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REPORT ON THE MORPHOLOGICAL ANALYSIS OF WASTE IN THE MUNICIPALITY OF KNJAŽEVAC

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REPORT

on determining the composition and assessment of the amount of waste in the Municipality of Knjaževac for all four seasons

1. INTRODUCTION

The report on determining the composition and assessment of the amount of waste in the Municipality of Knjaževac for all four seasons as part of the IPA cross-border cooperation project, and according to the contract with PUC Standard Knjaževac, was realized by the employees of the Department of Mineral and Recycling Technologies, Technical Faculty in Bor, University of Belgrade, with the support of members of the project team from Knjaževac:

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There are a number of different methodologies that are used to determine the amount and composition of waste, especially when considering smaller variations. Each of them has advantages and disadvantages, and it is necessary to choose the one that is most appropriate for the given conditions. The methodology to be used in this project is based on the considerations and analyses of methodologies and experiences in the EU Member States and in Serbia, and it is in accordance with the Law on Waste Management ("Sl. glasnik rs" No. 36/2009, 88/2010 and 14/2016) and the Rulebook on the methodology for collecting data on the composition and amount of municipal waste in the territory of the local self-government unit ("Sl. glasnik rs", No. 61/2010).

2. Basic information about the Municipality of Knjaževac

The Municipality of Knjaževac is located in the eastern part of Serbia, along the border with the Republic of Bulgaria, and it is a part of the Timočka Krajina region as its southernmost municipality. According to the statistical data from 2011, the Municipality covers an area of 1.202 km^2 and is the fourth largest municipality in the Republic of Serbia. The greater part of the Municipality of Knjaževac is the highland area. The municipality has 31.491 inhabitants, out of which 18.404 live in Knjaževac (2011

Census), which represents the administrative, economic and cultural center of the Municipality. According to the 2011 Census, the number of households in the municipality is 11.572, and the average number of members per household is 2,7. The average population density is 26 inhabitants per km^2, which classifies it as a less populated municipality. The population index for the entire municipality is only 84,7 for the period 2011/2001. In addition to Knjaževac, the Municipality of Knjaževac includes 85 villages with 13.087 inhabitants: Aldina Reka (1), Aldinac (16), Balanovac (242), Balinac (19), Balta Berilovac (133), Banjski Orešac (66), Beli Potok (165), Berčinovac (120), Božinovac (17), Bulinovac (174), Bučje (256), Valevac (214), Vasilj (596), Vidovac (23), Vina (292), Vitkovac (223), Vlaško Polje (114), Vrtovac (143), Gabrovnica (3), Glogovac (66), Gornja Kamenica (258), Gornja Sokolovica (19), Gornje Zuniče (420), Gradište (22), Grezna (285), Debelica (333), Dejanovac (15), Donja Kamenica (229), Donja Sokolovica (86), Donje Zuniče (374), Drvnik (7), Drenovac (98), Drečinovac (59), Žlne (98), Žukovac (63), Zorunovac (107), Zubetinac (110), Inovo (59), Jakovac (241), Jalovik Izvor (111), Janja (23), Jelašnica (133), Kaličina (224), Kalna (287), Kandalica (25), Koželj (96), Krenta (67), Lepena (95), Lokva (42), Manjinac (70), Miljkovac (86), Minićevo (779), Mučibaba (62), Novo Korito (126), Orešac (272), Ošljane (156), Papratna (5), Petruša (62), Podvis (261), Ponor (66), Potrkanje (72), Pričevac (25), Ravna (165), Ravno Bučje (15), Radičevac (29), Rgošte (266), Repušnica (0), Svrljiška Topla (79), Skrobnica (104), Slatina (90), Stanjinac (53), Staro Korito (23), Stogazovac (104), Tatrasnica (3), Trgovište (1855), Trnovac (165), Ćuštica (166), Crvenje (140), Crni Vrh (91), Šarbanovac (13), Šesti Gabar (88), Štipina (466), Štitarac (59), Štrbac (153), Šuman Topla (49). Data source is taken from the Statistical Office of the Republic of Serbia (2011 Census). The highest point on the territory of the Municipality is Midžor on Old Mountain with the elevation of 2.169m, which is also the highest peak in Serbia. The lowest point is at the elevation of 176m and it is located in the Knjaževac basin. The city of Knjaževac is located at the mouth of the Trgovški Timok and the Svrljiški Timok, which together form the Beli Timok. The climate is moderate and continental. The hottest month is July with the average temperature of $21,3^0C$, while the coldest is January with the average temperature of $-0,8^0C$. The average rainfall is 590,8 mm/m^2. On average, there are 306 sunny days and 30 snowy days during the year.

The Municipality of Knjaževac is connected with the surrounding cities and municipalities by roads of the total length of 491km, of which as much as 83% of them belong to the category of modern carriageways (Source: Statistical Office of the Republic of Serbia, 2015). However, the main roads are only 3km long, regional roads 185km and local roads 266km, so the local roads take up as much as 55% of total roads.

Knjaževac is known as the fruit and vineyard region due to the predominantly highland configuration. Grapevine was cultivated in this region during the period of the Roman Empire. Nowadays, grapevines, cherries, plums and blackberries are cultivated the most. The most well-known sectors of the economy, according to which the city is known, are the machine industry, the furniture industry, the textile industry, the food industry and the leather and footwear industry. Manufacturing companies in the Municipality of Knjaževac are PK „Dževrin“, PP „Venus“, „Desing“ – food industry, „Podvis“, „Šukom“, „Eko Star“ – metal processing industry, „Falk East“, „Gabiano“, „Serbina“, „Relaks“ – footwear industry, „Kids Beba“, „Lanteks“, „Azaro“, "Branka Dinić" – clothing industry, „Lanteks“, „Azaro“ – leather and textile industry, „Tina“ – furniture industry, "SCS Plus“ – wood processing industry. The level of employment of the population is decreasing. The private sector has the dominant place and role in the structure of the municipality's economy. Around 80% of the agricultural land is private property. The percentage of catering and tourism related to the structure of employment and generation of national income is just around 1,6%. Knjaževac has significant advantages and qualities in the development of infrastructure. It has sufficient quantities of healthy and quality drinking water. Organized water supply from the PUC system is also provided in the city and in 15 villages. Other settlements have their own water supply systems. Knjaževac is one of the few towns that have a separate system of wastewater collection, but it lacks the capacity of wastewater treatment, and it is directly released into the recipient (the Timok River).

The city is extremely well illuminated by the city lights. The needs for electric power are satisfied by the town’s electrical engineering. The municipality is the founder of 3 PUCs: PU Directorate for Development, Urban Planning and Construction of the Municipality, PUC Standard for the fields of water supply, sewerage and wastewater treatment, solid waste management and farmers’ market, and PUC Toplana for the town’s heating system. There are 3 primary schools with 23 facilities, one correctional primary school for juvenile delinquents, one primary music school, and 2 secondary schools (gymnasium and technical school). There is also a dormitory for secondary school students where 50 students are accommodated. Tourism and recreation center Babin Zub on Stara Planina, about 50-60km away from Knjaževac, and Rgoška Banja, located on the coast of the Svrljiški Timok, between the village of Rgoša and the Tresibaba and Podvis mine, are of great importance for the tourism industry. Health care is provided by the Health Center with medical stations in Minićevo, Kalna, around 30 rural clinics and a hospital, which has four departments (children, surgery, gynecology and internal medicine). The open Olympic swimming pool "Banjica" is located 5km away from Knjaževac, southwest of the Timok and on the right bank of the Svrljiški Timok. It is supplied with thermal water from the thermal spring of Rgoška Banja.

PUC Standard Knjaževac has been operating as a public utility company since 1970. One of the main activities of the company is the collection and transport of waste in the territory of the Municipality of Knjaževac. PUC Standard provides waste collection services for people in Knjaževac and 40 villages belonging to the territory of the Municipality of Knjaževac, as well as for business companies in the Municipality of Knjaževac. Waste is collected from households, shops, catering facilities, business facilities, streets, industrial facilities, public areas of the city, from institutions that work with organic materials, and others. Waste is disposed of once a week according to the weekly waste collection plan, for all inhabitants covered by the waste collection service. PUC Standard's working hours are five days a week, 260 days a year. Waste is collected and disposed of from 40 villages, out of a total of 85, by collecting it at collection points where 120 containers of 1,1m^3 are placed and collected once a week. Waste is collected in 40 containers of 1,1m^3 and disposed of once a week from the nature park "Stara Planina", particularly from the hotel and ski resort, and during the peak seasons twice a week. PUC Standard has 2 lifter trucks and 4 dumpster trucks, 1 combined dumpster truck that can collect individual housing waste through an 80-liter waste container and that can empty containers of 1.1m^3 and 5m^3, as well as 1 multi-cultivator machine for the collection and disposal of waste. The waste is deposited on the city's unregulated dump site, located near the banks of the Beli Timok. Unfortunately, there are also many unregulated landfills, which are used to dispose of various types of waste. The project for sanitation and closure of the main landfill in Knjaževac was made in 2006, but to date it has not been implemented.

The company has a total of 137 employees, out of which 22 employees are engaged in waste management, that is, waste collection and transportation: 1 Head of the working unit, 1 Manager, 2 Workers at the landfill, 13 workers collecting and transporting waste on every working day and 2 workers on PET packaging. Members of individual and collective city households are provided with the necessary number and type of containers (80l containers and 1,1m^3 or 5m^3 containers).

In addition to the collection of the municipal waste, the collection of PET packaging is carried out in the Municipality of Knjaževac as well. There are also PET packaging containers in locations where they are needed, next to the waste containers. In 2015, 11,20 tons of PET packaging were collected and handed over, 7,36 tons were collected and handed over in 2016, and 8,20 tons of PET packaging were collected and handed over in 2017. The secondary raw materials market in the Municipality of Knjaževac has not been developed. There are no economic and other incentive mechanisms for the use of waste materials. There is no separation of waste at the place of its formation neither by PUC Standard nor by the private sector. There is no established and developed training and awareness-raising system for waste management.

The city landfill in Knjaževac is located about 1 km away from the city center, and as such is in an unacceptable location because it is in the immediate vicinity of the city. The landfill has almost a square shape, with a surface of more than 3ha.

The development of the project for the transshipment station is in progress. The Municipality of Knjaževac belongs to the Timočka krajina region and is therefore included in the project for the Regional Landfill in Halovo. Considering the fact that the capacity of the city dump site in Knjaževac has been filled, and that the Regional Landfill in Halovo has not been realized yet, in the shortest amount of time, and after the construction of a transshipment station, PUC Standard Knjaževac will be forced to transport the waste to one of the nearest landfills in Niš or Pirot.

3. Determining the composition and quantity of municipal waste in the territory of the Municipality of Knjaževac

The methodology consists of two steps. The first step is to evaluate the generated quantities of municipal waste in the Municipality of Knjaževac by measuring the amount of municipal waste within a period of seven days before it is disposed of to the landfill. The second step is the sampling and analysis of the morphological composition of waste in accordance with the defined catalog for the classification of waste.

Prior to the analysis itself, labor power and equipment must be provided. Special attention should be paid to the safety and protection of workers during work. Three workers are sufficient for the purposes of sorting and analyzing the morphological composition of waste, an analyst and engineer in charge of controlling the process itself. The workers are obliged to wear a protective suit, boots and gloves in contact with the waste. The equipment needed to carry out the sorting process includes:

1. Measurement scale

2. Waste bins (marked by type of waste defined by the waste catalog).

3. Sieve (for easier and faster sorting and separation of larger waste from other waste, with openings of 20mm, thus obtaining separated so-called "fine elements" of less than 20mm, which are most often in the form of soil, ash and dust).

4. Auxiliary tools (shovels, brooms, rakes, nylon, scissors, cutting blades, etc.). When all conditions and all necessary equipment are provided, the sampling can begin, i.e. sorting and determining the morphological composition of waste as the final stage in the entire process. Waste sorting is done manually, each bin or waste type is measured separately, and the results are recorded in the table.

3.1. Measuring of generated quantities of waste in the Municipality of Knjaževac in the period from 18th-22nd of September 2017 (summer period)

The first step is to measure the mass of municipal waste generated from 18th-22nd of September 2017. The measurement was done in such a way that the first thing that was measured was the tare weight of trucks that collected waste in the Municipality of Knjaževac, that is, prior to leaving the facility and collecting waste.

Afterwards, the same trucks were measured while doing their regular routes in the collection of waste and when they were at full capacity (gross weight). The wheel scale in the agricultural combine "Dždervin" was used for all measurements. As already mentioned, measurements were made during the period of one week, as the Public Utility Company Standard from Knjaževac provides services of waste disposal for each household in the Municipality of Knjaževac for that particular period.

In the period from the 18th of September to the 22nd of September, 110 tons of waste were collected from the households within the Municipality of Knjaževac belonging to the collection system of the Public Utility Company Standard, the details are presented within the Table 1 and in Figures 1-4.

Table 1. Data on the amount of generated municipal waste measured in the period from the 18th of September to the 22nd of September 2017

Ordinal number	Vehicle	Net weight of waste, t
1	Dumpster truck (license plate KŽ 004-ZŠ)	27,48
2	Dumpster truck (license plate KŽ 004-DŠ)	27,30
3	Dumpster truck (license plate KŽ 007-XB)	29,86
4	Lifter truck (license plate KŽ 001-MN)	25,14
	TOTAL:	109,78

Bearing in mind that the number of inhabitants encompassed by the service is 27004, the obtained data on the generation of waste per inhabitant of the Municipality of Knjaževac per day is 0,58 kg / per inhabitant per day.

Figure 1. Collection and transport of municipal waste by dumpster truck (license plate KŽ 004-ZŠ)

Figure 2. Collection and transport of municipal waste by dumpster truck (license plate KŽ 004-DŠ)

Figure 3. Collection and transport of municipal waste by dumpster truck (license plate KŽ 007-XB)

Figure 4. Collection and transport of municipal waste by lifter truck (license plate KŽ 007-XB)

3.2. Determining the morphological composition of municipal waste in the Municipality of Knjaževac

The second part of the methodology is the determination of the morphological composition of municipal waste in the Municipality of Knjaževac. The summer analysis of the morphological composition of waste was done on the 19th of September, 2017 from the following sectors:

- City zone - individual housing
- City zone - collective housing and commercial zone
- Rural areas within the Municipality of Knjaževac

A sample of waste from an individual type of housing used for sorting was taken from Dr. Savić Street, while a sample of waste for sorting from a collective type of housing was taken from Branko Radičević Street. When it comes to the rural zone, the sample was taken from Gornje Zuniče village.

Containers were transported to a facility belonging to the Public Utility Standard from Knjaževac, where the analysis was carried out. The following equipment was used for the realization of the waste sorting process:

• 20 mm mesh sieve for easier and faster sorting and separation of larger waste

• 85 liters waste bins marked by the category of waste in which waste was disposed of for sorting by category and measurements

• Scale for measuring the amount of waste by category according to the designated catalog

Figure 5. Use of equipment during the process of waste sorting and measuring

Table 2 and Figures 6, 7 and 8 show in detail the results of the morphological composition of waste by the sector of housing for the summer period.

Table 2. Percentage of different categories of waste per sector of housing

Waste category	SECTOR OF HOUSING		
	Individual-City %	Collective-City %	Rural %
Food waste	36,92	65,09	43,12
Paper and cardboard	12,31	2,37	9,17
Plastics	10,77	11,83	11,01
Textiles	13,85	3,55	12,84
Rubber	1,54	3,55	0,92
Leather	0	0	1,84
Garden waste	10,77	0,59	6,42
Wood	0,31	1,78	0
Glass	0	1,78	2,75
Metal	6,15	3,55	2,75
Aggregates	1,54	0,59	0
Hazardous waste	0,46	0,59	3,67
Rest	5,38	4,73	5,51
TOTAL:	100,00	100,00	100,00

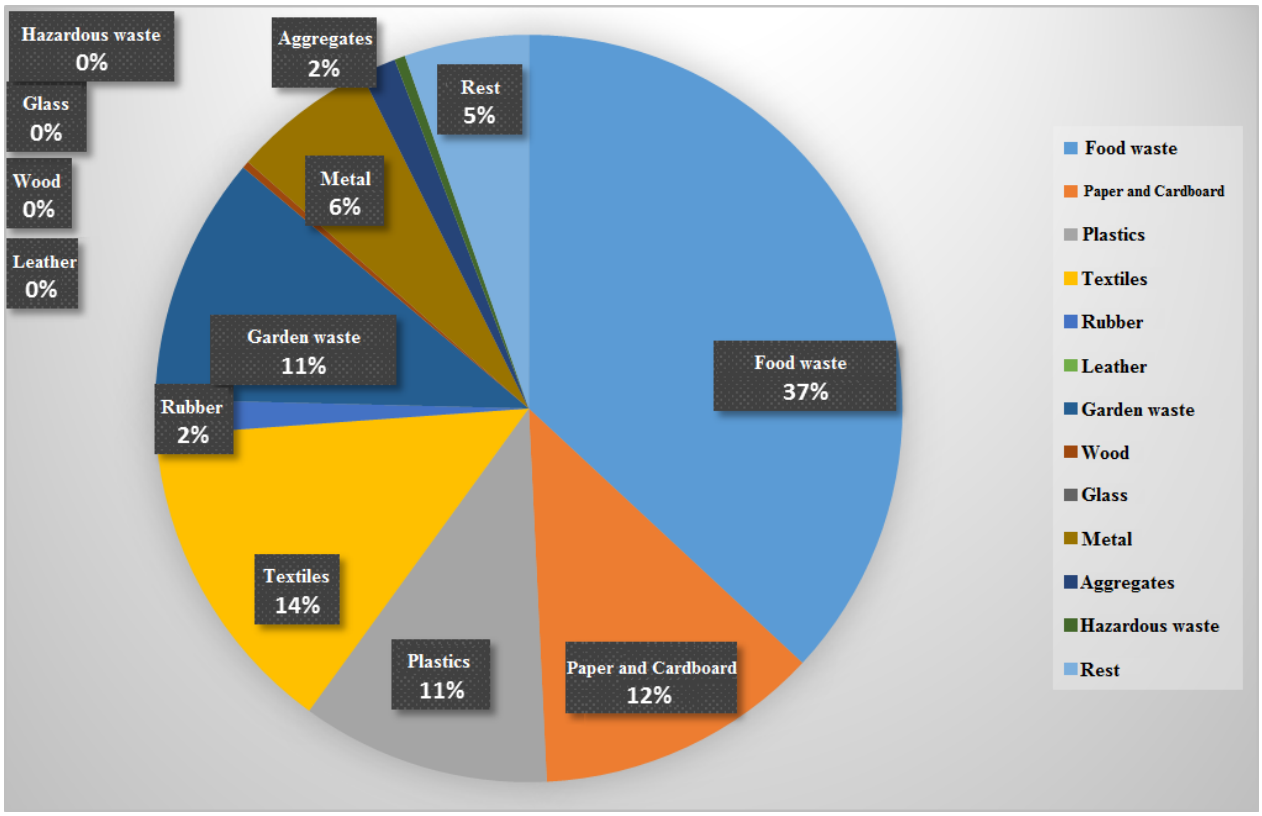

Figure 6. Percentage of different categories of waste per sector of housing for the individual-city housing sector

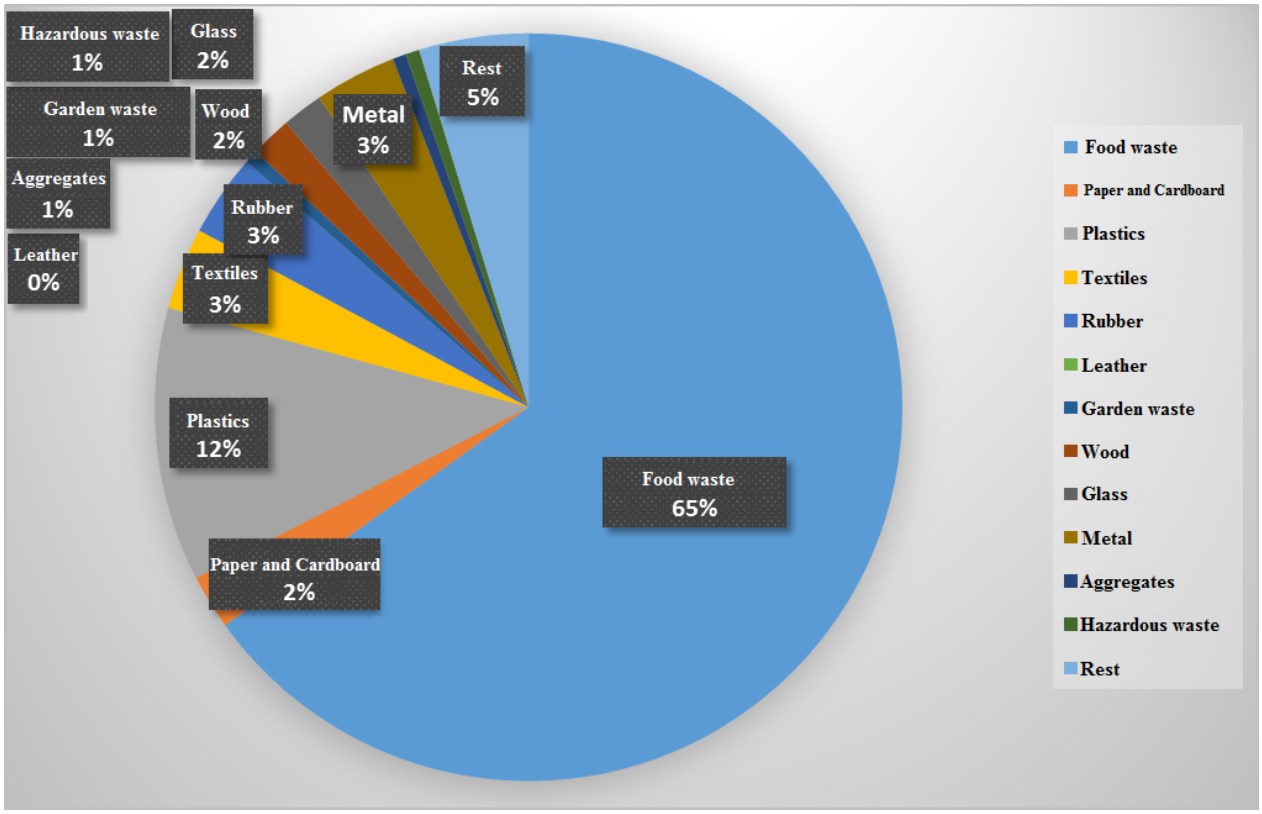

Figure 7. Percentage of different categories of waste per sector of housing for the collective-city housing sector

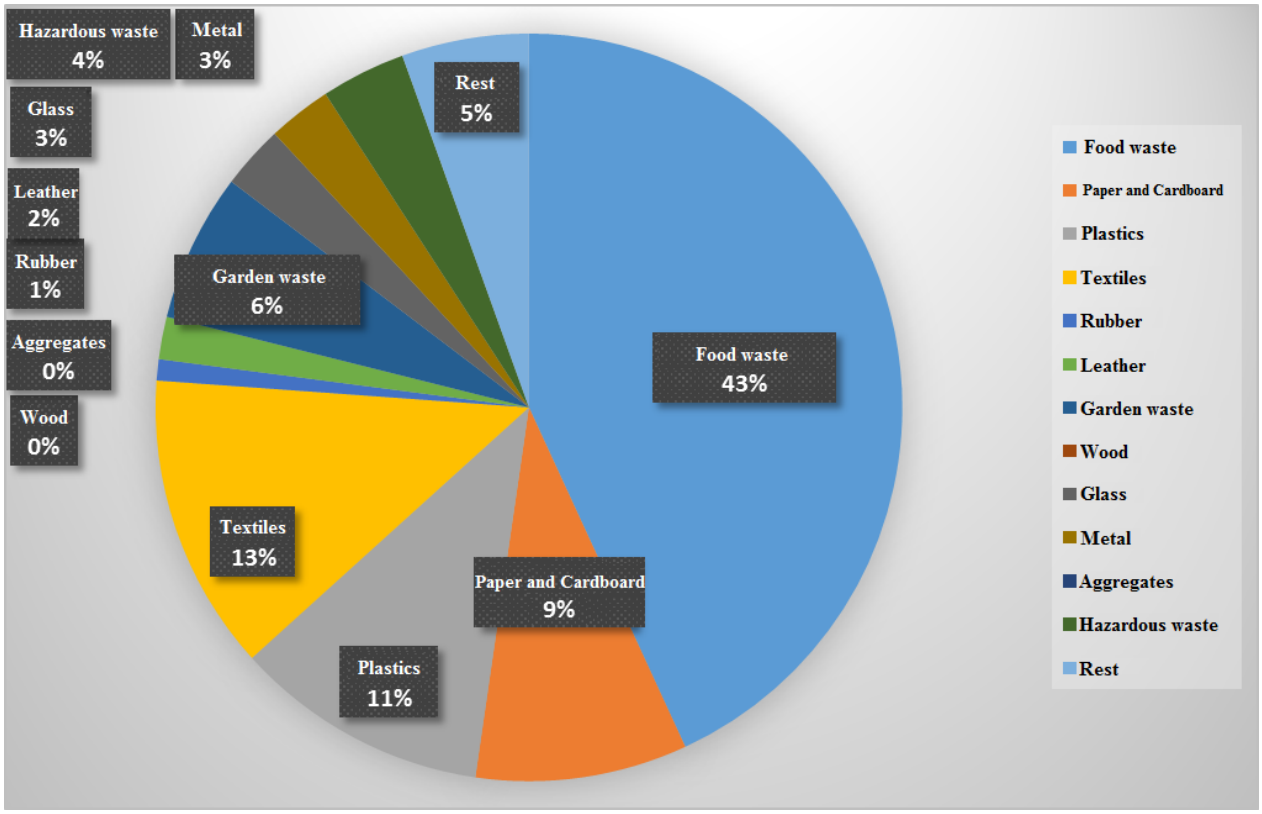

Figure 8. Percentage of different categories of waste per sector of housing for the rural sector

Table 3 and Figure 9 show the results of the morphological composition of waste calculated for the entire Municipality of Knjaževac in the summer period.

Table 3. Average morphological composition of waste for the Municipality of Knjaževac

Waste category	Percentage of components %
Food waste	50,05
Paper and cardboard	7,32
Plastics	11,23
Textiles	9,28
Rubber	2,20
Leather	0,49
Garden waste	5,37
Wood	1,22
Glass	1,46
Metal	4,15
Aggregates	0,73
Hazardous waste	1,37

Rest	5,13
TOTAL:	100,00

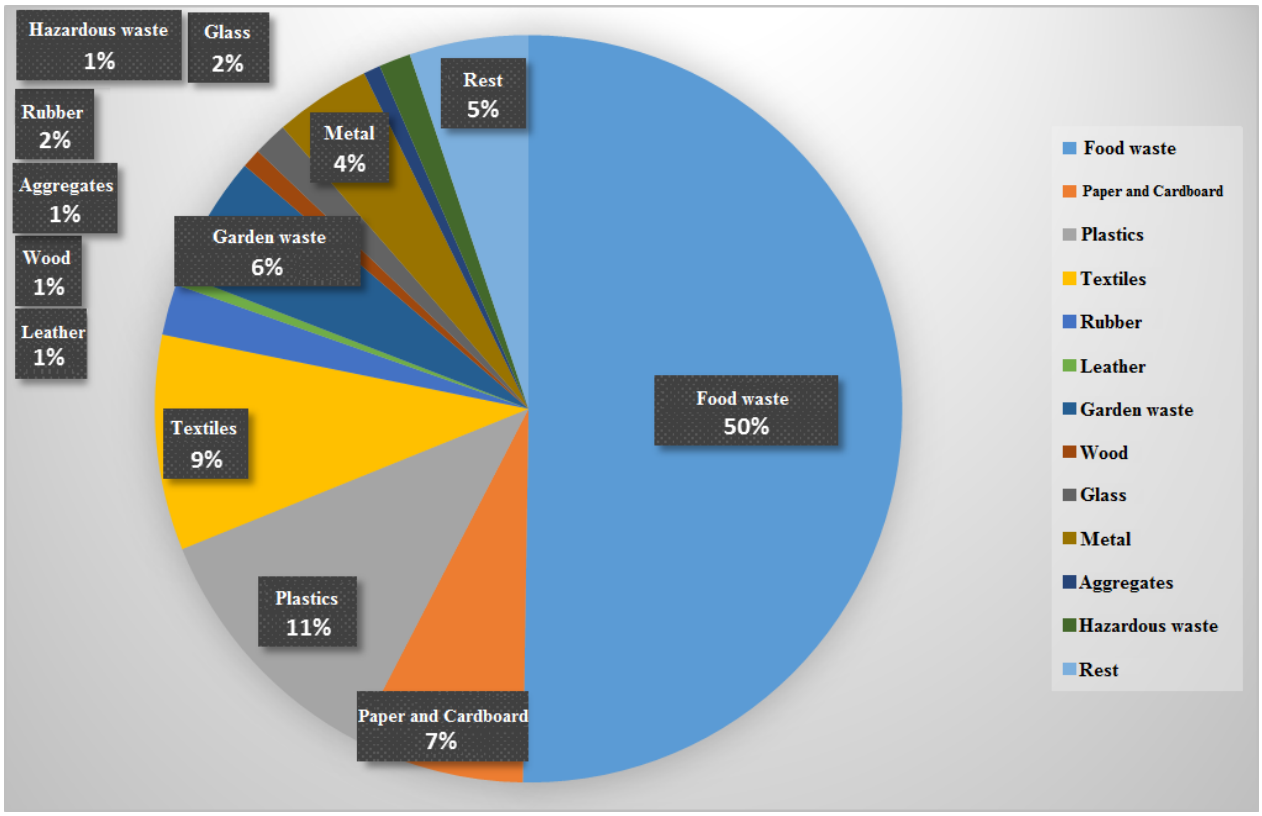

Figure 9. Average morphological composition of waste for the Municipality of Knjaževac

By analyzing the obtained results, one can notice the increased textile waste in the individual-city and rural housing sector where the larger amount of waste was represented in the form of baby diapers. It was logical to expect the smaller amount of garden waste and the larger amount of food waste in the collective-city sector, but the smaller amount of packaging waste, primarily paper and cardboard, is probably the result of separate collection of this type of waste.

If the morphological composition for the entire Knjaževac municipality is observed, one can say that the most dominant category of waste is the total organic type of waste with the share of as much as 55,42%, i.e. with the share of garden waste of 5,37% and other biodegradable waste of as much as 50,05% observed individually.

It should be noted that in the Municipality of Knjaževac there is a separate collection and separation of PET packaging material organized by the Public Utility Standard from Knjaževac. There are also two private companies that have a license and are engaged

in the collection of mainly packaging waste. These quantities are not known and would certainly influence the change in the content of certain components of waste to some extent.

4. Data on the composition and amount of municipal waste in the territory of the Municipality of Knjaževac in the autumn period

The methodology consists of two steps. The first step is to evaluate the generated quantities of municipal waste in the Municipality of Knjaževac by measuring the amount of municipal waste within a period of seven days before it is disposed of to the landfill. The second step is the sampling and analysis of the morphological composition of waste in accordance with the defined catalog for the classification of waste.

4.1. Measuring of generated quantities of waste in the Municipality of Knjaževac in the period from 6th-10th of November 2017 (autumn period)

The first step is to measure the mass of municipal waste generated from 6th-10th of November 2017. The measurement was done in such a way that the first thing that was measured was the tare weight of trucks that collected waste in the Municipality of Knjaževac, that is, prior to leaving the facility and collecting garbage.

Afterwards, the same trucks were measured while doing their regular routes in the collection of waste and when they were at full capacity (gross weight). The wheel scale in the agricultural combine "Dževrin" was used for all measurements. As already mentioned, measurements were made during the period of one week, as the Public Utility Company Standard from Knjaževac provides services of waste disposal for each household in the Municipality of Knjaževac for that particular period.

In the period from the 6th of November to the 10th of November, 128 tons of waste were collected from the households within the Municipality of Knjaževac belonging to the collection system of the Public Utility Company Standard, the details are presented within the Table 4 and in Figures 10-13.

Table 4. Data on the amount of generated municipal waste measured in the period from the 6th of November to the 10th of November 2017:

Ordinal number	Vehicle	Net weight of waste, t
1	Dumpster truck (license plate KŽ 004-ZŠ)	15,98
2	Dumpster truck (license plate KŽ 004-DŠ)	10,22
3	Dumpster truck (license plate KŽ 007-XB)	26,76
4	Dumpster truck (license plate KŽ 013-ŠE)	31,80
5	Lifter truck (license plate KŽ 001-MN)	21,16
6	Lifter truck (license plate KŽ 013-JU)	21,98
	TOTAL:	127,90

Figure 10. Collection and transport of municipal waste by dumpster truck (license plate KŽ 004-ZŠ)

Figure 11. Collection and transport of municipal waste by dumpster truck (license plate KŽ 004-DŠ)

Figure 12. Collection and transport of municipal waste by dumpster truck (license plate KŽ 013-ŠE)

Figure 13. Collection and transport of municipal waste by lifter truck (license plate KŽ 001-MN)

Bearing in mind that the number of inhabitants encompassed by the service is 27004, the obtained data on the generation of waste per inhabitant of the Municipality of Knjaževac per day is 0,68 kg / per inhabitant per day.

4.2. Determining the morphological composition of municipal waste in the Municipality of Knjaževac

The second part of the methodology is the determination of the morphological composition of municipal waste in the Municipality of Knjaževac. The autumn analysis of the morphological composition of waste was done on the 6th of November, 2017 from the following sectors:

• City zone - individual housing

• City zone - collective housing and commercial zone

• Rural areas within the Municipality of Knjaževac

A sample of waste from an individual type of housing used for sorting was taken from Cara Dušana Street, while a sample of waste for sorting from a collective type of housing was taken from Branko Radičević Street. When it comes to the rural zone, the sample was taken from Trgovište village.

Containers were transported to a facility belonging to the Public Utility Standard from Knjaževac, where the analysis was carried out. The following equipment was used for the realization of the waste sorting process:

• 20 mm mesh sieve for easier and faster sorting and separation of larger waste

• 85 liters waste bins marked by the category of waste in which waste was disposed of for sorting by category and measurements,

• Scale for measuring the amount of waste by category according to the designated catalog

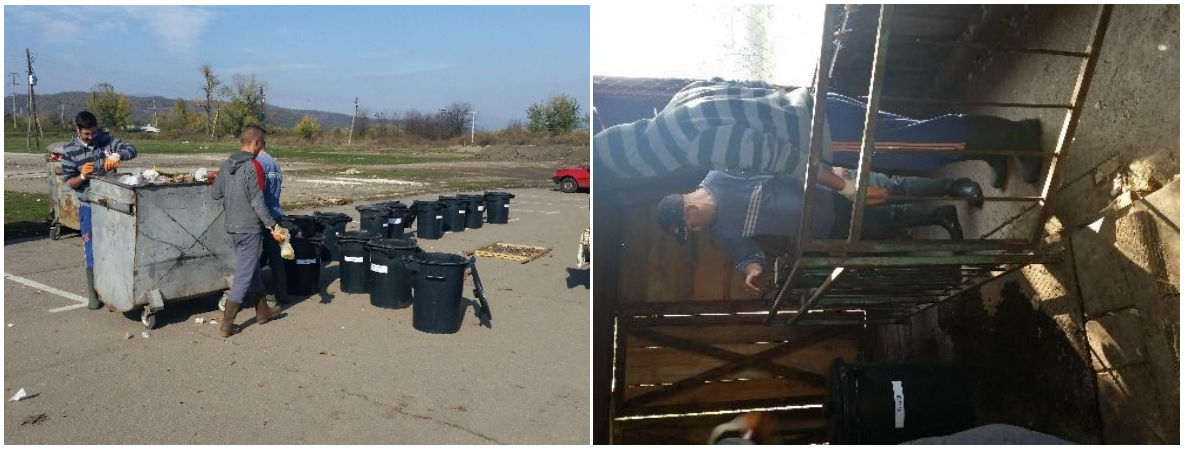

Figure 14. Use of equipment during the process of waste sorting and measuring

Table 5 and Figures 15, 16 and 17 show in detail the results of the morphological composition of waste by the sector of housing for the autumn period.

Table 5. Percentage of different categories of waste per sector of housing

Waste category	SECTOR OF HOUSING		
	Individual-City %	Collective-City %	Rural %
Food waste	32,20	66,67	34,71
Paper and cardboard	5,08	8,13	13,22
Plastics	25,42	17,89	18,18
Textiles	13,56	3,25	16,53
Rubber	0,17	0	0,17
Leather	0	0	0
Garden waste	11,86	0,90	8,26
Wood	0	0	0,33
Glass	0,51	0,49	1,32
Metal	0,34	0,16	0,66
Aggregates	0	0	0
Hazardous waste	0,68	0,65	0,83
Rest (Ash)	10,17 (50% ash)	1,30 (50% ash)	5,79 (85% ash)
TOTAL:	100,00	100,00	100,00

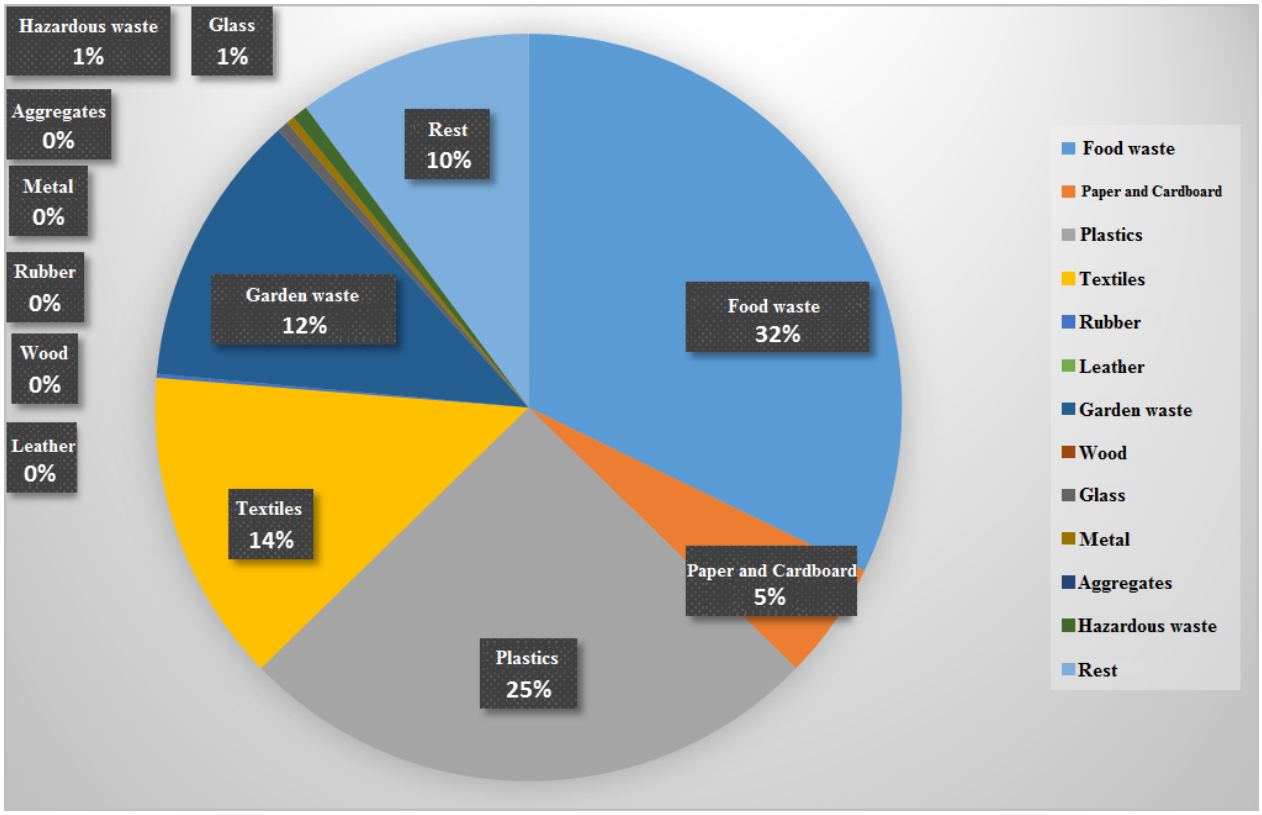

Figure 15. Percentage of different categories of waste per sector of housing for the individual-city housing sector

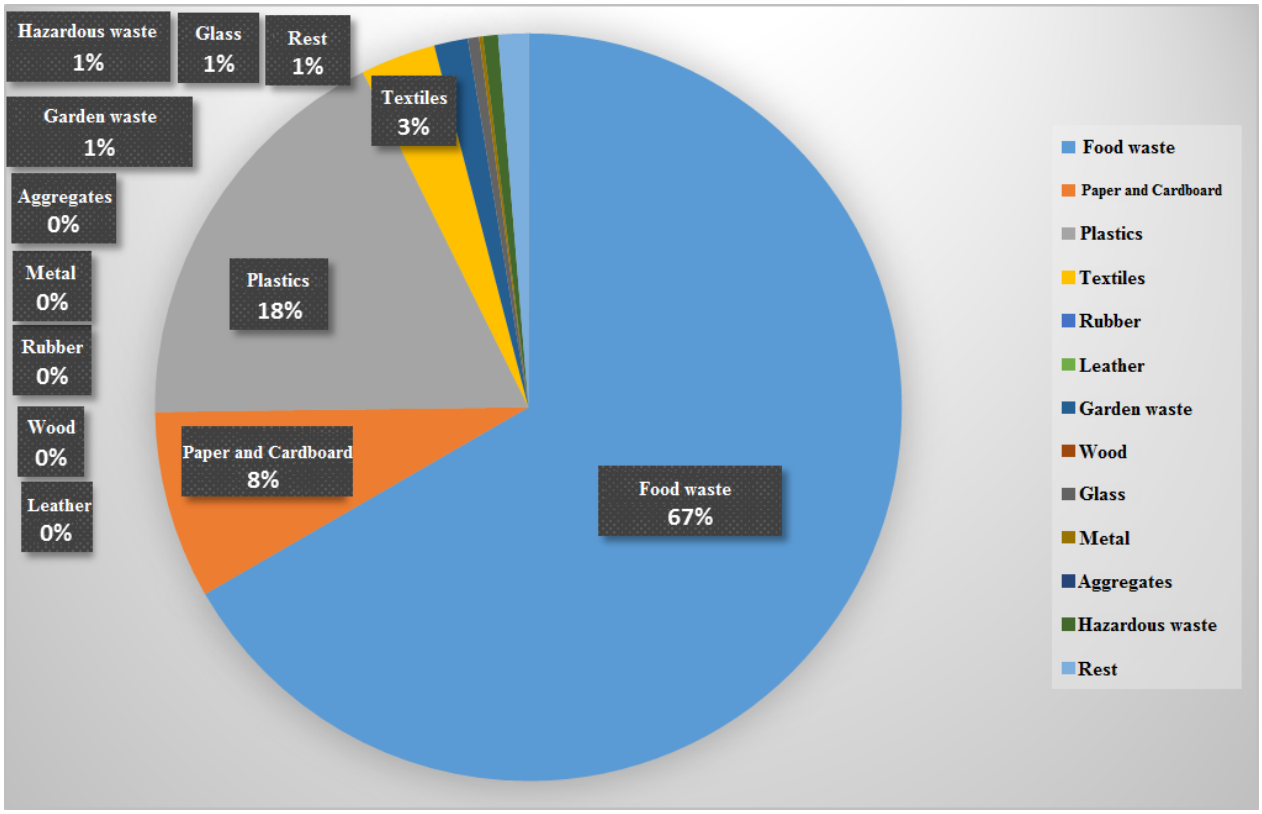

Figure 16. Percentage of different categories of waste per sector of housing for the collective-city housing sector

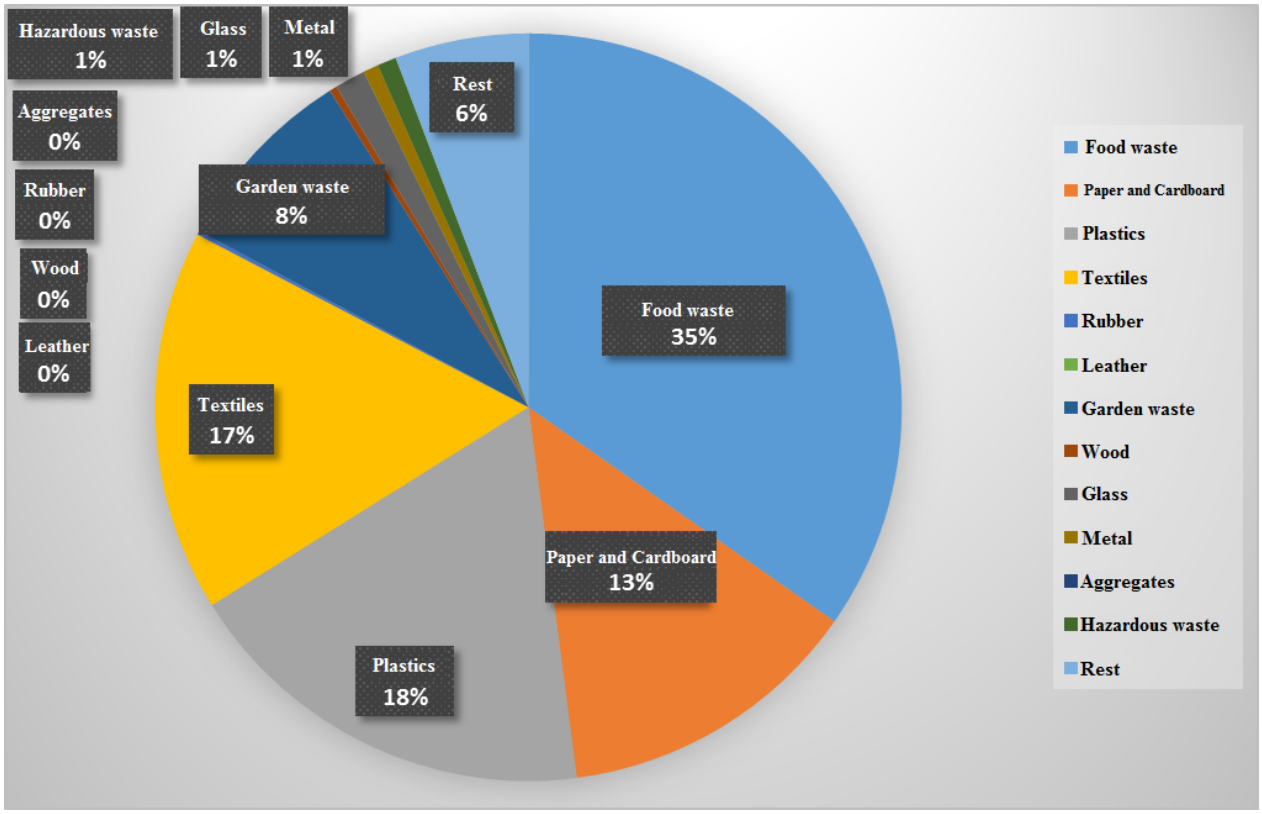

Figure 17. Percentage of different categories of waste per sector of housing for the rural sector

Table 6 and Figure 18 show the results of the morphological composition of waste calculated for the entire Municipality of Knjaževac in the autumn period.

Table 6. Average morphological composition of waste for the Municipality of Knjaževac

Waste category	Percentage of components %
Food waste	44,75
Paper and cardboard	8,84
Plastics	20,44
Textiles	11,05
Rubber	0,11
Leather	0
Garden waste	7,13
Wood	0,11
Glass	0,77
Metal	0,39
Aggregates	0
Hazardous waste	0,72
Rest	5,69 (62% ash)
TOTAL:	100,00

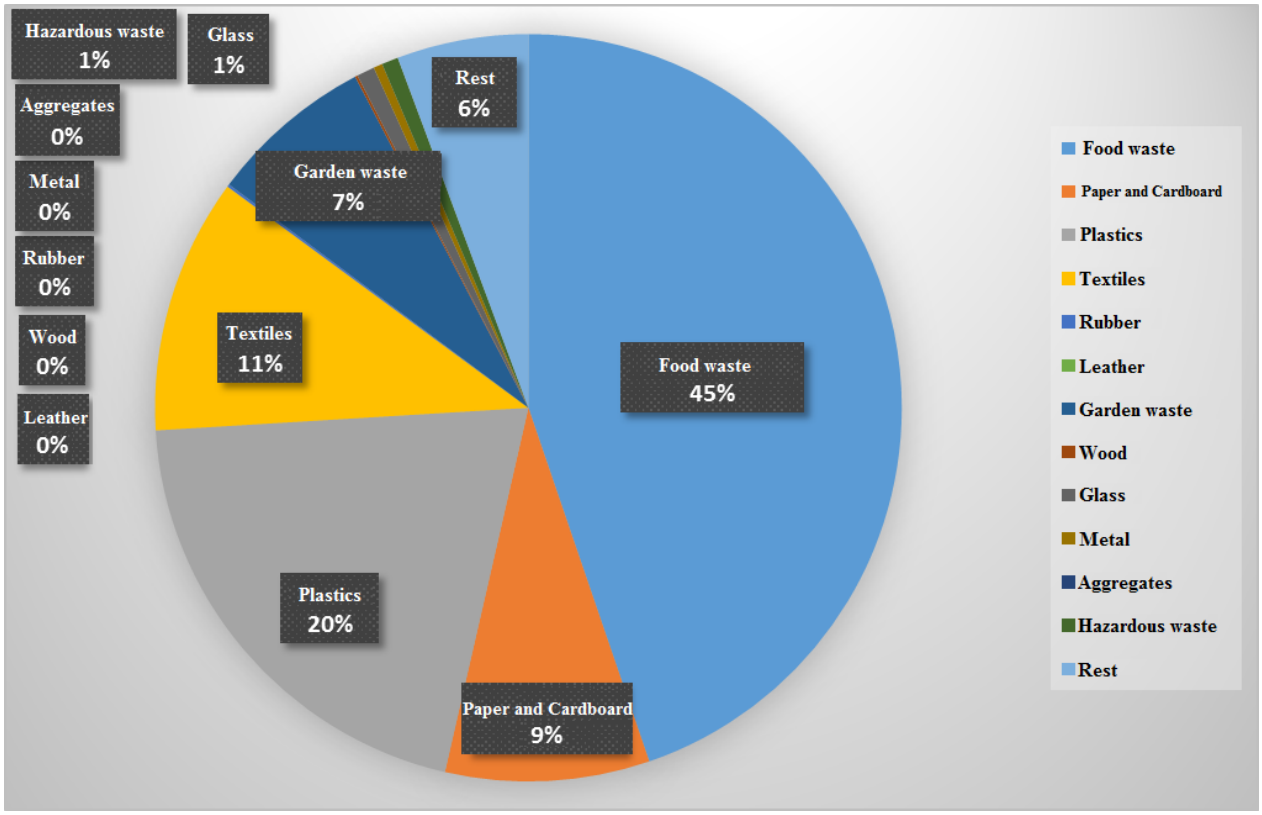

Figure 18. Average morphological composition of waste for the Municipality of Knjaževac

By analyzing the obtained results, one can notice the increased textile waste in the individual-city and rural housing sector where the larger amount of waste was represented in the form of baby diapers. Increased amount of garden waste in the individual-city and rural sectors is the result of the increased amount of sawdust and wood residue due to the preparation for the heating period for winter, as well as due to dry leaves. A greater amount of packaging waste was noted, mostly plastic, in relation to the summer period, probably as a result of the reduced separate collection of this type of waste. In particular, the extremely high amount of food waste should be noted in the collective-city housing sector, as high as 66,67%.

If the morphological composition for the entire Knjaževac municipality is observed, one can say that the most dominant category of waste, similarly to the summer period, is the total organic type of waste with the share of as much as 51,88%, i.e. with a share of garden waste of 7,13% and other biodegradable waste of as much as 44,75% observed individually.

5. Data on the composition and amount of municipal waste in the territory of the Municipality of Knjaževac in the winter period

The methodology consists of two steps. The first step is to evaluate the generated quantities of municipal waste in the Municipality of Knjaževac by measuring the amount of municipal waste within a period of seven days before it is disposed of to the landfill. The second step is the sampling and analysis of the morphological composition of waste in accordance with the defined catalog for the classification of waste.

5.1. Measuring of generated quantities of waste in the Municipality of Knjaževac in the period from 5th-9th of March 2018 (winter period)

The first step is to measure the mass of municipal waste generated from 5th-9th of March 2018. The measurement was done in such a way that the first thing that was measured was the tare weight of trucks that collected waste in the Municipality of Knjaževac, that is, prior to leaving the facility and collecting garbage.

Afterwards, the same trucks were measured while doing their regular routes in the collection of waste and when they were at full capacity (gross weight). The wheel scale in the agricultural combine "Dževrin" was used for all measurements. As already mentioned, measurements were made during the period of one week, as the Public Utility Company Standard from Knjaževac provides services of waste disposal for each household in the Municipality of Knjaževac for that particular period.

In the period from the 5th of March to the 9th of March, 124,5 tons of waste were collected from the households within the Municipality of Knjaževac belonging to the collection system of the Public Utility Company Standard, the details are presented within the Table 7 and in Figures 19-22.

Table 7. Data on the amount of generated municipal waste measured in the period from the 5th of November to the 9th of March 2018:

Ordinal number	Vehicle	Net weight of waste, t
1	Dumpster truck (license plate KŽ 004-ZŠ)	30,32
2	Dumpster truck (license plate KŽ 004-DŠ)	29,76

3	Dumpster truck (license plate KŽ 007-XB)	33,24
4	Lifter truck (license plate KŽ 001-MN)	31,18
	TOTAL:	124,50

Figure 19. Collection and transport of municipal waste by dumpster truck (license plate KŽ 004-ZŠ)

Figure 20. Collection and transport of municipal waste by dumpster truck (license plate KŽ 004-DŠ)

Figure 21. Collection and transport of municipal waste by dumpster truck (license plate KŽ 007-XB)

Figure 22. Collection and transport of municipal waste by lifter truck (license plate KŽ 001-MN)

Bearing in mind that the number of inhabitants encompassed by the service is 27004, the obtained data on the generation of waste per inhabitant of the Municipality of Knjaževac per day is 0,66 kg / per inhabitant per day.

5.2. Determining the morphological composition of municipal waste in the Municipality of Knjaževac

The second part of the methodology is the determination of the morphological composition of municipal waste in the Municipality of Knjaževac. The winter analysis of the morphological composition of waste was done on the 9th of March, 2018 from the following sectors:

• City zone - individual housing

• City zone - collective housing and commercial zone

• Rural areas within the Municipality of Knjaževac

A sample of waste from an individual type of housing used for sorting was taken from Vojvode Putnika Street, while a sample of waste for sorting from a collective type of housing was taken from Branko Radičević Street. When it comes to the rural zone, the sample was taken from Trgovište village.

Containers were transported to a facility belonging to the Public Utility Standard from Knjaževac, where the analysis was carried out. The following equipment was used for the realization of the waste sorting process:

• 20 mm mesh sieve for easier and faster sorting and separation of larger waste

• 85 liters waste bins marked by the category of waste in which waste was disposed of for sorting by category and measurements,

• Scale for measuring the amount of waste by category according to the designated catalog

Figure 23. Use of equipment during the process of waste sorting and measuring

Table 8 and Figures 24, 25 and 26 show in detail the results of the morphological composition of waste by the sector of housing for the winter period.

Table 8. Percentage of different categories of waste per sector of housing

Waste category	SECTOR OF HOUSING		
	Individual-City %	Collective-City %	Rural %
Food waste	44,50	51,41	23,16
Paper and cardboard	11,71	7,71	4,09
Plastics	12,88	20,57	12,26
Textiles	4,68	7,71	13,62
Rubber	0,12	0	0
Leather	0	0	0
Garden waste	0,7	0	0,54
Wood	0	0	1,36
Glass	0,23	3,86	2,72
Metal	0,59	2,57	4,09
Aggregates	0	0	0
Hazardous waste	1,17	1,03	0
Rest (Ash)	23,42 (80% ash)	5,14 (composite)	38,15 (85% ash)
TOTAL:	100,00	100,00	100,00

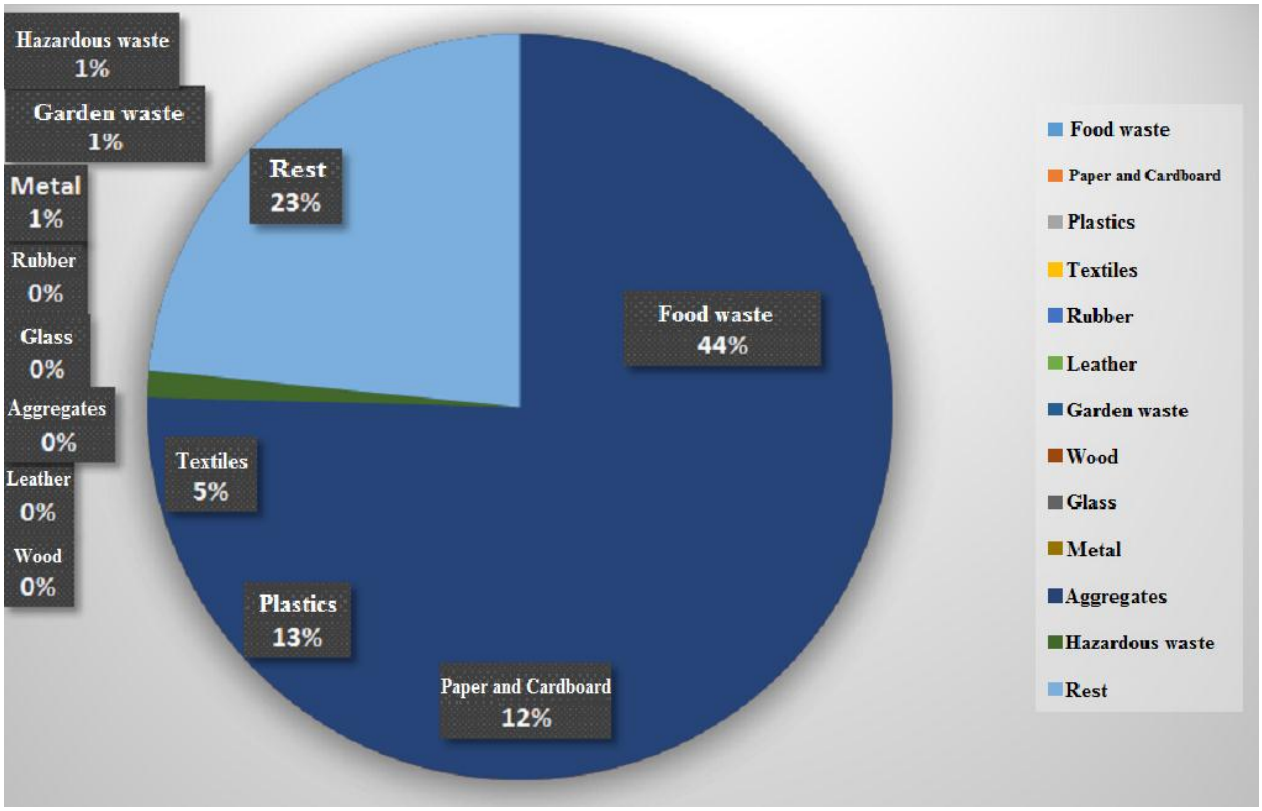

Figure 24. Percentage of different categories of waste per sector of housing for the individual-city housing sector

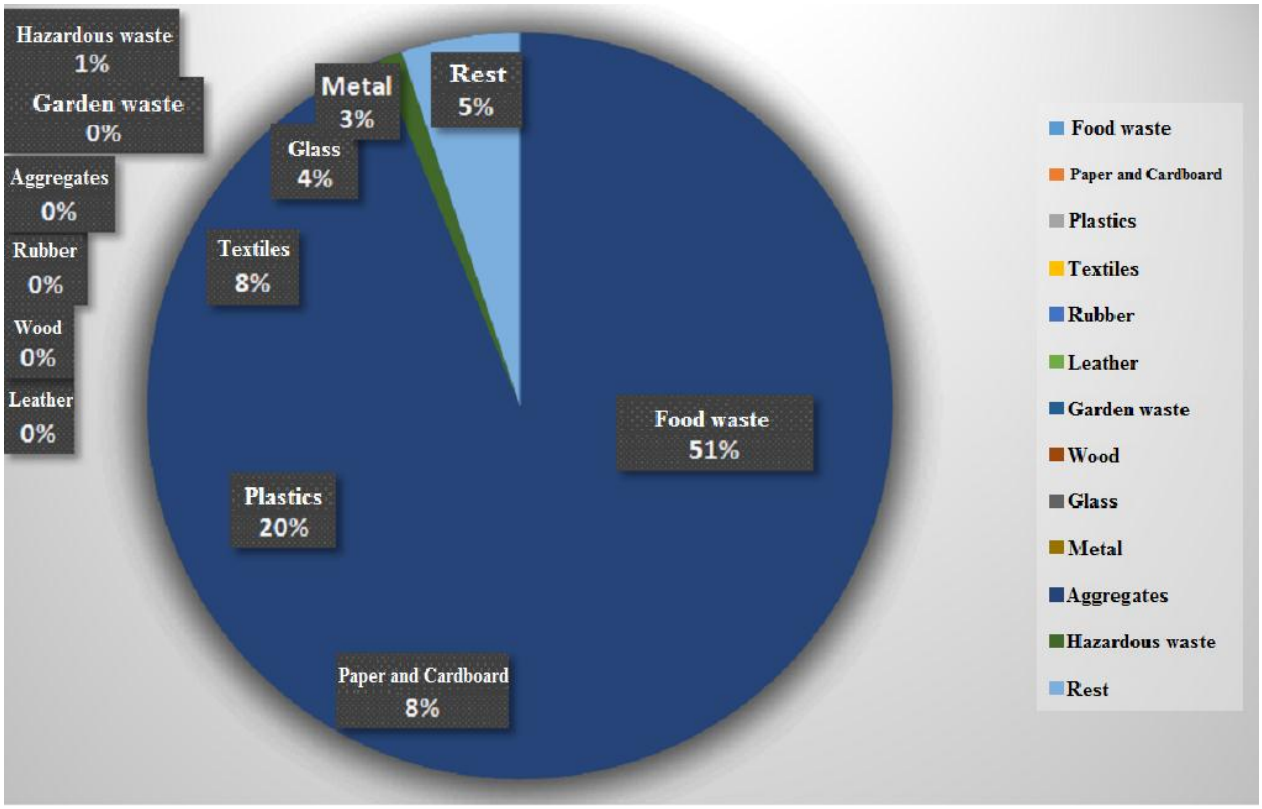

Figure 25. Percentage of different categories of waste per sector of housing for the collective-city housing sector

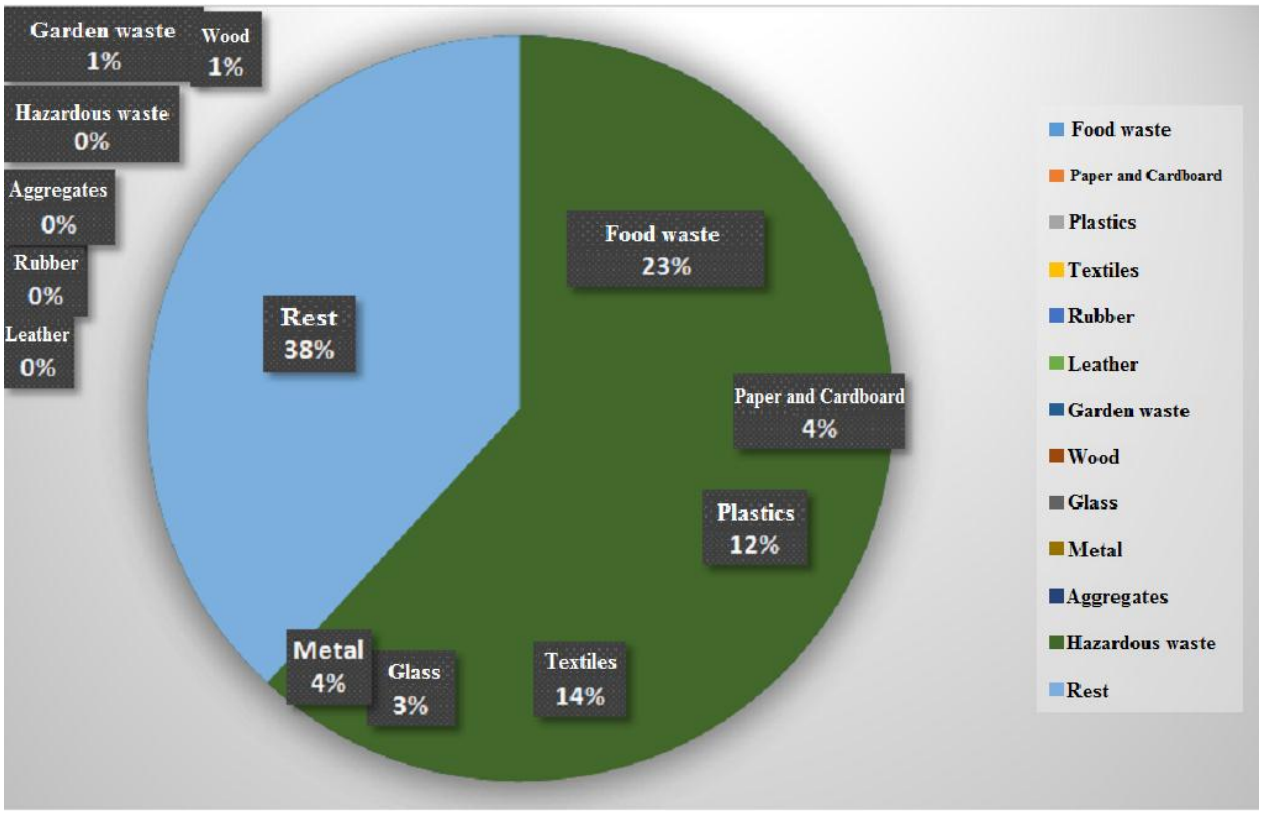

Figure 26. Percentage of different categories of waste per sector of housing for the rural sector

Table 9 and Figure 27 show the results of the morphological composition of waste calculated for the entire Municipality of Knjaževac in the winter period.

Table 9. Average morphological composition of waste for the Municipality of Knjaževac

Waste category	Percentage of components %
Food waste	37,94
Paper and cardboard	8,09
Plastics	14,16
Textiles	8,60
Rubber	0,05
Leather	0
Garden waste	0,51
Wood	0,51
Glass	1,87
Metal	2,28
Aggregates	0
Hazardous waste	0,71
Rest	25,29 (80% ash)
TOTAL:	100,00

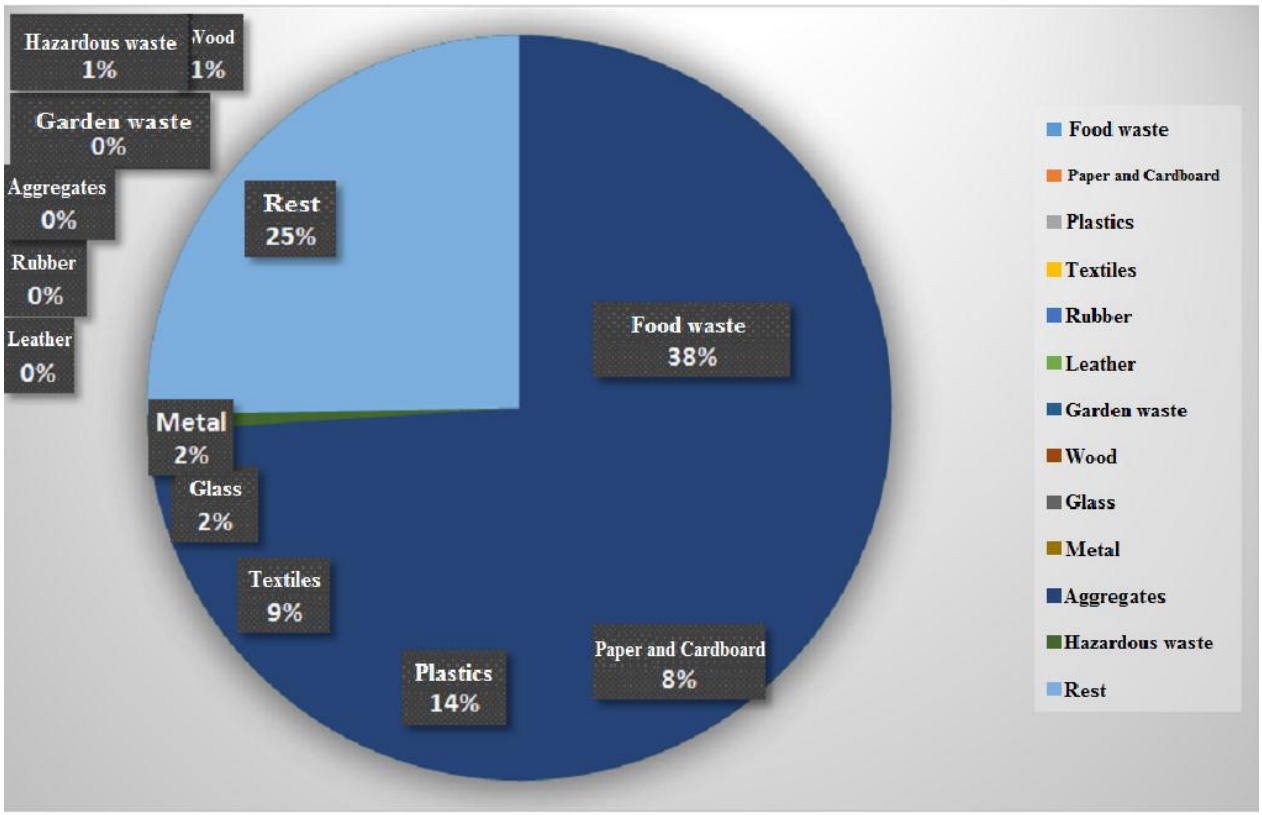

Figure 27. Average morphological composition of waste for the Municipality of Knjaževac

By analyzing the obtained results, one can notice the increase of the “rest” type of waste in the individual-city sector with 23,42% and the rural housing sector with 38,15% where the larger amount of waste was represented in the form of ash. It is interesting to note the particularly small amount of garden waste in all three of the housing sectors, which is typical for the winter period. A greater amount of packaging waste was noted, mostly plastic with 20,57%, in the collective-city housing sector in relation to the summer period when it was 11,83%, probably as a result of the reduced separate collection of this type of waste due to the winter conditions. The winter period also had an extremely high amount of food waste in the collective-city housing sector, as high as 51,41%, which is still a 15% decrease compared to the summer and autumn period.

If the morphological composition for the entire Knjaževac municipality is observed for the winter period, one can say that the most dominant category of waste is the food waste with the share of 37,94%, which presents a 7% decrease from the autumn period and 12% decrease from the summer period. The share of garden waste is just 0,51%,

which is typical for the winter period. The increase of the “rest” type of waste should be noted, which went from 5% in the summer and autumn period to 25% in the winter period. The largest part of this type of waste (80%) is taken up by ash.

6. Data on the composition and amount of municipal waste in the territory of the Municipality of Knjaževac in the spring period

The methodology consists of two steps. The first step is to evaluate the generated quantities of municipal waste in the Municipality of Knjaževac by measuring the amount of municipal waste within a period of seven days before it is disposed of to the landfill. The second step is the sampling and analysis of the morphological composition of waste in accordance with the defined catalog for the classification of waste.

6.1. Measuring of generated quantities of waste in the Municipality of Knjaževac in the period from 26th-30th of March 2018 (spring period)

The first step is to measure the mass of municipal waste generated from 26th-30th of March 2018. The measurement was done in such a way that the first thing that was measured was the tare weight of trucks that collected waste in the Municipality of Knjaževac, that is, prior to leaving the facility and collecting garbage.

Afterwards, the same trucks were measured while doing their regular routes in the collection of waste and when they were at full capacity (gross weight). The wheel scale in the agricultural combine "Dževrin" was used for all measurements. As already mentioned, measurements were made during the period of one week, as the Public Utility Company Standard from Knjaževac provides services of waste disposal for each household in the Municipality of Knjaževac for that particular period.

In the period from the 26th of March to the 30th of March, 110,6 tons of waste were collected from the households within the Municipality of Knjaževac belonging to the collection system of the Public Utility Company Standard, the details are presented within the Table 10 and in Figures 28-31.

Table 10. Data on the amount of generated municipal waste measured in the period from the 26th of March to the 30th of March 2018:

Ordinal number	Vehicle	Net weight of waste, t
1	Dumpster truck (license plate KŽ 004-ZŠ)	26,10
2	Dumpster truck (license plate KŽ 004-DŠ)	27,17
3	Dumpster truck (license plate KŽ 007-XB)	29,40
4	Lifter truck (license plate KŽ 001-MN)	27,96
	TOTAL:	110,63

Figure 28. Collection and transport of municipal waste by dumpster truck (license plate KŽ 004-ZŠ)

Figure 29. Collection and transport of municipal waste by dumpster truck (license plate KŽ 004-DŠ)

Figure 30. Collection and transport of municipal waste by dumpster truck (license plate KŽ 007-XB)

Figure 31. Collection and transport of municipal waste by lifter truck (license plate KŽ 001-MN)

Bearing in mind that the number of inhabitants encompassed by the service is 27004, the obtained data on the generation of waste per inhabitant of the Municipality of Knjaževac per day is 0,585 kg / per inhabitant per day.

6.2. Determining the morphological composition of municipal waste in the Municipality of Knjaževac

The second part of the methodology is the determination of the morphological composition of municipal waste in the Municipality of Knjaževac. The spring analysis of the morphological composition of waste was done on the 29th of March, 2018 from the following sectors:

• City zone - individual housing

• City zone - collective housing and commercial zone

• Rural areas within the Municipality of Knjaževac

A sample of waste from an individual type of housing used for sorting was taken from Svetozara Markovića Street, while a sample of waste for sorting from a collective type of housing was taken from 9. Brigade Street. When it comes to the rural zone, the sample was taken from Donje Zuniče village.

Containers were transported to a facility belonging to the Public Utility Standard from Knjaževac, where the analysis was carried out. The following equipment was used for the realization of the waste sorting process:

• 20 mm mesh sieve for easier and faster sorting and separation of larger waste

• 85 liters waste bins marked by the category of waste in which waste was disposed of for sorting by category and measurements,

• Scale for measuring the amount of waste by category according to the designated catalog

Figure 32. Use of equipment during the process of waste sorting and measuring

Table 11 and Figures 33, 34 and 35 show in detail the results of the morphological composition of waste by the sector of housing for the spring period.

Table 11. Percentage of different categories of waste per sector of housing

Waste category	SECTOR OF HOUSING		
	Individual-City %	Collective-City %	Rural %
Food waste	33,38	44,84	24,62
Paper and cardboard	7,26	6,73	2,34
Plastics	7,26	20,18	5,86
Textiles	17,42	4,48	2,34
Rubber	0	0,67	0
Leather	0	0	0
Garden waste	17,42	0,67	34,00
Wood	0	0	0
Glass	0,44	4,48	0,59
Metal	4,35	2,24	1,76
Aggregates	2,90	4,48	0
Hazardous waste	0,87	2,24	0,35
Rest (Ash)	8,71 (80% ash)	6,73 (composite)	28,14 (85% ash)
TOTAL:	100,00	100,00	100,00

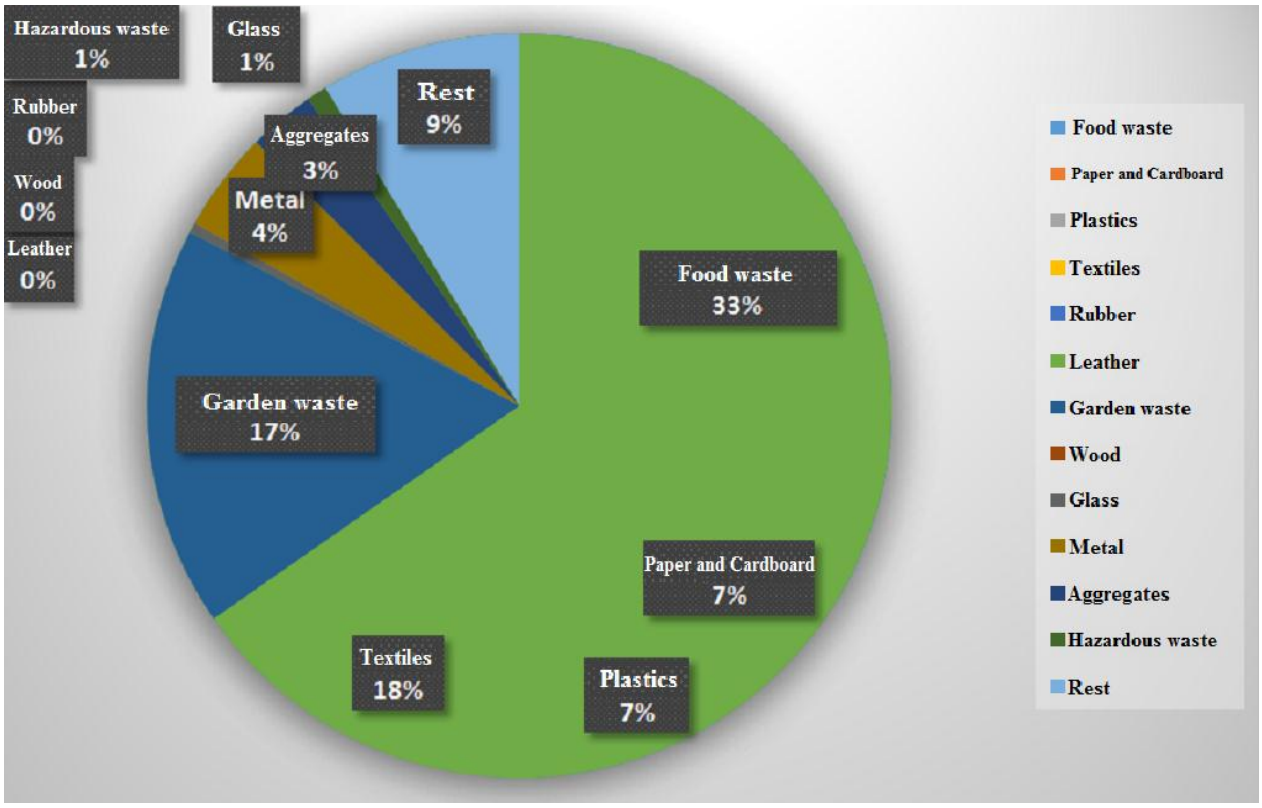

Figure 33. Percentage of different categories of waste per sector of housing for the individual-city housing sector

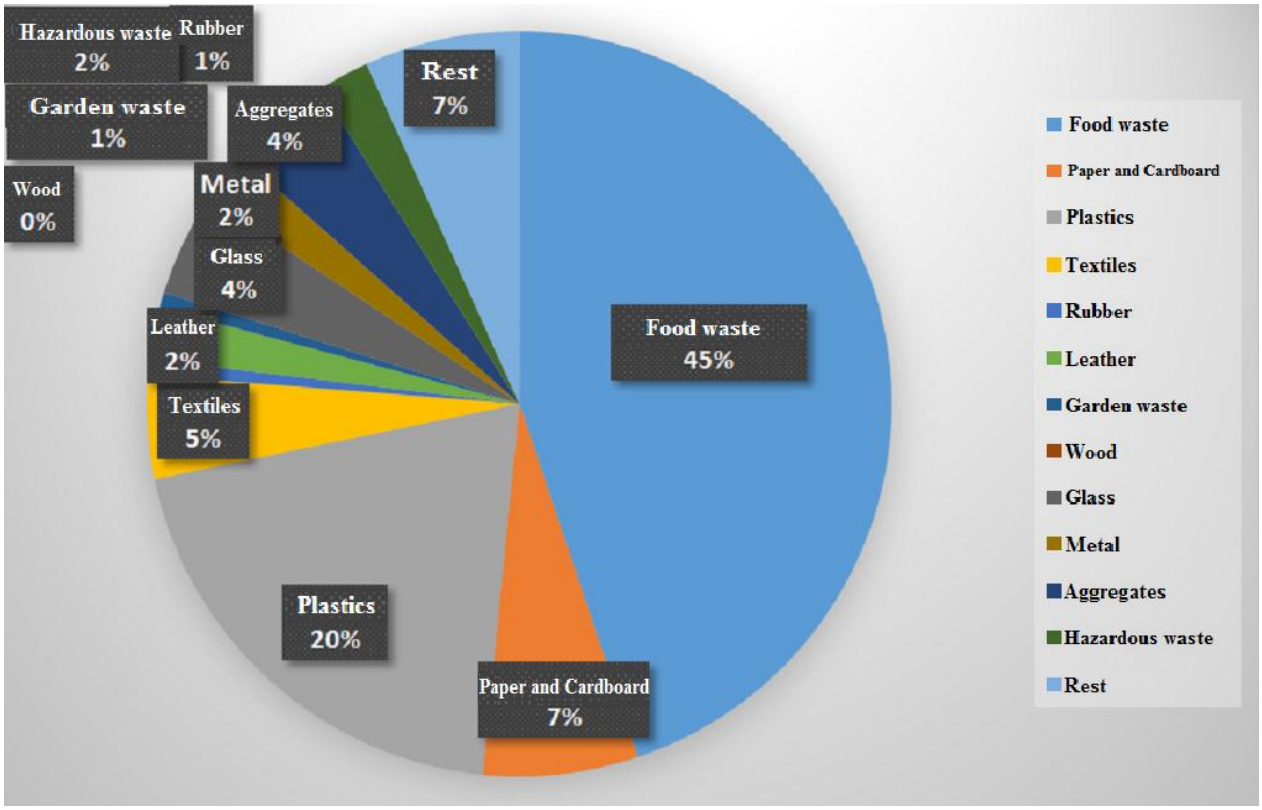

Figure 34. Percentage of different categories of waste per sector of housing for the collective-city housing sector

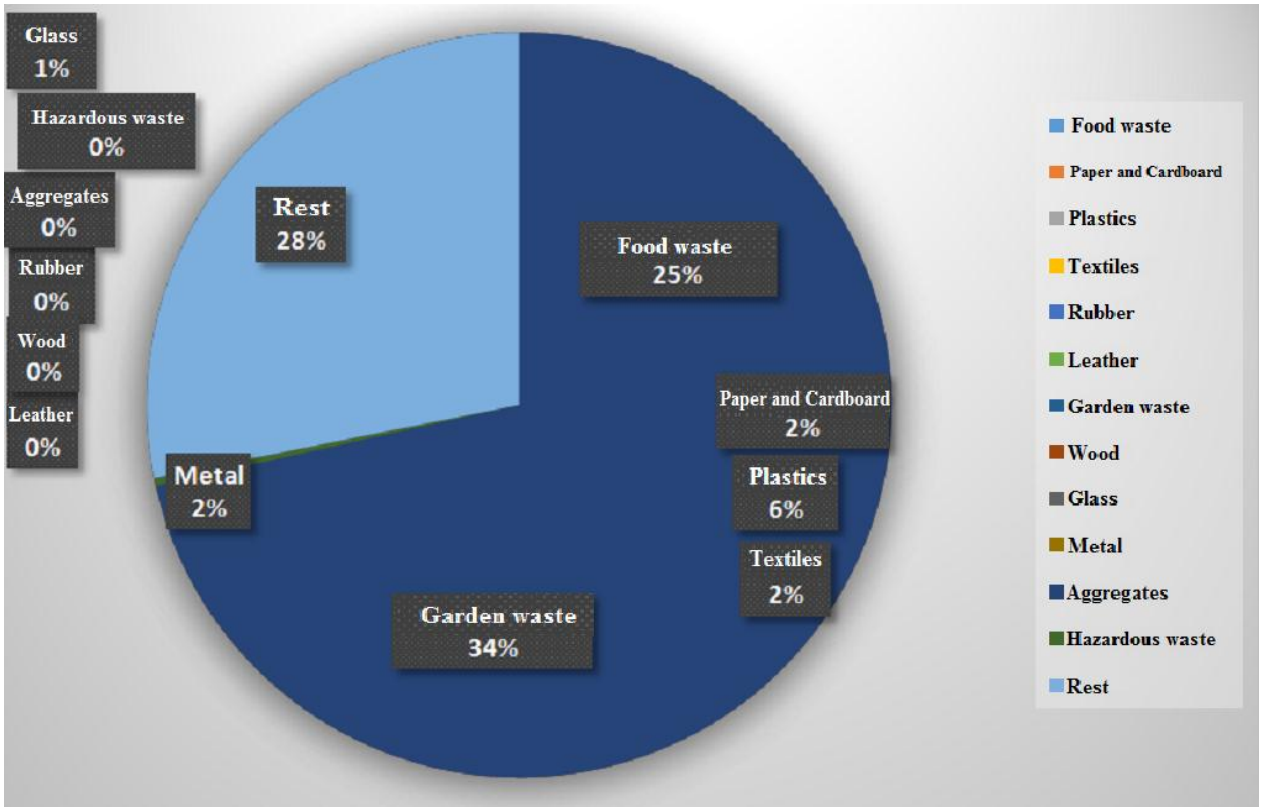

Figure 35. Percentage of different categories of waste per sector of housing for the rural sector

Table 12 and Figure 36 show the results of the morphological composition of waste calculated for the entire Municipality of Knjaževac in the spring period.

Table 12. Average morphological composition of waste for the Municipality of Knjaževac

Waste category	Percentage of components %
Food waste	32,19
Paper and cardboard	5,03
Plastics	9,56
Textiles	8,05
Rubber	0,15
Leather	0,50
Garden waste	20,77
Wood	0
Glass	1,41
Metal	2,77
Aggregates	2,01
Hazardous waste	0,96
Rest	16,60 (76% ash)
TOTAL:	100,00

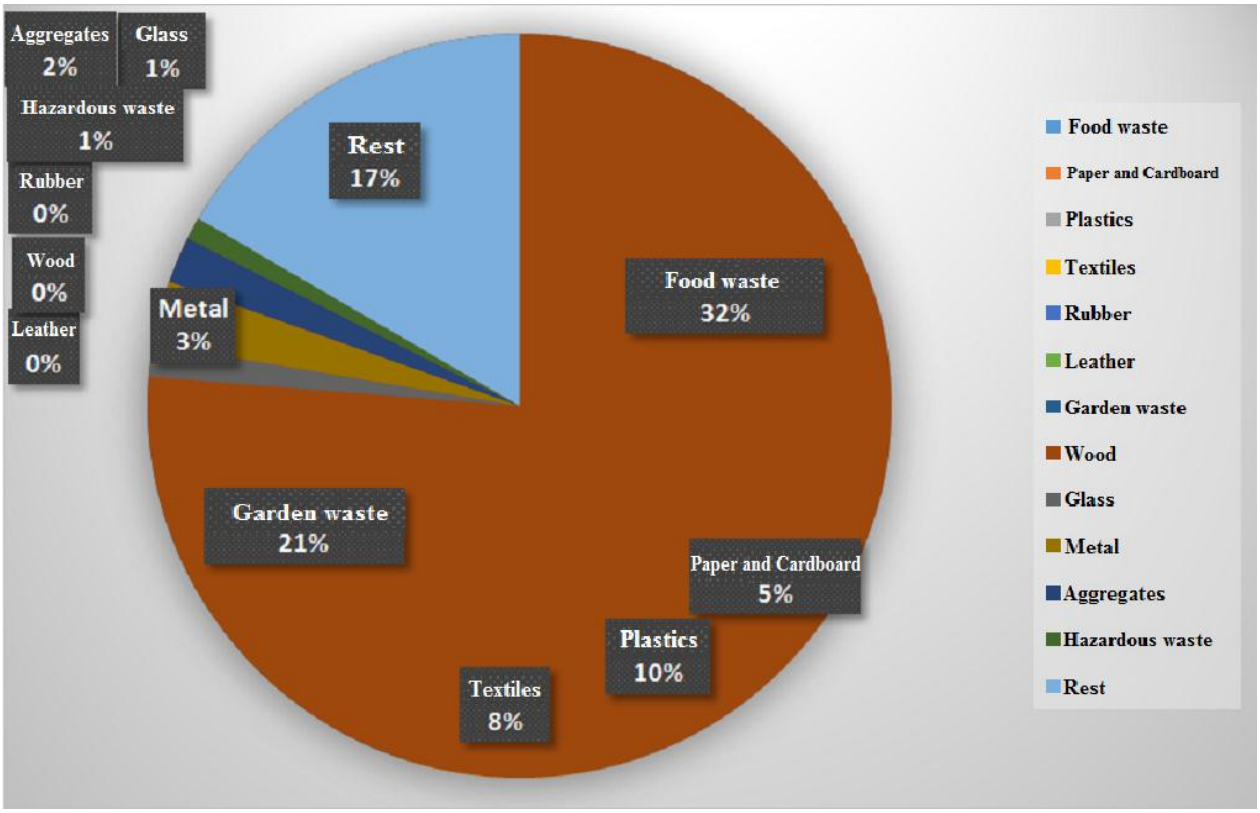

Figure 36. Average morphological composition of waste for the Municipality of Knjaževac

By analyzing the obtained results, one can notice the increase of the “rest” type of waste in the individual-city 8,71% and rural sector 28,14%, where the larger amount of waste was represented in the form of ash. It is interesting to note the increase of garden waste, which amounted to 17,42% in the individual-city housing sector and 34% in the rural sector, as a result of the increase of backyard activities. Similarly to the winter period, a greater amount of packaging waste was noted, mostly plastics with 20,18%, in the collective-city housing sector in relation to the summer period when it was 11,83%, probably as a result of the reduced separate collection of this type of waste. Large amounts of food waste were also present in all three housing sectors.

If the morphological composition for the entire Knjaževac municipality is observed for the spring period, one can say that the most dominant category of waste is the total organic type of waste with the share of 52,96%. The share of garden waste is 20,77%, which is an increase of 15% in comparison to the summer and autumn period, and 20% when compared to winter period. The share of food waste is 32,19%, which is a

decrease of 6% from the winter period, 13% from the autumn period and 18% from the summer period.

7. Data on the composition and amount of municipal waste in the territory of the Municipality of Knjaževac for all periods

Table 13 shows the amount of collected waste in the Municipality of Knjaževac for all four periods, and in total. The average amount of waste in kilograms per capita per day and year is also given.

Table 13. Data on the amount of generated municipal waste in Knjaževac Municipality

Period	Waste generation, t/year.	Waste generation per capita	
		kg/cpt. day	kg/cpt. year
Summer	1431,1	0,581	212,0
Autumn	1667,3	0,677	247,1
Winter	1622,9	0,659	240,5
Spring	1442,1	0,585	213,5
	6163,4	**0,625**	**228,1**

The total amount of generated municipal waste in the Municipality of Knjaževac amounts to 6163,4 tons of solid waste per year. Comparing this data with data from 2010, when the total amount of waste amounted to 5800 tons, there is a slight increase in the amount of waste. Based on the results of the measurements it can be noticed that the population of the Municipality of Knjaževac generates an average of 0,625 kg of municipal waste per day (228,1 kg / year), which is significantly below the average of the population of the Republic of Serbia generating 0,87 kg of municipal waste / day (318 kg / year).

Table 14 and Figures 37, 38 and 39 show the results of the morphological composition of waste per housing sector for all four periods.

Table 14. Percentage of different categories of waste per sector of housing

Waste category	SECTOR OF HOUSING		
	Individual-City %	Collective-City %	Rural %
Food waste	37,37	59,26	30,14
Paper and cardboard	9,34	5,66	6,58
Plastics	13,65	16,56	11,33

Textiles	11,86	4,36	10,60
Rubber	0,43	1,44	0,22
Leather	0,00	0,44	0,37
Garden waste	9,56	0,74	13,85
Wood	0,07	0,65	0,44
Glass	0,29	2,31	1,75
Metal	2,77	2,22	2,34
Aggregates	1,08	1,09	0,00
Hazardous waste	0,83	1,00	1,02
Rest (Ash)	12,76	4,27	21,37
TOTAL:	100,00	100,00	100,00

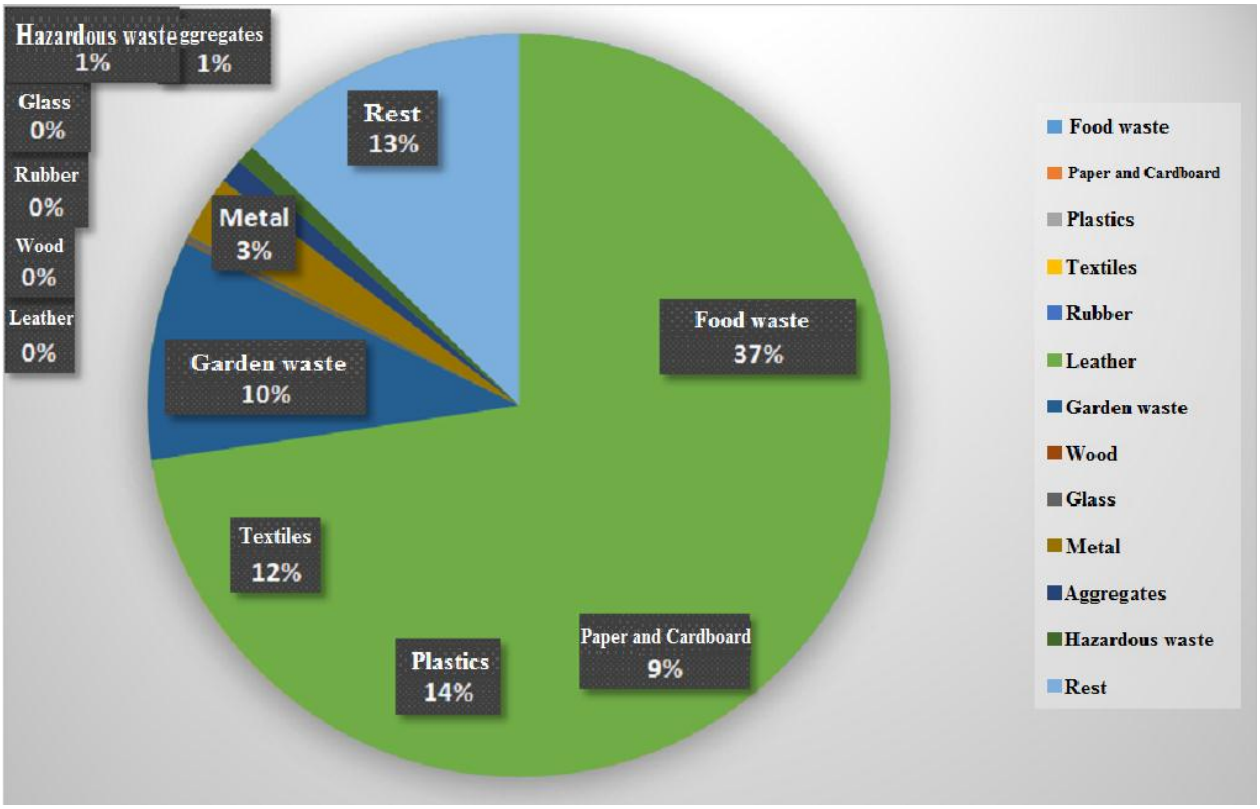

Figure 37. Percentage of different categories of waste per sector of housing for the individual-city housing sector

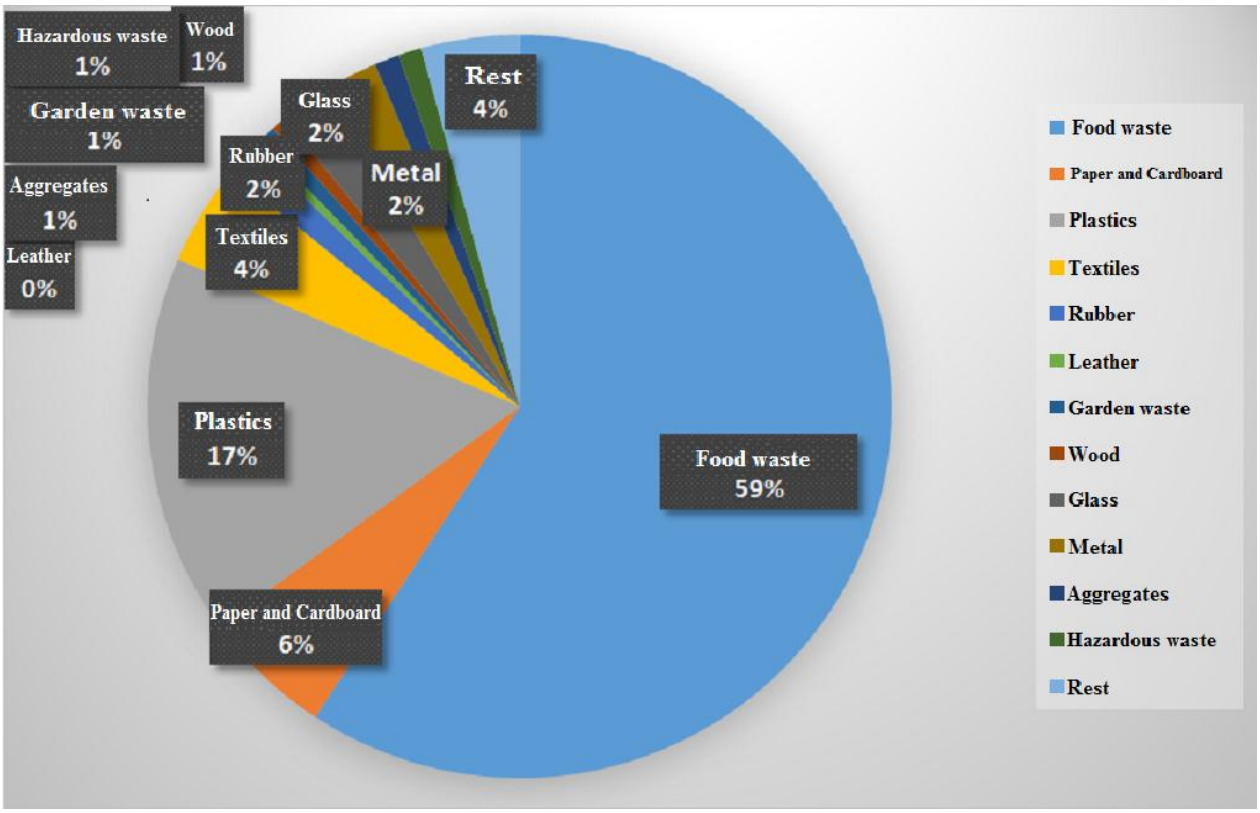

Figure 38. Percentage of different categories of waste per sector of housing for the collective-city housing sector

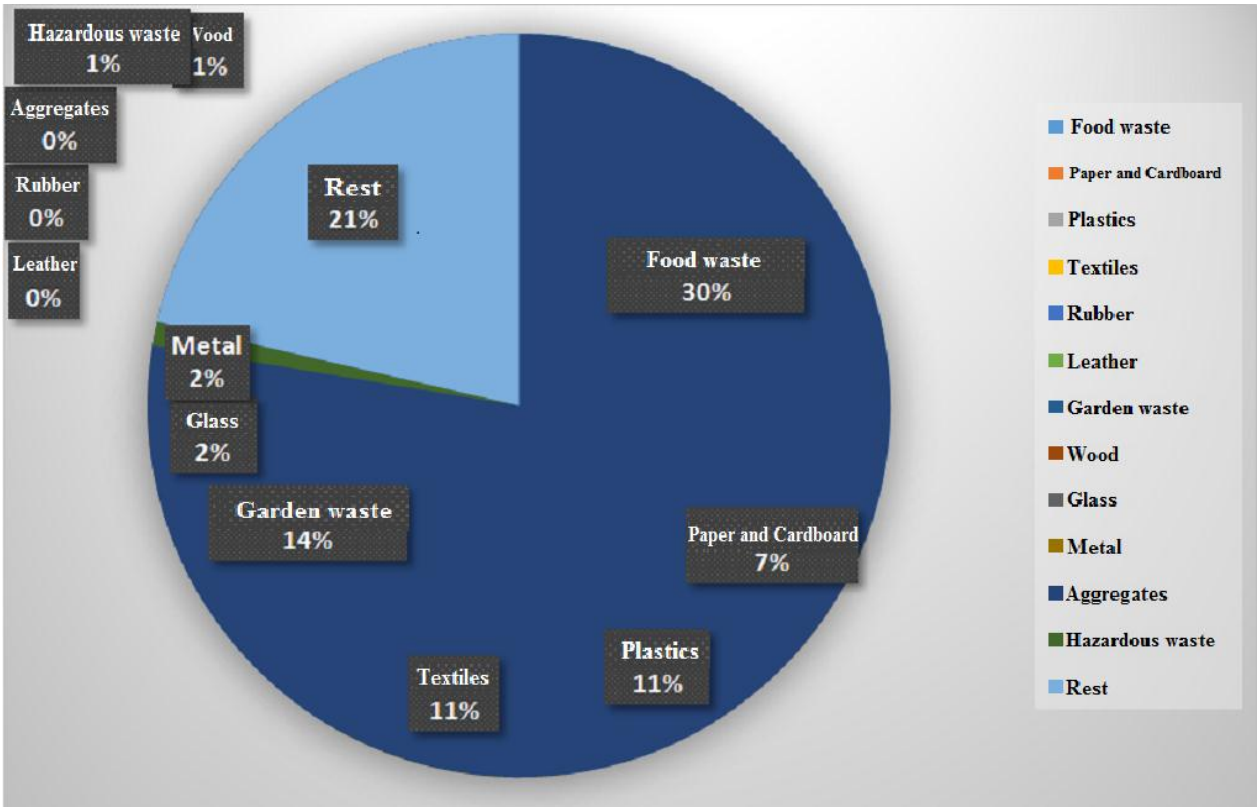

Figure 39. Percentage of different categories of waste per sector of housing for the rural sector

Table 15 and Figure 40 show the results of the morphological composition of waste calculated for the entire Municipality of Knjaževac for all four periods.

Table 15. Average morphological composition of waste for the Municipality of Knjaževac

Waste category	Percentage of components %
Food waste	41,27
Paper and cardboard	7,29
Plastics	13,69
Textiles	9,21
Rubber	0,65
Leather	0,26
Garden waste	8,47
Wood	0,37
Glass	1,39
Metal	2,46
Aggregates	0,70
Hazardous waste	0,95
Rest	13,28
TOTAL:	100,00

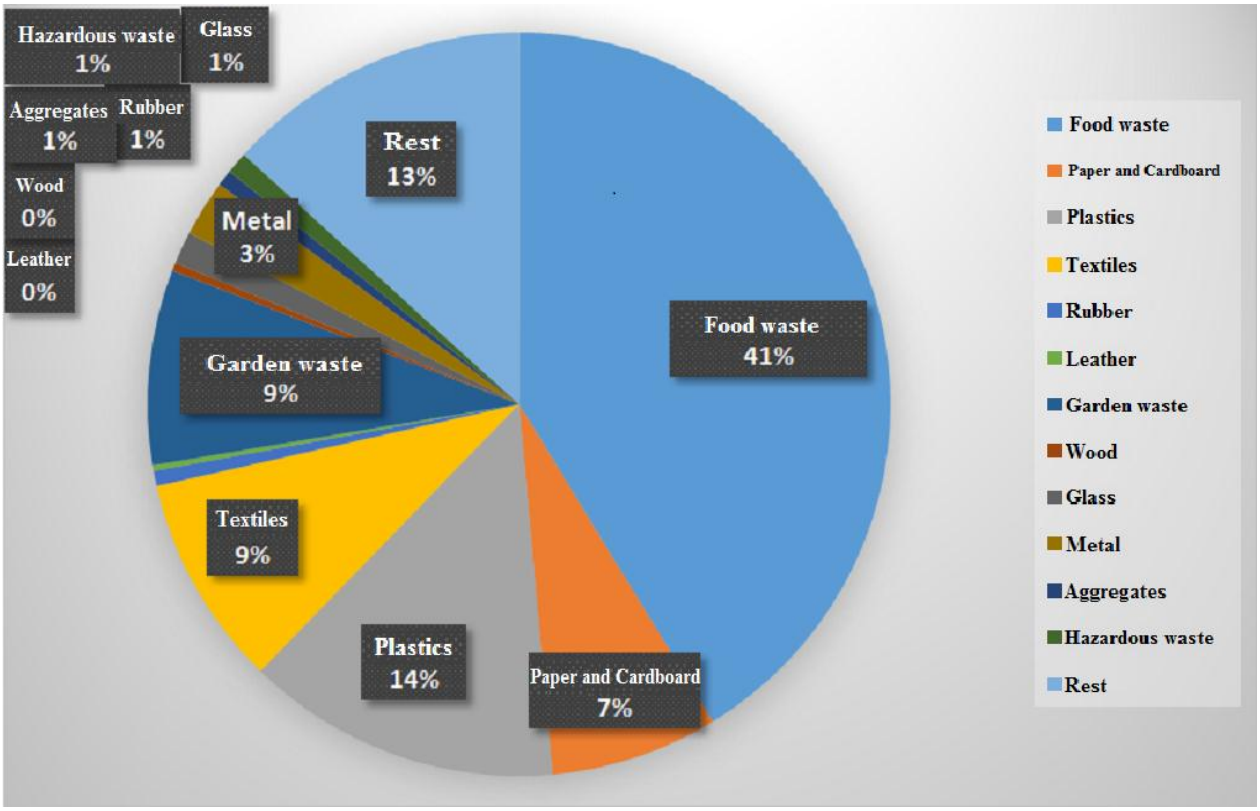

Figure 40. Average morphological composition of waste for the Municipality of Knjaževac

By analyzing the obtained results for all four periods it can be noticed that food waste has the highest percentage in all three housing sectors, in the collective-city housing sector as much as 59,26%, the individual-city housing sector 37,37% and the rural sector 30,14%. The increased amount of garden and "rest" type of waste (ash) in the individual-city and rural housing sector in relation to the collective-city housing sector is logical due to jobs in the yard and individual heating.

If the morphological composition for the entire Knjaževac municipality is observed for all four periods, the most dominant category of waste is the total amount of organic waste with a share of 49,74%, which is at the average level for the Republic of Serbia. The share of garden waste is 8,47%, and the share of food waste is 41,27%. The total plastic waste makes 13,69%, which is not a small matter, given the separate collection of PET packaging and that in 2017 8,2 tons of plastic waste were collected and sold. The percentage of paper and cardboard (7,29%) is slightly lower than the average in the Republic of Serbia (13,57%). The existence of individual collectors of recyclables has certainly contributed to the smaller amount, primarily of cardboard,

paper and cans. Higher amounts of “rest” type of waste (ash) of 13,28% are the result of heating in the winter months. A slightly higher percentage of textiles (9,21%) is caused by higher amounts of disposable diapers.

8. Concluding remarks

Based on the results of the analysis of the amount and composition of municipal waste in the Municipality of Knjaževac, it can be concluded:

• An average of 0,625 kg of municipal waste per day is generated in the Municipality of Knjaževac, which is significantly below the average of the population of the Republic of Serbia generating 0,87 kg of municipal waste per day.

• The average morphological composition for the entire Municipality of Knjaževac is at the level of the average morphological composition for the entire Republic of Serbia.

• The share of biodegradable waste of about 50% indicates the possibility and justification for the introduction of treatment of this type of waste in the following period.
• The amount of recyclable waste materials (paper, plastic, metal and glass) is about 25%, which is not negligible considering the fact that part of the recyclables is separately classified and not registered by recording the morphological composition of municipal waste.

• When analyzing the morphological composition of municipal waste by sectors and the average numbers for all three sectors, almost identical data was observed in all records for the individual-city sector and the average numbers. This observation is very interesting from the point of view of a quick analysis of waste composition by sampling and analysis of waste only from the individual-city housing sector, which also represents the morphological composition for the entire Municipality of Knjaževac.

Based on the analysis of waste composition, it is concluded that a pilot project should be done for the introduction of the Waste Disposal System "Two Bins and Bags" for organic, other and recyclable waste, respectively.