers. Thus the delivery distance could have extended above the tolerable limit which means higher efficiency of BMSW collection system. In the view of comparison of these both sites through the use indicator of Waste generation per capita per year (Teixeira et al. 2014 and CML et al. 2014) is also evident a difference in the achieved value 122 kg·person^{-1} year^{-1} (site A) and 20 kg person^{-1} year^{-1} (site B) in the last year of measurement 2015.

An assessment of the mean values of input data (site A) further proves a statistically significant relation between the relative amount of BMSW in RMSW and the average monthly BMSW production (r = 0.7193, α = 0.05, n = 16). In other words, the Relative amount of BMSW in the rural area A depends on the average monthly BMSW production by settings of collection parameters, from the perspective of the overall size of this site. The positive relationship was furthermore enriched by regression analysis; however this does not necessarily reflect a causal relation (in fact, only non-manipulated areas were observed). Thus, the relative amount of BMSW in RMSW is influenced by non-measured factors. Furthermore, as the distribution of regression residuals around the x-axis shows, there exist some differences between the real (observed) and predicted (fitted by the regression model) values of the variables in the regression equation. An increasing number of C_{BMSW} 0.24 m^3 containers was influence the analysed components and additionally a families participating at least once per month in separating/total number of families also could play a certain role like as another factor with the possible influence. (Martinho, G., et al., 2017).

CONCLUSIONS

The principal objective of the present study was an evaluation of BMSW collection in sites A, B, C and D in the period of 2012–2015. The authors also studied the influence of the average monthly BMSW production on the relative amount of BMSW in RMSW at the side of rural area with effective collection.

The study proves that the average monthly BMSW production influence the relative amount of BMSW in RMSW and mathematically defines this dependence. Available data for individual quarters of 2012–2015 confirm the following regression compensation straight line of the average monthly BMSW production **p** and the relative amount of BMSW in RMSW **T** in rural area A: T = 0.0242 + 0.0143.p.

The decrease of BMSW in RMSW at site A indicates that the directive on landfills can be followed with well-chosen technological parameters of separate BMSW collection at a given site. It confirms the statistically significant relation. Improperly adjusted technological parameters at site B indicate that this site has total monitored results parallel to referential areas without separate collection. It means then, that the municipality has only an increase in costs for BMSW disposal without concrete positive effects of separate BMSW collection and on the environment.

Hence it is necessary to continually analyse the collection data, rigorously evaluate and carry out immediate remedial measures and optimize the biodegradable municipal solid waste technological parameters at given sites with separate collection.

ACKNOWLEDGEMENTS. The work has been supported by the Internal Grant Agency of Czech University of Life Sciences Prague, Project No. 2017:31180/1312/3124.

REFERENCES

Bilitewsky, B., Hardtle, G. & Marek, K. 1997. *Waste Manegement*. 1st ed. Verlag Berlin Heidelberg, DEA, Springer, 430 pp.

Bolaane, B. 2006. Constraints to promoting people centred approaches in recycling. *Habit. Int.* **30**, 731–740.

Consonni, S., Giugliano, M. & Grosso, M. 2005. Alternative strategies for energy recovery from municipal solid waste, Part B, emission and cost estimates. *Waste Management* **25**, 137–48.

Epstein, E. 1997. The Science of Composting. Boca Raton, CRC Press, 487 pp

Greg, Jay.S. 2010. National and regional generation of municipal residue biomass and the future potential for waste-to-energy implementation. *Biomass & Bioenergy* **34**, 379–388.

Imhoff, ML., Bounoua, L., Ricketts, T., Loucks, C., Harriss, R. & Lawrence, WT. 2004. Global patterns in human consumption of net primary production. *Nature* **429**, 870–3.

Kotoulová, Z. 2001. *Návrh variant logistického systému, metod a kritérií hodnocení. [Proposed Options and Methods of Evaluation Criteria for the Assessment of the Logistics System]*. Praha, ČEU, 54 pp.

Maimoun, M.A., Reinhart, D.R., Gammoh, F.T & Bush, P.M. 2013. Emissions from US waste collection vehicles. *Waste Management* **33**, 1079–1089.

Martin, M., Williams, I.D. & Clark, M. 2006. Social, cultural and structural influences on household waste recycling: a case study. *Resour. Conserv. Recycl*. **48**, 357–395.

Martinho, G., Gomes, A., Santos, P., Ramos, M., Cardoso, J., Silveira, A. & Pires, A.2017. A case study of packaging waste collection systems in Portugal – Part I: Performance and operation analysis. *Waste Management (2017)*, http://dx.doi.org/10.1016/j.wasman.2017.01.030

Oskamp, S., Zelezny, L., Schultz, P.W., Hurin, S. & Burkhardt, R. 1996. Commingled versus separated curbside recycling: does sorting matter? *Environ. Behav*. **28**, 73–91.

Papageorgiou, A., Barton, J. R. & Karagiaannidis, A. 2009. Assessment of the greenhouse effect impact of technologies used for energy recovery from municipal waste. *Journal of environmental management*. **90**, 2999–3012.

Porteous, A. 2005. Why energy from waste incineration is an essential component of environmentally responsible waste management. *Waste Management* **25**, 451–9.

Porteous, A. 2005. Why energy from waste incineration is an essential component of environmentally responsible waste management. *Waste Management* **25**: 451–459.

Powell, J.C. 1996. A lifecyle assessment and economic valuation of recycling. *J. Environ. Plan. Manage* **39**, 97–112.

Rogge, N. & De Jarger, S. 2013. Measuring and explaining the cost efficiency of municipal solid waste collection and processing services. *Omega 41*. **4**, 653–664.

Shaw, P.J., Lyas, J.K. & Hudson, M.D. 2006. Quantitative analysis of recyclable materials composition: tools to support decision making in curbside recycling. *Resour. Conserv. Recycl*. **48**, 263–279.

Šmilauer, P. 2007. *Moderní regresní metody. [Modern Regression Methods]*. České Budějovice, Biologická fakulta JU, 168 pp.

Tchobanoglous, G. & Kreith., F. 2002 *Handbook of solidwaste management.* 2nd ed. New York, USA, McGraw-Hill, 505 pp

Tchobanoglous, G., Theisen, H. & Vigil AS., 1993. *Integrated Solid Waste Management*.1st ed. New York, McGraw-Hill, 978 pp.

Teerioja, N., Moliis, K., Kuvaja, E., Ollikainen, M., Punkkinenm, H. & Merta, E. 2012. Pneumatic vs. door-to-door waste collection systems in existing urban areas: a comparison of economic performance. *Waste Management* **32**, 1782–1791.

Teixeira, C.A., Russo, M., Matos, C. & Bentes, I. 2014. Evaluation of operational, economic, and environmental performance of mixed and selective collection of municipal solid waste: Porto case study. *Waste Manage. Res.* **32**, 1210–1218.

Vehlow, J. 2007. Union waste management strategy and the importance of biogenic waste. *Journal of Material Cycles and Waste Management*. **9**, 130–139.

Vitousek, P., Ehrlich, P.R., Ehrlich, A.H. & Matson, P. 1986. Human appropriation of the products of photosynthesis. *BioScience* **36**, 363–73.

Vrbová, M. & Balner, P. 2009. *Hospodaření s odpady v obcích*. [Waste Treatment System in Municipalities]. 1st ed. Praha, EKO-KOM, a.s., 184 pp.

Wang, F.S., Richardson, A.J. & Roddick, F.A. 1997. Relationships between set-out rate, participation rate and set-out quantity in recycling programs. *Resour. Conserv. Recycl.* **20**, 1–17.

Wilson, C.D.H. & Williams, I.D. 2007. Curbside collection: a case study from the north-west of England. *Resour. Conserv. Recycl.* **52**, 381–394.

Yildiz-Geyhan, E., Yilan-Çiftçi, G., Altun-Çiftçioglu, G.A. & Kadirgan, M.A.N. 2016. Environmental analysis of different packaging waste collection systems for Istanbul – Turkey case study. *Resour. Conserv. Recycl*. **107**, 27–37.