USING MOTIVATIONAL SYSTEMS TO SORT WASTE EFFECTIVELY IN CZECH MUNICIPALITIES

Eva URBANOVÁ[1], Vlastimil ALTMANN[1]

[1]Department of Machinery Utilization, Faculty of Engineering, Czech University of Life Sciences Prague, Kamýcká 129, Prague 6, 165 21, Czech Republic

Abstract
In order to sort the utilizable elements of communal waste in municipalities of the Czech Republic more effectively, we can use the methods of the PAYT motivational systems ("Pay as you throw"), which respect to the economical, ecological and technological aspects of the given process. The implementation of the motivational system based on the collection of sorted waste from door to door and filing the collection containers and bags by means of bar codes was monitored in a selected town in the Central Bohemian Region. Over the monitored pilot period of the last quarter of 2018, the implementation of the MESOH system in the monitored town demonstrably reduced the amount of mixed communal waste by 5.1 tons compared with the same period in 2017. At the same time, there was an increase in the production of the monitored commodities - paper and cardboard by 7.5 tons, plastics by 2.5 tons. When the motivational system went into live operation in the first quarter of 2019, there was a reduction in the amount of mixed communal waste by 52.8 tons, and the production of paper and cardboard increased by 1 ton, with plastic increasing by 0.7 tons, compared with the last quarter of 2018. Based on detailed monitoring of the potential amount of different waste to be separated, we can state that the potential of raw materials to be sorted amounts to 76 or 83 % of all house waste, depending on the type of the built-up area, which documents the possibility to meet EU requirements. Mixed communal waste only represents 17 or 24 % in the monitored built-up areas.

Key words: *municipal solid waste; motivation; waste sorting.*

INTRODUCTION

In order to reduce the costs of waste management, many municipalities in the Czech Republic have started to implement different motivational measures with the aim of increasing the amount of sorted waste and decreasing the amount of mixed communal waste (SKO) deposited in landfills. Regarding the given motivational system, it is important to make sure that citizens don't start creating illegal landfills in order to reduce the amount of mixed communal waste. This negative feature can be prevented by implementing motivational criteria that do not compensate the citizens only on the basis of the amount of sorted waste, but also on the basis of a reduced amount of mixed communal waste. The main emphasis is on the prevention of the generation of waste *(Xevgenos, Papadaskalopoulou, Panaretou, Moustakas, & Malamis, 2015; Sakai et al., 2017).*

Waste recycling is one of the conditions of waste management sustainability. As the production of waste increases, the environmental capacity decreases, increasing the demand to transport waste to greater distances *(Ferrão et al., 2014; Bonelli, Bosio, Cavallo, Gianolio, & Marengo, 2016).*

Goals have been set regarding the production of communal waste stemming from the goals of the EU. The current goal is to increase the recycling of communal waste to one half of the current amount by 2020. This will bring about a reduction in the amount of mixed communal waste in landfills. According to available data for 2015, the Czech Republic was currently at 36 % *(Expósito & Velasco, 2018; Kling, Seyring, & Tzanova, 2016; Seyring, Dollhofer, Weißenbacher, Bakas, & McKinnon, 2016)*.

Key tools for greater effectiveness in sorting waste in Czech municipalities are legislative, economical and institutional tools. Economical tools are namely represented by a fee for mixed communal waste *(Puig-Ventosa & Sastre Sanz, 2017; Chifari, Lo Piano, Matsumoto, & Tasaki, 2017).*

It is possible to achieve greater effectiveness of sorting utilizable elements of communal waste in municipalities by means of implementing the methods of motivational systems ("Pay as you throw"). When implementing this system, the system of waste collection must be changed. The methods are either based on charging mixed communal waste or implementing a system of discounts based on the amount of sorted waste. "Door to door" waste collection is associated with these methods. The principle

of these systems lies in the filing of collected containers and bags by means of bar codes *(Brown & Johnstone, 2014; Morlok, Schoenberger, Styles, Galvez-Martos, & Zeschmar-Lahl, 2017; Šauer, Pařízková, & Hadrabová, 2008)*.
The aim of this study is to gradually analyze data regarding the amount of individual commodities based on monitoring the implementation of the MESOH motivational system in a selected town in the Central Bohemian Region, and to determine the possible annual potential of the amount of sorted elements within the municipality based on monitoring 6 households that monitored their household waste for 4 months. The MESOH motivational system is based on the volume of main commodities (plastics, paper, mixed communal waste) collected by the waste collection company. The containers and bags are marked with bar codes, which simplifies the identification of individual households, determining the amount of waste in the household and the level of sorting of individual elements of communal waste. By means of bonus compensations, MESOH not only takes into account waste collection but also the effectiveness of filling up the containers, bags, and the reduction of waste production.

MATERIALS AND METHODS

The actual analysis of the current state of waste management and determining the costs of its individual activities was realized in a monitored town in the Central Bohemian Region with 4,770 citizens (as of 2019). The composition of mixed municipal waste was analyzed and a solution for a better yield of sorted collected waste was suggested. Data were processed using Excel (proportional representation, frequency of occurrence) and basic statistical methods (averages and deviations of values). There are 2 main types of built-up areas in the town (central and suburban).
Based on the analysis, the town has determined the main goals in changing the waste management system:

- Greater utilization of waste container volume
- Implementation of a container registry
- A proposal for a change to choose a more economical and effective system of the town's waste management
- Improvement of the town's waste management services for citizens

The implementation of the registration system for containers and newly also for bags, distributed to the town citizens free of charge, was the main tool for change.
The next part of the analysis within the monitored location dealt with the assessment of the potential amounts of all basic separated commodities with the aim of reducing non-utilizable mixed communal waste. Based on EU directives, it will be necessary to sort 60 % of the overall municipal waste in individual municipalities for recycling in 2025, and this number will grow to 70 % in 2030. There were 6 households that took part in detailed monitoring (3 from the central built-up area and 3 from the suburban built-up area). There were 9 citizens altogether in both types of built-up areas. The households monitored the production of their waste for a period of 4 months (1 month in each quarter), focusing on the possible sorted segments.

RESULTS AND DISCUSSION

Based on the results of the town's waste management analysis, there was a change in the approach to waste sorting as of October 1, 2018, when the MESOH system was launched in pilot mode. The traditional container collection of sorted waste was extended by the collection of plastic and paper in bags directly in the households. Each household received bags and bar codes to attach to the bags. Within the monitored period of the pilot implementation of the MESOH system from October 1, 2018 to December 31, 2018, there were 26.97 % of participating households.
The result of the MESOH system assessment in the reference location over the first monitored period (pilot implementation in the last quarter of 2018) demonstrated an increase in sorting of communal waste segments and a concurrent reduction in mixed municipal waste production, which brings about a reduction of costs for mixed communal waste collection and the lowering of costs for the removal of this waste for the citizens. To ensure comparable conditions, the last two quarters of 2017 and 2018 were compared (Tab. 1).

Tab. 1 Production of waste in the town over the last quarters of 2017 and 2018

Commodities	4Q 2017 t	4Q 2018 t
Mixed communal waste (SKO)	315.2641	310.1554
Paper and cardboard	36.9231	44.4203
Plastic	26.3912	28.9139
Total	378.5784	383.4896

Tab. 1 and Fig. 1 - 2 show that the production of SKO decreased by 5.1 tons (2 %) upon the implementation of the MESOH system, and there was also an increase in the production of the monitored commodities - by 7.5 tons (2 %) of paper and cardboard and by 2.5 tons (1 %) of plastic.

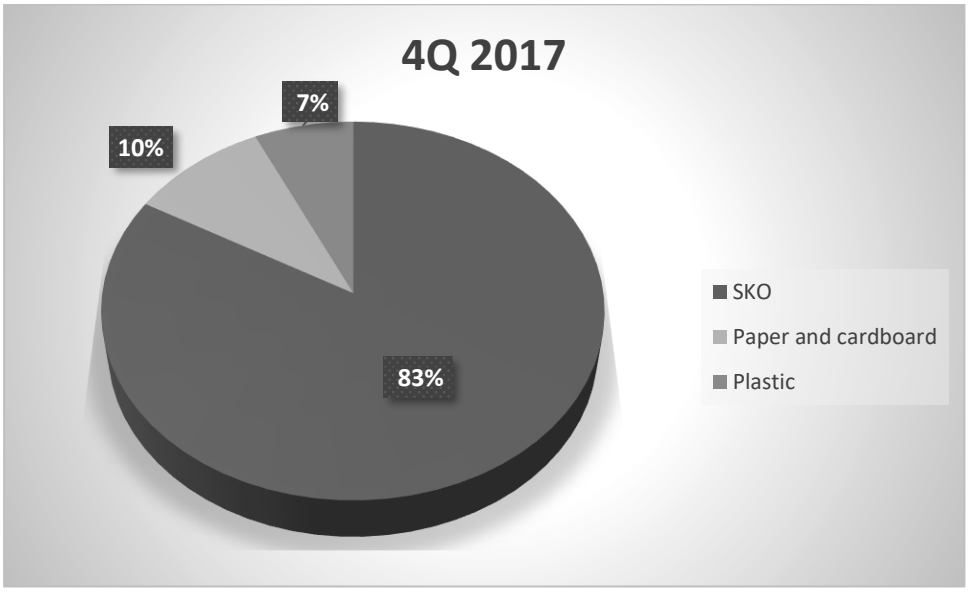

Fig. 1 Graphic representation of the production of monitored commodities in the town over the last quarter of 2017

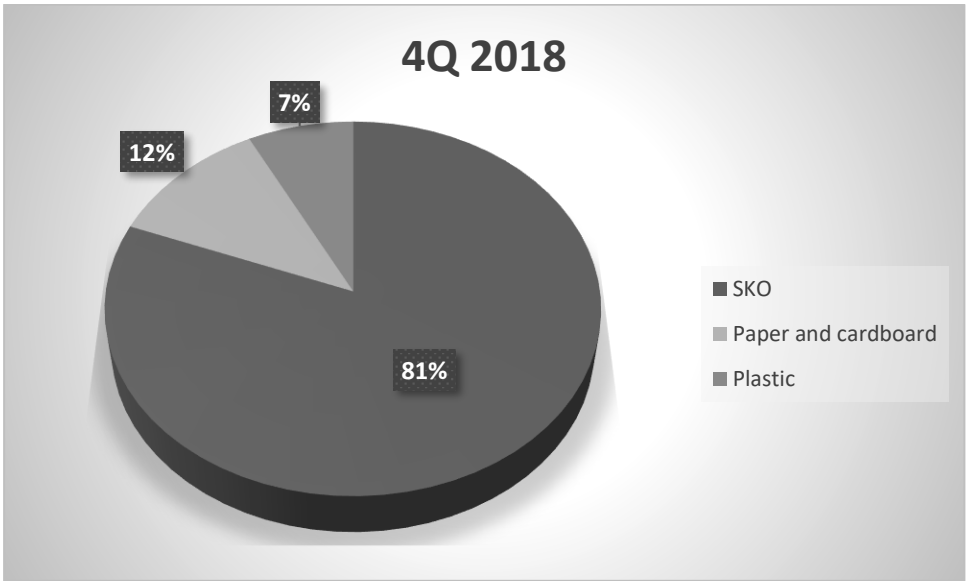

Fig. 2 Graphic representation of the production of monitored commodities in the town over the last quarter of 2018

The MESOH motivational system was implemented full-scale in the monitored reference locality as of January 1, 2019. According to the results shown in Tab. 2, it is obvious that over the first quarter of 2019 there was a reduction of the production of SKO by 52.8 tons (4 %) compared with the fourth quarter of 2018 (Fig. 2), and by 55.3 tons (8 %) compared with the first quarter of 2018 (Fig. 3).

Tab. 2: Production of waste in the town over the first quarter of 2018 and 2019

Commodities	1Q 2018 t	1Q 2019 t
Mixed communal waste (SKO)	312.5722	257.3154
Paper and cardboard	30.7320	45.4651
Plastic	22.7261	29.6649
Total	366.0303	332.4454

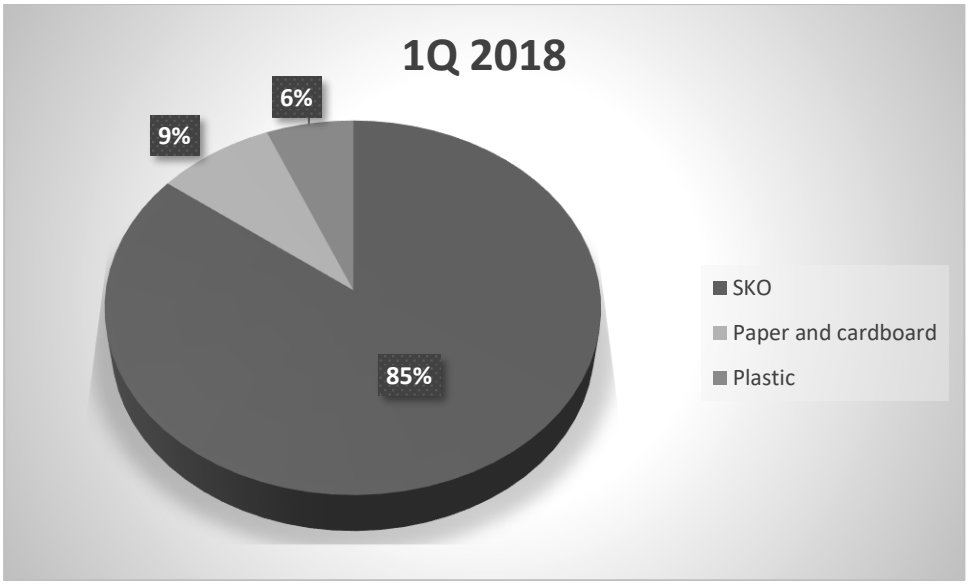

Fig. 3: Graphic representation of the production of monitored commodities in the town over the first quarter of 2018

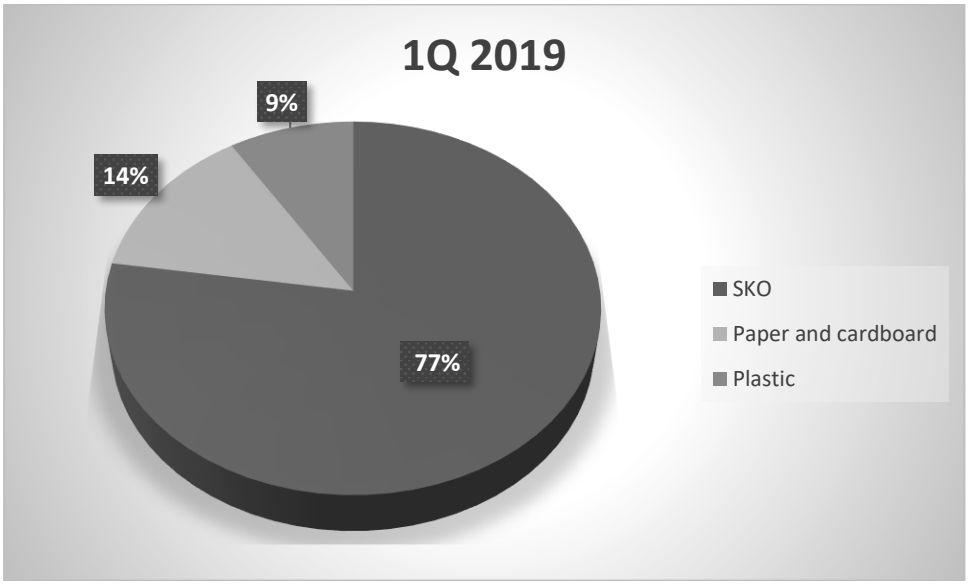

Fig. 4: Graphic representation of the production of monitored commodities in the town over the first quarter of 2019

The results of monitoring the potential production of all basic separated raw materials in the monitored households are shown in Tab. 3. Apart from paper and glass, raw materials like glass, metals, Tetrapak and bio waste were also sorted. For the sake of comparison carried out in Fig. 1- 4, other commodities besides paper and glass were labelled as other sorted commodities, see Tab. 4 and Fig. 5 and 6.

Tab. 3: Production of basic sorted commodities per citizen according to the type of built-up area

Built-up area	SKO	Paper and cardboard	Plastic	Glass	Metal	Bio waste	Tetrapak	Total
	kg	kg	kg	kg	kg	kg	kg	kg
Central	8,683	3,545	13,277	4,582	1,087	17,657	1,931	50,761
Suburban	10,847	4,810	10,914	4,699	1,354	9,630	3,446	45,70

Tab. 4: Production of monitored commodities per citizen according to the type of built-up area

Built-up area	SKO	Paper and cardboard	Plastic	Other sorted commodities
	kg	kg	kg	kg
Central	8,683	3,545	13,277	25,257
Suburban	10,847	4,810	10,914	19,129

Table 4 clearly indicates that there is still a high potential for sorting other commodities in the households within the monitored location and that the amount of SKO in both types of built-up areas decreased significantly, see Fig. 5 and 6.

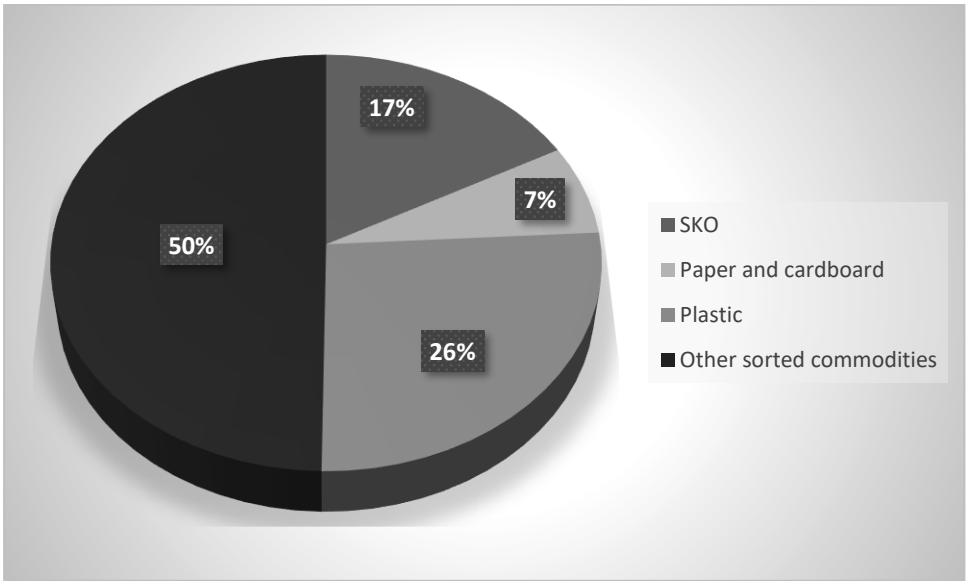

Fig. 5: Graphic representation of the production of individual commodities per citizen in the central built-up area

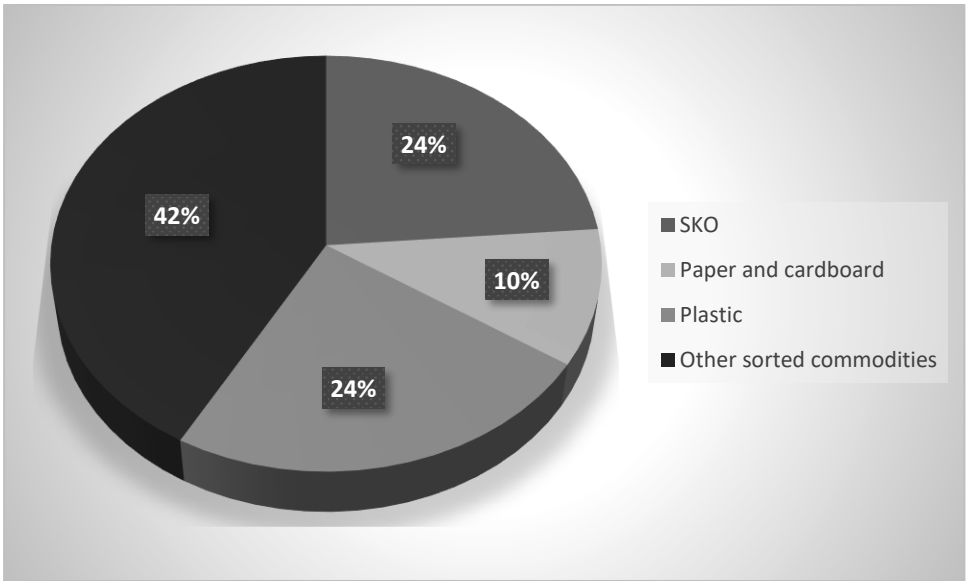

Fig. 6: Graphic representation of the production of individual commodities per citizen in the suburban built-up area

For the sake of comparison and making a prediction of waste development in the monitored town, Table 5 shows the results of waste production in a selected municipality in the South Moravian Region, which has been using the MESOH system since 2018. It is obvious that the amount of SKO decreased by nearly 45 tons, the production of paper and cardboard increased by 6.6 tons, and the production of plastic increased by 13 tons over the course of 5 years.
The measurement results are comparable to those reported by other authors (Benešová, L. a kol. (2011), Kaufman, P. & Báreková, A. (2010); Kotoulová, Z. (2001); Slejška, A. (2004)).

Tab. 5: Results of waste production in the selected municipality following the implementation of the MESOH system in 2013

Year	SKO t	Paper and cardboard t	Plastic t
2013	282.69	36.56	30.26
2014	276.38	41.42	40.12
2015	229.67	37.44	42.09
2016	243.55	42.28	41.18
2017	237.74	43.17	43.23

CONCLUSIONS

In association with the implementation of the new waste sorting system in the monitored town, changes were observed although the new system has only been implemented recently. The amount of SKO decreased demonstrably by 5.1 tons over the period of pilot implementation and the amount of individual sorted segments increased, especially regarding monitored plastic - by 2.5 tons, and paper and cardboard - by 7.5 tons. There was a further reduction in the amount of SKO by 52.8 tons over the first quarter of full-scale operation of the new motivational system in town, with the amount of plastic increasing by 0.7 tons and paper and cardboard increasing by 1 ton.
When monitoring the potential amount of sorted waste, it is apparent in both types of built-up areas that out of the overall amount of communal waste within households, it is possible to sort up to 76 or 83 % of all waste in the monitored built-up areas. SKO only represented 17 or 24 % in the monitored built-up areas.
Consistent sorting also brought about an increase in paper and plastic collection by 10 - 11 % compared with the monitored period of 1Q 2019.

Based on these detailed analyses of 6 households and based on results from other municipalities that have been participating in the MESOH system for a longer period of time, it is possible to state that a transformation is achievable in meeting the EU requirements for increasing the amount of sorted communal waste for recycling in such a way that 50 % of all communal waste is recycled in 2020, and up to 70 % in 2030. The monitored households have already achieved this. It will therefore be necessary to change the system of collection and removal within the municipality's territory regarding the potentially higher amount of all sorted waste in such a way so as to ensure that all sorted amounts are actually removed from the municipalities. This may be achieved by changing technological parameters such as the amount and size of containers, the interval of collection and the carrying distance.

ACKNOWLEDGMENT

This study was supported by the Internal Grant Agency of Czech University of Life Sciences Prague, Project No. 2018: 31180/1312/3124.

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Corresponding author:
RNDr. Ing. Eva Urbanová, Department of Machinery Utilization, Faculty of Engineering, Czech University of Life Sciences Prague, Kamýcká 129, Prague 6, 165 21, Czech Republic, e-mail: urbanovae@tf.czu.cz