Cemetery waste management in Poland. A case study for Wrocław city

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Abstract: The annual amount of cemetery waste in Wrocław does not exceed 1% of generated municipal waste. The largest amount of cemetery waste is generated in autumn months. For the Osobowicki cemetery, the total volume of containers for selective waste collection has doubled since 2013 and now constitutes 49% of the total volume of containers. Research of the content of selected waste containers revealed the segregation of glass, plastics and biodegradable waste in the range from 81% to 92%. For the St. Lawrence cemetery the volume of containers for selective waste collection constitutes only 6% of the total volume of containers there. Despite these difficulties, the degree of separation of glass and plastics is very high (from 89% to 94%). Increase of the volume of containers for biodegradable waste would reduce the high share of green fraction (from 22% to 38%) in non-biodegradable waste containers.

1 Introduction

Cemeteries are places of worship and remembrance of the deceased. Due to the strongly religious and reflective nature of these objects, it is desirable that there are places neat and well-kept. Cemeteries are one of the elements of spatial development in which waste is generated.

Two basic sources of cemetery waste (CW) can be distinguished. The first of them, which generates about 10% of the waste, is associated with the care and renovation activities in the cemetery. As a result, biodegradable waste (leaves, grass, branches), sand, stones, soils and debris are formed. Second and most dominant source of CW are items brought to the cemetery by visitors in order to decorate and clean-up tombstones This group includes: live and artificial bunches, flowers, candles and cartridges, plastic pots, various types of packaging (plastic, cardboard), as well as textile waste [1–5]. The above-mentioned waste is very often included in the group of multi-material waste. After use, decorative elements are transformed into a stream of waste, which visitors want to get rid of quickly and "on the spot".

Due to the fact of CW generation, it is necessary to create a waste collection system. According to the Act [6], cemeteries are divided into municipal and denominational ones.

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Maintenance of municipal cemeteries (MC) belongs to the city's self-government authorities and denominantional cemeteries (DC)- to the parish. According to Polish legislation [7, 8], waste from cemeteries is classified as a municipal waste group, a subgroup of waste from gardens and parks (including cemeteries) – **20 02**. Packaging waste is also generated in the cemeteries – group **15**.

Due to the fact that CW belong to the municipal waste (MW) group, their management is specified by statute [9], which imposes an obligation to conduct selective waste collection (SC). With regard to CW, a SC system should include glass, plastic and biodegradable waste. The problem in CW collecting may result in the variability of the amount of waste generated over time. In the post-holidays periods (Christmas, Easter, All Saints Day) the amount of waste generated at cemeteries increases significantly [1]. In addition, the collected waste is difficult to process. Literature data show that even a selectively collected biodegradable waste stream, due to impurities, cannot be subjected to composting [10]. There are also no data about effectiveness of the SC of CW.

The following article aims to show the system of CW collection on selected cemeteries located in Wrocław (Poland). Based on the analysis of the research carried out as part of the master's diploma theses at the Faculty of Environmental Engineering of the Wrocław University of Science and Technology in 2013–2018 [2–5], the effectiveness of waste SC system was estimated.

The problem of CW management is rarely mentioned in scientific publications. Therefore it was almost impossible to base the obtained research results on other literature reports. For this reason, this publication seems to be purposeful, as one of the pioneering issues related to the management of CW in Poland, on the example of the Wrocław city.

2 Case study for Wrocław city

Wrocław city is located in the south-western part of Poland and is the capital of the Lower Silesian Voivodship. The city has over 670,000 inhabitants and covers area of 293 km^2. There are 6 MCs and 15 DCs in the city. MCs are characterized by a much larger area (1.27 km^2) than DCs (0.25 km^2). The largest MCs are: Osobowicki cemetery (0.53 km^2), Psie Pole cemetery (0.40 km^2) and Grabiszyński cemetery (0.28 km^2). The largest DCs in Wrocław are: St. Lawrence cemetery (0.04 km^2) and St. Family cemetery.

According to the Polish law [6] the MCs are supervised by the president of Wrocław city. In practice, all Wrocław MCs are managed by the Board of Municipal Cemeteries. All of these facilities are served by WPO ALBA S.A. Wrocław. From season 2012/2013, the SC of CW fractions at MCs has been introduced. In the implementation year, the total volume of biodegradable SC containers, located at 6 MCs, was 158.4m^3 . The volume of glass and plastic fraction containers was 73.4 m^3 and 19.5 m^3 respectively [1]. The volume of containers for non-biodegradable wastes was 393.8 m^3, which accounted for 61% of the total container volume. With the increase of cemeteries 'users' awareness about waste segregation, the number of containers for SC is gradually increasing.

For DCs, where the denominational community is responsible for managing cemeteries, the situation is different. Due to the separate governing bodies of each of the DC, the waste collection system is dispersed and run by various enterprises. Currently, on most DCs at least the fraction of biodegradable waste is released.

Research [1] showed that the total amount of CW generated in Wrocław constitutes about 1% of the total MW stream. Stejskal [11] obtained similar results for 11 cemeteries in Brno (Czech Republic). The largest amount of waste is generated in the following months: October, November and December (successively 32.9%, 19.5% and 13.7% of the total CW stream) [1]. Increased waste stream is associated with the cleaning and preparing

tombstones in pre- and post-holiday periods. A similar trend in the variability of the amount of CW produced over time was noticed in research for Wodzisław Śląski city (Poland) [3]. The estimated research for Wrocław [12] also retains the trend of changes in the amount of waste generated in the annual cycle. According to calculations, 39.5% of the CW stream is generated in the autumn season.

2.1 System of selective waste collection at the Osobowicki municipal cemetery

Osobowicki Cemetery is the largest MC of Wroclaw city with an area of 0.53 km^2. There are currently around 100,000 graves on its site, and burials are still carried out [2]. In 2012 SC of CW, including the fraction of biodegradable waste, glass and plastics, was introduced. Table 1 presents the number and volume of containers for CW in the implementation year 2013 and in 2018.

Table 1. Quantity and total volume of waste containers at the Osobowicki Cemetery in 2013 and 2018 [1, 3].

Type of waste container	**2013**			**2018**		
	Number, pcs.	Volume, m^3	Total volume, m^3	Number, pcs.	Volume, m^3	Total volume, m^3
Non-biodegradable waste	218	1.10	239.80	189	1.10	207.90
Biodegradable waste	61	1.10	67.10	151	1.10	166.10
Green waste	-	-	0.00	12	0.24	2.88
Plastic	50	0.12	6.00	71	0.24	17.04
Glass	50	0.12	6.00	59	0.24	14.16
TOTAL	**379**	**-**	**318.90**	**482**	**-**	**408.08**
Including:						
for SC waste	**161**		**79.10**	**293**		**200.18**

As shown in Table 1, the quantity and volume of containers for SC in 2018 was much higher than in 2013. Year 2013 was the implementation period of SC system. In this time public awareness about the correct waste fractions distribution was very low. In 2013 the share of SC containers constituted only 25%. In season 2013/2014 only about 15% of the CW stream was collected selectively [1].

Over the 5 years period, the total number of containers for waste collection has increased by over 100. The quantity and volume of containers for non-biodegradable waste decreased by 29 pieces and 32 m^3, which is a decrease by 13% compared to 2013. After 5 years since the introduction of the SC system, the overall demand for the volume of SC containers has increased from 79 m^3 to 200 m^3. The volume of containers for biodegradable waste increased almost 2.5 times. Very similar results were also reported for glass and plastic fraction containers. In 2018, the volume of SC containers accounted for 49% of the total volume of the CW containers A sufficient number of containers and their good deployment in the cemetery ensure a well-functioning waste collecting system.

The overall increase in the total volume of containers for waste collection by 27.5% undoubtedly indicates an increase in the amount of CW generated over the analyzed period of time. This trend is consistent with the simultaneously increasing total MW stream. However, it is positive, that from 2013 only the number and volume of containers for biodegradable waste, glass and plastic fraction increased (from 25% to 49%).

The SC waste system is not limited to setting containers for waste fractions. The actual degree of segregation is closely related to the users of the cemetery. Paper [2] includes research about content of individual waste fractions in SC containers. The research methodology included mass analysis of the content of selected containers for non-biodegradable and biodegradable waste as well as for glass and plastics. Obtained results allowed for calculating the percentage composition of each analyzed waste fraction in SC containers. The analyzed waste fractions included: green waste, soil, glass, plastic and other waste, i.e., paper, textiles, metals, wood, stones and other waste groups. The research was carried out in spring (12/05/2018 and 05/06/2018). The results are shown in Table 2.

Table 2. Percentage composition of individual waste fractions in selected containers for non-biodegradable and selectively collected waste at the Osobowicki Cemetery on 12/05/2018 (I) and 05/06/2018 (II) [2].

Waste fraction	**Non-biodegradable waste container composition, %**				**Biodegradable waste container composition, %**		**Glass waste container composition, %**		**Plastics waste container composition, %**	
	I		II		I	II	I	II	I	II
Green	17		13		**81**	**85**	0	0	0	0
Soil	3		6		**2**	**7**	0	0	0	0
Glass	32	**∑=8 3%**	20	**∑=8 7%**	8	0	**90**	**92**	0	0
Plastic	18		42		2	3	5	7	**81**	**92**
Other	30		19		7	5	5	1	18	8

As shown in Table 2, the share of selectively collected fractions in the SC containers ranged from 81% to 92%. These results show a high degree of CW segregation. In the best way the fraction of glass was separated. The main contamination of the glass fraction was made of plastics (from 5% to 7%), including mainly unseparated plastic cartridges. Selectively separated plastic fraction consisted mainly of paraffin contaminated cartridges as well as pots and bags. In containers for plastic fraction, the only hazardous CW-eternal candles- was found. They include batteries, which are a source of power. For the biodegradable waste container, the largest contamination was glass and plastic fraction. In addition, it was observed that a greater share of the green fraction in each container had green conifer waste. For biodegradable waste containers , the total share of this fraction was 50% and 47% in series 1 and 2 respectively.

The content of biodegradable waste in containers for non-biodegradable waste was 13% and 17%. In addition, the significant content of analyzed containers was SC fractions of glass and plastics: 32–20% and 18–42% respectively. As shown in Table 1, the number of containers for non-biodegradable waste at Osobowicki Cemetery is 189, while the number of containers for glass, plastic and biodegradable waste is, in sequence, 59, 71 and 151. These data suggest that containers for non-biodegradable waste are still the most accessible for the cemetery users. Increasing the number of containers for SC waste and locating them near containers for non-biodegradable waste could increase the separation degree of glass, plastic and green fraction.

2.2 System of selective waste collection at the St. Lawrence denominational cemetery

St. Lawrence Cemetery is one of the largest Roman Catholic cemeteries in Wrocław, with area of 0,04 km^2. Still in 2015, there was no full system of selective waste collection. Table 3 presents the number and volume of containers for CW in period 2015–2018.

Table 3. Quantity and total volume of waste containers at the St. Lawrence cemetery in 2015 and 2018 [4, 5].

Type of waste container	**2015**			**2018**		
	Number, pcs.	Volume, m^3	Total volume, m^3	Number, pcs.	Volume, m^3	Total volume, m^3
Non-biodegradable waste	15–30	1.10	16.50–33.00	27	1.10	29.70
Biodegradable waste	-	-	-	1	1.10	1.10
Plastic	-	-	-	2	0.24	0.48
Glass	-	-	-	4	0.24	0.24
TOTAL			**33.00**			**31.52**
Including						
for SC waste:	**-**	**-**	**-**	**7**	**-**	**1.82**

Results presented in table 3 show, that the number and volume of containers for CW in 2015 and 2018 are similar. However, because of changes in the total available volume of waste containers throughout the year, data from 2015 are hard to compare. In 2018, containers for selective collection of biodegradable fraction, glass and plastics were used. However, volume of these containers was only about 6% of the total volume of all available containers.

In analysis [4] it was noted, that no information about SC waste system was posted on the cemetery area. Another problem is bad location of SC containers. Containers for glass and plastics were located in three places: at the main entrance gate to the cemetery, at the main intersection of cemetery alleys and at the back of the cemetery area. The only container for biodegradable waste was placed at the back of the cemetery. Most of the graves are too far away from this container. Therefore, cemetery users throw green waste into non-biodegradable waste containers, which are located along the entire length of the main cemetery paths. The only solution of this problem may be to increase the number of containers for SC and to place them at the main intersections of internal roads of the cemetery.

As in the case of the Osobowicki cemetery, for the St. Lawrence cemetery research about effectiveness of SC were also conducted. In tests containers for non-biodegradable waste (1, 2 and 3), glass waste (4 and 5) and plastic waste (6) were used. The research methodology and division of waste into fractions was the same as in point 2.1. Tests were carried out after Easter, on 24/04/2018. For research at St. Lawrence cemetery, the key stage was appropriate selection of analyzed containers. For testing the composition of non-biodegradable waste containers, intentionally containers located at different distances from biodegradable, glass and plastic fraction containers were used. The container 1 was in the largest and container 3 in the shortest distance from the container for the biodegradable fraction. The results are summarized in tables 4 and 5.

The obtained results indicate that despite the largest distance of container 1 from the biodegradable waste container, the percentage content of green fraction was the lowest (20.6%). The highest share of green fraction in the analyzed containers was recorded for the container 2 located in the middle part of the cemetery. A high content of plastics fraction was observed for container 3, which results from the lack of SC containers in this area of cemetery. Interestingly, for the container 3 placed close to the container for plastic, content of this fraction was almost 45%. That could be caused by a high filling degree of the container for plastic fraction (about 90%) during the research.

Table 4. Percentage composition of individual waste fractions in selected containers for non-biodegradable waste at St. Lawrence cemetery on 24/04/2018 [4].

Waste fraction	Biodegradable waste container (1) composition, %		Biodegradable waste container (2) composition, %		Biodegradable waste container (3) composition, %	
Green	20.6		38.4		22.1	
Soil	4.9	∑= **79.4%**	2.4	∑= **61,6%**	3.1	∑= **77,9%**
Glass	18.3		11.9		9.2	
Plastic	39.2		9.6		44.5	
Other	17.0		37.7		21.1	

Table 5. Percentage composition of individual waste fractions in SC containers at the St. Lawrence cemetery on 24/04/2018 [4].

Waste fraction	Glass waste container (4) composition, %	Glass waste container (5) composition, %	Plastic waste container (6) composition, %
Green	0.1	0.0	0.0
Soil	0.0	0.0	0.0
Glass	**93.7**	**91.8**	8.2
Plastic	5.8	6.5	**89.0**
Other	0.5	1.7	2.8

The results presented in Table 5 shows the SC degree of glass and plastic fractions ranging from 89% to 94%. The largest contamination for the glass fraction were plastics and vice versa – for plastics – glass. Similar results for glass and plastic fraction containers were recorded for research at the Osobowicki Cemetery (table 2). The contamination of the glass fraction results mainly from multi-material construction of candles. Their SC should include separating the glass part from the plastic cartridge. This, however, requires additional work from the cemetery users.

The results obtained and summarized in Tables 4 and 5 show that the users of the cemetery are the most decisive in determining the degree and efficiency of selective waste collection. Even the correct placement of CW containers does not guarantee compliance with the rules of selective waste collection system.

3 Conclusion

Cemeteries are public facilities on which waste is generated. CW collection should be carried out in a selective way, including the fraction of biodegradable waste, glass waste and plastics. The impact on the SC efficiency has the number of waste containers as well as their appropriate location in the cemetery area. The human factor is also decisive.

There are 6 MCs and 15 DCs in Wrocław city. The annual amount of emerging cemetery waste accounts for about 1% of the total weight of generated MW. The amount of CW varies throughout the year. The largest amount of generated CW is observed in autumn months – October, November and December. This is mainly related to the celebration of Catholic holidays.

On MCs in the years 2012–2013, SC systems were implemented. For the biggest MC-Osobowicki cemetery- the volume of containers for selective waste collection is currently almost 50% of the total volume of containers and is twice as high as in the implementation year 2013. Research of the content of waste fractions in SC containers revealed the segregation of glass, plastic and biodegradable waste at the level of 80–90%. Reducing the

number of containers for non-biodegradable waste in favour of containers for SC of biodegradable, glass and plastic waste would allow to increase the degree of waste segregation.

The situation in DCs is different. Results clearly indicate that at the St. Lawrence cemetery the number of SC containers is too small. Mass analysis of containers for collection of glass and plastic waste showed the content of these fractions in the range from 89% to 94%. Unfortunately, too small volume of biodegradable waste container and its bad location caused a high content of green fraction (from 20% to 38%) in non-biodegradable waste containers. However, the high separation degree of glass and plastic fractions suggests that increasing the volume of containers for SC, including containers for biodegradable waste, would enable a more efficient separation of waste fractions.

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