

INCREASING THE LEVEL OF MUNICIPAL WASTE RECYCLING IN POLAND, ON THE EXAMPLE OF THE KRAKOW METROPOLIS

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Purpose: The aim of the article is to analyze the recycling levels achieved in Krakow and the municipalities of the Krakow Metropolis and to identify the factors that influence these results. In order to increase recycling rates in municipalities, a calculation method has been proposed that can help estimate the amount of biodegradable waste composted in households.

Design/methodology/approach: To achieve the goal of analyzing recycling levels in municipalities, data from the Local Data Bank of the Central Statistical Office and the Małopolska Marshal's Office were used. The proposed method for calculating the mass of composted biodegradable waste was based on exemplary declarations on composting of biodegradable waste posted on municipal websites and indicators such as the amount of kitchen waste generated/person/year and the amount of green waste generated in kg/m² of green areas.

Findings: The analysis of recycling levels shows the problems that municipalities may have in achieving the limits set by the European Commission. Actions must be taken to increase recycling rates in municipalities, and one of them may be a proposed method for calculating the amount of composted biodegradable waste in households. Failure to achieve recycling levels will result in administrative penalties imposed by the Provincial Inspectorates of Environmental Protection (WIOŚ) and failure to meet sustainable development goals.

Research limitations/implications: Municipalities have household declarations regarding composting of biodegradable waste. The continuation of the research concerned checking the correctness of data in municipalities on the size of plots and the area of green areas using satellite maps, e.g. geoportal.gov.pl

Practical implications: The work uses an original calculation method, helpful in estimating the amount of biodegradable waste subjected to composting. Municipalities could use this method, which would help estimate the neglected amounts of this type of waste in households. By using the proposed method, the management of the biodegradable waste fraction would be more transparent and reliable, which would help increase the achieved recycling levels.

Social implications: The implementation of the proposed solution could change the approach of waste producers to the segregation of municipal waste and influence greater attention during segregating biodegradable waste. Consequently, this would also improve waste management and improve the results in achieving sustainable development goals in municipalities.

Originality/value: The article is an attempt of response to the need to achieve higher and higher levels of recycling. The proposed solution has implementation value and is addressed to organizations managing waste management in local government units.

Keywords: recycled materials, waste management, sustainability, circular economy, recycling rate.

Category of the paper: Research paper.

1. Introduction

The transformation towards a circular economy is one of the goals of the European Green Deal, alongside others leading to the ecological transformation of Europe (European Green Deal, 2024). Waste is a function of consumption, but can be reincorporated into productive activities through recycling (Bongers, Casas, 2022). Hence, it is so important to increase the level of recycling to meet the requirements of the circular economy legislative package, which requires a significant increase in waste recycling goals in the coming years. The transformation of the economy towards an economy that efficiently uses resources, including natural raw materials, is part of national smart specialization and affects both the Polish economy and the natural and social environment (Closing the loop, 2015). Acting in accordance with the circular economy concept involves the maximum use of waste and its reduction based on the 6R concept: refuse, reduce, reuse, recover, give back for recycling (recycle), think about what you can do better (rethink) (Krajowa inteligentna specjalizacja, 2024). Therefore, from an ecological and economic point of view, the most effective method is to segregate waste at the place of its creation (so-called at the source), which is beneficial for increasing recycling levels.

The problem of the constantly growing amount of waste collected in landfills has forced the European Commission to introduce broad changes in waste management in member states. Particularly significant changes affected countries that joined the EU structures after 2004. An example is Poland, where the waste revolution began with the entry of the Waste Act on 1 July, 2013 (Ustawa z dn. 14 grudnia 2012). It imposed on communes the obligation to manage municipal waste generated by commune residents and other waste producers. Fees for municipal waste management were transferred to waste producers. This change resulted from the Act of 1 July, 2011 amending the Act on maintaining cleanliness and order in municipalities and certain other acts (Ustawa z dn. 17 grudnia 2020).

Due to the specificity and complexity of waste management problems, many municipalities in Poland have problems with achieving the required recycling levels. The problem clearly requires appropriate action by municipalities to meet the necessary requirements to achieve the established recycling levels in the EU. Failure of administrative units to meet the required levels of waste recycling will result in the imposition of administrative penalties by the Provincial Inspectorates of Environmental Protection (WIOŚ), which will be covered from municipal budgets. The consequence of these penalties may be higher fees for the collection of municipal waste from households and companies, set by municipal councils (Różowicz, 2023).

The aim of the article is to analyze the recycling levels achieved in Krakow and the municipalities of the Krakow Metropolis and to try to identify the factors that influence these results. To achieve this goal, data from the Central Statistical Office (GUS) and the Małopolska Marshal's Office were used. In the following, a calculation method is being proposed that could help in estimating the amount of biodegradable waste composted in households. Currently, this waste is difficult to verify in terms of its quantity by the authorities responsible for recording it. An appropriate approach and application of the solution proposed in this article could significantly increase the achieved recycling levels in municipalities.

2. Waste Management in Poland

Waste management in Poland is carried out in accordance with legal guidelines, systematically amended and harmonized with European Union regulations. One of the most important regulations regarding waste management in the EU is Directive 2008/98/EC of the European Parliament and of the Council of 19 November 2008 on waste and repealing certain directives (Dyrektywa 2008/98/EC). In Poland, regulations regarding waste management are included in the Act of December 14, 2012 on waste (Ustawa z dn. 14 grudnia 2012). Moreover, under this Act, national and provincial Waste Management Plans are applied and updated - the latest regulation covers activities until 2028 (Uchwała nr 96). Waste management plans also include activities to prevent waste generation, which are implemented in particular based on the National Waste Prevention Program. (Ustawa z dn. 14 grudnia 2012, Lisowska, 2017). Additionally, environmental impact forecasts and strategic environmental impact assessments are formulated (Ministerstwo Klimatu i Środowiska). The second important regulation for waste management in Poland is the Act of September 13, 1996 on maintaining cleanliness and order in municipalities (Ustawa z dn. 13 września 1996), which transfers responsibility for municipal waste management in Poland to municipalities. The scope of this responsibility includes: selective collection, cleaning of the commune, storage and disposal of waste (Ustawa z dn. 13 września 1996). Waste producers should also comply with the above-mentioned requirements act and guidelines of the Unified Waste Segregation System (JSSO), which has been in force in Poland since July 1, 2017. Segregation takes into account the following waste fractions and container colors: paper (blue), metals and plastics (yellow), glass (green or white for transparent glass, if separation occurs), BIO (brown), mixed waste (black) (Nasze śmieci JSSO). The commune settles accounts with individual households, cooperatives and communities that are responsible for organizing collections in their area (Ustawa z dn. 13 września 1996). Waste producers in the commune also use the so-called PSZOK, i.e. Selective Municipal Waste Collection Points, where someone can leave, among others,

bulky waste, construction waste, green waste, used tires, e-waste and chemicals (Nasze śmieci PSZOK).

The proper management of waste management is controlled by the Provincial Inspectorates of Environmental Protection (WIOŚ) and the commune head, mayor or president of the city (Ustawa z dn. 27 kwietnia 2001). Penalties for non-compliance with the requirements are imposed on enterprises by the Provincial Inspectorate of Environmental Protection. However, if waste producers fail to segregate waste, the act does not provide for a penalty, but rather an increased fee imposed by municipalities. According to the law, it may be at least twice and at most four times higher than the fee for segregators (Ustawa z dn. 13 września 1996). Leaving waste in unauthorized places is also prosecuted by the Police and is punishable by a fine under Art. 75 of the Code of Petty Offenses up to PLN 500 (Ustawa z dn. 20 maja 1971).

3. Recycling Levels in Poland

Fulfilling recycling requirements is difficult due to the multitude of problems encountered by Member States and the different initial situations when introducing changes in this area. The recycling rate of municipal waste in the EU shows a long-term relationship between macroeconomic variables and recycling performance at national and regional levels. Therefore, sociodemographic, economic and institutional factors are important for the levels achieved in different member states (Hondroyiannis et al., 2024). Significant improvements are still needed at company, product design, collection system and market level (Antonopoulos et al., 2021). Attention is also paid to the qualitative aspects of recycling and it is proposed to establish a supplementary recycling index that would combine the quantitative and qualitative aspects of recycling in one measure. (Roithner, Rechberger, 2020). Another challenge is still waste producers' environmental education (Pawul, Sobczyk, 2011).

Recycling rates for municipal waste are set out in Directive 2008/98/EC of the European Parliament and of the Council of 19 November 2008 on waste and repealing certain directives (Dyrektywa 2008/98/EC). In Poland, changes were introduced regarding the recycling levels of municipal waste by the Act of 17 December, 2020 amending the Act on maintaining cleanliness and order in municipalities and certain other acts (Ustawa z dn. 17 grudzień 2020). The levels mentioned are included in the National Waste Management Plan 2028 (KWPGO) (Uchwała nr 96). From 2021, the recycling level is determined for total municipal waste as the ratio of the amount of municipal waste recycled to the amount of municipal waste generated. The act indicates new values for municipal waste recycling levels that municipalities will be obliged to achieve in the years 2021-2035. The increase in the recycling rate is set as follows: 20% for 2021, 25% for 2022, 35% for 2023, 45% for 2024 and 55% in 2025. In the following

years, these amounts will increase by 1 percentage point, up to 60% in 2030. In 2035, the recycling rate will reach 65% and will also apply in subsequent years (Ustawa z dn. 17 grudnia 2020). Municipalities that will not fulfill the provisions of the Act, will be subject to a fine calculated separately for the required level: preparation for reuse and recycling of municipal waste; reducing the mass of biodegradable municipal waste sent to landfill (Ustawa z dn. 17 grudnia 2020).

In order to meet the set targets for municipal waste recycling rates, Poland will need to carry out the following actions: (Kopeć et al., 2023).

- implement the Waste Prevention Program (ZPO) and reduce the amount of waste generated,
- increase public awareness and knowledge about ZPO, also in the field of food ZPO,
- increase organic recycling by promoting composting of bio-waste by residents,
- ensure selective collection of bio-waste from residents and catering establishments.

One of the mentioned waste fractions, which poses many problems and has great potential for a higher level of recycling, is biodegradable waste (Kłopotliwa frakcja). This is a group of waste in which it is difficult to verify their quantity by the authorities responsible for recording them. It should be noted that the waste producers themselves do not pay enough attention to appropriate segregation and thus the separation of this fraction from mixed waste. There is often a lack of motivation, specific patterns and appropriate encouragement to deal appropriately with biodegradable waste (Szyba, Muweis, 2022).

One of the regulations specifying the method of calculating the levels of preparation for re-use and recycling and the conditions for including the mass of municipal waste in the mass of municipal waste prepared for re-use and recycled is the Regulation of the Minister of Climate and Environment of 3 August, 2021 on the method of calculating the levels of preparation for re-use and recycling reuse and recycling of municipal waste (Rozporządzenie Ministra Klimatu i Środowiska z dn. 3 sierpnia 2021). It also specifies the treatment of bio-waste until December 31, 2026. Bio-waste constituting municipal waste that has not been separately collected, but has been subjected to aerobic or anaerobic treatment, is classified as recycled waste, provided that it meets the conditions for including the mass of municipal waste in recycled waste. In the document you can find out how to calculate the levels of preparation for re-use and recycling of municipal waste for waste codes: 20 01 08 (biodegradable kitchen waste), 20 02 01 (biodegradable waste), 19 05 03 (non-compliant compost – unusable) (Rozporządzenie Ministra Klimatu i Środowiska z dn. 3 sierpnia 2021).

The Regulation presents formula (1) and information how to calculate the level of preparation for reuse and recycling of municipal waste:

$$P = \frac{M_r}{M_w} \quad (1)$$

where:

P - level of preparation for reuse and recycling of municipal waste.

M_r - total weight of municipal waste prepared for reuse and recycled.

M_w - total weight of municipal waste generated (Rozporządzenie Ministra Klimatu i Środowiska z dn. 3 sierpnia 2021).

The biggest problem is still education and encouragement to segregate this fraction of waste in multi-family homes, where there is little space for segregation of this fraction of waste, and their collection is carried out in common garbage shelters. A solution could be to encourage people to collect biodegradable waste in special paper bags and throw them into waste containers. This solution operates in Sweden, where the achieved recycling levels are very high (Domżał, 2017).

According to waste data from marshal reports for 2020, in 831 municipalities from 11 Polish voivodeships the required levels of preparation for reuse and recycling were not achieved in 2020 (Szczepański, 2020).

4. Methodology and Results

4.1. Object of Research

The subject of the analysis of municipal waste recycling levels was Kraków and the communes belonging to the Krakow Metropolis. Krakow is a dynamically developing city, as evidenced by the increase in the number of inhabitants from 761,000 in 2015, to over 803 thousand in 2022. The Krakow Metropolis includes 14 communes (see Fig. 1). Four of them are urban-rural communes (Świątniki Górne, Skawina, Niepołomice and Wieliczka) and the remaining ones are rural communes (Zielonki, Michałowice, Kocmyrzów-Luborzyca, Igołomia-Wawrzeńczyce, Biskupice, Mogilany, Czernichów, Liszki, Zabierzów, Wielka Wieś). The average population density in these communes is 317 people/km² (the lowest in the Igołomia-Wawrzeńczyce commune - 123 people/km², the highest in the Wieliczka commune - 614 people/km²). The mentioned communes were inhabited by approximately 330,000 people in 2022. A total of 1,133,000 people lived in the Krakow Metropolis in 2022. (GUS).



Figure 1. Communes belonging to the Krakow Metropolis.

Source: (Metropolia Krakowska)

4.2. Municipal waste collected from households *in Krakow and communes of the Krakow Metropolis

Households are obliged to collect five fractions of municipal waste, i.e. glass, paper and cardboard, plastics and metals, biodegradable waste and mixed waste. Biodegradable waste is divided into two types i.e. biodegradable kitchen waste and biodegradable waste. A detailed list of collected municipal waste along with their codes and container colors is provided in Table 1.

Table 1.

Type and code of municipal waste generated in households

Type of waste	Waste code	Color of the waste container (bag).
Plastics	20 01 39	Yellow
Metals	20 01 40	Yellow
Glass	20 01 02	Green
Paper and cardboard	20 01 01	Blue
Biodegradable kitchen waste(kitchen)*	20 01 08	Brown
Biodegradable waste (green)*	20 02 01	Brown
Mixed waste	20 03 01	Black

* in the text, instead of the full name of the waste, the names written in brackets will also be used.

Source: Rozporządzenie Ministra Klimatu z dn. 2 stycznia 2020

The above mentioned waste fractions are collected by their producers into bags or containers marked with appropriate colors (see Table 1) and collected by companies that collect segregated waste (glass, paper and cardboard, plastics and metals) and mixed waste and both types of biodegradable waste (MPO Kraków).

Collected municipal waste from households should be recycled or reused, in accordance with the concept of circular economy (Circular Economy). The level of preparation for reuse and recycling of municipal waste in 2022 was required to be at least 25%. The adopted goal in 2022 was achieved in all analyzed municipalities (see table 2). In 2024, the required levels should reach 45%. As the data in Table 2 show, in some communes (including Kraków) this may be difficult to achieve. One of the reasons is biodegradable waste due to its quantity and difficulties in collecting related to the nuisance caused by odors and the presence of insects and rodents.

Table 2.

Levels of preparation for use and use in Krakow and the municipalities of the Krakow Metropolis in 2022

Community	% in years	
	2021	2022
Kraków	28	27
Biskupice	49	46
Czernichów	32	32
Igołomia-Wawrzeńczyce	14	27
Kocmyrzów-Luborzyca	47	42
Liszki	b.d.	29
Michałowice	45	29
Mogilany	27	32
Niepołomice	41	36
Skawina	38	38
Świątniki Górne	34	38
Wieliczka	20	26
Wielka Wieś	32	43
Zabierzów	20	34
Zielonki	21	39

Source: Dane z Urzędu Marszałkowskiego Województwa Małopolskiego.

Data on the amounts of municipal waste collected in Krakow and the Krakow Metropolis are presented in Table 3. In 2022, over 340,000 tons of waste were collected, including almost 260,000 tons in Krakow. Almost 257 thousand tons of mixed waste (code 20 03 01) was collected. The largest number of them is approximately 197,000 tons were collected in Krakow, and among the communes of the Krakow Metropolis. The most of them were collected in Wieliczka (over 12.5 thousand tons). The smallest amount of mixed waste was collected in the Igołomia-Wawrzeńczyce Commune (over 1.2 thousand tons).

Among the recycled fractions, the most biodegradable waste (approximately 62.5 thousand tons) was collected (20/02/01). Among the communes, the largest amount was collected in the Krakow Commune (approximately 52 thousand tons). Among the communes belonging to the Krakow Metropolis, most of them were collected in the Niepołomice Commune (approximately 3.7 thousand tons). The second largest amount of biodegradable waste collected was the Zabierzów Commune, where almost 1.7 thousand tones of waste was collected in 2022.

Table 3.

Number of tons of municipal waste collected separately in households in Krakow and municipalities of the Krakow Metropolis in 2022

Community	Plastics and metals ¹	Glass ¹	Paper and cardboard ¹	Biodegradable waste	Biodegradable kitchen waste	Mixed waste	Sum of waste fractions
	in tons						
Świątniki Górne	333.18	248.21	160.22	521.08	0	1 828.16	3090.85
Mogilany	277.21	449.38	334.46	32.88	1 170.93	2 945.76	5210.62
Skawina	1 224.62	633.82	402.30	589.12	709.76	8 899.50	12 459.12
Czernichów	516.06	343.12	110.54	567.15	0	3 539.74	5076.61
Liszki	339.66	532.42	405.18	126.46	595.84	2 208.49	4208.05
Zabierzów	726.78	830.94	483.02	1696.87	542.24	4 756.94	9036.79
Wielka Wieś	0.00	425.14	243.74	1090,7	0	2 787.90	3456.78
Zielonki	1 170.87	1 038.14	812.96	41.98	1 497.54	5 588.42	10 149.91
Michałowice	269.13	311.94	318.70	536.2	0	2 341.10	3777.07
Kocmyrzów-Luborzyca	524.03	397.98	309.93	1 096.34	0	3 364.54	5692.82
Igołomia-Wawrzeńczyce	0.00	122.12	0.00	0	0	1 249.42	1371.54
Niepołomice	925.49	853.20	628.30	3 755.29	245.70	6 411.76	12819.74
Biskupice	173.22	314.46	217.18	402.12	0	1 777.70	2884.68
Wieliczka	1 437.55	791.36	802.89	369.69	331.14	12 508.68	16 241.31
<i>Total communes</i>	<i>7 914.38</i>	<i>7 292.23</i>	<i>5 229.42</i>	<i>10,843.02</i>	<i>5,093.15</i>	<i>60 208.11</i>	<i>80 644.14</i>
Kraków	24 515.65	18 796.77	20 062.88	51,659.07	22,116.72	196 537.11	259 912.41
<i>Total Krakow and communes</i>	<i>32 430.03</i>	<i>26 089.00</i>	<i>25 292.30</i>	<i>62,502.09</i>	<i>27,209.87</i>	<i>256 745.22</i>	<i>340 556.55</i>

¹GUS

²Dane z Urzędu Marszałkowskiego Województwa Małopolskiego

Biodegradable waste also includes kitchen waste (code 20 01 08). A total of over 27.2 thousand tons of waste were collected. Most of them, almost 18 thousand tons were collected in Krakow. From the municipalities surrounding Krakow – the communes of Zielonki collected almost 1.5 thousand tons and Mogilany almost 1.2 thousand tons. In the communes of Świątniki Górne, Czernichów, Wielka Wieś, Michałowice, Kocmyrzów-Luborzyca and Igołomia-Wawrzeńczyce, no records were kept of the collected amounts of selectively collected kitchen waste. Table 3 shows that in 2022, almost 90,000 tons of both fractions of biodegradable waste were collected.

Households also generate waste from glass, paper and cardboard, as well as biodegradable kitchen waste. In 2022, were collected over 26,000 tons of glass (code 20 01 02), almost 25.3 thousand tons of paper and cardboard (code 20 01 01) and over 32 thousand tons of plastics (code 20 01 39) and metals (code 20 01 40).

4.3. Analysis of recycling rates of biodegradable waste collected from Krakow and the Municipalities of the Krakow Metropolis

As previously written, two types of biodegradable waste are generated in households, i.e. biodegradable kitchen waste (code 20 01 08) and biodegradable waste (code 20 02 01). Kitchen bio-waste is organic waste generated at home from fruit and vegetable remains (peelings, spoiled fruit and vegetables, etc.), food remains (without meat and bones), coffee and tea grounds, egg shells, groats, pasta, rice. The second type of bio-waste is green waste from home gardens, i.e. grass, leaves, flowers and their stems, branches, etc. Both types of waste (except branches) are collected by their producers in brown bags or containers of the same color and taken away by waste collection companies that also collects mixed municipal waste.

Unfortunately, some biodegradable waste is thrown into mixed waste. This most often happens in multi-family houses with chutes. Some of it is composted by producers living in single-family homes. This form of development should be used more widely because it reduces the costs of collection and development incurred by municipalities.

The amount of biodegradable waste generated in households is difficult to estimate because it is related to the place of residence of the producers of this waste.

Favoino and Giavini estimate that these quantities are as follows: (Favoino, Giavinim, 2020).

- in cities – 40 kg/inhabitant/year,
- in the suburbs – 160 kg/inhabitant/year,
- in rural areas – 200 kg/inhabitant/year.

In order to determine the amount of biodegradable waste collected in the municipalities of the Krakow Metropolis, the average weight of biodegradable waste per inhabitant was calculated. The calculations used the data from Table 2 on the amount of biodegradable waste collected from households in Krakow and the municipalities of the Krakow Metropolis in 2022 and the data on the number of inhabitants is in Table 4. The calculation results are in Table 4.

Table 4.

Amount of biodegradable waste and biodegradable kitchen waste per capita in Krakow and the municipalities of the Krakow Metropolis in 2022

Commune	Number of inhabitants		Waste in kg/capita	
	total	people/km ²	biodegradable (20 02 01)	kitchen (20 01 08)
Kraków	803 280	2 457,6	64.3	27.5
Świątniki Górne	11 100	545,3	46.9	0.0
Mogilany	16 200	370,4	2.0	72.3
Skawina	44 000	441,0	13.4	16.1
Czernichów	15 300	182,5	37.1	0.0
Liszki	18 400	255,5	6.9	32.4
Zabierzów	29 300	294,4	57.9	18.5
Wielka Wieś	16 500	340,7	66.1	0.0
Zielonki	27 200	559,0	1.5	55.1
Michałowice	13 200	257,6	40.6	0.0
Kocmyrzów-Luborzycza	18 000	216,6	60.9	0.0
Igołomia-Wawrzeńczyce	7 900	125,4	0.0	0.0
Niepołomice	32 800	340,4	114.5	7.5
Biskupice	11600	281,0	34.7	0.0
Wieliczka	68 000	682,5	5.4	4.9

Source: (Dane z Urzędu Marszałkowskiego Województwa Małopolskiego, 2023, GUS).

The data in Table 4 shows that the amounts of collected biodegradable waste per inhabitant vary significantly, also in municipalities of a similar nature. An example is the urban-rural communes of Niepołomice and Wieliczka. In the first one, 122 kg/person of both types of waste was collected, and in the second one, 10.3 kg/person. It was similar in the agricultural communes of Czernichów and Igołomia-Wawrzeńczyce. In the first one, 37.1 kg/person (including 0 kg of kitchen waste) was collected, and in the second one, 0 kg of both types of waste.

Continuing the analysis of the amount of waste generated per capita in individual communes, it was found that in 2022 the most biodegradable waste was generated by a resident of Niepołomice - 114.5 kg/person/year. In second place was Kraków, 64.3 kg/person, and in third place was the Kocmyrzów-Luborzycza Commune, 60.9 kg/person. In the case of the mentioned communes, only in Kraków the value given by Favoino and Giavini was exceeded. However, in urban and rural communes, which can be compared with the suburbs of cities, they were much lower. The situation was similar in rural communes.

It seems that assuming the amount of waste generated per capita is not very precise, because we have two types of biodegradable waste. The amount of kitchen waste certainly depends on the number of inhabitants, while the amount of biodegradable waste with code 20 02 01 depends on the size of the plot and the method of its development.

4.4. Increasing levels of reuse and recycling of municipal waste

The amendment to the Act on maintaining cleanliness and order in municipalities allows for reducing waste collection fees for residents who declare home composting of bio-waste. (Ustawa z dn. 13 września 1996). The municipalities of the Krakow Metropolis apply different

criteria when calculating reliefs. The Igołomia-Wawrzeńczyce commune applies a discount of PLN 5/person. In the case of one or two-person households with large plots, it may not be a sufficient incentive to set up home composters. The Niepołomice commune applies a lump sum of PLN 20 per farm (Miasto gmina Niepołomice). In this case, single-person households with small plots of land receive excessive relief. Establishing home composters is not conducive to the need to submit declarations, the completion of which is complicated and may contain imprecise data. In the Wieliczka Commune, information should be provided on the number of inhabitants of the property, the estimated capacity of the composter in m^3 , the estimated annual amount of kitchen bio-waste and green bio-waste from gardens and green areas that will be managed in this composter (Ekowieliczka).

Composting waste by households allows municipalities to reduce the costs associated with the disposal of municipal biodegradable waste. However, there is a problem with determining the mass of this waste intended for composting in home gardens. Due to the obligation of municipalities to achieve the designated recycling levels, they should consider the possibility of including composted waste in the mass of biodegradable waste collected. This would allow for increasing indicators of the level of preparation for reuse and recycling of municipal waste. For this purpose, the authors of the publication proposed a method for calculating the mass of composted waste in households. The first step should be a declaration from the owners or users of the property, which should include the area of the plot - S_d and the green area - S_z in m^2 . The plot area is known to the owner and the commune because it is used to calculate land tax. The area of the green area can be measured by the owner and the given size can be checked. The mass of biodegradable waste - M_b can be calculated from the equation (2):

$$M_b = M_z + M_k \text{ [kg/year]} \quad (2)$$

where:

M_z - mass of green waste from the backyard plot (grass, leaves, plant remains vegetables, branches of ornamental and fruit bushes and trees),

M_k - mass of kitchen waste.

The mass of green waste and the mass of kitchen waste can be calculated using the dependencies: (3) and (4):

$$M_z = S_z * m_z \text{ [kg/year]} \quad (3)$$

$$M_k = m_k * N \text{ [kg/year]} \quad (4)$$

where:

$m_z = 1,5-2,0$ [kg/ m^2 and year],

$m_k = 60-80$ [kg/person and year].

Coefficient values m_z i m_k were adopted according to: (Oszacowanie poziomu kompostowania bioodpadów).

A family of four, living in a house with an area of approximately 120 m², built on a plot of 300 m², with 150 m² of green area produces annually $M_z = (1,5-2,0)*150,0 = 225,0$ to 300,0 kg of green waste and $M_k = (60-80)*4 = 240$ to 320 kg of kitchen waste.

The estimated total weight of biodegradable municipal waste collected per year from a sample household is approximately 465 to 620 kg. The amount of biodegradable household waste collected will vary from month to month. As shown in Figure 2, kitchen waste is produced at an almost constant rate throughout the year. Green waste, on the other hand, is produced in greatest quantity from May to November. This is related to the growing season of plants and cleaning work in home gardens.

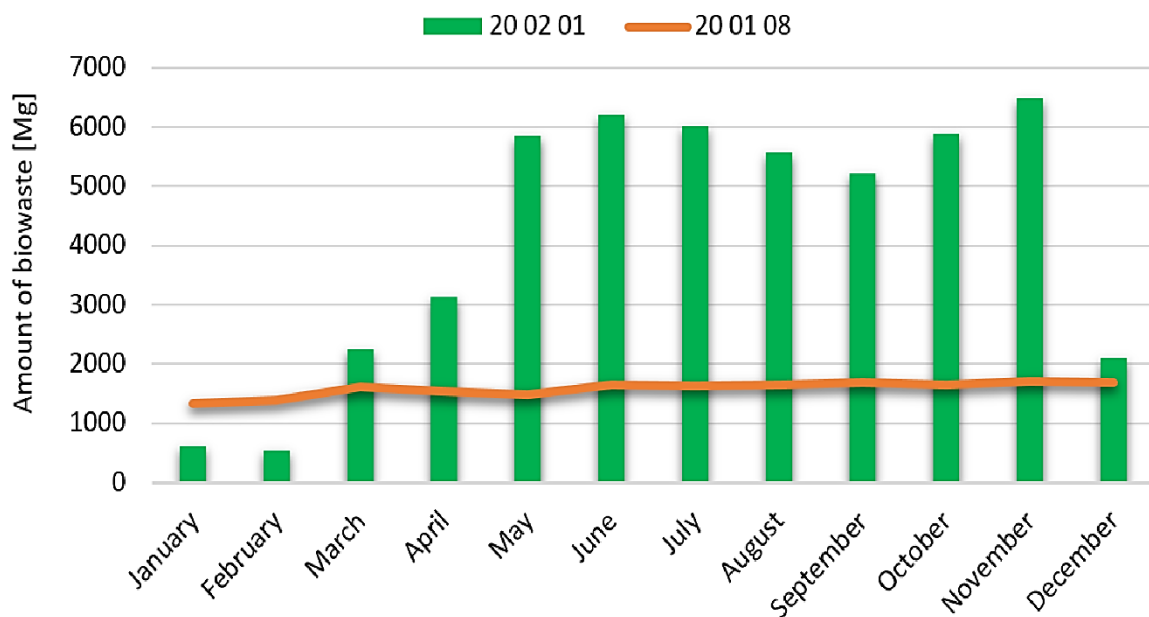


Figure 2. Amount of municipal biowaste collected Krakow in 2022.

Source: Szyba, Mikulik, 2023.

5. Summary

Recycling rates set by the European Commission are increased every year and are expected to reach 65% by 2035. In Poland, in 2023, the recycling rate was only 28% (Ecoekologia.pl). Biodegradable waste, which is one of the municipal waste fractions, plays an important role in achieving the recycling levels set for municipalities in Poland. Unfortunately, this fraction of waste is still neglected and is reluctantly segregated by waste producers, and its stream ends up in mixed waste. Households that separate biodegradable waste (green and kitchen) can do it in two ways. One of them is collecting waste into brown bags or containers or composting it in home composters. The information contained in the article shows that a significant part of biodegradable waste is disposed of in composters, especially in households located in rural

communes of the Krakow Metropolis where agricultural production is carried out. The compost produced is used as a natural fertilizer. In rural and urban-rural communes, financial discounts are introduced for running a home composter. On farms where large amounts of biodegradable green and kitchen waste are generated, collecting waste into bags is impossible due to their limit. The valuable mass of waste that can be included in recycling rates is incalculable. For these reasons, the aim of the article was to analyze the recycling levels achieved in Krakow and the municipalities of the Krakow Metropolis and to identify the factors that influence these results. To improve the current indicators, a calculation method was proposed that could help estimate the amount of biodegradable waste composted in households. A tool that could help collect data to estimate the mass of waste would be a survey for households declaring composting of biodegradable waste. Property owners and managers should provide the plot area, green areas and the number of people in the household in the application form. Based on this information, the amount of waste composted per year in a given household would be estimated.

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