ANALYSIS OF THE STRUCTURE OF MUNICIPAL WASTE IN INDIVIDUAL REGIONS OF SLOVAKIA IN THE YEARS 2011 – 2022

Ľubica Hurbánková[1]

Abstract: The aim of this post is to analyze the structure of municipal waste in the individual regions of Slovakia. The analysis is based on data for the years 2011–2022, sourced from the database of the Statistical Office of the Slovak Republic. Despite being the smallest in area, the Bratislava Region records the highest values of municipal waste among all the regions of Slovakia. Comparable values were observed in the Nitra Region. The lowest volume of municipal waste was found in the Banská Bystrica and Trenčín Regions, with the Banská Bystrica Region being the largest region in Slovakia by area. Regarding the structure of municipal waste, in 2022, the Bratislava Region produced the most – 16% of Slovakia's total municipal waste, while the Banská Bystrica and Trenčín Regions produced the least – 10%. Between 2011 and 2022, the total volume of municipal waste in Slovakia increased by 47%. The Bratislava Region (8.19%) and Nitra Region (7.14%) contributed the most to this increase, with the indicator in the Bratislava Region rising by as much as 53.85% when comparing these two years. The lowest increase was recorded in the Trenčín Region at 36.06%. The smallest contribution to the overall increase in municipal waste was found in the Trenčín (4.05%) and Košice (4.44%) Regions.

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Introduction

Waste management is a crucial factor influencing the environment. Proper waste management can minimize negative environmental impacts and improve the quality of air, water, and soil. Improper waste management can lead to numerous problems. Therefore, it is important that waste management is guided by the principles of sustainable development and that the amount of waste being sent to landfills is minimized.

In recent years, waste production has been on the rise. This trend is not just a problem for Slovakia but for the entire world. Given the current situation, there are growing concerns that the current high consumption of resources will lead to their depletion, which could result in a gradual reduction in their usage. This would naturally mean a slowdown or even a halt in societal progress and development.

Literature review

Many authors deal with the analysis of municipal waste in their works. Iacoboaea et al. (2013) deal with the impact of improper management of municipal waste on the health of residents. These also have a negative effect on soil, air and water pollution (Canzalo et. al. 2014, He et. al. 2020). Turcott et al. (2018) state that there is a need to focus on limiting the increase in waste. They recommend using waste as a resource, which minimizes the use of other natural resources. Boornod (2015) dealt with increasing public participation in the separation of municipal waste, specifically economic and social factors. Storino et al. (2018) presented a new municipal waste management system, namely composting, which aims to motivate residents to participate more in waste management. Taušová and spol. (2020) found in their paper that, in addition to social and economic factors, other factors also influence waste management, such as the awareness of residents about the importance of waste sorting. In a study by Dehghanifard and Dehghani (2018), changes in the amount of paper and plastics in) municipal waste were evaluated. The results showed that the separation of paper and plastics and their recycling is important. The authors found that almost half of municipal waste consists of packaging waste. Increasing the number of separated commodities is limited by the lack of sorting facilities. It is necessary to constantly increase the environmental behavior of residents and awareness of the importance of separation and its correct implementation.

Methodology and research methods

For the analysis of municipal waste, selected time series characteristics and contribution method will be used in the paper.

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Contribution method

As Vojtková (2016) states, the contribution method is used to analyse the total (additive) quantities *Y*. These quantities are created by the sum of the individual components:

$$\boldsymbol{Y} = \sum_{\boldsymbol{i=1}}^{\boldsymbol{n}} \boldsymbol{y^i} \tag{1}$$

where: Y is a total (additive) quantity,

y^i are individual components.

Hurbánková and Sivašová (2018) list the following steps that must be followed, when applying this method:

1. First, the relative increase of the total quantity is calculated, which expresses how this quantity changed in the given period compared to the previous period:

$$\boldsymbol{k_{\Delta t}} = \frac{\boldsymbol{Y_t - Y_{t-1}}}{\boldsymbol{Y_{t-1}}} = \frac{\boldsymbol{d(Y)}}{\boldsymbol{Y_{t-1}}} = (\boldsymbol{k_y - 1}) \tag{2}$$

2. Subsequently, we calculate the relative increases of the individual components, with the help of which we find out how the individual components changed in the given period compared to the previous one:

$$\boldsymbol{k_{\Delta t}} = \frac{\boldsymbol{y_t^i - y_{t-1}^i}}{\boldsymbol{y_{t-1}^i}} = \frac{\boldsymbol{d(y^i)}}{\boldsymbol{y_{t-1}^i}} = (\boldsymbol{k_y^i - 1}) \tag{3}$$

3. In the next step, we calculate the structural numbers, which express the share of the individual components in the total additive quantity. We calculate the shares in the period $t - 1$ on the assumption that the analogous share of the component on the total quantity will remain the same during the continuous trend of this quantity:

$$\boldsymbol{s_{t-1}^i} = \frac{\boldsymbol{y_{t-1}^i}}{\boldsymbol{Y_{t-1}}} \tag{4}$$

4. The last step is the calculation of the contribution that the *i*-th component contributed to the relative increase of the total additive quantity:

$$\left(\frac{\boldsymbol{y_t^i - y_{t-1}^i}}{\boldsymbol{y_{t-1}^i}}\right) * \frac{\boldsymbol{Y_{t-1}^i}}{\boldsymbol{Y_{t-1}}} = \left(\boldsymbol{k_y^i - 1}\right) * \boldsymbol{s_{t-1}^i} \tag{5}$$

The contribution of each additive component is equal to the product of its relative increase and the share of the total quantity in the previous period. As stated by Hindl and Hronová (1997), the relative increase of the total quantity is equal to the sum of the contributions of the individual components:

$$\sum_{\boldsymbol{i=1}}^{\boldsymbol{n}} \left(\frac{\boldsymbol{y_t^i - y_{t-1}^i}}{\boldsymbol{y_{t-1}^i}}\right) * \frac{\boldsymbol{Y_{t-1}^i}}{\boldsymbol{Y_{t-1}}} = \frac{\boldsymbol{1}}{\boldsymbol{Y_{t-1}}} \sum_{\boldsymbol{i=1}}^{\boldsymbol{n}} (\boldsymbol{y_t^i - y_{t-1}^i}) = \frac{\boldsymbol{1}}{\boldsymbol{Y_{t-1}}} \left(\sum_{\boldsymbol{i=1}}^{\boldsymbol{n}} \boldsymbol{y_t^i} - \sum_{\boldsymbol{i=1}}^{\boldsymbol{n}} \boldsymbol{y_{t-1}^i}\right) = \frac{\boldsymbol{Y_t - Y_{t-1}}}{\boldsymbol{Y_{t-1}}} \tag{6}$$

Results and discussion

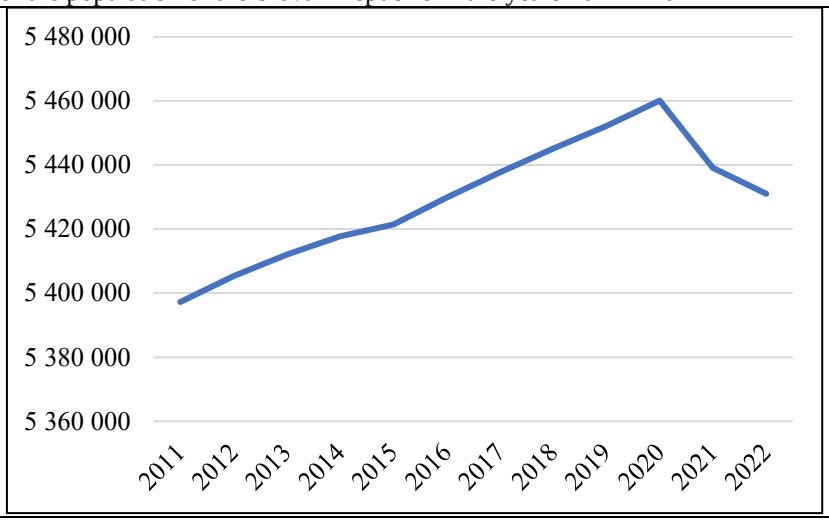
This section of the paper will be dedicated to analyzing the current state and trends in municipal waste production across the regions of Slovakia. Selected characteristics of time series will be used to analyze the trend, and the contribution method will be applicated to determine the contribution of each region to the overall increase in municipal waste volume. The data source for the analysis of municipal waste production is the environmental database on the amount of municipal waste from 2011 to 2022, compiled by the Statistical Office of the Slovak Republic. The database consists of total municipal waste reported in tons according to the territorial unit classification in the NUTS3 breakdown. To enable comparison of municipal waste production across the regions of Slovakia, it was necessary to convert

the data to a per capita basis. These figures are drawn from the database of demography and social statistics in the area of population for the years 2011 to 2022.

Analysis of the current state of municipal waste

The population size is one of the main factors influencing municipal waste production. In 2022, Slovakia had a population of 5,431,026 people. The long-term trend in Slovakia's population is characterized by a slight increase. Since 2011, when the population reached 5,397,251, the number has gradually been rising.

Figure 1: Trend of the population of the Slovak Republic in the years 2011 – 2022



Source: Statistical Office of the Slovak Republic, own processing

Based on Graph 1, we can conclude that the population of the Slovak Republic has shown a slightly increasing trend. The most significant change occurred in 2021 and 2022, where a marked decline in population was observed. Various factors may have contributed to this decrease, including the negative impact of the COVID-19 pandemic. The pandemic affected the overall population not only in Slovakia but also in other countries, not only due to the disease itself, which claimed hundreds of thousands of lives, but also through the measures implemented to control it, such as restrictions on movement, the closure of schools, shops, and businesses. Some residents may have been forced to leave Slovakia due to financial insecurity or job loss. Additionally, a trend of emigration has been observed in Slovakia recently, with many people moving abroad in search of work or better living conditions. These factors may have influenced the total population of Slovakia in 2021 and 2022.

Table 1 presents the values of municipal waste production in Slovakia from 2011 to 2022 and their trends. The analyzed indicator exhibited a fluctuating development trend, with an average annual increase of 0.34%. It can also be stated that municipal waste production in 2022 increased by 47% compared to 2011. The largest year-over-year increase in waste production was recorded in 2020 compared to 2019, with a rise of 9.58%, which is an absolute increase of 227,000 tons of municipal waste compared to the previous year.

Table 1: Municipal waste production in Slovakia in thousands of tons in 2011-2022, its absolute and relative change

Year	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**	**2022**
Indicator (in thousands of tons)	1 767.0	1 750.8	1 744.4	1 830.2	1 888.5	1 953.5	2 137.0	2 325.2	2 369.7	2 596.7	2 705.3	2 597.5
Absolute change	-	-16.2	-6.3	85.7	58.3	65.0	183.5	188.2	44.5	227.0	108.6	-107.9
Relative change	-	0.9908	0.9964	1.0491	1.0318	1.0344	1.0939	1.0881	1.0192	1.0958	1.0418	0.9601
Base index	1.0000	0.9908	0.9872	1.0358	1.0687	1.1055	1.2094	1.3159	1.3411	1.4696	1.5310	1.4700

Source: Statistical Office of the Slovak Republic, own calculations according to Labudová et al. (2021)

Analysis of the structure of municipal waste production

After summarizing the nationwide results, we will conduct a more detailed analysis of municipal waste production in the individual regions of Slovakia. This analysis will allow us to better understand how municipal waste production is developing at the regional level and how each region contributes to the overall municipal waste production in Slovakia.

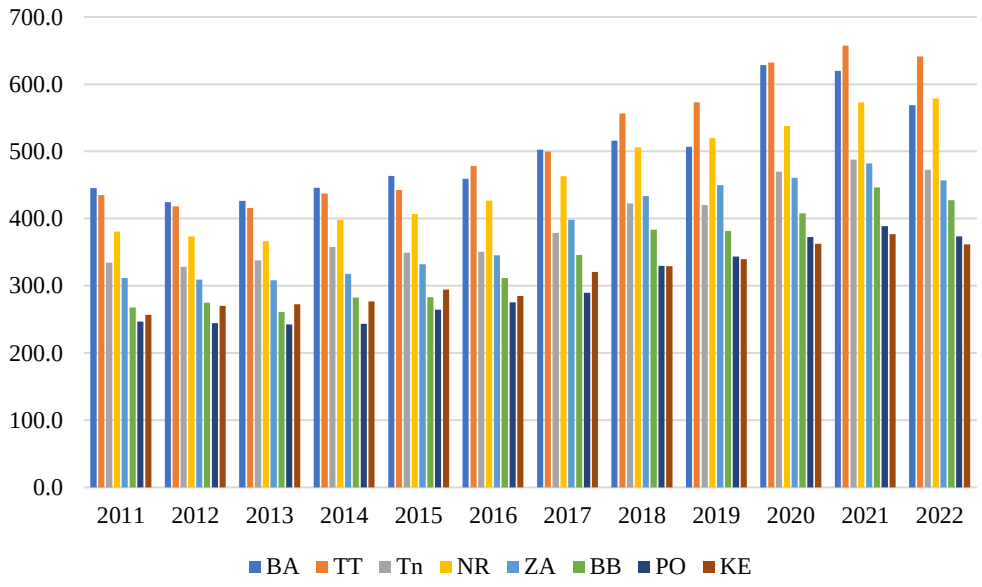
Table 2: Production of municipal waste in kilograms per inhabitant in individual regions of Slovakia in the years 2011 – 2022

Region	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
BA	445.4	424.2	426.5	446.0	463.4	459.4	502.4	516.1	506.6	628.2	620.0	569.0
TT	434.9	418.1	415.8	437.5	442.6	478.3	500.0	556.5	573.3	632.2	657.2	641.1
TN	334.4	328.3	337.6	357.7	349.2	350.5	378.6	422.8	420.2	469.8	488.0	472.5
NR	380.8	373.5	366.2	398.0	407.0	426.8	463.2	505.8	519.9	538.0	573.0	578.6
ZA	311.6	309.0	308.1	317.8	332.1	345.5	398.1	433.6	449.9	460.6	482.0	456.9
BB	267.7	275.0	260.8	282.6	282.8	311.7	346.0	383.4	381.4	407.7	446.4	427.1
PO	246.7	244.2	242.3	243.5	264.4	275.3	289.6	329.7	343.3	372.4	388.8	373.3
KE	257.0	270.0	272.4	276.6	294.6	285.0	320.4	329.2	339.8	362.7	376.7	361.6

Source: Statistical Office of the Slovak Republic

Table 2 shows the values of municipal waste production per capita in the regions of Slovakia from 2011 to 2022. Based on the data in this table and its graphical representation in Graph 2, we found that the Bratislava Region (despite being the smallest region in Slovakia by area) and the Trenčín Region have the highest values of municipal waste production per capita. Since 2018, the Nitra Region has also reached comparable values. On average, the indicator increased the most annually in the Banská Bystrica Region, by 4.34%, and the least in the Bratislava Region, by 2.25%. The lowest volumes of the analyzed indicator were recorded in the regions of eastern Slovakia.

Figure 2: Production of municipal waste in kilograms per inhabitant in individual regions of Slovakia in the years 2011 – 2022



Source: Statistical Office of the Slovak Republic, own processing

For further analysis, we will use the contribution method. Based on the calculations in Table 3, we found that municipal waste production increased the most in 2022 compared to 2011 in the Bratislava Region (by 53.85%) and the least in the Trenčín Region (by 36.06%). The Bratislava Region had the highest share of total municipal waste production in 2011 (15.20%), while the Banská Bystrica Region had the lowest share (10%). The Nitra Region's share of total municipal waste production in 2011 was only 0.33 percentage points lower than that of the Bratislava Region. Overall, municipal waste in Slovakia increased by 47% in 2022 compared to 2011. The Bratislava Region contributed the most to this increase, accounting for 8.19%, while the Trenčín Region contributed the least, with 4.05%.

Table 3: Calculation of the contribution method of municipal waste production in individual regions of Slovakia in 2011 and 2022

Region	2011	2022	Relative increase	Structural number	Contribution
BA	268 588.4	413 229.3	0.5385	0.1520	0.0819
TT	241 246.8	362 454.1	0.5024	0.1365	0.0686
TN	198 684.2	270 332.9	0.3606	0.1124	0.0405
NR	262 702.1	388 805.1	0.4800	0.1487	0.0714
ZA	214 632.4	314 698.6	0.4662	0.1215	0.0566
BB	176 751.8	264 555.3	0.4968	0.1000	0.0497
PO	200 950.5	301 469.5	0.5002	0.1137	0.0569
KE	203 434.4	281 911.8	0.3858	0.1151	0.0444
SR	**1 766 990.5**	**2 597 456.7**	**0.4700**	**1.0000**	**0.4700**

Source: Statistical Office of the Slovak Republic, own calculations

Conclusion

The goal of waste management is to minimize the negative impact of human activities on the environment and ensure sustainable development. Additionally, waste management helps reduce the amount of waste sent to landfills, thereby minimizing the negative effects on soil and water. This is achieved through the rational handling of waste, ensuring its collection, sorting, processing, and disposal in a way that minimizes its impact on the environment and human health.

For this reason, we decided to focus this paper on waste management in Slovakia, evaluating the current state and developments over the past decade. The primary aim was to conduct a detailed analysis of waste management, with a particular focus on municipal waste.

From the detailed analysis of municipal waste production, we concluded that production in 2022 increased by 47% compared to 2011. However, this increase cannot be attributed to a significant rise in population, as the population grew by only 0.63% in 2022 compared to 2011. A notable increase in municipal waste production was already observed in 2020, which can be partially attributed to the COVID-19 pandemic. Regarding the regional analysis across Slovakia, the most significant increase in the analyzed indicator from 2011 to 2022 was in the Bratislava Region, where we observed a growth of 53.85%. This region also contributed the most to the overall increase in this type of waste, accounting for 8.19% of the total increase.

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References

Boonrod, K., Towprayoon, S., Bonnet, S., & Tripetchkul, S. (2015). Enhancing organic waste separation at the source behaviour: A case study of the application of motivation mechanisms in communities in Thailand. *Resources, Conservation and Recycling*, *95*, 77-90.

Canzano, S., Capasso, S., Di Natale, M., Erto, A., Iovino, P., & Musmarra, D. (2014). Remediation of groundwater polluted by aromatic compounds by means of adsorption. *Sustainability*, *6*(8), 4807-4822.

Cervantes, D. E. T., Martínez, A. L., Hernández, M. C., & de Cortázar, A. L. G. (2018). Using indicators as a tool to evaluate municipal solid waste management: A critical review. *Waste management*, *80*, 51-63.

Dehghanifard, E., & Dehghani, M. H. (2018). Evaluation and analysis of municipal solid wastes in Tehran, Iran. *Methods X*, *5*, 312-321.

He, L., Shao, F., & Ren, L. (2021). Sustainability appraisal of desired contaminated groundwater remediation strategies: an information-entropy-based stochastic multi-criteria preference model. *Environment, development and sustainability*, *23*(2), 1759-1779.

Hindls, R. & Hronová, S. (1997). The trend of the domestic product in terms of the contribution of individual factors. [Vývoj domáceho produktu z hlediska přispění jednotlivých faktorů.] *Political economy* [*Politická ekonomie*], 5, 671-673.

Hurbánková, Ľ., & Sivašová, D. (2018). *Economic statistics I*. [*Hospodárska štatistika I*.] Bratislava: EKONÓM.

Iacoboaea, C., Luca, O., & Petrescu, F. (2013). An analysis of Romania's municipal waste within the European context. *Theoretical and empirical researches in urban management*, *8*(4), 73-84.

Labudová, V., Pacáková, V., Sipková, Ľ., Šoltés, E., & Vojtková, M. (2021). *Statistical methods for economists and managers*. [*Štatistické metódy pre ekonómov a manažérov*.] Bratislava: Wolters Kluwer.

Storino, F., Plana, R., Usanos, M., Morales, D., Aparicio-Tejo, P. M., Muro, J., & Irigoyen, I. (2018). Integration of a communal henhouse and community composter to increase motivation in recycling programs: overview of a three-year pilot experience in Noáin (Spain). *Sustainability*, *10*(3), 690.

Taušová, M. et al. (2020). Analysis of municipal waste development and management in self-governing regions of Slovakia. *Sustainability*, *12*(14), 5818.

Statistical Office of the Slovak Republic (2024) [cit. 29.02.2024]. Retrieved from: https://datacube.statistics.sk/#!/view/sk/vbd_dem/om7102rr/v_om7102rr_00_00_00_sk

Statistical Office of the Slovak Republic (2024) [cit.29.02.2024]. Retrieved from: https://datacube.statistics.sk/#!/view/sk/VBD_SK_WIN/zp3001rr/v_zp3001rr_00_00_00_sk

Vojtková, M. et al. (2016). *Business demography: theoretical aspects and empirics*. [*Demografia podnikov: teoretické aspekty a empíria*.] Pardubice: Univerzita Pardubice.