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ANALYSIS OF THE MATERIAL COMPOSITION OF MIXED MUNICIPAL SOLID WASTE IN THE KOŠICE REGION OF THE SLOVAK REPUBLIC

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Abstract

This work focuses on the analysis of material composition of mixed municipal solid waste (MSW) in the city of Košice, the second largest city in Slovakia, and in the village of Poproč, which is representative of the region. The paper describes the characteristics of the monitored localities, the methodology and the original evaluation procedure. The analysis of the mixed MSW composition in Poproč was performed in 2009-2010, and in Košice in 2011. In both cases, the analysis was carried out in each season in four campaigns according to a regular interval of waste collection. 36 samples were analyzed in Košice with an average weight of 236.1 kg, and 4 samples were analyzed in Poproč with an average weight of 208.2 kg. The mixed MSW was sorted into categories and subcategories. The biodegradable waste had the highest content at both sites. The content of the biodegradable MSW in Poproč was about 25% lower than in Košice because of the built-up area type. The content of packaging was 24% in Košice and 29% in Poproč.

Key words: analysis, material composition, mixed municipal solid waste (mixed MSW), sieving, sorting

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1. Introduction

In Slovakia, about 1.2 million tons of mixed MSW are produced per year, which represents approximately 67% of the total amount of MSW (Fig. 1) (Klinda et al., 2010).

According to the Decree of the Ministry of Environment of the Slovak Republic No. 284/2001 Coll. which defines the Waste catalogue the mixed MSW belongs to a Group 20 - municipal wastes with the catalog number 20 03 01. MSW is defined as waste collected by a municipality. It refers to waste generated in households, small business, office buildings and institutions such as schools, hospitals, government buildings, waste from parks and street

cleaning. Mixed MSW is a part of municipal waste which consists of non-separated solid waste from households and waste with similar characteristics and composition.

In Slovakia, the mixed MSW disposal is carried out mainly in two ways: landfilling (86%) and incineration with or without energy recovery (Ministry of Environment of Slovak Republic, 2010). Slovakia has only two incineration plants (in Bratislava and Košice) for incineration of mixed MSW. The fees for landfilling are currently growing up. A fee for landfilling mixed municipal waste is in range of 5-10 euros per ton, depending on waste composition. On the other hand, one tone of mixed MSW has a caloric value of 8-12 MJ/kg (IEA, 2003),

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which is comparable to a caloric value of brown coal. From that reason, mixed MSW can be considered as a secondary raw material for energy recovery.

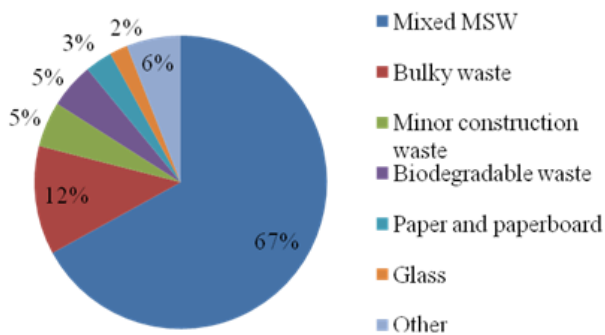


Fig. 1. The composition of MSW in Slovakia (Klinda et al., 2010)

The main component of mixed MSW is biodegradable waste. According to the EU, biodegradable MSW going to landfills must be reduced to 75% of the total amount (by weight) of biodegradable MSW produced in 1995 by the year 2006, to 50% by 2009 and to 35% by 2016 (EC Directive, 1999).

Slovakia is one of the EU Member States, which can take advantage of a four-year delay, considering the heavy reliance on landfilling. This means that the target years are 2010, 2013 and 2020. To meet the EU goals, Slovakia takes steps to reduce the amount of landfilled biodegradable MSW mainly through recycling, composting, biogas production or the use of waste as a source of secondary raw materials and energy. Since January 1st 2010, a separate collection of four components of MSW - paper, plastics, glass and metals is required for all municipalities in Slovakia. Directive 2008/98/EC of the European Parliament and of the Council of 19 November 2008 sets recycling goals for MSW disposal for the Member States, namely 50% for paper, metals, plastic and glass from households by 2020 (EC Directive, 2008). Simultaneously, it is necessary to meet the goals for the reduction of landfilled biodegradable MSW, as mentioned above. In this regard, the identification of the mixed MSW composition is the key factor from which all necessary steps and measures for the achievement of the defined goals are derived.

Mixed MSW is highly heterogeneous in terms of qualitative and quantitative material composition. Its amount and composition depend on the population size and demographic characteristic, and simultaneously on the market development and the community consumption. According to the mixed MSW composition it is possible to assume the yield of separated collection as well as to define the insufficiencies in this field.

There are many similar studies that have been carried out in different countries (Banar and Ozkan, 2008; Burnley et al., 2007; Riber et al., 2009), with either the original methodology, or the methodology

transposed from other sources. However, the local conditions must be taken into account.

The mixed MSW composition is influenced by several factors which must be considered in the planning, sampling and analysis process (ASTM D5231 – 92, 2008; Gidakaros et al., 2006; SAEFL, 2004). These are mainly: the seasons, the age structure of population, built-up area types and methods of heating, collection intervals and separate collection parameters (number and location of containers for separated waste, separately collected commodities) and so on. The analysis of the mixed MSW composition in Košice and Poproč was carried out for the following reasons:

- The long-term absence of relevant objective data about the mixed MSW composition in the region.
- The variability of the material composition and amount of mixed MSW produced under the influence of economic and social situation.
- New possibilities for mixed MSW disposal resulting from the European and Slovak standards.

In the years 2009 – 2011, the analysis of the mixed MSW composition was performed independently in the regional city of Košice in Eastern Slovakia and in Poproč village that is 37 km far from Košice. Poproč is a member of Regional Associations of Municipalities *Rudohorie* which includes 16 municipalities. This Association chose the village of Poproč as a representative of this region due to the number of inhabitants, their age structure and an established waste management system.

The main goal of the analysis was to define the material composition of the mixed MSW as well as the amount of packaging. In Poproč, other MSW streams were monitored too, such as bulky waste, separately collected fractions, etc. While the analysis in Košice was based on the SWA-Tool methodology recommendations (European Commission, 2004a, b), in Poproč the mixed MSW composition was analyzed according to the Kotoulová methodology (Kotoulová, 2001). The results could be compared, because the methodologies in the comparing parameters were not significantly different.

1.1. Characteristics of the studied region

Slovakia, a member of the European Union, is a landlocked country in Central Europe with the area of 49 035 km. About 5.4 million inhabitants live in Slovakia. Slovakia borders with the Czech Republic, Austria, Hungary, Ukraine and Poland. The capital city is Bratislava. The population density is approximately 110.8 inhabitants/km²; there are 2891 independent municipalities, including 138 towns (2010). Bratislava and Košice are the largest cities in population. More than 57% of population lives in cities. Slovakia is divided into 8 regions, and the Košice region is one of the regions with the largest population (Statistical Office of the Slovakia, 2012).

The Slovak Republic is a parliamentary democracy and the official language is Slovak. Since May 2004 it has been a member state of the European

Union, and since December 2007 it has been a member of the Schengen area. Since January 2009 it has been a member of the European Monetary Union with the official Euro currency (European Union, 2013). Slovakia is in the North Temperate Zone. Its geographical position is in the middle of Europe. The city of Košice, the second largest city in Slovakia, is located in the eastern part of Slovakia. The population of Košice is about 240000 (Statistical Office of the Slovakia, 2012). Of the total number of inhabitants, 15.4% is in the pre-productive age (persons aged 0-18 years), 62.8% in the productive age and 21.8% in the post-productive age.

The MSW disposal in Košice is carried out by Kosit, Inc. Company, whose amount of the MSW disposal was about 49000 t in 2011 (Kopernický, 2011). Separate collection of paper, plastic, glass and metal has been introduced there. In summer 2011, multilayer composite materials started to be separated as well (for example Tetra Pak packaging materials). In 2011, the total amount of separately collected MSW in Košice was nearly 5000 tons of paper and paperboard, 2500 t of glass, 1800 t of metals and 700 t of plastic (Kopernický, 2011). The mixed MSW is recovered/disposed in the MSW incinerator of Kosit, Inc. Company. Produced heat is used for purposes of an incineration plant and for heating one of the district of Košice. Currently, the Kosit, Inc. Company is starting a production of electricity from the mixed MSW. The mixed MSW collection and transport interval is 2-3 times a week depending on the district. For analysis of the mixed MSW composition, it was necessary to divide Košice area into three sections according to the building types and used waste containers:

- The section of multi-storey buildings – 4 districts mostly with 1100 l waste containers,
- The rural section – 11 districts mostly with 110 and 120 l litter bins,
- The mixed section – 4 districts with both built-up area types and both container types (waste containers and litter bins).

Poproč is in the Košice region, in the Košice-okolie district. Poproč has 2736 inhabitants (by December 31st 2009). Of the total number of inhabitants, 16.8% is in the pre-productive age, 62.9 % in the productive age and 20.3% in the post-productive age. Separate collection of paper, plastic, glass, multilayer composite materials and metal containers has been launched. The amount of the MSW disposal in 2009 was about 630 t, from which 85 t (13.5 %) was collected separately. Specifically, it was 19.5 t of paper and paperboard, 47.2 t of glass, 9.5t of plastic and 4.5 t of WEEE. At present, all generated mixed MSW is landfilled (Kvokačka, 2011). The rural buildings are very typical for Poproč. Therefore, there was no need to divide this area according to the built-up type. The mixed MSW is collected in 110 l litter bins at two-week intervals.

The map of Slovakia showing the studied localities is shown in Fig. 2.

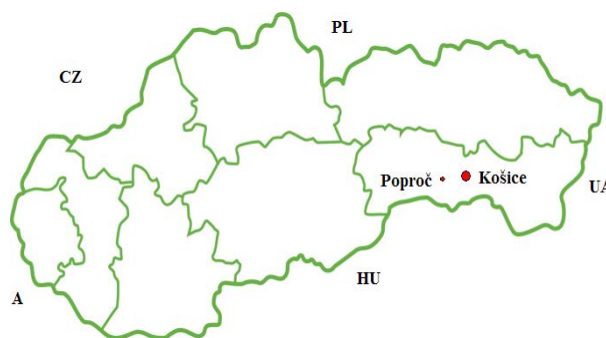


Fig. 2. The Slovakia map showing the studied locations

2. Experiments

2.1. Methodology for sampling and analysis

In both localities, the analysis of the mixed MSW composition was carried out during one year in each season. The cycle of sample collection was the same in each season, which followed a regular mixed MSW collection interval, thus representative sampling was ensured. In Košice, one part of the district from residential, rural and mixed section was selected based on the average age structure and number of inhabitants for sampling and analysis because of the impossibility to analyze all generated mixed MSW. In Poproč, all generated mixed MSW was analyzed for a specified time period.

One collecting vehicle was considered a general sampling unit, from which 200 kg samples were taken. The vehicle was emptied in an open area and the waste was homogenized. The samples with the total volume of about 1 m³ and a weight of 200 kg were taken from a pile of dumped waste by a hydraulic rotary loader from 5 different places. These samples were manually sorted into defined categories and subcategories. As a guide for separation of the finest fraction the screens were used. The finest fraction was a separate category.

In both localities, a similar approach for sampling was used, consisting of the following main steps:

1. Analyzed waste (one collecting vehicle) from the selected part/district of the city of Košice in each section was collected and transported to a designated location. The days of collection and analysis were the same as the days of the regular collection interval. In case of Poproč, the mixed MSW was collected from the whole village.

2. All the waste was weighed and the data were recorded in the form (date, district, weight of all waste, etc.).

3. The mixed MSW from the vehicle was dumped and homogenized and a sample with a total volume of about 1 m³ and weight of about 200 kg was taken by the hydraulic rotary loader.

4. Each sample was sorted separately. The sorting procedure was following (Fig. 3).

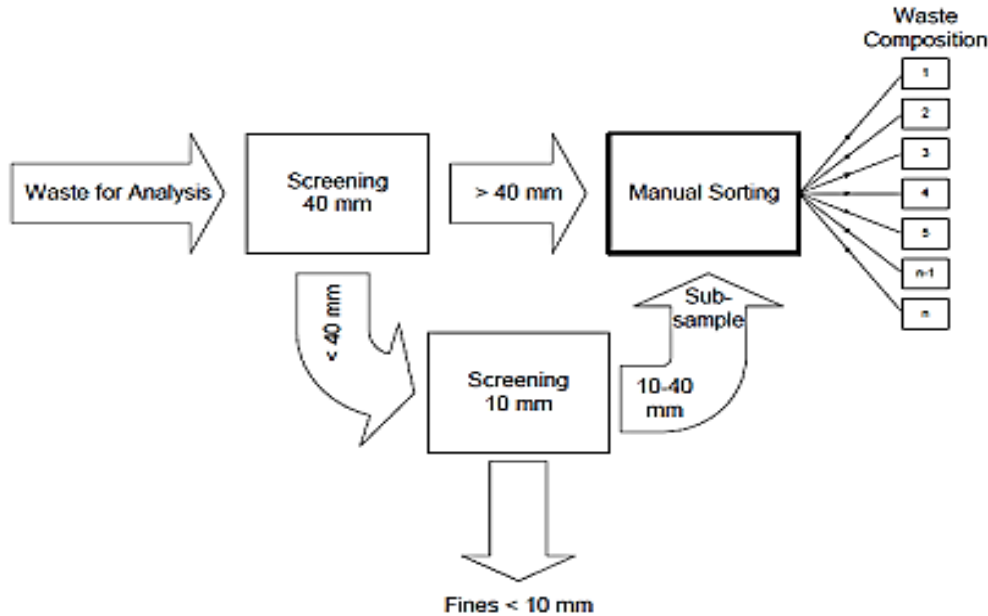


Fig. 3. The sorting procedure (Brasov Waste Analysis Final Report, 2004)

- Separation of the waste into the fractions + 4 cm and +1 - 4 cm by screening with 4 cm mesh screen-table.
- Sorting of the + 4 cm fraction into the waste categories mentioned above.
- Dividing of the +1 - 4 cm fraction into the fraction - 1 cm and fraction +1 - 4 cm by screening with 1 cm mesh screen-table.
- The - 1 cm fraction was reported as the category: fine fraction < 1 cm.

5. The obtained categories and subcategories were weighted; the data were recorded and statistically evaluated.

The following main sorting categories were adopted:

- Košice – 12 main categories: paper, glass, plastic, metals, biodegradable waste, multilayer composite materials, wood, textile and shoes, WEEE, inert waste, hazardous waste, and fine fraction < 1 cm.
- Poproč – 10 main categories: paper, glass, plastic, metals, biodegradable waste, textile, inert waste, hazardous waste, fine fraction, and combustible waste.

2.2. Sampling and analysis

The mixed MSW sampling and subsequent analysis was performed in each season in both localities using the same method. The data of each component weight were recorded in the protocol, they were evaluated separately for each section and season and subsequently the total results were calculated. Nine samples were analyzed in the Košice analysis in each season; it means 36 samples with the average weight of 236.2 kg altogether. Four samples (one for each season) with the average weight of 208.2 kg were analyzed in Poproč.

2.3. Analysis evaluation

2.3.1. Košice

The evaluation of the analysis of the mixed MSW material composition according to the sections, seasons and total was performed. The multi-storey building section results and rural section results in each season were obtained by a simple arithmetic average of the partial results. Another situation occurred in the case of the mixed section.

There the samples from the multi-storey building type (from 1100 l containers) and also from the rural building type (from 110 l litter bins) were taken and they were evaluated separately. For this reason it was impossible to carry out a simple arithmetic average for the mixed section. In order to gain the total results of the mixed section, it was necessary to consider the amount of the mixed MSW from one week from both types of containers, so that the results represented the real situation using the following formula (Eq. 1):

$$m1w1 + m2w2 = m3w3 \quad (1)$$

Therefore (Eq. 2):

$$w3 = (m1w1 + m2w2) / m3 \quad (2)$$

where:

$w1, w2, w3$ – wt. % of the waste category,
 $m1$ – an average weight of the mixed MSW generated per one week (collected interval) in the mixed section from 110 l litter bins,
 $m2$ – an average weight of the mixed MSW generated per one week (collected interval) in the mixed section from 1100 l containers,
 $m3$ – an average weight of the mixed MSW generated per one week (collected interval) in the mixed section together.

A calculation of the average weight of the mixed MSW collected per one week was carried out by following (Eq. 3):

$$m_{1,2,3} = c_i * n_c * m \tag{3}$$

where: c_i – collection interval, n_c – a number of containers/bins, m – an average weight of one filled container/bin

Data was provided by Kosit, Inc. Company. In the analysis evaluation for one season from all sections together, the amount of generated mixed MSW in each section was calculated similarly as Eq. (1) (Eq. 4):

$$m_1w_1 + m_2w_2 + m_3w_3 = m_4w_4 \tag{4}$$

Therefore (Eq. 5):

$$w_4 = (m_1w_1 + m_2w_2 + m_3w_3) / m_4 \tag{5}$$

where: w_1, w_2, w_3, w_4 – wt. % of the waste category, m_1, m_2, m_3 – an average weight of the mixed MSW generated per one week in each section, m_4 – a total amount of the mixed MSW generated per one week together. The total year results were calculated by the arithmetic average of the particular season results.

2.3.2. Poproč

Due to the fact that in Poproč only one sample was analyzed each season, the evaluation of the analysis data was carried out by a simple arithmetic average of the partial results.

3. Results and discussion

3.1. Material composition of mixed MSW

The total results of the mixed MSW material composition analysis according to the seasons and the summary in Košice and Poproč are shown in Fig. 4 and Fig. 5. For the comparison of results, the

combustible waste from the Poproč analysis was divided into the categories of biodegradable waste and wood. Multilayer composite materials were removed from the paper category and evaluated as a separate category. The comparison between the composition of the mixed MSW from each section in Košice and in Poproč is shown in Fig. 6.

3.2. Representation of packaging

Packaging of various material composition comprised 29% of the total amount of the mixed MSW. In Košice, it was almost 24%. The comparison of packaging material representation from the both sites is shown in Fig. 7. The presented study aimed at the comparison of the mixed MSW material composition results of analysis, which was carried out in the city of Košice and the village of Poproč in the Slovak Republic. In terms of the generation and composition, the age structure is an important factor. From this perspective it is possible to say that the localities are very similar. At both localities approximately 17% of the population is in the pre-productive, 63% in the productive and 20% in the post-productive age.

Both analyses were carried out in each season. In the case of Košice, it was shown that the seasons had a minimal impact on the content of components in mixed MSW. As for Poproč, the situation was different. The biodegradable waste content was higher in autumn than in other seasons, and this fact can be related to the end of the gardening season and preparation of gardens for winter. The biodegradable waste had the highest content in both localities in each season, nearly 50% in Košice and about 25% in Poproč.

The reason for the high content of biodegradable waste is the absence of its separate collection and well-functioning separate collection of other commodities. On the other hand, 25 % difference between the content of biodegradable waste in Košice and Poproč is caused by the building type.

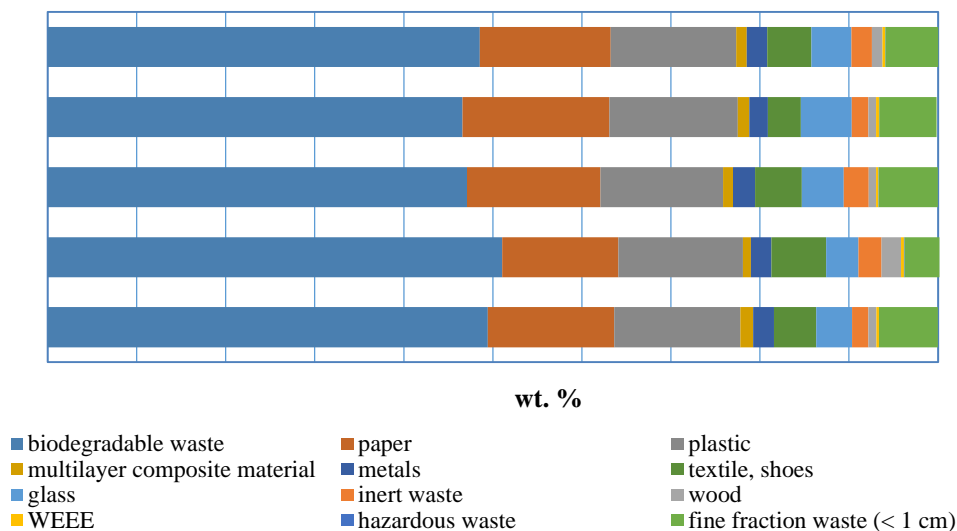


Fig. 4. The mixed MSW composition in each season and total - Košice

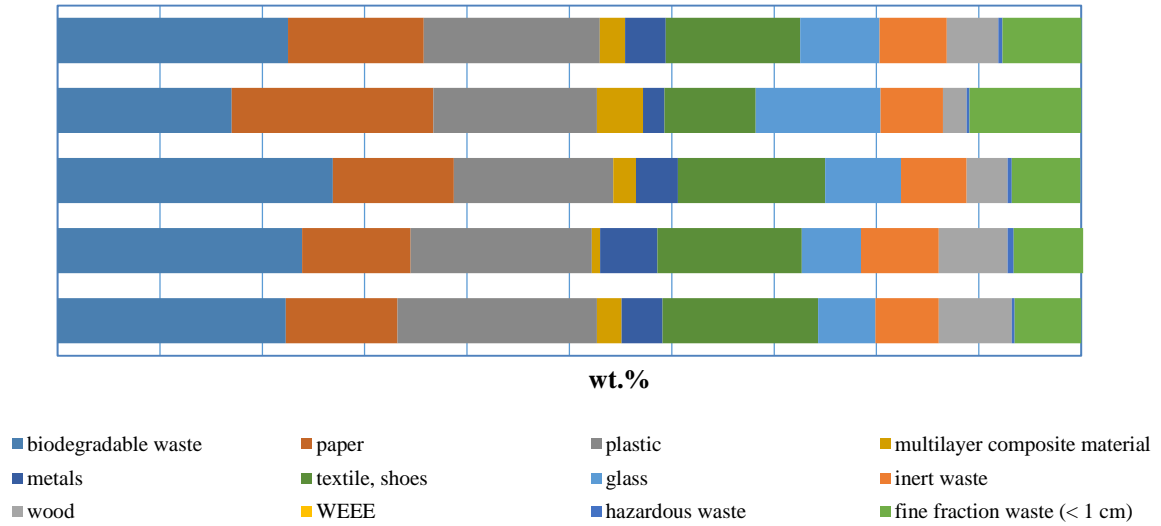


Fig. 5. The mixed MSW composition in each season and total – Poproč

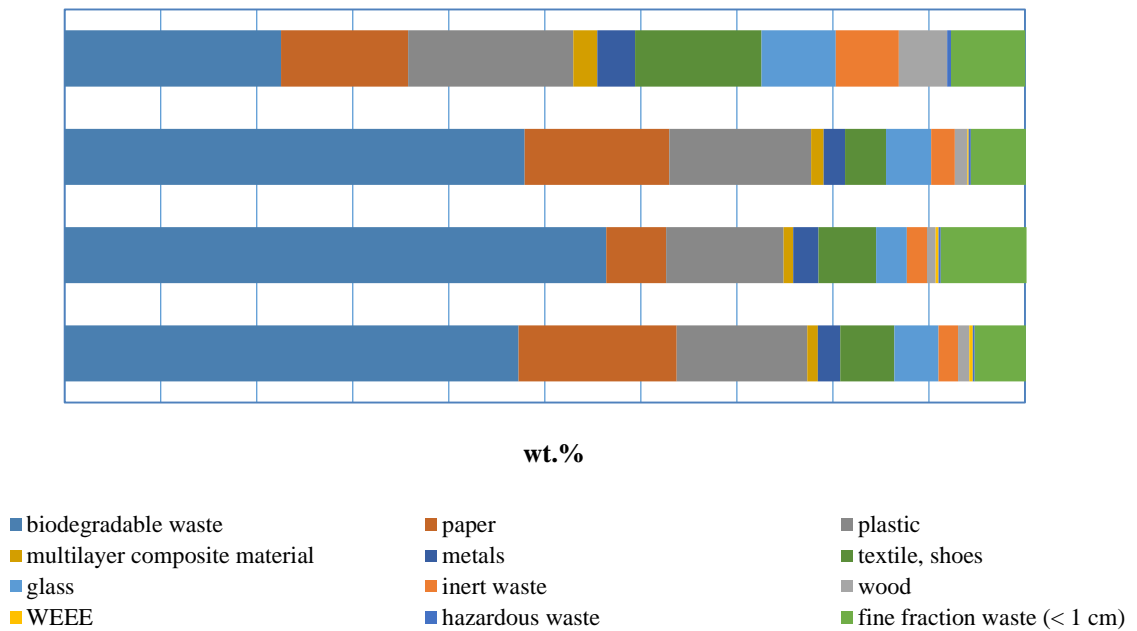


Fig. 6. The mixed MSW composition in each section in Košice and Poproč

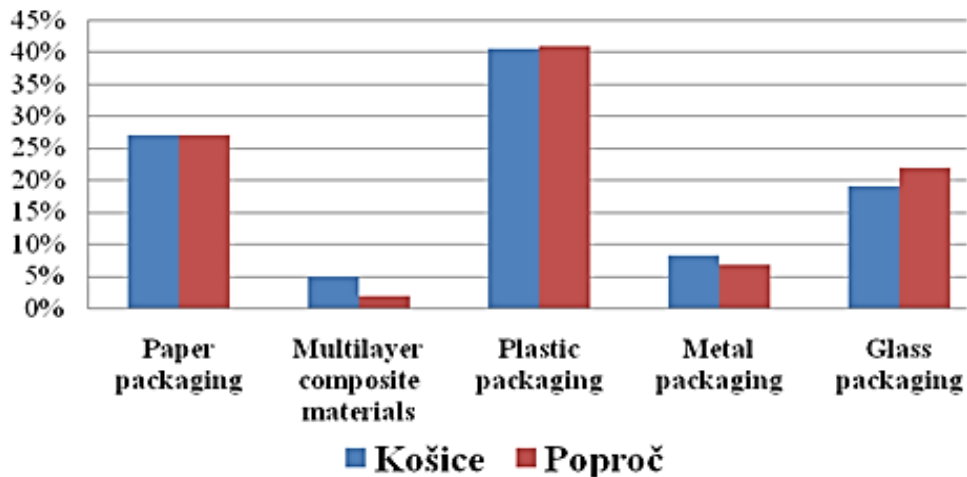


Fig. 7. Material composition of packaging in Košice and Poproč

In the rural section of the village Poproč probably more of this kind of waste is generated, but its lower content in the mixed MSW is caused by individual composting or feeding. The content of paper and plastic at both sites is comparable, as well as the amount of other minor commodities, with the exception of textiles, wood and inert waste. The above-mentioned commodities have a slightly higher content in the village of Poproč which is related to the low content of biodegradable waste. The relatively high content of textiles in both sites points to the absence of a possible introduction of separate collection of this commodity.

The comparison of the mixed MSW composition in various sections revealed that the built-up area type has a relatively high impact on the mixed MSW composition in Košice, in particular the content of biodegradable waste. In the multi-storey building section biodegradable waste was 47%, as for the rural section, it was 57%. This difference may be caused by the increased generation of biodegradable waste as a result of the private garden ownership. It is also obvious from the comparison of the biodegradable waste content between the rural sections of Košice and Poproč. In Poproč, where the rural section is predominant too, the content of biodegradable waste is less than 25% and in the same building type in Košice it is 57%. This fact points to the absolutely unsatisfactory situation in the area of separate collection of biodegradable waste and the absence of home composting by the population of Košice living in private houses.

In the future, this situation must be solved. A large part of such waste can be used for energy recovery. In Kosit, Inc. Company, a project for electricity production from the mixed MSW is currently being carried out. On the other side, the city of Košice has built a composting facility for composting of biodegradable waste from various sources. The analysis of the mixed MSW composition both in Košice and Poproč focuses on the packaging as well. The packaging content in Košice was 24% and in Poproč 29%. By comparing the material composition it was found out that in both cases plastic packaging had the highest content (40%). In Košice, a higher content of multilayer composite material was found than in Poproč. The reason was the later introduction of separate collection of this commodity in Košice. Paper packaging reached the second highest content (27%), followed by glass (19-22%) and metals (7-8%).

4. Conclusion

The results of the analysis of mixed MSW material composition in both localities showed high content of biodegradable waste and insufficiencies in separate collection. Effective separate collection can lead to the reduction of landfilled waste to a minimum, as it is required by the EU. However, the Košice city does not have an intention to separate the

biodegradable waste from the mixed MSW in the future. Anyway, Slovakia tries hard to comply with the EU waste requirements. The implementation of the results published in this paper could contribute to this effort.

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