Verification of the effectiveness of municipal waste prevention (case study)

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Abstract

The basis of our experiment were 4 different model families, living in different conditions and in different parts of the Slovak Republic (district Trnava – city Trnava) and district Ružomberok – city Ružomberok and the village Likavka). In particular, the members of these households had different habits and behaviours in relation to waste and the environment. In 4 model families in the individual months in 2019 (from January 1 to December 31 2019) we tracked the amount of their produced municipal waste. At the same time, if the household separated selected components of municipal waste, their weight was determined (e.g., plastics, metals, multilayer composite materials, paper, glass, biowaste). The aim of our case study is to point out the obvious and fundamental differences in the behaviour of 4 different Slovak model families, which we had the opportunity to monitor not only in terms of the total production of mixed municipal waste (MMW) but also in terms of the number of selected types of sorted components throughout 2019. The results of individual members of the model families were compared with the average amount of waste produced per capita in 2019 in the Slovak Republic (435 kg) and in the EU (450 kg). Despite the fact that members of the Model family 4 separated a considerable amount of waste (143.11 kg), in 2019 they produced the largest amount of MMW (471.48 kg) because used disposable baby diapers were also disposed of within it. The Model family 1, in which members are not involved in waste sorting, produced MMW (388.63 kg) and all this was disposed of by collection and subsequent landfilling. MMW in the Model family 2 accounted for a smaller amount (138.00 kg) due to the sorting of waste in this household. By involving members of the Model family 3 not only in waste separation but also in waste prevention, the smallest amount of MMW was produced in this household - only 2.39 kg. By comparing 4 model families in terms of their year-round production of municipal waste, separated components, or waste prevention, we point out that different behaviour in waste management also brings different results.

Keywords: *municipal solid waste, waste separation, waste prevention, zero-waste*

Introduction

The exponential growth of population, urbanization, industrialization, the development of the social economy[1] and particularly the rapid growth of the urban population the growth of production and consumption, the high demand for new products, and improved living standards[2,3,4] have resulted in an increase in the amount of municipal solid waste (MSW) generation throughout the world. Recent estimates suggest that the global MSW exceeds 2 billion tons per year, which is a potential threat to environmental dilapidation[1,5]. The problem of waste has become an increasingly serious issue in the 21st century due to a growing global population, consumerism, and a linear approach to industrialization[3,6,7]. Waste production increases in proportion to the income of the population and consequently increases the economic and environmental costs associated with waste disposal[8]. The volume of MSW is increasing due to the increased living standards of inhabitants, and households present a rather dominant subject that creates MSW[9].

Recycling is the most suitable way of dealing with waste products. Worldwide the recycling activities are being encouraged and consumers are motivated to participate in these activities through different

schemes[10]. One of these options is the proper separation of municipal waste in households. Improving the recycling performance in order to recover qualitative materials, save resources and keep waste out of landfills belongs to the pressing challenges of our time[11].

Our current culture is based on ownership and also on buying and producing everything we desire, not what we really need[12]. People have fallen under the spell of consumer life, in which even durable products are slowly becoming consumer products. With the increasing production of waste, problems also come around – some no longer solvable by recycling.

The growth of waste production, the high rate of landfilling, and the low rate of waste minimization require more efficient waste management than ever before[4].

In 2019, the average Slovak produced 435 kg of waste, i.e., each inhabitant of the Slovak Republic produced approximately 1.2 kg of municipal solid waste (MSW) per day. From 1995 to 2007, the amount of MSW produced per capita in the Slovak Republic per year was maintained at around 300 kg (302 kg in 1995, 309 kg in 2007), since 2008 there has been a gradual increase in the annual production of MSW per capita (331 kg in 2008, 333 kg in 2010, 339 kg in 2014, 393 kg in 2017) and in 2018 for the first time, we exceeded the limit of 400 kg of MSW production per year (427 kg). In the years 2007 – 2019, the total production of MSW in the Slovak Republic increased by approximately 42%. Although in comparison with the production of municipal waste in EU countries, the Slovak Republic is one of the countries with the lowest amount of municipal waste per capita, we are still among the countries with the highest share of landfilling (landfill rate in 2017 – 61%, in 2018 – 55%, in 2019 – 50.6%) and a relatively low rate of municipal waste recycling (year 2017 – 29%, year 2018 – 36%, year 2019 – 39%)[13,14]. In 2019, the average EU citizen produced around 450 kg of waste. The EU average was 45% in 2019, while in Slovakia only 39%[15].

Individuals are becoming more aware that the age of undisturbed consumerism is coming to an end and that their individual behaviours have a direct impact on the surrounding environment and on the lives of future generations[16]. Nowadays, the concepts of waste prevention and zero-waste are beginning to spread. In both cases, it is a change in the lifestyle of the consumer or household. Their main goal is to prevent the production of total waste.

Zero-waste is a visionary concept for confronting waste problems in our society and has been presented as an alternative solution for waste problems in recent decades[17,18]. Household waste minimisation has earlier been studied as a part of voluntary simplicity (a way of life practised by individuals whose ideology calls for minimizing consumption and maximizing reduction) [19,20]. The principles behind zero-waste living are, by the followers of the zero-waste movement, formulated as the five Rs: Refuse, Reduce, Reuse, Recycle, Rot – in that order. Refuse what you do not need. Reduce what you do need. Reuse by using reusables. Recycle what you cannot refuse, reduce, or reuse. Rot (compost) the rest. The goal is to send no waste to landfill or incineration[21,22,23].

Zero-waste and waste prevention have been addressed by several authors in their books[12,24,25,26], who state that is a philosophy based on a set of practices aimed at preventing as much waste as possible. The waste-free approach is based on the individual's decision to reduce the amount of waste they produce every day with the help of small solutions and then apply them to their daily life. This is not just about better waste sorting and recycling, but also thinking about our consumer habits so that the problem is solved at the source because everything will become waste eventually. The best waste is considered to be the one that is never produced; therefore, this philosophy involves the consumer to act responsibly.

The aim of our case study is to point out the obvious and fundamental differences in the behavior of 4 different Slovak model families, which we had the opportunity to monitor not only in terms of the total production of mixed municipal waste, but also in terms of the number of selected types of sorted components throughout all months 2019.

Methodology

The basis of our experiment were 4 model families with different behaviour in relation to waste and the environment:

1. Model family 1 without waste separation and without waste prevention
2. Model family 2 with waste separation and without waste prevention
3. Model family 3 with waste separation and with waste prevention
4. Model family 4 with waste separation and with partial waste prevention and with the exception of disposable baby diapers

We selected model families in 2 parts of the Slovak Republic, in the districts of Trnava (city of Trnava) and Ružomberok (city of Ružomberok and the village of Likavka), with different types of settlement (complex housing construction – flat, individual housing construction – family house), with different gender structure and with different age representation of participants (child – 4 and 18 months, woman – 25, 29, 35, 50 and 83 years, man – 27, 31, 38 and 60 years), with different attitudes to waste separation and with different household equipment (e.g. car, pet). The age categories of the survey participants were registered as of 1 January 2019. In the survey, it was not important for individual families to have the same number of people in the household, as the resulting measurements, which we compared, were converted to the amount of waste produced per person. We compared the obtained data with Slovak (the year 2019 – 435 kg per capita) and European statistics (the year 2018 – 492 kg per capita) on waste and we also compared them between model families.

In the examined model families in the individual months of 2019, we obtained the amount of their produced municipal waste. We were also interested in the number of sorted units, of course, if the model family sorted the waste. The first group of sorted units were plastics, metals, multilayer composite materials (PMMCM), which were weighed as 1 commodity as they were collected together, the second group was glass, the third group was paper, the fourth group was the residual mixed waste and if the model family sorted biowaste, we included this in the fifth group. The monitored families recorded all data on the quantities of waste produced in prepared sheets (weight in grams, respectively in kilograms) during the whole year 2019 (from 1 January 2019 to 31 December 2019). In the case of the lower weight of waste produced in a given month, the amount was weighed using the kitchen or hanging scales, and if the waste was heavier, we used personal digital scales.

Model family 1 consisted of 3 members with an age structure: 60 years (male), 50 years (female), and 27 years (male). All 3 members were economically active. They lived in a three-room apartment in Ružomberok. There was only 1 garbage bin in the household, into which they threw all kinds of waste. Family members were not very interested in the prevention of waste and their subsequent disposal, they did not separate the produced waste at all. They took care of 1 cat in the household. They had 2 motor vehicles at their disposal, which they used mainly for commuting to work, for shopping, and occasionally for travel outside the city. Since all members of the household were employed, the diet of each of them was the same, i.e., breakfast and dinner at the place of residence and lunch outside the place of residence (at work).

Model family 2 consisted of a young couple aged 29 (female) and 31 (male) living in a larger two-room apartment in Trnava. They were partly interested in waste separation. There were 3 bags in the household for waste separation: one for mixed waste, the other for plastics, metals, and multilayer composite materials, and the third for paper. They took care of 1 dog at home. They owned 1 personal motor vehicle, also used mainly for business trips, shopping, and occasionally for trips outside the city to visit the family. Both spouses are employed, so they have regular breakfast and dinner at the place of residence and lunch outside the place of residence (at work).

Model family 3 consisted of 2 members (2 women). They lived in a family house in the Ružomberok district. An older pensioner at the age of 83 and her caregiver at the age of 25. The younger woman, who took care of the whole household, such as grocery shopping, cleaning, cooking, was very interested in how much waste she produced and how it was necessary to sort the produced waste. Subsequent purchases were also based on her interest and opinion. They had a few buckets set aside for waste

sorting, or other storage items into which they sorted waste (e.g., paper boxes). They did not have any pets. They did not own any motor vehicles, so they used public transport to travel to the city. They prepared breakfast, lunch, and dinner at home.

Model family 4 consisted of 4 members, spouses aged 35 (female) and 38 years (male), and 2 children aged 4 months and 18 months. Due to the fact that there were 2 children in the household, we asked the partners to use disposable baby diapers for changing children during the year 2019 (3 – 5 pieces a day – an older child only to sleep). The family lived in a three-room apartment in the city of Trnava. The man was working, and the woman was on maternity leave. The family sorted the waste into separate and marked containers and was very interested in actively reducing the waste produced. The only exception in the waste prevention process was the use of disposable diapers. There were no pets in the household and the family-owned 1 motor vehicle used mainly for commuting and shopping. Breakfast, lunch, and dinner were prepared at home (Table 1).

Table 1: Conditions of 4 model families in a case study

Model family	Flat	Family house	Car	PMMCM separation	Paper and glass separation	Biowaste separation	Pet (animal)	Waste prevention
1	yes	--	2	--	--	--	yes	--
2	yes	--	1	yes	yes	--	yes	--
3	--	yes	--	yes	yes	yes	--	yes
4	yes	--	1	yes	yes	yes	--	yes*

*Legend: PMMCM – plastic, metals, multilayer composite materials; * partially waste prevention and with the exception of disposable baby diapers*

The monitored families recorded data on the waste produced during one year from January 2019 to December 2019, while the records were checked continuously during the year (once a month). Based on year-round data, we evaluated the results of measuring the amount of waste produced by model families, compared, and calculated the data of the degree of separation of each family according to the general formula. We used the following formula to obtain the separation rate value[27]:

$$LS_{MSW} = \frac{m\ component\ 1 + m\ component\ 2 + m\ component\ 3 + m\ component\ n}{m_{MSW}} \times 100\ [\%]$$

where: the level of municipal waste sorting ($\mathbf{LS_{MSW}}$) is the value of separated municipal waste per year expressed in %; m component is the weight of the sorted municipal waste component; $\mathbf{m_{MSW}}$ is the total weight of municipal waste; **m component 1** represents in our case plastics, metals, multilayer composite materials; **m component 2** represents paper; **m component 3** represents glass and **m component n** other separated commodities such as biowaste and etc. We compared the average results of the weight share of individual components of mixed municipal waste in individual model families with the analyses of mixed municipal waste for individual (34 municipalities in the Slovak Republic) and complex (16 municipalities in the Slovak Republic) housing construction. These analyses were carried out by the non-profit civic association Friends of the Earth Slovakia (SPZ) and the Institute of Circular Economics[28] (Figure 1).

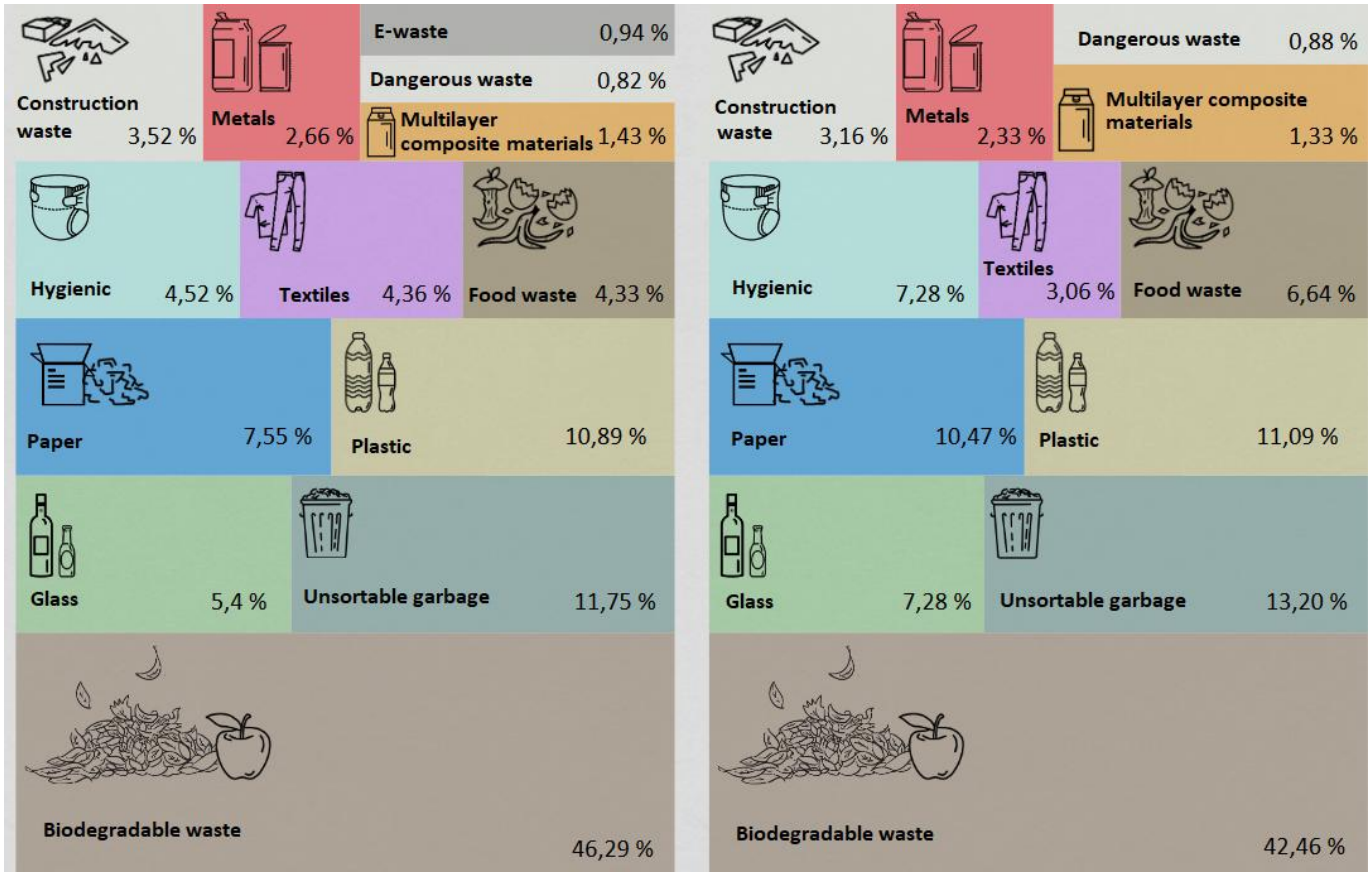


Figure 1: The weight fraction of individual components of mixed municipal waste, individual housing construction (left) and complex housing construction (right).
Source: Madajová, Belicová, Maleš, 2018

Results and Discussion

Model family 1 without waste separation and without waste prevention

During the observed period, Model family 1 produced a total of 388.63 kg of municipal waste (Table 2), which equals to 129.54 kg of municipal waste per member of this household. This number is significantly smaller than the national average and lower than the European average per capita. In the case of the national average, 1 member of the Model family 1 produced 70.22% less municipal waste and in the case of the European average, 1 member produced 73.67% less municipal waste. The average weight of municipal waste produced in 1 month in this household was 32.39 kg.

The members of Model family 1 described themselves as people who did not care how the produced waste was further treated. They stated the waste disposal fees being too high as a reason for this lack of interest. Therefore, the family made no effort to reduce its waste production. They bought food in default packaging materials and when choosing food, they did not look at its packaging, but rather at the price of the product. They did not separate their waste. All generated municipal waste ended up in a mixed container and subsequently at the Biela Púť solid municipal waste landfill in Ružomberok without the possibility of further use. As for the free storage of oversized waste (furniture) or chemicals (paints) in the collection yard, the family used this option. However, they threw out ordinary hazardous waste such as old medicines or non-functional disposable batteries into the rubbish bin for mixed municipal waste in their household.

Table 2: Waste weight results of Model family 1 in 2019

Model family 1 without waste prevention and waste separation (in kilograms)	
Month	**Total waste**
January	37.60
February	38.65
March	30.86
April	33.85
May	24.81
June	30.85
July	23.20
August	30.10
September	28.25
October	38.58
November	33.06
December	38.82
Total	388.63

Table 2 shows that the months of January, February, October, and December are the months with the largest waste production (approximately 38 kg). Since they take care of 1 cat in the household, it was necessary to clean the cat toilet at least twice a year (February, October) by changing the bedding. With this exchange, the waste in the given months increased mixed municipal waste by 10 kg. In December, the increased production of waste was related to the Christmas holidays, and in February they found that flour worms had multiplied in 10 kg of flour, so it had to be discarded. They had the lowest waste production in May and July. In May, the family spent most of their free time in a garden outside the city, eating their vegetables. In July, 2 members of the household were on a two-week holiday. The third member was thus alone at home for half a month, so he produced significantly less waste than a family of three.

Although the family produces a significantly lower amount of waste compared to national and European statistics, despite this being a household that does not separate the basic components of municipal waste and all the waste generated is only landfilled without any other recovery.

Model family 2 with waste separation and without waste prevention

During 2019, Model family 2 produced a total of 258.09 kg of municipal waste (Table 3), which represented 129.05 kg of municipal waste per 1 household member. As the family did not make a significant effort to avoid waste, this amount is almost the same as for the first family. Compared to the national average, they produced 70.33% less waste per person and, compared to the European average, they produced 73.77% less waste per person. The average weight of generated waste in 1 month was 21.5 kg of waste. Unlike Model family 1, however, members of this household separate municipal waste in 5 basic components: plastics, metals, multilayer composite materials, paper, and glass. The amount of separated waste components was a total of 120.09 kg, which equals to 60.05 kg of separated waste per member of the household.

Table 3: Waste weight results of Model family 2 in 2019

Model family 2 with waste separation (in kilograms)					
Month	**PMMCM**	**MMW**	**Paper**	**Glass**	**Total waste**
January	4.20	9.60	3.20	1.50	18.50
February	3.90	8.20	2.30	1.30	15.70
March	5.00	15.10	3.09	2.30	25.49
April	4.25	9.40	1.75	0.90	16.30
May	3.00	14.40	2.70	1.00	21.10
June	5.70	14.00	5.80	1.80	27.30
July	3.10	10.90	6.40	1.00	21.40
August	4.90	16.00	4.90	4.70	30.50
September	5.10	12.50	6.00	1.00	24.60
October	4.60	9.20	1.60	1.20	16.60
November	3.00	10.40	4.30	3.40	21.10
December	2.90	8.30	4.00	4.30	19.50
Total	49.65	138.00	46.04	24.40	258.09
Share (%)	19.24%	53.47%	17.84%	9.45%	100.00%

Legend: PMMCM – plastic, metals, multilayer composite materials;
MMW – mixed municipal waste

Table 3 shows that the largest amount of waste was generated in this household in March, June, and August. In March, higher waste production was related to repainting and cleaning the whole apartment, in June the amount of waste increased due to larger purchases of household goods and appliances, and in August the household organized a larger celebration with friends and family. On the contrary, the months of February, April, and October had the lowest amount of waste produced due to a 1-week business trip of 1 household member. For this family, we must also consider a certain amount of waste generated, which is related to the care of the dog. These were metal and plastic packaging that was properly separated in this household.

Model family 2 also did not significantly try to reduce the generation of waste, but it cared about the environment, so they honestly separated their waste. They bought most of the food in common packaging materials. In part, to reduce waste, especially plastic waste, they did not benefit from not buying more plastic bottles because they owned a water filter kettle. They also had an appliance for making yogurts at home, so they did not produce unnecessary disposable plastic packaging. They did not use a single application that could help them decide how to separate the waste or help reduce their waste. In the management of oversized waste (furniture, carpet, refrigerator) or hazardous waste such as used cooking oil, the family used the possibility of free delivery to the collection yard. Hazardous waste, such as discharged disposable batteries, was thrown into the trash for mixed municipal waste, but the old medicines were handed over to the pharmacy after expiration. Compared to Model family 1, they produced almost the same amount of waste, but it should be noted that almost half of this waste returned to circulation due to separation for further processing.

Comparing the average results of the weight share of individual components of mixed municipal waste prepared by the Institute of Circular Economics[28], we found that in the case of complex housing construction (Figure 1) the share of plastic, metal, and tetra pack (PMMCM) components is 14.75%, paper 10.47% and glass content 7.28%. From the data of Model family 2, whose members live in a flat, in 2019 these shares were found higher in PMMCM by 4.49%, in a paper by 7.37%, and in the commodity glass by 2.17% (Table 3). Since mixed municipal solid waste in this household formed not only the remainder, i.e. unsorted components but also biodegradable waste, we counted these two

commodities together. According to the results of INCIEN (2018)[28], the average results in housing conditions show a share of 3 components (food waste, biodegradable waste, and unsortable garbage) of a total of 62.30%, and in Model family 2 we found a share of unsortable garbage of 53.47%, a share lower by 8.83%, as stated in the analysis for complex housing construction prepared on the basis of 16 municipalities in the Slovak Republic.

Model family 3 with waste separation and with waste prevention

Two members of Model family 3, living in a family house, produced a total of 236.84 kg of municipal waste in 2019 (Table 4), which represented 118.42 kg of municipal waste per 1 household member. The average amount of waste generated in 1 month was 19.74 kg of waste. This family tried to significantly reduce the production of their waste and of the total amount they produced, 50.05 kg was returnable glass, which was returned to circulation by proper separation, and 83.15 kg of biodegradable and food waste, which was composted in their own composter in their garden. If we deduct the amount of waste in the form of biowaste and returnable glass from the total amount of waste generated in this household, the total amount of waste produced by this household in 2019 was only 103.64 kg, which represented only 51.82 kg of waste per member. Compared to the national average, 1 member of this household produced 88.09% less municipal waste and compared to the European average 89.47% less waste. The average weight of waste generated in 1 month in this household reached the value of only 8.64 kg of waste.

Table 4: Waste weight results of Model family 3 in 2019

Model family 3 with waste separation and with waste prevention (in kilograms)								
Month	**PMMCM**	**MMW**	**Paper**	**Backed up glass**	**Non-returnable glass**	**Biowaste**	**Total waste 1**	**Total waste 2**
January	2.55	0.20	2.35	3.80	1.60	5.70	16.20	6.70
February	1.65	0.12	4.00	5.20	4.10	4.50	19.57	9.87
March	1.73	0.14	2.73	5.45	4.35	7.35	21.75	8.95
April	2.5	0.15	3.04	4.00	1.80	8.40	19.89	7.49
May	2.7	0.25	2.09	3.80	3.30	7.90	20.04	8.34
June	2.2	0,20	3.10	3.25	2.50	9.50	20.75	8.00
July	1.55	0.18	3.80	4.80	4.15	8.35	22.83	9.68
August	2.65	0.25	2.45	3.15	2.85	6.50	17.85	8.20
September	2.00	0.22	3.10	4.00	3.55	7.65	20.52	8.87
October	2.90	0.25	2.25	3.65	3.18	4.55	16.78	8.58
November	1.64	0.15	2.19	4.55	3.05	7.25	18.83	7.03
December	2.85	0.28	4.15	4.40	4.65	5.50	21.83	11.93
Total 1	26.92	2.39	35.25	50.05	39.08	83.15	236.84	-
Share 1 (%)	11.37%	1.01%	14.88%	21.13%	16.50%	35.11%	100.00%	
Total 2	26.92	2.39	35.25	-	39.08	-	-	103.64
Share 2 (%)	25.97%	2.31%	34.01%	-	37.71%	-	-	100.00%

Legend: PMMCM – plastic, metals, multilayer composite materials; MMW – mixed municipal waste; Total 1 – the amount of waste produced in 2019, including returnable glass and biowaste; Total 2 – the amount of waste produced in 2019 without returnable glass and biowaste; Total waste 1 – summary of all waste commodities for individual months of 2019; Total waste 2 – summary of commodities without returnable glass and biowaste for individual months of 2019

Members of Model family 3 tried to prevent the production of waste in several ways and were also interested in what happens to the generated waste. They bought food, as well as other products, exclusively without packaging and, if this was not possible, they preferred products that were not wrapped in plastic, despite the higher price of the product. They carried exclusively their own textile bags, glass containers or nets for non-packaged purchases. They did not use any disposable products such as plastic cutlery or straws. They did not buy bottled water in PET bottles; they used their own stainless steel and reusable glass bottles for the water. Food scraps were packaged in decomposable textile wipes with beeswax, that are reused. They mainly bought loose tea, which they leached in a metal sieve. They replaced the classic shampoo with its solid version. Plastic toothbrushes were replaced by bamboo brushes, which can be composted, and toothpaste was replaced by tooth-tablets. They stopped using disposable make-up removers and instead bought reusable and washable ones. A significant reduction in waste was also ensured by a domestic composter, in which they disposed of all types of biodegradable waste and kitchen waste that is suitable for the composter. Overall, they tried to eat "without waste". The Model family 3 also dealt with the lifestyle of minimalism in general, so they tried to buy only the necessary and needed things. When it came to buying textiles, family members tried to shop mainly in second hands. They did not use any app for responsible waste management, as they searched all the information on the Internet. In 2019, they did not produce any oversized waste or chemicals. In other years, they used the possibility of bringing such types of waste free of charge to the nearest collection yard. Expired medicine was handed over at the pharmacy, the batteries were thrown into designated boxes (electrical stores) and the used cooking oil was handed over at the nearest gas station.

Both values of Total waste 1 and Total waste 2 in Table 4 show that the month in which the most waste was generated was December. The heavier weight of waste during this month was mainly related to the preparations for the Christmas holidays. The least waste was produced in January, when 1 member of the household travelled for a week's stay.

In comparison with the average results of the weight share of individual components of mixed municipal waste according to analyses in individual housing construction in 36 municipalities (Figure 1) (INCIEN, 2018), we found that the share of plastic, metal and multilayer composite materials (PMMCM) was lower by 3.61% in the Model family 3 for Total waste 1 (including returnable glass and biowaste), where in our measured values the figure was 11.37% and in the average results in individual housing construction the figure was 14.98% (INCIEN, 2018)[28]. However, if we compared these values only after subtracting the amount of returnable glass and biowaste (Total waste 2) with INCIEN analyses (2018), we got higher values for the commodities plastics, metals, and multilayer composite materials (PMMCM) by 10.99%. However, it is necessary to mention that in this household in 2019 no e-waste, construction waste or hazardous waste were produced, which in the analysis according to INCIEN (2018)[28] have a certain representation in the production of waste in family houses. The share of unsortable mixed waste in the average data of family houses according to INCIEN (2018)[28] (Figure 1) was 11.75% and in Model family 3 we observed much lower values not only in Total waste 1 (lower share by 10.74%), but also in Total waste 2 (lower share by 9.44%). For the paper component, the Model family 3 had a 7.33% (Total waste 1) and 26.46% (Total waste 2) higher share of this component compared to the average results in the analysis for single-family homes (7.55%). We compared the share of glass and biowaste in the Model family 3 with the average values only in the value of Total waste 2 (i.e., after subtracting returnable glass and biowaste, which the members composted in their own composter). According to INCIEN (2018)[28], the average proportion of glass was 5.40% and for the Model family 3 it was 37.71%, which is 32.31% more.

However, it should be noted that these higher values of the share of non-returnable glass also arose from the fact that family members often preferred glass to plastic as the packaging of certain foods when shopping. Part of this non-returnable glass was used repeatedly in the household, especially in the summer months at the time of fruit and vegetable canning. Biodegradable waste in the Model family 3 had a share of 35.11% and in average results it had a share of 50.62% (Food waste 4.33% and Biodegradable waste 46.29%) (Figure 1). In this household, the share in the commodity biowaste was 15.51% lower than the average analyses in family houses according to INCIEN (2018)[28]. The lower share of bio-waste in this household reflects not only a more reasonable purchase of food products and produce, but also the preparation of food and meals for household members with the smallest possible production of food waste and biodegradable waste.

Model family 4 with waste separation and with partial waste prevention and with the exception of disposable baby diapers

In 2019, Model family 4 produced municipal waste in the total amount of 614.59 kg (Table 5), which equals to 153.65 kg per member of the household and the average weight of generated municipal waste in 1 month was 51.22 kg. However, we can deduct from this total produced amount of municipal waste the amount of biowaste and kitchen waste (fruit peelings, vegetables, and food scraps) that were composted in the household in the home composter. After deducting the amount of biowaste generated (100.39 kg), this household produced a total of 514.20 kg of waste in 2019. That was 128.55 kg per 1 household member and the average amount of waste generated in this household was 42.85 kg. Due to the fact that there were 2 children in the household, the spouses were willing to use disposable baby diapers for both children during 2019 for the purposes of this study. It turned out that a considerable amount of unsortable waste was produced by the use of disposable baby diapers (52.82% and 63.14%, respectively) (Table 5). In the course of 2019, waste weighing 324.65 kg was generated in this household from disposable baby diapers, which were thrown into a container of unsortable MSW. If instead of disposable diapers, reusable textile baby diapers were used, the amounts of unsortable mixed waste would be considerably lower in this household. Nevertheless, each member of the Model family 4 produced 70.45% less waste per person compared to the national average and 73.87% less waste compared to the European average.

Table 5: Waste weight results of Model family 4 in 2019

Model family 4 with waste separation and with partial waste prevention and with the exception of disposable baby diapers (in kilograms)								
Month	**PMMCM**	**MMW**	**DBD**	**Paper**	**Glass**	**Biowaste**	**Total waste 1**	**Total waste 2**
January	0.58	8.90	30.78	5.45	1.30	7.81	54.82	47.01
February	0.58	5.28	25.22	2.22	0.94	9.16	43.40	34.24
March	1.10	4.20	30.56	1.10	0.85	10.05	47.86	37.81
April	0.44	23.55	31.33	1.78	0.34	7.50	64.94	57.44
May	0.36	16.20	33.68	0.50	1.21	6.90	58.85	51.95
June	0.55	15.13	29.74	0.47	0.34	8.81	55.04	46.23
July	4.25	21.65	28.65	2.40	0.94	8.79	66.68	57.89
August	0.21	12.89	14.25	0.58	0.73	7.42	36.08	28.66
September	2.50	10.48	25.67	1.81	1.12	9.16	50.74	41.58
October	0.35	13.07	28.13	0.91	0.74	7.79	50.99	43.20
November	0.30	6.06	23.75	0.79	0.96	8.10	39.96	31.86
December	1.50	9.42	22.89	1.40	1.12	8.90	45.23	36.33
Total 1	12.72	146.83	324.65	19.41	10.59	100.39	614.59	-
Share 1 (%)	2.07%	23.89%	52.82%	3.16%	1.72%	16.33%	100.00%	-
Total 2	12.72	146.83	324.65	19.41	10.59	-	-	514.20
Share 2 (%)	2.47%	28.56%	63.14%	3.77%	2.06%	-	-	100.00%

Legend: PMMCM – plastic, metals, multilayer composite materials; MMW – mixed municipal waste; DBD – disposable baby diapers; Total 1 – the amount of waste produced in 2019, including biowaste; Total 2 – amount of waste produced in 2019 without biowaste; Total waste 1 – summary of all waste commodities for individual months of 2019; Total waste 2 – summary of commodities without biowaste for individual months of 2019

Table 5 shows that the months in which the most waste was produced were April and July. During these months, the apartment of this household was reconstructed and for this reason the amount of

unsortable mixed waste increased. The least waste was produced in August, when the whole family was on a 2-week holiday abroad.

Members of this household have long been trying to prevent waste. Even considering that they have 2 infant children, they are bothered by the state in which we leave the environment for future generations. Through their conscious behaviour, they try to prevent the generation of waste. During 2019, members of this household tried to buy food as much as possible in their own textile and net bags and containers. Instead of plastic bottles, they used metal bottles, which they supplemented with drinking water from the public water supply if necessary. They used bee-wax napkins for food scraps for multiple uses. They composted their kitchen waste and biowaste in a home composter. Most shifts occurred in the bathroom, where they have introduced several changes in previous years, e.g. replacement of classic disposable razor blades with 1 metal razor with replaceable razor blades, disposable make-up remover pads replaced with acceptable textile ones, stopped using shampoo and shower gel in plastic packaging, but bought solid shampoo and solid soap, instead of classic toothbrushes they used composable ones, toothpaste in plastic was swapped for dental tablets, they bought deodorants in glass or made them at home, they did not use classic plastic-wrapped washing gels for washing clothes, but they made their own washing gel from soap at home. The family uses the possibility of free disposal of, for example, oversized waste at the collection yard. The family did not use apps for information on how to dispose of individual waste commodities but searched for them on the Internet. After expiration, the drugs are returned to the pharmacy and the discharged batteries are taken to electronics stores. During 2019, they began using several rechargeable batteries in the home.

Comparing the average results of the weight fraction of individual components of mixed municipal waste for complex housing construction (INCIEN, 2018)[28] (Figure 1), we found that the share of plastic, metal, and tetra pack components (PMMCM) was lower in the Model family 4 at Total waste 1 (biowaste included) by 12.68%, wherein our measured values the figure was 2.07% and in average results, the figure was 14.75%. And also, for Total waste 2 (after deducting biowaste) this share was lower by 12.28%. For paper, the Model family 4 had a share of this component of 3.16% (Total waste 1 with biowaste) and 3.77% (Total waste 2 after deducting biowaste) and the average results according to analyses in complex housing (INCIEN, 2018)[28] were 10.47%, i.e., in both cases, it was a lower share by 7.31%, resp. 6.70%. Another component was glass, where the average results of the analyses in complex housing construction (INCIEN, 2018)[28] the share of glass was 7.28% and in the Model family 4 this share was in both cases (Total waste 1 and Total waste 2) by 5.56%, respectively by 5.22% lower. Biodegradable waste and kitchen waste accounted for 49.10% on average. In the Model family 4, this type of waste had a share of 16.33%, i.e., it was 32.77% lower. The share of unsortable mixed waste in the average data is 13.20% and in the results of the Model family 4 was 23.89% (Total waste 1), resp. 28.56% (Total waste 2). Both of these data were higher by 10.69%, respectively 15.36%.

Our findings are consistent with those from other previous studies. One of the examples of evaluating the waste behaviour of the population (number of samples 682) is an exploratory study z city of Mexicali, capital of the state of Baja California located in the Northwest part of Mexico bordering to the North with the city of Calexico, California in the United States. The objective of selected research was to know the composition and quantity of residential solid waste generated by family typology and socioeconomic strata (low, medium, high) on example 125 families. Residential solid waste samples were characterized and identified by collection and analysis as field data in five categories: Organics, Non-organic, Containers, Inerts and Other types of waste. The results showed that the per capita and the average family waste generation varies according to the family typology and to the socioeconomic stratum where the family belongs. Per capita waste generation of the complete sample is 0.981 kg daily, not considering typology and strata variables, when socioeconomic strata was included in the analysis per capita waste generation varies, in the low-income strata is 0.886 kg, in the medium is 1.04 kg and in the higher is 1.058 kg. In contrast waste composition did not show any difference, except for some of the categories such as garden waste, newspaper, textiles and disposable diapers, these wastes explain the lifestyles of the generators. The largest share of generated residential solid waste was accounted for by organic waste, especially food waste (35.05%) and garden waste (16.27%), followed by sanitation wastes (8.54%), plastic waste (6.60%) and disposable diapers (4.15%). On the contrary, the smallest share fell on Polystyrene (0.02%), Plasticized paper (0.01%), Cellophane paper (0.01%) and Waxed

paper (0.03%). The results of the study confirm the resulting variability within the observed families. Environmental problems associated with the generation of waste are part of societal changes where family units play an important role[29].

The quantification the amount and composition of waste generated by households and household waste management behaviourism the city of Buenos Aires (Argentina) assesses next study. A total was evaluated of 525 households classified and weighed their waste during a week and completed a questionnaire on current and potential pro-environmental behaviours. Average daily waste generation was 430 g on person, but total amount of waste varied widely among households. Every household complete one protocol consisted of weighing and recording all household waste produced throughout a week. The protocol was classified into five categories: (1) paper and cardboard (all types of paper and cardboard including Tetra Pak® containers); (2) plastic (all types of plastic); (3) other recyclable waste (metal, glass, fabric); (4) organic waste (food and garden waste) and (5) non-recyclable (e.g. disposable napkins, diapers, pet excrement, cat litter, dirty unwastable containers). Within households currently sorting waste, 68% sorted between 5 and 9 different materials (categories) and a minor fraction of participants (5%) sorted only between 1 and 2 categories. Half the household (50%) separated organic waste, 29% corresponded to recyclable materials and the rest to non-recyclables (21%). Over half the householders sorted e-waste whereas fabric, cooking oil and yard trimmings were sorted by less than 30% of households. Most participants (57%) belonged to households with one or two members; an intermediate portion (35%) was formed by three to four members and only a minor fraction (8%) by five to nine members. Among the household characteristics which could indirectly affect waste generation and composition, only 5% of the households had at least one child under 3 years old (using diapers) and 42% cohabited with at least one pet, mostly cats and/or dogs. Food cooking and eating habits showed that 95% of the participants had at least one home-cooked meal (lunch or dinner) while only 5% declared to have both meals from out- of-home sources. In turn, 93% had at least one meal at home whereas only 7% stated to have eaten both meals outdoors, irrespectively of the source (home or out-of-home). Household composition modified waste generation as people having babies or pets generated more waste per capita than the rest of participants. Likewise, participants cooking at least one meal at home generated more organic waste than the rest. Most participants cooked and had at least one meal at home, thus we conclude that kitchen waste during cooking accounted for their larger amount of organics[30].

An anthropological case study in 5 apartment buildings (residents between 11 and 81 years of age, from 112 households) in the Copenhagen area, Denmark was analysed the relationship between the local municipal waste system and its users. The residents performed waste separation with different intensification and the majority of households (93%) has a yet unrealized potential to separate more waste. The residents stretching to separate as-much-as-possible-waste (7%) expressed strong sustainable values, or they had a daily life with sufficient available time (e.g., retired, unemployed, had a part-time job) to engage in waste separation. The critical barriers identified were cultural perceptions of household order, challenges regarding interim storage in the household, (bio)waste was perceived as disgusting, challenges regarding hygiene and potential extra cleaning, mistrust to the system, convenience of residents, etc. Eight households (7%) expressed strong commitment (sorting all waste possible), 88% separated what was convenient, and six persons (5%) did not sort waste (non-separators) [31]. Next study found to reveal how recycling programmes in Sweden and Bulgaria influenced inhabitants' participation in separation of household waste. The waste separation behaviour of 111 university students from Kalmar, Sweden and 112 students from Plovdiv, Bulgaria. The results showed that a lack of proper conditions for waste separation can prevent individuals from participating in this process, regardless of their positive attitudes. When respondents were satisfied with the local conditions for waste separation their behaviour instead depended on their personal attitudes towards waste separation and recycling.[3] Next study estimate solid waste generation and its composition from 424 households in Medan City (Sumatera island, Indonesia), in 8 sub-districts to ascertain their statistical relationship with geographic location and level of income of household. The average waste generation was 0.222 kg per person daily. Of the total weight, organic waste formed the largest fraction at 61.35%, followed by plastic waste at 17.55%, paper at 8.20%, and rest represented other materials. The amount of household waste generated in each geographic location was different, but it no significant difference within the different income level[32].

Degree of separation in model families

Waste separation is a necessary prerequisite for effective waste management, and it is the most effective means to promote the recycling of domestic waste. It is a key link to realize the harmlessness, reduction and resource utilization of waste. Therefore, it is considered as the top priority in domestic waste management[33]. Pro-environmental behaviour is influenced by internal factors (for example, knowledge, values and attitudes, emotions, motivation and locus of control) and external factors (for example, infrastructure, social and cultural factors, and the economic situation) [34].

To determine the degree of separation in model families 2 – 4, we used the formula given in Methodology. We did not calculate this figure for the Model family 1 because the members of the family do not sort waste. After adding the individual data into the formula, the value of the separation rate for the Model family 2 was 46.53%. The result of the separation rate in the Model family 3 was 98.99%, while this high figure reflects the lifestyle of the members of this model family with significant prevention of mixed municipal waste. The resulting value of the separation rate in the Model family 4 was 23.28%. This extremely low number, despite efforts to prevent waste, is due to the use of many disposable diapers. If we compare these data with the average data of the Slovak Republic, then model families 2 and 3 had a higher degree of separation than the national average in 2019 (by 7.53% and by 59.99%). The Model family 4 had a separation rate lower by 15.72%. If we compare the results of the separation rate of these 3 model families with the average EU data, then Model family 3 achieved a significantly higher separation rate (by 53.99%) and also Model family 2 achieved a higher separation rate, but only by 1.53%. Model family 4 achieved a lower value from the EU average (by 21.72%) due to its degree of separation.

By separating waste, we can primarily reduce the amount of waste deposited in landfills, increase the preparation of still usable waste for reuse in the recycling process and thus save primary resources. The stimulating factor for Slovak towns and municipalities is the differentiation of fees for landfilling waste depending on the achieved percentage of separate waste collection, i.e., the level of municipal waste sorting. This means that if a city or municipality achieves a low level of municipal waste sorting, it pays a higher fee for depositing waste in a landfill. The fee rate is set in the Regulation of the Government of the Slovak Republic no. 330/2018 Coll.[35], which establishes the rates of fees for waste disposal and details related to the redistribution of income from fees for waste disposal. Increasing the efficiency of separate waste collection as well as the overall production of municipal waste depends mainly on the environmental awareness of citizens.

Recycling is a plausible path to reduce the amount of waste generated in the country in a sustainable way[36]. Even if the best recycling strategy is adopted, it will only be successful if it is managed well[37]. Waste sorting is the least that each of us should do for our planet, because the growth of waste generation is a serious problem. Only properly sorted waste into individual components can be further recycled – i.e., returned to circulation. Of course, in addition to sorting waste for recycling itself, we should also prevent the production of waste.

Conclusion

From January 1 to December 31, 2019, we monitored and subsequently evaluated the amounts of municipal waste in 4 different model families in Slovakia. The model families differed from each other in the total amount of municipal waste produced, in the amount of waste per 1 family member, in the involvement in sorting, and in the prevention of waste production.

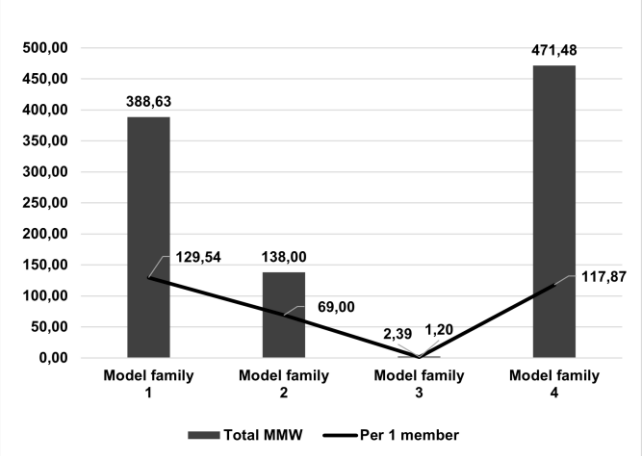
Members of the Model family 1 not only do not make any effort to reduce the amount of waste but also do not sort their generated waste. This family of three produced a total of 388.63 kg of municipal waste in 2019, which represents 129.54 kg per member (Graph 1, 2). The amount of waste generated per 1 member of this household is incomparably lower compared to the average amount per 1 inhabitant of the Slovak Republic (435 kg). Unfortunately, the entire amount of mixed municipal waste, in this case, was disposed of in the most common way in the Slovak Republic so far – landfilling. Several steps have been recommended to members of this household on how to behave more responsibly in relation to the

environment, including reducing the amount of waste generated in this household and the need to sort the basic components of municipal waste, of course in accordance with current legislation.

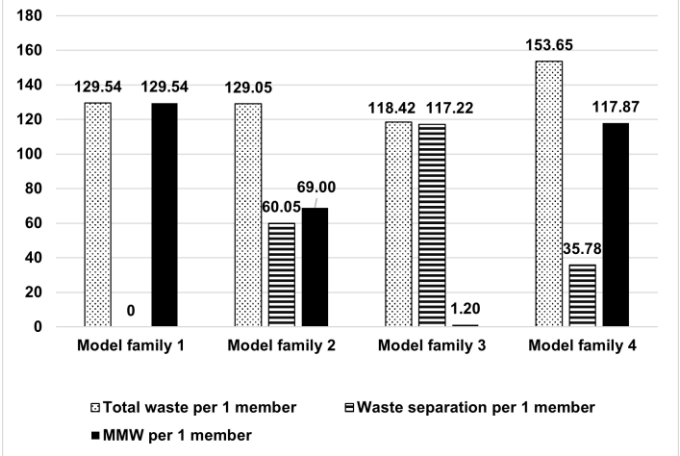
The two-member Model family 2 produced a total of 258.09 kg (129.05 kg per 1 member) in the evaluated period, but mixed municipal waste accounted for a smaller amount due to waste sorting in this household – 138.00 kg (53.47%) (Graph 1, 2). 69.00 kg of mixed municipal waste was produced per 1 member (Graph 2). The remainder was sorted components, plastics, metals, multilayer composite materials (49.65 kg, 19.24%), paper (46.04 kg, 17.84%), and glass (24.40 kg, 9.45%). The separation rate in 2019 in this model family reached 46.53% (120.09 kg, 60.05 kg of separated components per member) (Graph 2). To further reduce the production of waste, we recommended members of this household to establish their own composter for the recovery of biodegradable waste, to start shopping in their own containers, preferably in non-packaging stores, or to try to replace plastic packaging with other, better recyclable alternatives, such as glass, paper, etc.

Two members of the Model family 3 strive to prevent waste and are interested in the zero-waste lifestyle. In 2019, they produced a total amount of waste 236.84 kg – an amount approximately the same as the Model family 2, 118.42 kg per member (Graph 2). Of this total amount, up to 234.45 kg (98.99%) accounted for the separated waste components; plastics, metals, and multilayer composite materials (26.92 kg), paper (35.25 kg), glass (returnable and non-returnable together 89.13 kg), and biowaste (83.15 kg), which they disposed of in their own composter in the garden. They sorted 117.22 kg of various types of waste per 1 household member (Graph 2). Mixed municipal waste accounted for the smallest amount of all evaluated model families in 2019, i.e., 2.39 kg per the whole household (1.20 kg per 1 member) (Graph 1, 2). Due to the zero-waste lifestyle, we recommended to the members of this household the search for other alternatives for products where they still produce waste, especially plastics, metals, and multilayer materials.

Graph 1: Total generated quantities of waste and recalculation per 1 household member in model families 1 – 4 in 2019



Graph 2: The total amount of waste generated, amount of separated components, and amount of mixed municipal waste in terms of 1 household member in model families 1 – 4 in 2019



Model family 4 belongs to a group of young people who try to live in accordance with the zero-waste lifestyle. In the future, they want to follow this lifestyle more and they know that they are only at the beginning of it. In 2019, this young family consisted of 2 adults and 2 children aged 4 months and 18 months who needed diapers (an older child only 3-5 pieces a day to sleep). We asked the couple to use disposable baby diapers during the year 2019. In total, they produced 614.59 kg of all types of waste in this household, which equals to 153.65 kg per member (Graph 2). With this amount, they reached higher values than the Model family 1, whose members do not sort waste at all (by 24.11 kg). Compared to other model families, the weight of their mixed municipal waste was the highest (471.48 kg, per member 117.87 kg) (Graph 1, 2). Of the total amount of mixed municipal waste, disposable baby diapers

accounted for 324.65 kg (68.86%). After deducting disposable baby diapers, the value of mixed waste would be 146.83 kg (36.71 kg per member). By separation, they sorted a total of 143.11 kg of waste (35.78 kg per member) (Graph 2). The share of separated components was 23.28%, of which the highest share was biowaste (100.39 kg), which the couple composted in a home composter. In addition, 12.72 kg of plastics, metals, and multilayer composite materials, 19.41 kg of paper, and 10.59 kg of glass were sorted. Even in this model family, other more sustainable alternatives may be tried in areas where they still produce waste.

To increase the level of municipal waste sorting, in which the Slovak Republic lags behind the most developed countries and the European average, it is necessary to increase the motivation of citizens in the area, introduce effective municipal waste management systems that would motivate citizens to produce less mixed municipal waste and a higher level of sorting[38]. Each of us should be interested in how the waste we produce is treated. Instead of fast consumer life, we should slow down and buy only the products that we absolutely need. The basis for minimizing the production and harmfulness of waste is gentle and lower consumption. In order to produce less waste, it is necessary to reduce consumption in particular. We can start by resisting the temptation to buy what we do not need. By not buying too many products, we not only reduce the amount of waste and save natural resources, but also our finances.

Households can minimize residual waste and increase the volume of materials recycled by improving waste separation and changing purchasing behaviour. Changes in household purchase behaviour can contribute to the reduction and improved sorting of solid waste as well. Households may purchase reusable products or decrease their consumption altogether[39].

Waste volume is influenced by the decisions of individuals, connected with their lifestyles. Therefore, it is necessary to increase public awareness of waste economy principles and to increase the ecological behaviour of the general public. Ecological behaviour is based on recycling, as well as the preventive behaviour of individuals[9]. We should all realize that waste does not simply disappear, just because we no longer see it after being thrown in the trash. Waste is not just something we loathe and smell. It is a raw material that we can further process and enhance. The solution to reducing waste production should also be the transition to a circular economy, where each waste is considered a raw material. Recycling is no longer enough for the waste problem alone. We, as individuals, should act responsibly and, at least in small incremental steps, begin to reduce the production of our waste. Although some people honestly separate their waste, in the best case they also recover it by composting and generally prevent its production, there are still very few of these people. People with a consumer type of behaviour, insufficient waste recovery, and insufficient information on the state of waste management are more prevalent. As Anne Marie Bonneau, a well-known blogger and representative of zero-waste in California, says: “We don't need a handful of people doing zero-waste perfectly. We need millions of people doing it imperfectly.”

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Preverenie efektívnosti predchádzania vzniku komunálneho odpadu (prípadová štúdia)

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Súhrn

Základom nášho experimentu boli 4 rozdielne modelové rodiny, žijúce v rôznych podmienkach a v rôznych častiach SR (okres Trnava – mesto Trnava) a okres Ružomberok – mesto Ružomberok a dedina Likavka). Členovia týchto domácností mali predovšetkým rozdielne návyky a správanie vo vzťahu k odpadom a k životnému prostrediu. V 4 modelových rodinách sme v jednotlivých mesiacoch v roku 2019 (od 1.1.2019 do 31.12.2019) získavali množstvo ich vyprodukovaného komunálneho odpadu. Zároveň, ak domácnosť separovala vybrané zložky komunálneho odpadu, ich hmotnosť bola zisťovaná (napr. plasty, kovy, viacvrstvové kombinované materiály, papier, sklo, bioodpad).

Cieľom našej prípadovej štúdie je poukázať na evidentné a zásadné rozdiely v správaní sa 4 rôznych slovenských modelových rodín, ktoré sme mali možnosť sledovať nielen z hľadiska celkovej produkcie zmesového komunálneho odpadu, ale aj z hľadiska množstva vybraných druhov vytriedených zložiek v priebehu celého roka 2019. Zistené výsledky jednotlivých členov modelových rodín boli porovnané s priemerným množstvom vyprodukovaného odpadu na 1 obyvateľa v roku 2019 v SR (435 kg) a v EÚ (450 kg).

Aj napriek tomu, že členovia modelovej rodiny 4 vyseparovali značné množstvo odpadu (143.11 kg), v roku 2019 vyprodukovali najväčšie množstvo zmesového komunálneho odpadu (471.48 kg), pretože v rámci neho boli likvidované aj použité jednorazové detské plienky. Modelová rodina 1, ktorej členovia nie sú zapojení do triedenia odpadu, vyprodukovala zmesový komunálny odpad (388.63 kg) a celé toto množstvo bolo likvidované zberom a následným skládkovaním. Na zmesový komunálny odpad v modelovej rodine 2 pripadalo z dôvodu triedenia odpadu v tejto domácnosti menšie množstvo (138 kg). Zapojením členov modelovej rodiny 3 nielen do separácie odpadu, ale aj do predchádzania vzniku odpadu sa v tejto domácnosti vyprodukovalo najmenšie množstvo zmesového komunálneho odpadu, iba 2.39 kg.

Porovnávaním 4 modelových rodín z hľadiska ich celoročnej produkcie komunálnych odpadov, vyseparovaných zložiek, príp. predchádzaniu vzniku odpadov, poukazujeme na to, že odlišné správanie v nakladaní s odpadmi prináša aj odlišné výsledky.

***Kľúčové slová**: tuhý komunálny odpad, separácia odpadu, predchádzanie vzniku odpadu, nulový odpad*