

COMPARATIVE ANALYSIS OF THE WASTE MANAGEMENT SYSTEM EFFICIENCY IN SOME COUNTIES FROM ROMANIA AND POLAND

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Abstract: In recent years, technology and innovation have also reached the field of waste. They provide an excellent opportunity to improve policies aimed at minimizing waste generation and achieving resource efficiency. However, the degree of introduction of innovative equipment and practices varies significantly from one territory to another. The comparative analysis carried out on within 5 years, showed noticeable changes in the counties in Romania and Poland initiated by the EU and national legislation which indicated an increase in the amount of waste recovered. However, the achieved efficiency of limiting the deposited waste was different at the level of exceeding 70 % and higher of 0.10 kg an average indicator of waste accumulation per capita in Bacau County. Two counties mainly difference composition of municipal waste with predominance of biodegradable waste (60 %) in Bacau County and glass waste (35 %) in Nowy Sącz County with raw material properties. Differences were also noticeable in the case of hygiene fees with exceed of average value 20 EUR in Nowy Sącz County. The gradual increase in the amount of recycled waste and covering all residents with hygiene services should be considered beneficial which indicates an improvement in environmental awareness.

Keywords: waste management, recycling, disposal, indicators

1. INTRODUCTION

Waste is a growing problem in both highly developed and still developing countries as well as in underdeveloped countries [1].

Municipal waste management is a complex activity starting primarily from the composition and diversity of the waste generated [2]. Although the municipal waste represents approximately however, 7-10% of the total waste generated in the European Union (EU) is one of the most complex to manage, and the way it is managed is generally a good indication of the quality of the global waste management system in a country [3].

The challenges in municipal waste management are determined by the fact that they have a very complex and mixed composition, are in close proximity to citizens, have a very high degree of public visibility and have consequences for the environment and public health [4].

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Therefore, municipal waste management requires a very complex system, an efficient collection scheme, an efficient sorting system and proper monitoring of waste streams, the active involvement of citizens and operators, the adaptation of infrastructure to the specific composition of waste and a detailed financing system [5-7].

One of the factors preventing waste production in both Poland, Romania, and member states the European Union (EU) is the application of the waste hierarchy [8]. European policy is based on the "waste hierarchy", which sets priorities for operational waste management: it primarily encourages the prevention or reduction of waste and the reduction of its hazardousness, reuse and only then recovery waste by recycling, and other recovery operations, such as energy recovery [9, 10]. Last in the hierarchy is waste disposal, which includes waste storage and incineration. The transition to a circular economy is also a priority at Member State level [11]. In the circular economy, the value of products, materials and resources is kept in the economy for as long as possible and waste generation is kept to a minimum. The transformation of waste into resources is one of the main elements underlying the circular economy [12].

A key role in waste management has waste accumulation rates which have been used by some researchers [13, 14]. From 2005 to 2018, the average amount of municipal waste measured per capita decreased in the EU. However, trends may vary from country to country. For example, while the amount of municipal waste per capita has increased in Denmark, Germany, Greece, Malta and the Czech Republic, it has decreased in Bulgaria, Spain, Hungary, Romania and the Netherlands [15-17].

In absolute terms, the highest amount of municipal waste per capita was recorded in Denmark, Malta, Cyprus and Germany, and the lowest in Hungary, the Czech Republic, Poland and Romania [15-17].

According to 2018 statistics, 46% of all municipal waste in the EU is recycled or composted. However, waste management practices vary widely from one EU Member State to another and very few countries still dispose of large amounts of municipal waste [15-17].

The practice of waste disposal remains popular in Eastern and Southern Europe. According to the Eurostat study (2018) Poland (34%) Romania (14%) occupies the last two places in terms of municipal waste disposal at landfills [15-17].

Hence comparison of waste management systems in Poland and Romania should help to improve the efficiency of their implementation as well as the manner of their further management [18].

The aim of the paper is to perform a comparative analysis of the efficiency of the waste management system between two counties in Romania (Bacău County) and Poland (Nowy Sącz County) period in 2014-2018.

2. MATERIAL AND METHODS

The article presents analysis of efficiency of waste management in selected counties in Romania and Poland. Data were based on amount of collected municipal waste. In the work were used annual statistical data of inhabitants from analysed counties, amount of selectively collected waste: paper and cardboard, glass, plastic, metal and mixed waste. Data included in the work were came from annual waste management statistical reports and owner observations [19, 20]. On this basis, 5 types of waste i.e. non-selectively collected waste, selectively collected waste, and the total waste was presented indicators of waste accumulation per capita per day, contribution of selected kinds of household waste and sanitation fee per capita.

The qualitative-quantitative analysis was covered amount of municipal waste collected in five years taking into account descriptive statistics (minimum, maximum and average).

3. PRESENTATION OF THE STUDIES COUNTIES

3.1. Bacău County, Romania

From an administrative point of view, Bacău County includes: 3 municipalities: Bacău, Onești and Moinești, 5 cities: Buhuși, Comănești, Dărmănești, Slănic-Moldova and Târgu Ocna, 85 communes and 491 villages. Viewed

in the Romanian territory as a whole, Bacău has a North-Eastern position, with a total area of 6,621 km² (Figure 1).

The agricultural areas cover over 50% of the surface of all the administrative-territorial units in the county, except for the municipality of Bacău, where the lands are largely occupied by constructions, as well as the localities from the mountain area and high hills. At the level of Bacău county, the Natura 2000 Network consists of 3 special avifauna protection areas and 11 sites of community importance representing a total of 8.25% of the county's surface. The relief forms develop in the form of steps: 27% Siret Meadow, 11% Moldavian Plateau, 28% Eastern Subcarpathians and 34% mountainous region.

In 2014, according to the results of the available statistical data, the resident population of the county was 606,975 inhabitants, in 2018 reaching 591,035 inhabitants. Consequently, the population density decreased from 113.29 inhabitants/km² in 2014 to 112.08 inhabitants / km² in 2018 (Table 1). For the population of Bacău County, the trend is continuing to decrease [19].

Table 1. Amount of inhabitants in Bacau County in 2014-2018.

County	Year					Average
	2014	2015	2016	2017	2018	
Bacau	606,975	604,567	600,549	595,534	591,035	599,732

3.2. Nowy Sącz County, Poland

Nowy Sącz County is a unit of territorial administration and local government in Lesser Poland Voivodeship, Southern Poland, on the Slova border (Figure 1). The county contains 6 cities Krynica-Zdrój, Nowy Sącz (additional county), Stary Sącz, Grybów, Piwniczna-Zdrój, Muszyna and 11 rural communes with 151 villages. Nowy Sącz is the greatest city. The County covers an area of 1,608 km² [20].



Fig. 1. Location of Bacău County in North–Earth Romania (Southeastern Europe) and Nowy Sącz County in Southern Poland (East-Central Europe).

Most of the county's area is covered by mountain and upland areas (foothills), as well as the river valleys of the Dunajec with its main tributaries: the Poprad and the Kamienica. The main settlement center of the region is the Sądecka Basin which is a mountain range in the Western Carpathians.

Nowy Sącz County has a tourist and agricultural character with a small industrial stamp in the city of Nowy Sącz. The development of tourism is a great advantage of the county. It is favored by forms of nature protection, such as Natura 2000 areas, a landscape park, nature reserves, ecological areas and natural monuments [21].

In 2014, according to the available statistical data, the population of Nowy Sącz County was 296,797 inhabitants, and in 2018 – 300,590 inhabitants, which showed an increase trend in the population density from 184,46 inhabitants/km² in 2014 to 187,02 inhabitants/km² in 2018 (Table 2). On the other hand, the downward trend is noticeable in Nowy Sącz [22].

Table 2. Amount of inhabitants in Nowy Sącz County in 2014-2018.

County	Year					Average
	2014	2015	2016	2017	2018	
Nowy Sącz	296,797	297,857	223,400	300,072	300,590	283,743

4. WASTE MANAGEMENT

4.1. Generation of waste

In Bacau County, municipal waste management is the responsibility of municipalities, which can perform these duties either directly (through specialized services within the Local Councils) or indirectly (by delegating this responsibility on a contract basis to specialized and authorized companies for sanitation services).

The sanitation service in Bacau County has expanded from year to year, so that almost the entire population benefits in 2018 from this service (Figure 2).

Nowy Sącz County, municipal waste management is the responsibility of municipalities, which can perform these duties indirectly by delegating this responsibility on a contract basis to specialized and authorized companies for sanitation services selected in the tender procedure. According to the legislation in Poland in the county area from 2014 every property inhabited or uninhabited are covered collection of household waste (100%).

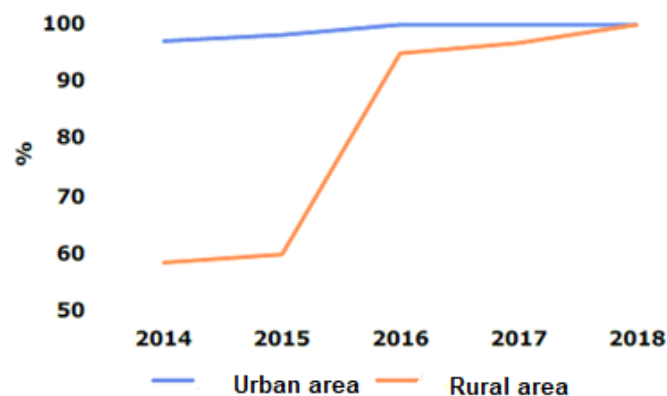


Fig. 2. The evolution of the degree of connection to the sanitation service in the period 2014-2018.

Nowy Sącz County, municipal waste management is the responsibility of municipalities, which can perform these duties indirectly by delegating this responsibility on a contract basis to specialized and authorized companies for sanitation services selected in the tender procedure. According to the legislation in Poland in the county area from 2014 every property inhabited or uninhabited are covered collection of household waste (100%).

Municipal waste collected in Bacau County is represented by household waste and similar generated in urban and rural areas from households, institutions, commercial units and economic operators, street waste collected from public spaces, streets, parks, green spaces, where it also adds construction and demolition waste (Table 3).

The amount of household collected in Bacau County had a continuous growth trend in the period 2014-2018, representing in 2018, 91.96 % of the total amount of municipal waste collected. Instead, the amount of waste resulting from construction and demolition varied during this period registering the maximum value in 2016 (36,552 Mg) and the minimum value in 2018 (4,562 Mg).

Table 3. Indicators of waste accumulation per capita in Bacau and Nowy Sącz County.

County	2014	2015	2016	2017	2018	Average
kg/cap/day						
Bacau	0.53	0.57	0.61	0.64	0.65	0.60
Nowy Sącz	0.46	0.48	0.50	0.53	0.52	0.50

Municipal waste collected in Nowy Sącz County is represented by household waste and similar generated in urban and rural areas from households, institutions, commercial units and economic operators, street waste collected from public spaces, streets. Construction and demolition waste come from households.

The amount of household waste collected in Nowy Sącz County showed an increase trend from 30,553 Mg to 35,970 Mg and domination of contribution at average level of 96,1%. Second position confirm much lower average of contribution of construction / demolition waste at showed significant increase trend by above 12,000 Mg. The maximum amount mentioned types waste were confirmed in 2017 (Table 4).

Table 4. Amount of selected types of collected municipal waste in Bacau and Nowy Sącz Counties.

County	Waste type	Year									
		2014		2015		2016		2017		2018	
		Mg	%	Mg	%	Mg	%	Mg	%	Mg	%
Bacau	household waste	104	72.5	106.315	75.9	127,846	73.6	140.333	86.0	141,285	91.96
	waste from municipal services	6.545	4.56	7.465	5.33	9,345	5.4	9.367	5.8	7,792	5.07
	construction/demolition waste	32.892	22.94	26.293	18.77	36,552	21	13.438	8.2	4,562	2.97
Total		143.44	100	140.073	100	173,743	100	163,138	100	153,639	100
Nowy Sącz	household waste	30,553	96.1	33,224	95.8	34,625	97.9	36,667	94.2	35,970	71.8
	waste from municipal services	211.5	0.7	18.1	0.1	27.35	0.1	519.36	1.3	314.64	0.6
	construction/demolition waste	1.033	3.2	1,441	4.2	708.11	2	1.719	4.4	13.788	27.5
Total		31,797	100	34,683	100	35,361	100	38,906	100	50,073	100

The average indicator of household waste generation in urban areas is 0.82 kg/capita/day in Bacau city and 0.61 kg/capita/day in other localities in urban areas while in rural areas it is 0.37 kg/capita/day.

Regarding the composition of household and similar waste, biodegradable waste represents the predominant amount (approximately 60%), being followed in similar proportions by paper and plastic waste (between 15 and 20%). Wood, glass and metal waste represents the smallest amount of municipal waste generated in Bacau County, Figure 3 (less than 5% each).

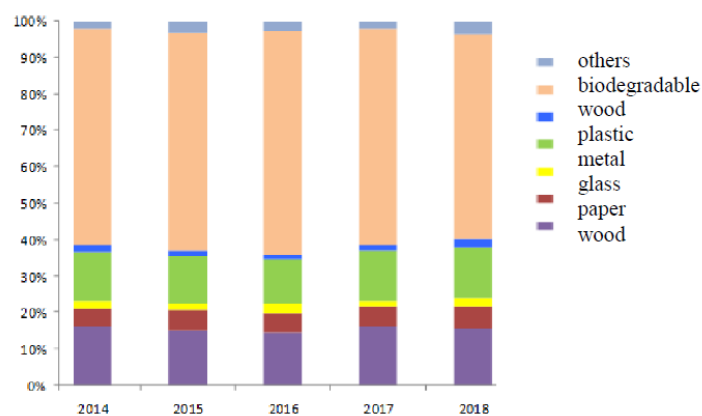


Fig. 3. Percentage composition of household and similar waste collected in the period 2014-2018 in Bacau County.

In Nowy Sącz County the average indicator of household waste generation in urban and rural areas is 0.33 kg/capita/day but in Nowy Sącz city is 0.67 kg/capita/day.

Regarding the composition of household and similar waste, it remains in the same range of variation for period 2014-2018 (Figure 4). The amount of waste that predominates in the composition of household waste is represented by glass waste (approximately 27-42%) and plastic 23-29%. The lowest contribution fell on metal waste (approximately 0.50-1.4%).

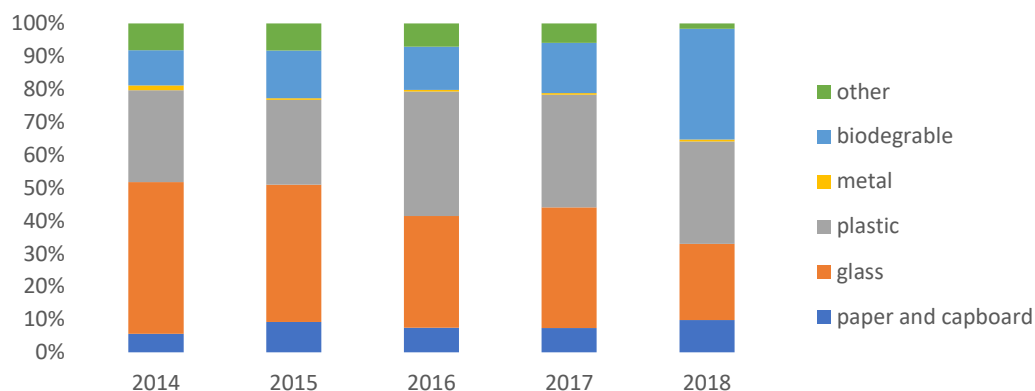


Fig. 4. Percentage composition of household and similar waste collected in the period 2014-2018 in Nowy Sącz County.

4.2. Waste and transport collection

At the end of 2018, the sanitation services in the 93 Territorial Administrative Units of Bacau County were provided by 7 sanitation operators (Figure 5).



Fig. 5. Coverage area of sanitation operators in Bacau County.

The collection of household waste in Bacau County is done mixed and separately.

The collection of mixed household waste is done as follows:

- In the urban environment, in the areas with individual dwellings, the collection is made from door-to-door, from each household, in 120-240 L, while in the block areas the waste is collected in points equipped with containers of 1.1 m³. The collection of mixed household waste it is performed daily between April 1 and October 1 and in the rest of the year once every three days.
- In rural areas, door-to-door collection is done at each private household, in 120 L and in hard-to-reach areas in collection points equipped with 1.1 m³ containers. The collection of mixed household waste it is done weekly.

Collection of recyclable waste in both urban and rural areas is done in three fractions (paper and cardboard waste, glass waste, plastic and metal waste).

The collection of separately collected recyclable waste is carried out at a time interval established by the operator together with the local public administration authority, as follows: paper and cardboard waste – once a week in urban zone and once a month in rural zone, plastic and metal waste – twice a week in urban zone and once a week in rural zone; glass – once a month in both urban and rural areas.

Separate collection of biodegradable waste is done only in urban areas. The separate biowaste collection system is made from "gate to gate" for 80% of individual households in Onești, Moinești, Comănești, Tg. Ocna, Dărmănești and Moinești.

At the end of 2018, the separate biodegradable waste collection system in rural areas was not implemented. According to the legislation in force, in Romania the sanitation taxes are paid by all owner of inhabited and uninhabited properties and are established by local authorities. Thus, at the level of 2018, the sanitation fee in Bacau County for the inhabitants of the urban area was approximately 40 euro / year and for the inhabitants of the rural area 17 euro/year.

In turn the sanitation services in 16 Territorial Administrative Units of Nowy Sącz County were provided by 17 sanitation operators at the end of 2018 (Figure 6).

The collection of household waste in Nowy Sącz County is done separately and mixed. Separate collection in both urban and rural areas is done in 5 fractions (paper and cardboard waste, glass waste, plastic waste, metal waste, biodegradable waste).

The collection of segregated household waste is done as follows:

- In the urban environment, in the areas with individual properties, the collection is made collection is done at each private household by use of bags in 120-240 L, while in the block areas the waste is collected in points equipped with containers of 1.1 m³.
- In rural areas, door-to-door collection is done at each private household, in bags of 120 L or 240 L. From urban and rural environment segregated household waste are collected at least once month (Nowy Sącz city once week).

The collection of mixed household waste is done as follows:

- In the urban environment, in the areas with individual properties the collection is made from each household by use of bags or bins with capacity of 120-240 L, while in the block areas the waste is collected in points usually are equipped with containers of 1.1 m³ and 5 m³.
- In rural areas, door-to-door collection is done at each private household, in 120 L.



Fig. 6. Coverage area of sanitation operators in Nowy Sącz County (100%).

From urban and rural environment mixed household waste are collected at least once month (Nowy Sącz city once week).

In two time per year usually is organized collection of bulky waste. In studied period an average amount of collected bulky waste amounted of 1,810 Mg at the increase trend.

Additionally, households waste can be collected by citizens in municipal waste selectively collection points, whose located in the communes of Nowy Sącz County.

According to the legislation in force, in Poland the sanitation taxes are paid by all owner of inhabited and uninhabited properties, which are established by local authorities from 2014. In 2018 the sanitation fee in Nowy Sącz County for the inhabitants of the urban area was approximately 60 euro / year and for the inhabitants of the rural area 36 euro / year.

4.3. Recovery/disposal of waste

The main operations of recovery / disposal of municipal waste resulting in Bacau County are represented by storage and recycling (Table 5).

In Bacau County, the infrastructure for waste storage includes 5 non-compliant landfills - closed and rehabilitated in accordance with the legal provisions and a landfill in Bacau which currently serves the entire county. Regarding the recycling of municipal waste, this operation is done in 6 accredited facilities in the county.

Degree of recycling and waste storage in analysed counties differed significantly. In Bacau County here is a trend of household waste storage, with an average of 89.46 % of the total amount of household waste, for the period 2014-2018.

Table 5. Degree of recycling and waste storage in Bacau and Nowy Sącz Counties for the period 2014-2018.

County	Recovery/disposal (%)	Year					Average
		2014	2015	2016	2017	2018	
Bacau	Recycling	10.4	11.55	11.6	8.7	10.45	10.54
	Storage	89.6	88.45	88.4	91.3	89.55	89.46
Nowy Sącz	Recycling	29.90	22.29	25.70	23.83	34.38	27.22
	Storage	70.10	77.71	74.30	76.17	65.62	72.78

In second County the best contribution fell on deposited waste at the average 72.78%. Amount of recycled waste increase of approximately 4 %. This completely showed an increase in the share of waste recycled and a decrease in landfilled waste. But the main operations of recovery / disposal of municipal waste resulting in Nowy Sącz County are represented by storage and recycling.

On the area of Nowy Sącz County, there are 5 old landfill sites - closed and rehabilitating in accordance with the legal provisions and in Stary Sacz using landfill site for residual waste (after segregation). Regarding the recycling of municipal waste, this operation is done in two accredited facilities in the county. The most of household's waste are recycled off - site Nowy Sącz County. At the end of 2018 in Bacau County there were no facilities for pre-treatment of municipal waste before storage and no facilities for heat treatment of municipal waste.

In Nowy Sącz County there was installation for pre-treatment of municipal waste before storage but no facility for heat treatment of municipal waste at the end of 2018. In this County is located regional installation of solid waste management plant (sorting plant, 2 composting, landfill site).

5. DISCUSSION

The waste management in Poland and Romania are based on the law which is comply with the European Union regulations [23-26].

Based on data collected from the two counties of different localization in Europe, surface and amount of inhabitants the dominance was non-selectively municipal waste collection. In the greatest county (Bacau) collection of municipal landfill is realized by three fractions (paper and cardboard waste, glass waste, plastic and metal waste). Differently in lower county in five fraction including biodegradable. In particular, the collection of biodegradable waste should be considered advantageous [27].

In Bacau County was predominated amount of biodegradable waste (about 60%) but in Nowy Sącz County glass waste (about 35 %). Orlescu and Costescu [28] was also showed, domination share of biodegradable waste in Romania and Przydatek [29] also showed high contribution of glass in Poland (26%). The contribution of the last type waste in Bacau County was lower level of 5%. Generally, increase trend of collected household waste is noticeable in analysed counties at the level over 90% of the total amount of municipal waste collected. According to Özbay [30], people generate significant amounts waste is connected with increasing of the standards living.

In two counties the same types of municipal waste (household waste, waste from municipal services, construction/demolition waste) were collected on share from 80% to 90% of the total amount of municipal waste respectively for Bacau County and Nowy Sącz County. The efficiency of waste management is influenced by its availability, which in the analysed counties indicates the development of selective waste collection.

The main operations of recovery / disposal of municipal waste resulting in both counties are represented by storage and recycling. In Romania and Poland is noticeable significant participation of waste storage rate was of over 70%. In Bacau County municipal waste disposal rate exceeded of 20% the national average. On the other hand, in Nowy Sącz County this indicator did not exceed of 73% storage municipal waste and was lower than national average. According to some researches [31] in the new EU countries, the storage of waste dominates of waste management. Przydatek [14] considered of used waste accumulation indicators per capita as valuable in assessing the efficiency of waste management. Noticeable the average indicator of 0.60 kg / capita / day of household waste generation in Bacau County was higher than in Nowy Sącz County. Jigani et al. [32] showed the higher indicator of waste accumulation in Romania. Overall, this ratio has increased, as has the total amount of waste in spite of decrease of amount inhabitants in first mentioned county. Matsumoto [33] was observed that same increasingly trend of amount waste. These differences may result from the greater number of inhabitants living in mentioned county. According to Hage and Söderholm [34] results suggest that local geographic and demographic variables, including socio-economic variables, influence on waste accumulation rates.

Another element of waste management is transportation. This process is a fairly important segment of the overall waste management system that requires proper consideration in order to properly assess the entire burden of municipal waste management [35]. In two counties the level hygiene services was advanced at the highest in Nowy Sącz County. Apostol and Mihai [36] paid special attention to sanitation services of the rural areas.

One of the important elements of waste management is the cost of hygiene services. The costs of hygiene services include collection, transport, recovery, and disposal of municipal waste. In two counties, the fees for hygiene services were different. The higher of 20 EUR cost fees for hygiene services fell on Nowy Sącz County. Some researchers [37] related the increase of cost management to an increase in waste disposal.

6. CONCLUSIONS

In both counties the municipal waste management is the responsibility of the municipalities, which can perform these duties either directly (through specialized services within the Local Councils) or indirectly (by delegating this responsibility on a contract basis to specialized and authorized companies for services sanitation).

The coverage of sanitary sanitation services was at the level of 2018 in Bacau County of 98.24% in urban areas and 89.77% in rural areas and 100% in Nowy Sącz County. The communities in the two countries collect the same types of municipal waste (household waste, waste from municipal services, construction / demolition waste), the majority being household waste in both counties (approximately 80% of the total amount of municipal waste for Bacau county and 90% for from Nowy Sącz County).

The average amount of municipal waste generated by the inhabitants of Nowy Sącz County is slightly lower than that of Bacau County. However, the difference is more visible in the two main urban areas. Thus in the municipality

of Bacau the average amount of municipal waste for the period 2014-2018 was 0.82 kg/capita/ day while in Nowy Sącz it was 0.67 kg/capita/day.

Regarding the composition of household waste, it differs from one area to another. While in Bacau County the predominant amount of waste composition is represented by biodegradable waste (about 60%), in Nowy Sącz County the highest proportion is represented by glass waste (with an average of about 35%). At the opposite pole there are also differences between the two areas. Thus, the inhabitants of Bacau County generate small amounts of glass and wood waste (less than 5% of the total amount of household waste), while in Nowy Sącz County the lowest share is represented by metal waste (approximately 1 % of total amount of household waste).

Waste collection in the two counties is done both mixed and separately. While in Bacau County the separate collection is done on three fractions (paper and cardboard waste, glass waste, plastic and metal waste) in Nowy Sącz County the selection is done on five fractions (paper and cardboard waste, glass waste, plastics waste, metal waste, biodegradable waste).

According to the legislation in force, both in Romania and in Poland the sanitation taxes are paid by all owner properties. The sanitation fee in Bacau County for the inhabitants was approximately lower of 20 euro/year than in Nowy Sącz County.

The main operations of recovery / disposal of municipal waste resulting in both areas are represented by storage and recycling. Taking into account the recommendations of the European Union, Romania and Poland are among the least performing Member States in terms of municipal waste management, with a storage rate of over 70%. Bacau County far exceeds the national average and has a municipal waste disposal rate of almost 90%. On the contrary in Nowy Sącz County the level of almost 73% storage municipal waste was lower than national average.

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