THE IMPACT OF INTRODUCING SEPARATE BIOWASTE COLLECTION ON WASTE FLOWS IN THE TOWN OF SISAK, REPUBLIC OF CROATIA, IN THE PERIOD 2021 - 2025

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ABSTRACT

This paper examines the effect of introducing separate biowaste collection in the town of Sisak via container systems in the period from 2021 to 2025. Until 2024, biowaste was collected mainly through branch collection campaigns, recycling yards, and partly through home composting, while the majority ended up in mixed municipal waste. In March 2024, the distribution of individual and shared containers was launched, thereby establishing a more systematic collection system. The results indicate a substantial increase in the amount of separately collected biowaste, accompanied by a corresponding reduction in mixed waste. In 2023, 222.8 t of biowaste was collected, while in 2024 this figure increased to 1306.3 t, representing an increase of 486 %. During the same period, mixed municipal waste decreased from 9035.4 t to 7664.7 t (- 15.2 %). Service coverage reached 93.6 % of households and 96.4 % of legal entities. These findings suggest that the introduction of containers has enabled the diversion of a considerable share of biowaste from mixed municipal waste to separate collection, thereby contributing to the achievement of waste management objectives in accordance with the requirements of Directive (EU) 2018/851 and the Waste Management Act.

Keywords: *biodegradable waste, separate collection, composting*

INTRODUCTION

Waste management in urban areas has become one of the greatest challenges in the context of sustainable development. According to Directive (EU) 2018/851 amending the Waste Framework Directive 2008/98/EC, Member States were required to implement separate biowaste collection by 31 December 2023, which also includes its composting at source [1]. This obligation complements the existing separate collection of paper, glass, metals, and plastics, and is part of the broader circular economy package aimed at reducing waste generation and increasing the recycling rate within the European Union [2]. Local government units, particularly towns and cities, play a crucial role in implementing these obligations, as the largest share of municipal waste is generated in urban areas [3]. Until 2024, the Town of Sisak (Republic of Croatia) did not have an established system

for the separate collection of biowaste through individual containers for households. Biowaste was collected twice a year during campaigns for the collection of branches from pruning fruit trees, ornamental trees, and shrubs, as well as through recycling yards. Some users practiced home composting, while the remaining quantities were disposed of together with mixed municipal waste. The Town of Sisak secured co-financing for the procurement of biowaste containers through a public call issued by the Environmental Protection and Energy Efficiency Fund. In March 2024, the company Gospodarenje otpadom Sisak d.o.o. /*Sisak Waste Management Ltd./*, as the public service provider, began distributing individual and shared containers along with educational activities, thus establishing an organized system of biowaste collection at the household level. The aim of this paper is to analyse the effects of introducing containers for separate collection of biowaste on the quantities of biowaste and mixed municipal waste, as well as to assess the level of user coverage under the new system. The study is based on quantitative data on the amounts of waste collected during the period from 2021 to 2025, along with administrative data on the number of households, legal entities, and the distribution of containers in the Town of Sisak.

MATERIALS AND METHODS

The significance of biodegradable waste in the waste management system

According to the Ordinance on Waste Management in the Republic of Croatia [4], municipal biowaste includes several categories:

- 20 01 08 (biodegradable kitchen and canteen waste),
- 20 01 25 (edible oils and fats),
- 20 02 01 (biodegradable garden and park waste),
- 20 03 02 (market waste).

Analyses of the composition of mixed municipal waste [5] show that biowaste accounts for about 37 % of the total mass, with the largest share being kitchen waste (30.9 %), followed by garden waste (5.7 %) and skin and bones (0.5 %). These data confirm that biowaste has the greatest potential for reducing the total quantity of mixed municipal waste. Biowaste is characterized by its ability to decompose through biological processes; however, when disposed of together with mixed municipal waste, it contributes to methane generation at landfills [6]. Its high moisture content complicates the mechanical-biological treatment of mixed municipal and other disposed waste [7]. The decomposition of organic matter results in the formation of various chemical and biological pollutants, which can negatively affect air, water, and soil quality, posing risks to human health [8]. Separate collection and recycling of biowaste, either through composting or anaerobic digestion, reduces greenhouse gas emissions, returns nutrients to the soil, and enables energy production from biogas [9]. The waste management system in the Republic of Croatia is regulated by the Waste Management Act [10] and related bylaws. The Town of Sisak, as a local government unit, is obliged to provide waste management services to all users within its territory. The waste management system in the Town of Sisak includes the collection of mixed municipal waste as well as the separate collection of certain recyclable fractions. Paper and cardboard, along with mixed packaging (plastic, metal, multilayer, and glass), are collected through doorstep container systems. Bulky waste is managed through an annual collection campaign and via recycling yards. Until 2024, biowaste was disposed of through organized collection campaigns and recycling yards, and users were also encouraged to practice home composting. In 2015, a total of 600 free composters were distributed, co-financed by the Town of Sisak and the Environmental Protection and Energy Efficiency Fund. The composters were distributed to users in the Town of Sisak and in nearby settlements towards Zagreb, Kutina, and Sunja. A network of containers and a regular biowaste collection service were established in March 2024.

Methodology

The analysis conducted in this study is based on the data on waste quantities, users of public service, and the distribution of individual and shared containers for biowaste disposal. The waste quantities data cover the period from January 2021 to July 2025. Both monthly and annual quantities were used for each fraction (paper and cardboard, mixed packaging, mixed municipal waste, bulky waste, and biowaste). In addition, the quantities of collected biowaste are shown by source, comprising doorstep containers, recycling yards, branch collection campaigns, and collection outside the public service system (legal entities). The data on public service users refer to the period from 2023 to 2025 and are based on monthly reports on the number of consumption points, distinguishing between households and legal entities. These data are used to analyse user coverage within the system and include information on whether users have organized biowaste collection and how they manage it (individual or shared containers, home composting, or no declared option). The third dataset relates to the distribution of biowaste containers. Between October 2023 and August 2025, the number of containers allocated each month, and their cumulative totals were recorded, enabling the monitoring of the dynamics of container introduction into the system. The data were first consolidated by aggregating monthly waste quantities and presenting them on an annual level for each fraction. This approach enabled a clearer tracking of changes over the period, particularly when comparing the quantities of collected mixed municipal waste and biowaste before and after the introduction of containers. Accordingly, two periods were analysed:

- from January 2023 to February 2024,
- from March 2024 to August 2025.

In addition to waste quantities, user coverage within the system was also monitored. Particular attention was given to the share of households and legal entities covered by organized biowaste collection. Waste management methods include the use of containers or home composting. The analysis also incorporates data on the share of users who did not declare their method of biowaste management. The availability of containers in the Town of Sisak was monitored through monthly reports on the number of distributed individual and shared containers from October 2023 to August 2025. For each observed period, the cumulative number of containers in the system was recorded and compared with the number of households using public service. The allocated containers were provided in a volume of 120 litres for households, while legal entities and collective households used 770-liter containers. In this way, it was possible to track the dynamics of container introduction and assess the level of user coverage within the service.

RESULTS AND DISCUSSION

Annual amounts of collected waste in the Town of Sisak

Table 1 shows the annual quantities of collected waste in the Town of Sisak for the period from 2021 to 2025. The data include mixed municipal waste, biodegradable waste, bulky waste, as well as mixed packaging and paper and cardboard.

Table 1. Total quantities of collected waste in the Town of Sisak (2021 - 2025)

Year	Biodegradable waste (t)	Mixed municipal waste (t)	Mixed packaging waste (t)	Paper and cardboard (t)	Bulky waste (t)
2021	638.1	12328.5	1208.6	1008.6	161.5
2022	214.2	10681.5	1446.7	1106	926.6
2023	222.8	9035.4	1587.1	1190.9	1297.7
2024	1306.3	7664.7	1814.6	1324.9	1534.7
2025*	613	3557.3	1775.2	591	767.6

* until August

The presented data clearly show that the quantities of certain types of waste changed significantly during the observed period, with a particular emphasis on the increase in the biodegradable fraction and the simultaneous reduction of mixed municipal waste. Comparison of the results with available data [11] shows that the Town of Sisak has achieved significant progress in biowaste management in a short period of time. In 2024, a total of 1306.3 t of biowaste was collected in Sisak, representing an increase of 486 % compared to 2023 (222.8 t). This growth clearly confirms the effectiveness of the container system and illustrates that local measures can produce results comparable to European practices in a relatively short time [12]. At the same time, the quantity of mixed municipal waste decreased from 9035.4 t in 2023 to 7664.8 t in 2024, which is a decrease of 15.2 %. Looking at the period from 2021 to 2024, the total decrease is 37.8 % (from 12328.5 t to 7664.8 t). These figures clearly show that the increase in separately collected biowaste was achieved with a significant reduction in mixed municipal waste. In the first eight months of 2025, additional 613 t of biowaste were collected, which corresponds to 46.9 % of the biowaste collected in 2024. Although the data do not cover the entire year, they nevertheless suggest a stabilization of collected quantities at the level of the previous year. Overall, the results from the Town of Sisak confirm that the introduction of biowaste containers had a direct and measurable impact on waste flows. The amount of separately collected biowaste has increased almost fivefold in just one year, while mixed municipal waste has decreased by more than one third.

Monthly quantities of biodegradable and mixed municipal waste

Figure 1 shows the monthly quantities of biodegradable waste in the period from January 2023 to August 2025, with the red dashed line indicating March 2024, when the collection of biowaste through the container system began.

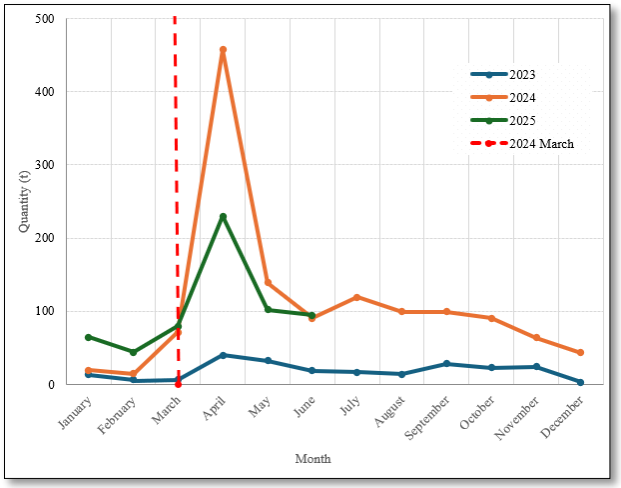

Figure 1. Monthly quantities of biodegradable waste before and after the introduction of containers

The data presented until March 2024, when separate collection of biowaste using containers was introduced, show monthly collected quantities ranging from 5 to 30 t, as biowaste was primarily separated through recycling yards and periodic collection campaigns. After the implementation of the above-mentioned measure in April 2024, a sharp increase was recorded, with a peak of almost 460 t, while in May the quantities exceeded 130 t. In 2025, the system reached a phase of stabilization, with average monthly values ranging between 60 and 120 t. The majority of biowaste originated from household and business containers (388 t in the first six months, accounting for approximately 63% of the total), while the contribution of collection campaigns was significantly lower than in the previous year. April 2025 once again recorded higher amounts (229 t), confirming seasonal fluctuations associated with gardening and yard maintenance activities. The differences observed between 2024 and 2025 do not indicate a decline in system efficiency, but rather a shift in the structure of sources. This shift reflects variations in the shares of households, businesses, and seasonal campaigns in the total quantities of collected biowaste.

The results presented in Table 2 show the quantities of biowaste and mixed municipal

waste before and after the introduction of containers, confirming the effect of implementing biowaste containers in March 2024.

Table 2. Comparison of the quantities of biodegradable and mixed municipal waste before and after the introduction of containers

Period	Total biodegradable waste (t)	Average monthly biodegradable (t)	Total mixed waste (t)	Average monthly mixed (t)
Before (January 2023 - February 2024)	1108	29.2	10556.4	879.7
After (March 2024 - August 2025)	1886	117.9	9838	447.2

In the period before the implementation of the measure (January 2023 - February 2024), a total of 1108 t of biowaste was collected, with an average of 29.2 t per month. At the same time, the amount of mixed municipal waste reached 10556.4 t, with an average of 879.7 t per month. After the introduction of containers (March 2024 - August 2025), a significant change in waste flow structure was recorded in the Town of Sisak. During this period, 1886 t of biowaste were collected, with an average of 117.9 t per month. Compared to the previous period, this represents an increase of 304 %. At the same time, the amount of mixed municipal waste decreased to 9838 t, or an average of 447.2 t per month, which represents a 49 % reduction compared to the period before the introduction of containers. These results confirm the direct effect of introducing containers on the increase of separately collected biowaste and the reduction of mixed municipal waste.

Coverage of users by the biowaste collection service

Table 3 shows the coverage of users with biowaste collection service in Sisak, while Table 4 shows the methods of biowaste management.

Table 3. Coverage of users with biowaste collection service in Sisak

Type of user	Total users	With bio service	Without bio service	Coverage (%)
Households	17079	15993	1086	93.6
Non-households	1174	1132	42	96.4

Table 4. Methods of biowaste management

Type of user	Home composting	With bins	No statement
Households	1516	10127	4350
Non-households	0	81	1051

Organized collection covers 93.6 % of households (15993 out of a total of 17079) and 96.4 % of legal entities (1132 out of a total of 1174). Such a level of coverage places Sisak among the towns and cities that have managed to implement a comprehensive biowaste collection system in a short period of time. Data presented in Table 4 further illustrate the methods of biowaste management. Among households, 1516 (around 9.5 %) practice home composting, while the majority - 10127 households (around 63.3 %) use the allocated containers. However, a significant share of households (4350, or 27.2 %) have not yet indicated their method of biowaste management. It is therefore justified to systematically promote home composting as complementary to the collection service. These results show that the system is established and that user coverage has reached a level greater than 90 %, in accordance with the obligations prescribed by law. However, the high proportion of users who have not declared their biowaste disposing method yet, particularly among legal entities, indicates the need for additional education and monitoring of the collection system to achieve its full impact on waste flows in the Town of Sisak.

Figure 2 shows the trend in the cumulative number of containers distributed compared to

the number of households in the Town of Sisak in the period from October 2023 to August 2025.

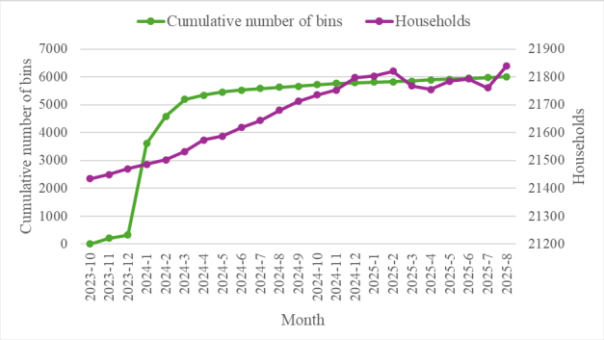

Figure 2. Cumulative number of containers

A sharp increase in the number of containers is clearly visible in the first quarter of 2024. At that time, based on user statements about their preferred model of separate collection, the distribution of biowaste containers began. In just three months (January - March 2024), the number of allocated containers increased from 330 to more than 5000, confirming the intensive implementation of the distribution process. After April 2024, the dynamics of container distribution slowed considerably, which was expected since most users were already covered. In the second half of 2024, the number of containers stabilized at around 5700, reaching 6009 by August 2025. This indicates that coverage of households with individual or shared containers was almost fully achieved. In parallel, the number of households in Sisak remained relatively stable, with only minor monthly fluctuations associated with the moving-in of residents into newly renovated apartments after post-earthquake reconstruction. Overall, the number of households increased from around 21434 in October 2023 to 21840 in August 2025, representing a growth of only 1.9 %. These results confirm that the sharp increase in biowaste quantities after March 2024 was primarily the result of the introduction and distribution of containers, rather than significant changes in the number of service users. Figure 2 clearly illustrates how a technical measure (the introduction of containers) has a decisive impact on establishing a sustainable system of separate collection of biowaste.

Figure 3 shows the distribution of biodegradable waste quantities by source of collection (collection campaigns, recycling yards, collection outside the public service, and household containers) in the period from 2021 to 2025.

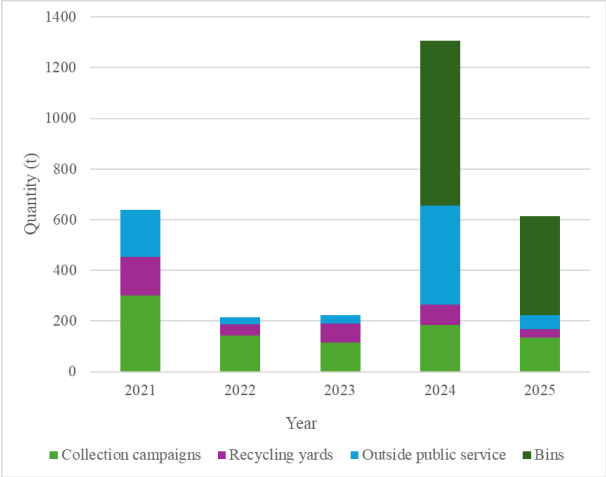

Figure 3. Biodegradable waste by source of collection (2021 - 2025)

In 2021, the largest share of biowaste originated from collection campaigns (300.45 t), while recycling yards and collecting outside the public service system also made a significant contribution. However, in the two following years (2022 - 2023), a decline in the total amount of collected biowaste was observed, particularly due to reductions in waste from recycling yards and collection campaigns. The year 2024 shows a sharp increase in total quantities, marking the first introduction of doorstep containers for biowaste separation. Their implementation in April 2024 resulted in the highest recorded amount of biowaste (457 t) during the observed period, while the quantities of biowaste collected outside the public service system also increased (391.42 t). This growth indicates substantial improvements in the quality of service available to users. In 2025, container-based collection remained the main source (388.41 t), despite a slight decrease in total quantities. This confirms and justifies investment in a biowaste management system. The presented results indicate a complete shift in the dynamics of biowaste collection. Instead of relying on occasional campaigns and recycling yards, collection is now based on an

established system and the continuous operation of household containers. Such an approach contributes to more stable waste flows and higher rates of separate collection. Consequently, this leads to reduced quantities destined for disposal and lower greenhouse gas emissions.

CONCLUSION

The analysis conducted in this study shows that the introduction of separate collection of biowaste via containers has a strong and measurable impact on waste flows in the Town of Sisak. The most significant change is reflected in the increase of separately collected biowaste and the simultaneous reduction of mixed municipal waste. In 2023, only 222.8 t of biowaste was collected, while in 2024, after the introduction of containers, this amount increased to 1306.3 t, representing an increase of 486 %. At the same time, the quantity of mixed municipal waste decreased from 9035.4 t to 7664.7 t, which is a decrease of 15.2 % in one year. Over the longer period, from 2021 to 2024, the total reduction in mixed municipal waste was 37.8 % (from 12328.5 t to 7664.7 t). In the first eight months of 2025, 613 t of biowaste was collected, which already represents 46.9 % of the total amount collected in 2024, indicating a gradual stabilization of the system. The high level of user coverage, with 93.6 % of households and 96.4 % of legal entities included, further confirms that the system was established on a broad scale in a short period of time. The experience of the Town of Sisak shows that targeted measures, supported by citizen participation, can quickly achieve significant results and serve as an example of good practice in biowaste management. Further improvement of the system requires continuous public education on proper biowaste separation. In addition, regular monitoring of service performance is essential to preserve the stability and sustainability of the achieved results.

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