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Selected Factors Affecting the Amount of Municipal Waste at Different Administrative Levels in Poland

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ABSTRACT
The amount of generated municipal waste depends not only on the population but also on consumption patterns and economic welfare. The aim of this paper was to present the structure of generated waste over the years in the European Union, Poland, in Subcarpathian Voivodeship, and in Rzeszow. It has been assumed that the SARS-CoV-2 pandemic, the political action of the government, and the higher standard of living of the society are the factors influencing the increase in the amount of waste generated by households and waste segregation. The paper analyses the waste management system using the official data collected and published by Statistics Poland – the Local Data Bank (LBD) and Eurostat. The amount of municipal waste and waste collected selectively from households was probably affected to the greatest extent by local regulations. According to the data presented, a sharp increase in the amount of municipal waste, including bulk waste and bio-waste, was observed in 2013 and 2014, which may be related to the amendment in 2013 applicable in Poland of the Act on maintaining order and cleanliness in communes. Unfortunately in the Eurostat database, no accurate data on selectively collected municipal waste is available, and in LBD this data is available for different time spans depending on the administrative level. This makes it difficult to draw unequivocal conclusions on the amount of generated waste and forecast changes.

Keywords: municipal waste management, segregation waste, SARS-CoV-2, social programs.

INTRODUCTION

Due to fast economic growth and spreading consumptionism, especially in developing countries, the amount of generated waste is increasing, whereas its disposal and storage are becoming a challenge. Many definitions of waste exist. According to Article 2 item 1 of the Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and Their Disposal of 1989, »Wastes« are substances or objects which are disposed of or are intended to be disposed of or are required to be disposed of by the provisions of national law" (Basel Convention Home Page 189). The UNSD Glossary of Environment Statistics (1997) describes waste as "materials that are not prime products (that is, products produced for the market) for which the generator has no further use in terms of his/her purposes of production, transformation or consumption, and of which he/she wants to dispose. Wastes may be generated during the extraction of raw materials, the processing of raw materials into intermediate and final products, the consumption of final products, and other human activities. Residuals recycled or reused at the place of generation are excluded. See also biological waste, solid waste, industrial wastes and household waste."

According to Article 3 item 1 of Waste Framework Directive No. 2008/98/WE and the Waste Act of 14 December 2012 (Journal of Laws of 2022, item 699), waste is defined as an "object which the holder discards or intends or is required to discard". However, a group of municipal waste is not uniform and may be very complex. For this reason, waste can be divided into several basic types (Fig. 1). EU waste management is currently governed by a package of directives adopted on 30 May 2018 amending the principal waste directives (Directive (EU) 2018/849, Directive (EU)

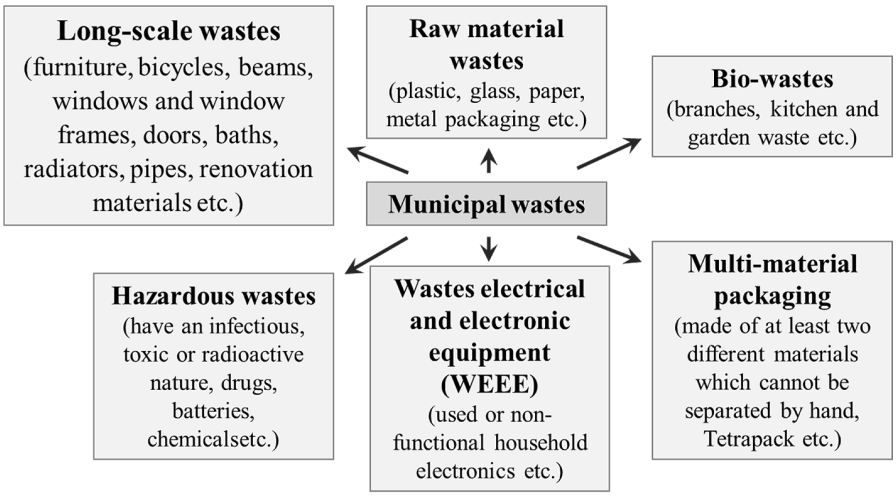

Figure 1. Division of municipal waste

2018/850, Directive (EU) 2018/851, Directive (EU) 2018/852). The so-called Circular Economy (CE) directives were ultimately adopted as a result of discussions and consultations held in the years 2014–2018 on respective propositions of changes put forward by the European Commission and the European Parliament.

Directive of the European Parliament and of the Council (EU) 2018/851 of 30 May 2018 amending Directive 2008/98/EC on waste (the so-called framework directive) contains, among others, the following provisions:

- increasing up to 55%, 60% and 65%, the targets regarding the preparation of municipal waste for re-use and recycling until 2025, 2030 and 2035, respectively;
- possible introduction of a target consisting in limiting the amount of generated food waste for 2030 (after analysis of national data);
- possible setting by 31 December 2024 of qualitative targets for the preparation for re-use and recycling of construction and demolition waste, textile waste, commercial waste, non-hazardous industrial waste and other waste streams, as well as possible setting of targets for the preparation for re-use of municipal waste and recycling of municipal bio-waste;
- introducing by 31 December 2023 the selective collection of bio-waste and/or home composting;
- reinforcing the obligations of entities marketing certain products (including products in packaging) to ensure financing for the collection and processing, including recycling, of post-consumer waste from these products within the so-called extended producer responsibility (EPR) – for the existing EPR systems in separate states (including, among others, Poland), the entities marketing products should ensure that at least 50% of the costs of managing post-consumer waste form these products (also including packaging) will be covered;
- introducing a system of monitoring the achievement of recycling targets.

The amount of generated waste results directly from production and consumption patterns. The very number of marketed products constitutes a challenge. Demographic changes, such as the increase of the number of single-person households, also affect the amount of generated waste (e.g. in connection with a larger number of small packaging). The pandemic and natural disasters occur suddenly and always have a tangible impact on waste management. Other factors, such as government politics, granting of additional benefits and subsidies, increase in earnings, change of lifestyle, are also elements affecting the structure of generated waste, and these changes are noticeable, however, slightly less sudden in nature. The amount of generated municipal waste depends not only on the population, but also on consumption patterns and economic welfare. The following factors also affect the type and amount of generated waste: type of area (city, rural areas) where waste is generated, density of population, type of development (single-family, multi-family), the number of tourists, existence of public utility facilities, as well as the existence, type, size, and number of commercial facilities and small industrial or service facilities. Table 1 summarises the most important factors affecting the amount and quality of generated waste. The European Union implements the economic

development policy in harmony with the environment, protection of its resources, protection of climate and biodiversity. The EU development strategy announced in December 2019 as European Green Deal (EGD) assumes that the European Union is to become climate neutral by 2050 while at the same time stimulating economic growth and improving the quality of life. Under EGD, the European Commission plans changes in the energy sector, transport, agriculture, as well as the steel, cement, telecommunication, textile, and chemical industries. According to the Circular Economy (CE) concept, preventing waste generation, preparation for re-use, and recycling are the top priorities. Other forms of recovery, including energy recovery, are as far down as on the fourth level of hierarchy (Fig. 2). Unfortunately, under Polish conditions, the system has not yet been operating smoothly enough to enable closing the material circulation. Waste segregation on the household level may facilitate sustainable waste management. However, in spite of the government's numerous efforts, much still needs to be done in practice when it comes to waste segregation in households (Kushwah et al. 2023). Adopting sustainable waste practices in line with cleaner production and circular economy philosophies can mitigate the carbon footprint of mishandling waste management (Nogueira et al., 2022; Wang et al., 2021). In this context, waste segregation at the household level is considered the best choice for waste reduction, recycling, and reuse (Kushwah et al. 2023). Waste separation at household level means sorting waste based on its properties or usage at the place of origin. Such separated waste benefits municipalities, the recycling industries, and other stakeholders (Wadehra and Mishra, 2018).

Table 1. Factors that may affect the amount and quality of generated municipal waste (Directive 2008/98/EC)

Factors influencing the quantity and quality of municipal waste generated	Correlation
Average household size (number of persons)	− Negative correlation with the amount of waste generated per person (Dyson and Chang 2005)
Residents' wealth (income/person/year) ownership car, area of dwelling/house, number of rooms legal title to owned property	− rented housing – less waste (Dennison et al. 1996) − increased affluence - increased waste generated (Gómez et al. 2009)
Age	− age range 16–19 – higher total amount of plastic waste generated plastic waste (Dennison et al. 1996) − older people - higher volume of waste generated (Tonglet et al. 2004)
Employment status	− share in the population of students/pensioners − strong negative correlation with amount of waste generated (Dennison et al. 1996)
Season of the year	− more waste in the spring - summer (Grygorczuk-Petersons and Wiater 2014)
Heating system	− central heating – more waste, less if fireplace or electric heating (Lebersorger and Beigl 2011)

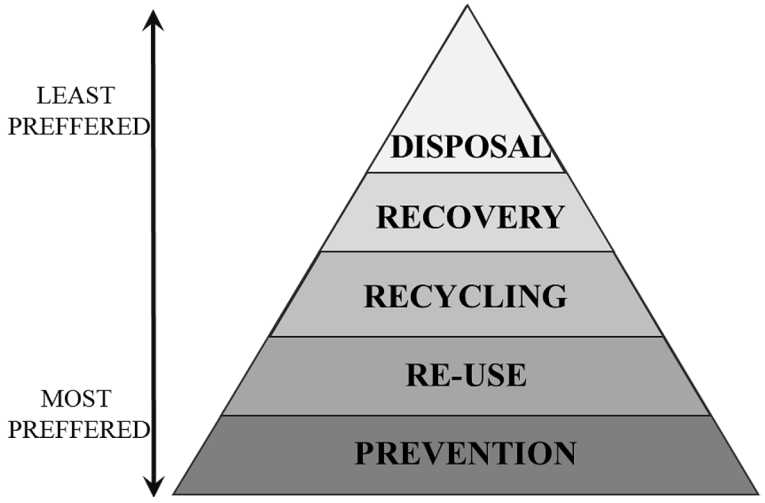

Figure 2. Waste hierarchy according to the European Union Directive

The aim of this paper was to present the structure of generated waste over the years in the European Union, in Poland, in Subcarpathian Voivodeship, and in Rzeszow. It has been assumed that the SARS-CoV-2 pandemic, the political action of the government and a higher standard of living of the society are the factors influencing the increase of the amount of waste generated by households and waste segregation.

METHODOLOGY

The paper analyses the waste management system using official data collected and published by Statistics Poland – the Local Data Bank (LBD) and Eurostat. Unfortunately, the data on selectively collected municipal waste provided by the LBD are available since 2003 on the level of poviats (Poland and Subcarpathian Voivodeship), and since 2017 on the level of communes (Rzeszow). As regards the data provided by Eurostat, there is no exact information about selectively collected municipal waste. The Pearson correlation coefficient between the mass of generated municipal waste and the number of inhabitants and the welfare of the society (Statistica 13.1) was also calculated.

RESULTS

According to the data presented by Eurostat, the amount of municipal waste generated in 2021 per person in the EU was 530 kg, i.e. 9 kg more than in 2020 and 63 kg more than in 1995. In total, the inhabitants of Europe generated 236.801 thousand tonnes of municipal waste in 2021. The generation of municipal waste differed greatly depending on the EU member state. In 2021, the largest amount of municipal waste was generated by the inhabitants of Norway and Luxembourg, with 799 kg and 793 kg per inhabitant, respectively, followed by Denmark (786 kg) and Belgium (759 kg). The lowest amount of generated municipal waste per person was registered in Romania, Albania and Poland, with 302 kg, 311 kg and 362 kg, respectively (6). In Poland, 121 million tonnes of waste were generated in 2021, of which 11.3% was municipal waste (13.7 million tonnes). It means an increase in the amount of generated municipal waste per one inhabitant of Poland from 344 kg in 2020 to 360 kg in 2021 (https://ec.europa.eu/eurostat/databrowser/view/env_wasmun/default/table?lang=en).

Table 2. The dependence of the mass of generated municipal waste on the number of inhabitants, the number of women, and gross earnings

Location	Population	Number of women	Gross earnings
European Union	0.77	0.74	0.96
Poland	-0.92	-0.93	0.99
Subcarpathian	-0.68	-0.67	0.84
Rzeszow	0.99	0.99	0.47

Note: Pearson correlation coefficient at $p < 0,05$. The grey colour indicates a statistically significant result.

An important factor affecting the amount of waste is the number of inhabitants of a given area, as well as gross earnings. According to Pearson's analysis, both in the EU and in Poland, the mass of generated waste depends on gross earnings of inhabitants, the number of inhabitants, and the number of women. In Subcarpathian Voivodeship, the mass of generated municipal waste depended only on gross earnings, in contrast to Rzeszow (Table 2).

Unfortunately, Eurostat database lacks the detailed data on the amount of selectively collected waste. Therefore, the analysis for this type of waste was performed taking into account only Poland, Subcarpathian Voivodeship, and Rzeszow.

In the case of Poland, gross earnings and the number of inhabitants affected the mass of the majority of selectively collected groups of waste, except for waste equipment and residual waste. Interestingly, the mass of selectively collected waste was negatively correlated with the number of the inhabitants of Poland and gross earnings. In the Subcarpathian Voivodeship, the correlation between the number of inhabitants and earnings on one part and the amount of selectively collected waste on the other part was observed only for glass, textiles and bio-fraction. A statistically meaningful correlation coefficient was obtained in the case of gross earnings and almost all selectively collected groups of waste (except for plastics and residual waste). In the area of Rzeszow, however, the mass of all analysed generated fractions of selectively collected waste was positively correlated only with the number of inhabitants and the number of women (Table 3).

For this reason, it is not possible to unequivocally determine the impact of the number of inhabitants and gross earnings on the mass of generated municipal waste. However, according to

Table 3. The dependence of the mass of generated selectively collected groups of municipal waste on the number of inhabitants, the number of women, and gross earnings

Parameter		Paper and cardboard	Glass	Plastics	Textiles	Bulk wastes	WEEE	Bio-wastes	Mix-wastes
Poland	Population	-0.91	-0.93	-0.9	-0.92	-0.87	-0.76	-0.95	0.85
	Number of women	-0.91	-0.93	-0.91	-0.9	-0.88	-0.74	-0.95	0.83
	Gross earnings	0.97	0.97	0.98	0.87	0.98	0.66	0.98	-0.78
Subcarpathian	Population	-0.86	-0.92	-0.08	-0.93	-0.79	-0.85	-0.96	0.79
	Number of women	-0.85	-0.92	-0.09	-0.93	-0.78	-0.81	-0.96	0.78
	Gross earnings	0.96	0.96	-0.22	0.96	0.94	0.91	0.99	-0.69
Rzeszow	Population	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99
	Number of women	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99
	Gross earnings	0.47	0.47	0.47	0.48	0.48	0.46	0.48	0.46

Note: Pearson correlation coefficient at $p < 0.05$. The grey colour indicates a statistically meaningful result.

Agbebeaku et al. (2022), variability of income, the number of people per household, and economic factors have a positive impact on the amount of generated waste. For example, an increase in the amount municipal waste in line with an increase in wealth is very well documented (Dennison et al. 1996, Dyson and Chang 2005, Gómez et al. 2009). It is highly probable that the size of the analysed area, thus, the number of inhabitants as well, influenced the correlation results presented in Tables 2 and 3.

It seems that a better quality of life and a higher income may encourage the inhabitants of a given region to changes related to the quality of daily living conditions. In Poland, a government program "Family 500+" according to the Act of 11th February 2016 on state support in raising children (Journal of Laws of 2016, item 195, as amended) has been applicable since 1st April 2016. Another factor affecting the mass of generated waste was the announcement on 11th March 2020 of the pandemic caused by coronavirus (SARS-CoV-2) by the WHO. Figure 3 presents the mass of municipal waste and selected fractions selectively collected in Poland, Subcarpathian Voivodeship, and Rzeszow in the years 2005–2021 and the impact of the two above factors on this mass.

While analysing the generated mass of municipal waste (Fig. 3a), it was found that it started growing since 2014. It may result from an amendment in 2013 of the Act of 25th January 2013 on maintaining order and cleanliness in communes (Journal of Laws of 2013, item 1593, as amended) valid in Poland since 1996, which obliged commune self-governments to collect municipal waste from real property owners, while the 500+ benefit did not have any effect on it. During the pandemic, the mass of this fraction of waste remained on a constant level only in Subcarpathian Voivodeship (405,707 Mg in 2018 and 409,518 Mg in 2020), and then increased. In Rzeszow, the mass of mixed municipal waste was found to increase, except for 2019 when a 16% decrease was registered in comparison to 2020. An interesting observation was made when analysing data on the mass of generated paper and cardboard (Fig. 3b). At the time of introducing the 500+ benefit in 2016, the mass of this fraction dropped by 12% for Poland and 23.5% for Subcarpathian Voivodeship. The announcement of the pandemic did not affect the generated mass of this fraction of waste. In the case of Rzeszow, a 114% increase in the mass of this fraction of waste was observed at the time of announcing the pandemic, followed by a decrease in 2021. A different correlation was observed for the selective collection of glass (Fig. 3c). The child benefit introduced in 2016 did not affect the mass of glass. However, the pandemic and related restrictions resulted in a 1.3-fold (Poland and Subcarpathian Voivodeship) and a 2.2-fold (Rzeszow) increase of this fraction. There is little difference in the course of changes in the mass of municipal waste, paper and cardboard, and glass for Poland and Subcarpathian Voivodeship. For plastics (Fig. 3d) in Poland, a stabilisation of the generated mass of this fraction in 2014 and an increase since 2017 were found. In the case of Subcarpathian Voivodeship, a sharp drop

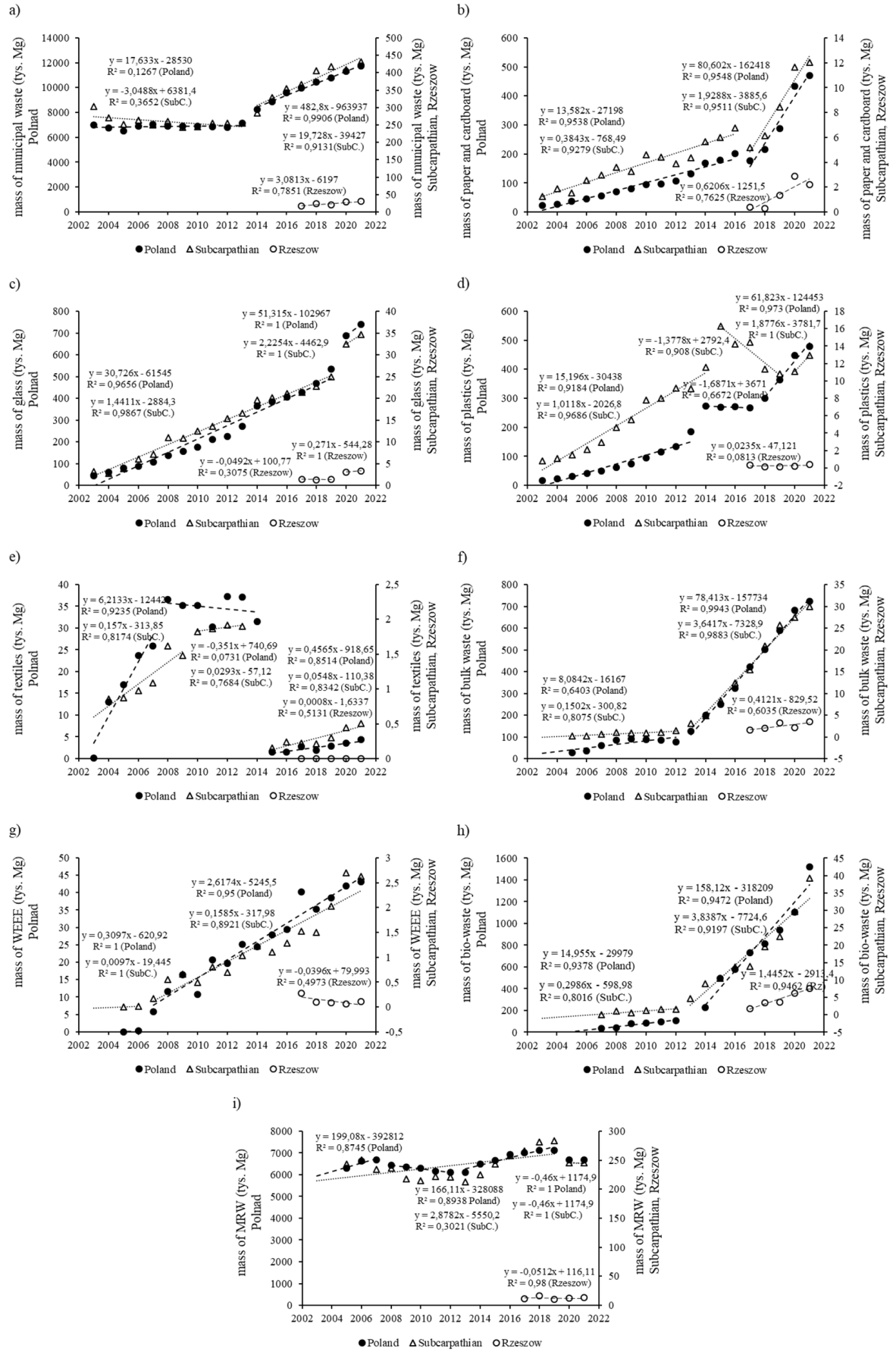

Figure 3. The mass of municipal waste and selected fractions selectively collected in Poland, Subcarpathian Voivodeship, and Rzeszow in the years 2005–2021

in the mass of this fraction of waste was registered in 2015, lasting until 2020, when it started to grow. The benefit did not affect the mass of this fraction of waste neither in the case of Poland nor Subcarpathian Voivodeship. It might seem that more money available to households would affect the mass of textiles in municipal waste. However, according to Fig. 3e, a sharp drop in the mass of this waste was observed in 2015, i.e. before the 500+ benefit was introduced. The pandemic did not cause a rapid increase in the share of this fraction in municipal waste either.

Growth of income often translates into a decision about a renovation or buying new electrical and electronic equipment. The mass of bulk waste (Fig. 3f) was not found to be affected either by the introduction of the additional cash benefit. A sharp increase in this fraction of waste occurred in 2013, which may be connected with the opening of the Points of Selective Collection of Waste (PSZOK), where inhabitants could deposit their bulk waste. In the case of Waste of Electrical and Electronic Equipment (WEEE) (Fig. 3g), a rapid growth of this fraction of waste was observed in 2017 in Poland, and it can be related to an inflow of additional funds to households. However, it was a one-time increase, as in 2018, a decrease in the mass of this waste was observed by 12% in the case of Poland, 1.5% in the case of Subcarpathian Voivodeship, and as much as 64% in the case of Rzeszow. In 2020, the announcement of SARS-CoV-2 related restrictions did not affect the mass of selectively collected waste equipment in Poland, while in Subcarpathian Voivodeship, a sharp increase was observed for this waste (by 33%), followed by a 3% drop. In Rzeszow, a further decrease (by 33%) in the mass of this fraction of waste was registered in 2020, and by as much as 84% in 2021.

In the case of biodegradable fraction (Fig. 3h) of municipal waste, an increased mass has been observed since 2013 both in Poland and in Subcarpathian Voivodeship. This fact may be related to the amendment of the Act on maintaining order and cleanliness in communes referred to above. The mass of this fraction of waste remained unaffected by the introduction of the 500+ benefit only in Subcarpathian Voivodeship. The pandemic, however, caused an increase in the amount of bio-waste by 37% in Poland and 32% in Subcarpathian Voivodeship. In Rzeszow, it was as much as 74%. The waste management system in Poland requires a separate collection of residual (mixed) waste, which after the process of biological stabilisation in plants for biological and mechanical treatment of municipal waste, is transferred to landfills. According to Fig. 3i, the introduction of 500+ did not affect the mass of this fraction of waste. There was an increase in the mass of collected residual waste in 2013, which can be related again to the amendment of the Act on maintaining order and cleanliness in communes. However, a clear impact may be observed after the introduction of SARS-CoV-2 related restrictions. The mass of this waste decreased both in Poland and in Subcarpathian Voivodeship by 6% and 13.5%, respectively. In the case of Rzeszow, a sharp decrease in the mass of mixed waste (by 37%) was found in 2019, followed by an increase by approx. 12% per year.

As presented above, the introduction of the additional cash benefit did not contribute to the mass of generated municipal waste. An increase in the mass of this fraction of waste in 2017 may be observed only in the case of waste equipment. Therefore, it can be assumed that the payment of the 500+ benefit over a period of one year contributed to a change of electrical and electronic equipment in Polish homes. The impact of the pandemic connected with SARS-CoV-2 virus is visible for all municipal waste and selectively collected fractions, i.e. glass, plastics, and bio-waste. This may result from the fact that the pandemic changed the lifestyle of people due to the remote work requirement. Reduced income, employment uncertainty, distribution system disruptions, lack of products, local increased prices and more free time also caused changes in the consumer habits of inhabitants. These factors affect the composition and structure of generated municipal waste. Tafa et al. (2022) also confirm the impact of the pandemic on the amount of generated waste in connection with the need to save, possible loss of employment, and impact on consumer spending.

The remote work requirement might have caused an increase in home deliveries of meals and food products, which in consequence created a growing demand for disposable plastic bags and food packaging materials. There are many studies on the increase in the number of personal protective equipment (PPE) (such as face masks, gloves, etc.) in the total mass of plastic waste. In Poland, however, this waste was directed to residual (mixed) waste, thus, it did not affect the mass of generated plastics. Interestingly, according to Fig. 3i, the mass of generated mixed waste

was reduced. This may be due to the use of cloth face masks and reusable shopping bags by the inhabitants of a given area. The impact of the pandemic on the mass of selectively collected glass is interesting. This may be caused by buying ready food portions in glass packaging and an increased consumption of alcohol during the period of the SARS-CoV-2 related restrictions. As presented in a report prepared by the University of Sheffield in collaboration with the Institute of Alcohol Studies, people drinking less alcohol reduced their average consumption of alcohol during the pandemic, while intensive drinkers increased their alcohol consumption.

The diet affected the mass of generated bio-waste. Panic buying at the beginning of the SARS-CoV-2 epidemic might have contributed to an increase in the level of food waste forming part of bio-waste. This is confirmed by studies (Li et al., 2021; Roe et al., 2021). The reduction of the generated mass of this waste might have also been due to better food planning and management, and the development of cooking skills. A literature review reveals that no single pattern exists. A reduction in food waste in households was observed in Italy and Romania (Amicarelli and Bux 2021; Burlea-Schiopoiu et al. 2021). However, in Serbia and Thailand, a higher amount of generated food waste was observed (Berjan et al. 2022). The quantity of wasted food depends on different social and demographic factors (e.g. the household size and the number of children), socio-economic factors (e.g. loss of income, government restrictions), behavioural factors (e.g. development of cooking skills, better meal planning, more effective food supplies), psychological factors (e.g. depression, fear, stress), situation-related factors (e.g. the time available to individual people), and cultural factors (e.g. eating at restaurants) (Everitt et al. 2022; Ozbük et al., 2022; Qian et al., 2020). Thus, the impact of SARS-CoV-2 on the behaviour connected with wasting food probably differs from country to country. An increase in the amount of bio-waste generated by household was observed also in Poland and in Subcarpathian Voivodeship. A drop in the mass of residual waste, to which inhabitants often throw bio-waste, was also found. Possibly, better food waste segregation would have resulted in even greater differences in the mass of these two fractions of waste. The information on correct sorting of waste is also important for efficient waste management. It is of key importance to effective recovery of raw materials and waste recycling. In 2017, the share of residual municipal waste in relation to the amount of all municipal waste was as much as 78% in Poland, 81% in Subcarpathian Voivodeship, and 64% in Rzeszow, reaching 62%, 58%, and 43%, respectively, in 2021. For comparison, this share in 2003 was 90% for Poland and 92% for Subcarpathian Voivodeship. Better waste segregation is certainly the result of numerous information campaigns, but also obligatory fees for waste disposal, which are higher for mixed municipal waste than in the case of segregated waste disposal. Separation and appropriate transfer of waste that can be subjected to biodegradation is equally important. The fact that the share of the separated bio-fraction in the total mass of mixed waste increased from 0.5% (Poland) and 0.004% (Subcarpathian Voivodeship) in 2007 to 15% and 9%, respectively, in 2021 is positive. In the case of Rzeszow, an increase from 10% in 2017 to 25% in 2021 was found. According to Osuch et al. (2016), it is the willingness to care about the natural environment, rather than financial factors that affect the decision to segregate waste to a greater degree. On the other hand, a lower price of products from recycling has a small impact on the fact of segregating municipal waste. This fact is confirmed by Kushwah et al. 2023; concern about the environment, expected guilt, awareness of consequences and health awareness have a considerable positive impact on waste segregation by inhabitants. The reason for household resistance to waste segregation may be a lack of trust in municipal waste collection companies. This is linked to the doubts about the waste handling practices of waste collection companies (Vassanadumrongdee and Kittipongvises, 2018). Also, an infrastructural barrier, which comprises segregated waste containers, waste collection stations and other sorting services, can contribute to poorer waste management by residents (Kushwah et al. 2023).

CONCLUSIONS

This paper analyses the impact of different factors on the mass of generated municipal waste. It was found that the amount of generated municipal waste and their selectively collected fractions cannot be unequivocally anticipated based on the number of inhabitants or gross income. A negative correlation between the mass of waste and the number of inhabitants and a positive

correlation between the mass of waste and gross income were observed. However, correct interpretation depends on the size of the analysed area. The amount of municipal waste and waste collected selectively from households was probably affected to the greatest extent by local regulations. According to the data presented, a sharp increase in the amount of municipal waste, including bulk waste and bio-waste, was observed in 2013 and 2014, which may be related to the amendment of the Act on maintaining order and cleanliness in communes. The introduction of the 500+ benefit should have had an impact on the increase in the amount of municipal waste, yet this was observed only in the case of waste equipment. The impact of the SARS-CoV-2 related pandemic was connected with a higher amount of selectively collected glass, plastics, and bio-waste. This may result from the consumption models of inhabitants connected with remote work, saving or availability of selected goods. Lack of availability of the information on the amount of waste generated by households is also worth noting. As presented in the methodology contained in Eurostat database, no accurate data on selectively collected municipal waste is available, and this data in the LBD is available for different time spans depending on the administrative level. This makes it difficult to draw unequivocal conclusions on the amount of generated waste and to forecast changes.

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