HUNGARIAN JOURNAL OF
INDUSTRY AND CHEMISTRY
Vol. 51(1) pp. 61–66 (2023)
hjic.mk.uni-pannon.hu
DOI: 10.33927/hjic-2023-09

INVESTIGATION OF REGIONAL DIFFERENCES IN THE ORGANIC FRACTION OF MUNICIPAL SOLID WASTE IN HUNGARY

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Municipal solid waste management is crucial in terms of the environment, sustainability and the circular economy. The directly landfilled organic fraction of municipal solid waste (OFMSW) offers a lot of potential with regard to energy recovery or as a soil substrate. In this study, the regional differences in Hungary according to various living structures and conditions (villages and urban areas) were demonstrated to provide a foundation for further usage or treatment. The fact that the biological fraction (leaves, kitchen waste and fine soil-like material) of OFMSW from typically urban areas like the examined city of Pécs is larger than in a rural area, e.g. Marcali District, was highlighted. On the other hand, the OFMSW from rural areas contains more hazardous materials such as medicinal ampoules due to the lack of possibilities to dispose of them suitably. After evaluating the composition of the OFMSW, the directly landfilled quantity of MSW could be further reduced. In conclusion, according to the high proportions of plastic and paper as well as its promising heating value, the largest particle size fraction (>4 cm) could be utilized as refuse-derived fuel (RDF) and the finer, organic material-rich fraction as a soil substitute following further purification.

Keywords: OFMSW, regional differences, RDF, MBT

1. Introduction

Despite being well-engineered, landfilling is one of the least favorable waste management methods because of the significant environmental risk presented by it (leaching, methane formation) [1]. The EU Landfill Directive to accelerate the transition to a circular economy has introduced restrictions on landfilling to decrease the total amount of municipal waste deposited to under 10% by 2035 without exception [2]. In Hungary, the OFMSW is less than 60-80 mm in diameter and separated by a trommel screen during Mechanical Biological Treatment (MBT). The OFMSW has a big share of the total quantity according to studies, 40-85% of the total MSW in fact [3] depending on the country concerned, the majority of which is found at least 100 mm below the surface [4]. Accordingly, the reduction in the organic fraction as a result of energy recovery or other utilizations will effectively fulfill the Directive. Regional differences were mainly observed in the composition of the OFMSW. Differences between nations and regions are observed, moreover, the causal factors are the various infrastructure developments, the current situation of the inhabitants and the classification of the categories [5]-[8]. The utilization of waste remains an unresolved issue worldwide. Due to its high level of plastic content, the OFMSW could be used in energy recovery as refuse-derived fuel (RDF) or as a raw material for pyrolysis/gasification. Besides, anaerobic digestion is also a promising solution to utilize the OFMSW [9]-[12]. On the other hand, fine fractions could be used in construction materials such as in bricks [13] as well as a substitute for planting soil throughout their analysis and purification [14]. Consequently, the importance of investigating the OFMSW can be recognized because its usage largely depends on its material composition and physico-chemical properties. In addition, the quality of waste streams could be improved by raising public awareness as well as educating people about the importance of waste separation and using the available services to not only separate the usual recyclable materials but also compost, kitchen waste, garden waste, etc.

2. Materials and methods

2.1. Raw materials

In this study, samples from two different Hungarian waste collection regions were examined, which were collected from the Marcali és Térsége Közszolgáltató

Received: 31 March 2023; Revised: 11 April 2023;
Accepted: 14 April 2023
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Nonprofit Kft. (MTKSZ) and Dél-Kom Nonprofit Kft. (Kökény). MBT technologies and the day of sampling were identical in both cases to ensure the OFMSW data could be evaluated by only considering the regional differences. Stabilization periods also apply in both technologies.

MBT is carried out on the non-hazardous waste inside the plants; the technological scheme of MBT is shown in *Figure 1*. The first step of mechanical processing is the weighing and shredding of the waste into particle sizes of <350 mm in diameter before the magnetic metals are separated. The next step is trommel sorting where the biological waste stream of particle size <60 mm in diameter (OFMSW) is removed for further treatment. The residue of OFMSW (>60 mm in diameter) passes through an Eddy Current Separator (ECS) where the non-ferrous metals are recovered before the air separation unit divides the waste stream into two parts. The heavy fraction containing mostly stones and bricks is dumped directly in a landfill site. The light and middle fractions are driven through a post-treatment shredder (<50mm) and a second magnetic separation where the excess ferrous metals are extracted from the waste stream. The residue for refuse-derived fuel (RDF) is baled. The input of the Kökény plant is 116,979,583 kg/year, moreover, the RDF and organic fraction produced are 39,528,620 kg/year (34%) and 46,899,164 kg/year (40%), respectively, based on data from 2018-2021 [15]. The capacity of the MTKSZ plant is smaller, the input of which was 25,185,980 kg according to data recorded in 2021 from which 10,444,850 kg (35%) was RDF and 11,746,624 kg (40%) the organic fraction [16].

2.2. Stabilization process

Before the stabilization process was conducted over 28 days, size separation was carried out by a CZ screen MS MICRO Mobil-type vibrating screener using screening nets 1, 2 and 4 cm in diameter. The masses of the different particle size fractions were recorded and the fractions larger than 1 cm in diameter transferred to an open container for stabilization. The sample was homogenized and left in a prism shape to cure. On the 7th day of every week, the screening process was repeated and its mass remeasured before the fractions bigger than 1 cm in diameter were stabilized in the container according to the same method. This procedure lasted 28 days (4 weeks). The fraction smaller than 1 cm in diameter was extracted from the stabilization process after every screening. To determine the moisture content (MC), after every screening process, 3 parallel samples were collected from the fraction <1 cm in diameter before being dried at 105 °C to constant weight in a drying oven and the MC calculated from the data.

2.3. Measurements using stabilized samples

The material composition of the different fractions was determined by hand sorting and the mass of each recorded. The fraction with a diameter of <1 cm was separated into two size ranges, namely 0-0.5 and

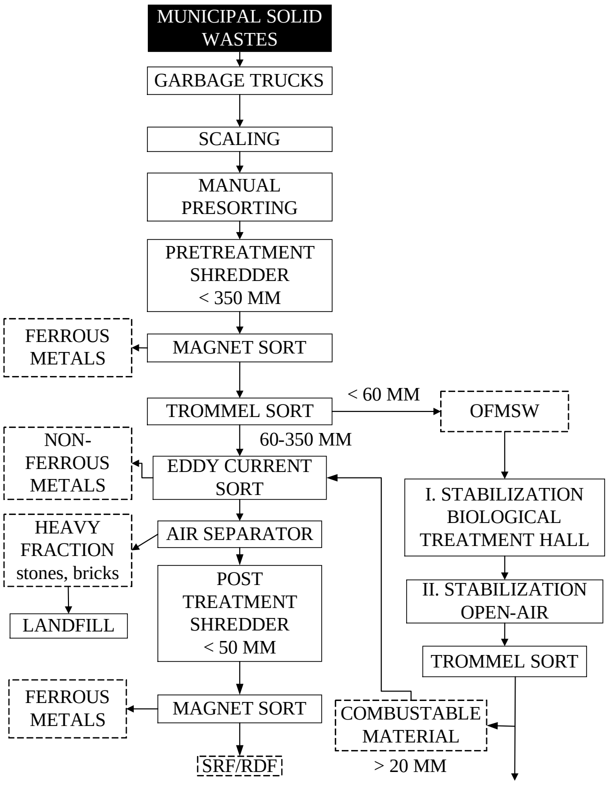

Figure 1. Technological scheme of the MBT plants in Marcali and Pécs

0.5-1 cm, the compositions of which were only defined as foreign and organic fractions because the fraction of <0.5 cm in diameter resembles a fine, soil-like material, while the one 0.5-1 cm in diameter contains more foreign material.

Furthermore, while investigating the utilization of OFMSW fractions for energy-recovery purposes, a lower heating value was detected from shredded samples dried to constant weight by a Parr 6200 Isoperibol calorimeter.

3. Results and Analysis

3.1. Mass loss

Figure 2 shows the mass reduction during the examined period. The mass loss over the first 7 days was the highest, that is, 29% (from 23.5 to 16.6 kg) and 34% (34.4 to 19.9 kg) in the cases of the Marcali and Pécs samples, respectively. After the second week, their masses stabilized, so the main mass loss occurred during the first 14 days. Accordingly, regarding the reduction in transportation costs, a two-week-long stabilization process is sufficient.

3.2. Moisture content

Figure 3 demonstrates the continuous decrease in moisture content throughout the stabilization process. The moisture content of the Marcali sample was higher at the beginning (54.43%) than in the Pécs sample (46.51%) but dropped rapidly. After 28 days, the MC of the Marcali and Pécs samples were 31.10 and 24.78%, respectively.

3.3. Particle-size distribution

During the 28-day-long stabilization process, the weights of each particle size fraction (<1, 1-2, 2-4 and >4cm in diameter) were recorded after every screening as presented in *Figure 4*. Although the fraction 2-4 cm in diameter was largest each week, the >4 cm one was also significant. In the case of the <1 cm fraction, the amount increased constantly as the stabilization process progressed. In the case of the Pécs sample, <1 cm-sized particles were produced in larger amounts because of their higher organic content and the fine particles derived from it.

3.4. Composition

Once the 28-day-long stabilization process had finished, the material composition of the different fractions of >1 cm in diameter was analyzed by hand sorting. The samples were categorized into 8 fractions: hazardous (batteries, medicinal ampoules, hygiene products), glass, stone (porcelain, bricks, gravel, rocks), textile, metal, organic (garden waste: leaves, pine cones, bark, twigs, seeds; kitchen waste: bones, food waste, etc.), paper and plastic (all types of plastics combined).
The composition of the fraction 1-2 cm in diameter was as follows: plastic (Pécs: 15%, Marcali: 10%), paper (Pécs: 15%, Marcali: 22%), organic (Pécs: 24%, Marcali: 13%), hazardous (Pécs: 3%, Marcali: 4%), glass (Pécs: 32%, Marcali: 33%), stone (Pécs: 8%, Marcali: 16%),

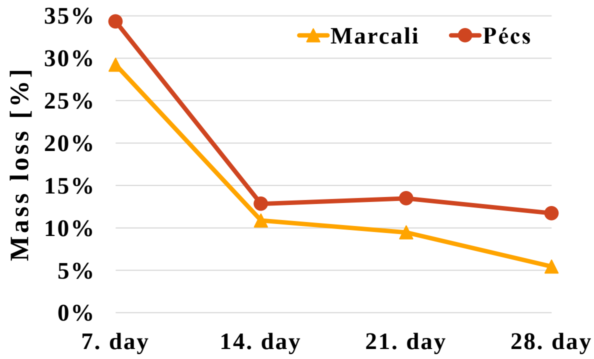

Figure 2. The mass loss of the Marcali and Pécs samples during the 28-day-long stabilization process compared to on Day 0

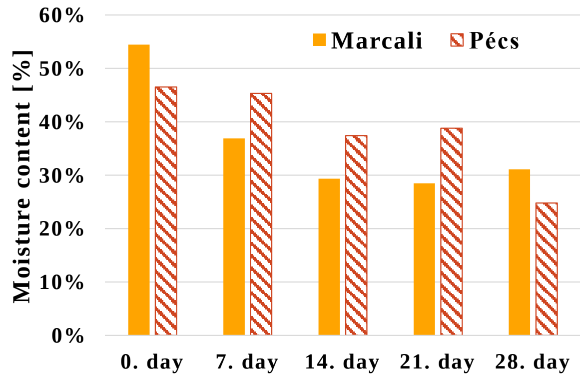

Figure 3. Moisture content of the <1cm particle size fractions from the Marcali and Pécs samples during the stabilization period

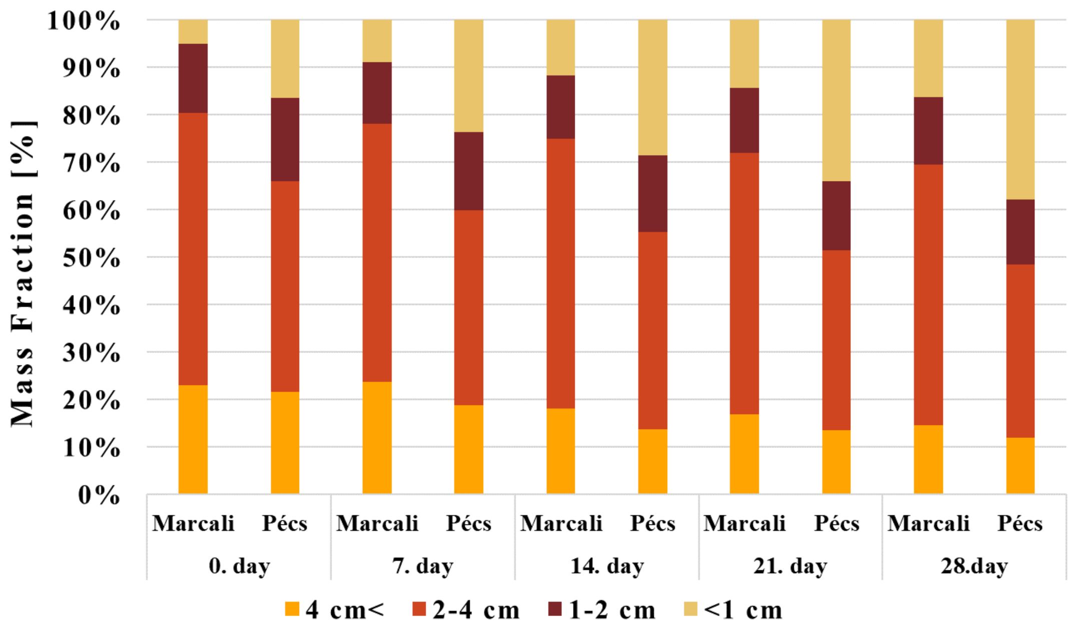

Figure 4. Composition of particle size fractions in samples from Marcali and Pécs during the stabilization process

textile (Pécs: 1%, Marcali: 0%) and metal (Pécs: 2%, Marcali: 2%). The composition of the fraction between 2-4 cm in diameter was the following: plastic (Pécs: 24%, Marcali: 15%), paper (Pécs: 18%, Marcali: 17%), organic (Pécs: 15%, Marcali: 14%), hazardous (Pécs: 0%, Marcali: 3%), glass (Pécs: 19%, Marcali: 25%), stone (Pécs: 24%, Marcali: 23%), textile (Pécs: 1%, Marcali: 2%) and metal (Pécs: 0%, Marcali: 2%). Compared to studies from other nations, even though it can be seen in Poland that the organic OFMSW fraction is almost twice as large as in Hungary, the plastic fraction >4 cm in diameter is approximately 10-40% depending on the season similar to in Hungary [17]-[18]. Another similar study in the vicinity of Taipei in Taiwan shows that food waste is responsible for 34% of OFMSW in total like in the areas investigated by us, while only 17% of it consists of plastic which is lower than the average in Hungary (~25-30%). In the vicinity of Taipei, paper has the biggest share of 43%, significantly higher than that recorded in Hungary (~15-30%) according to the samples from Pécs and Marcali [19].

Based on the results of hand sorting, the organic fraction that originated predominantly from kitchen waste is the largest with a diameter <4 cm. >4 cm in diameter, the organic fraction accounts for only 8% and 6% of the samples from Marcali and Pécs, respectively, which presumably originated mostly from garden waste. Although the proportion of the organic fractions 1-2 and 2-4 cm (12-15%) in diameter accumulated in equal measure in the Marcali sample, this total accounted for 38% in the Pécs sample from which 24% was found between 1 and 2 cm in diameter. The higher organic content could be a result of the different living conditions, which could be backed up by regional living and structural conditions. The area served by MTKSZ consists of 28 settlements, including 27 villages and 1 town (Marcali). 59% of the inhabitants, that is, 16,692 in total, live in village-like conditions in the 27 settlements of the region, 49% of which (11,541 habitants) live in the small town of Marcali. The Kökény plant collects waste from 319 settlements, of which 301 are villages and 18 are towns/cities (including Pécs). Two thirds (67%, 287,427) of the inhabitants live in urban areas and the county seat, Pécs, accounts for nearly half of them (145,985). 33% of the inhabitants live in rural areas (139,465). This data shows that in the case of the area served by Kökény, the majority of inhabitants come from urban areas, where the main residential form are blocks of flats instead of detached houses with gardens and their own yards, so most do not have the opportunity to compost or keep livestock, moreover, separating garden waste is neither compulsory nor widespread as a result so more organic matter ends up in the communal waste stream than is treated by MTKSZ. The differences are presented in *Figure 5*. This observation also applies to the quantity of the fine fraction of <1 cm in diameter which is more abundant in the urban area (Pécs) than in the countryside. The share of the plastic fraction increases as the particle size of OFMSW increases, therefore, for the fraction >4 cm in diameter, the proportion of plastics is about a third of the total mass in both samples (Pécs: 39%, Marcali: 33%). Regarding the fraction >4 cm in diameter, paper has the second biggest share with 29% (Pécs) and 27% (Marcali). It can be concluded that in the case of the plastic and paper fractions, the region does not influence their quantities too significantly.

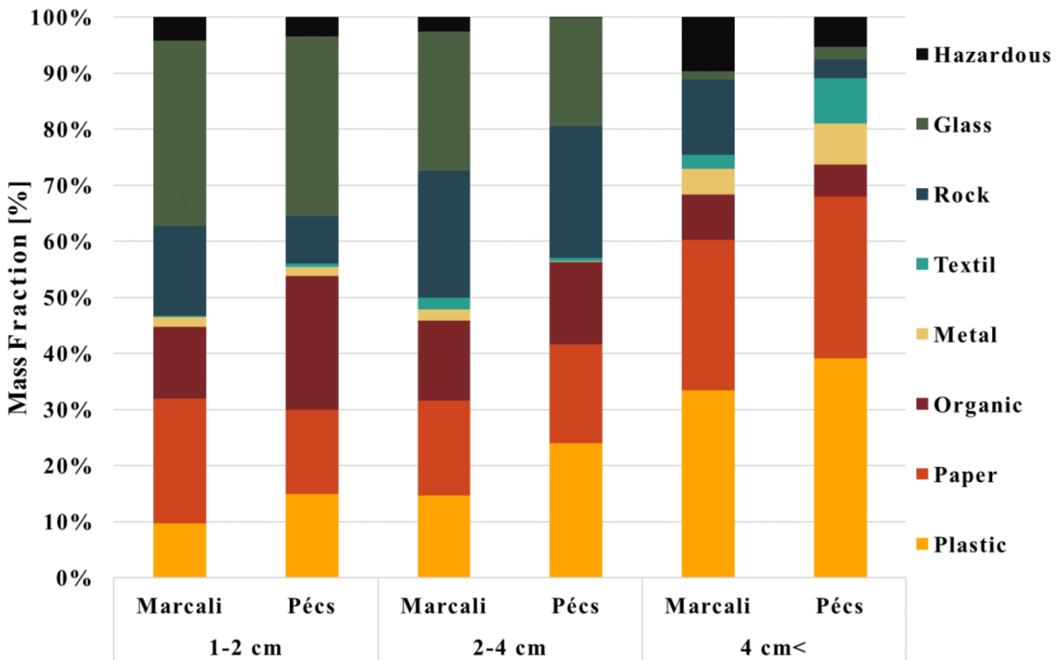

Figure 5. Material composition of the particle size fractions in samples from Marcali and Pécs after a 28-day-long stabilization process

The final third is divided among the rest of the fractions (organic (Pécs: 6%, Marcali: 8%), hazardous (Pécs: 6%, Marcali: 10%), glass (Pécs: 2%, Marcali: 1%), stone (Pécs: 3%, Marcali: 14%), textile (Pécs: 8%, Marcali: 3%) and metal (Pécs: 7%, Marcali: 5%)). It should also be mentioned that since the density of inert fractions such as glass, stone and ceramics is higher than their paper and plastic counterparts, their mass is significant even though they occur in small proportions. In the Marcali sample, the most hazardous material comprising 10% is found in the fraction >4 cm in diameter because it is more difficult to dispose of such waste correctly in rural areas. The glass fraction is mainly 1-2 cm in diameter as a result of fragmentation during waste processing.

3.5. *Lower heating value*

In the fractions between 2 and 4 cm in diameter, the lower heating values of samples from Marcali (12.28 MJ/kg) and Pécs (13.05 MJ/kg) are nearly as high as the average value of dry firewood (17-20 MJ/kg) [20]. In fractions with diameters >4 cm, the lower heating values are even higher (Marcali: 24.57 MJ/kg, Pécs: 22.68 MJ/kg) and comparable with brown coal (21-25 MJ/kg) [21]. The minimum heating value required according to WHO is 6500 MJ/kg for incineration plants [22]. The results regarding the heating values of the plastic fractions are shown in *Figures 6 and 7*. Due to the high lower heating value and plastic content as well as the low quantity of the organic fraction with a diameter of >4 cm, the average diameter following trommel sorting could be downsized to 4 cm instead of 6-8 cm.

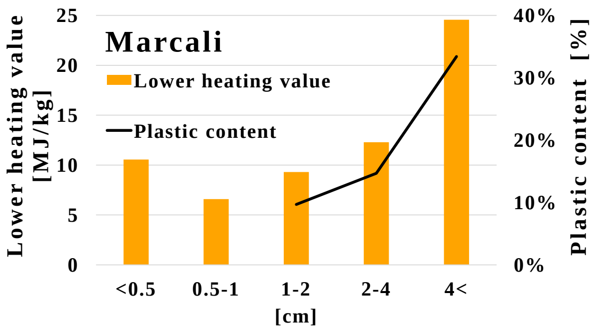

Figure 6. Lower heating values and plastic content of the samples from Marcali

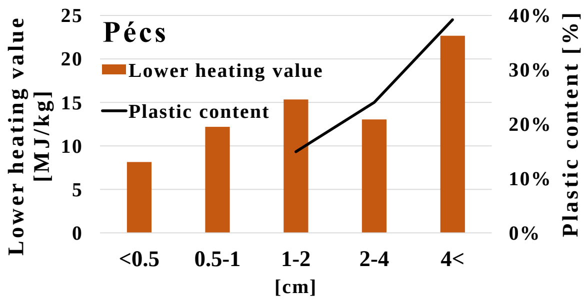

Figure 7. Lower heating values and plastic content of the samples from Pécs

4. Conclusion

The following observations can be made:

1. Since the size of the directly landfilled fraction of MSW can be reduced due to the separation of kitchen and food waste, the organic fraction of OFMSW is as high as 60% in the sample from Pécs.
2. The reduction in the average diameter following trommel sorting will improve the amount of plastic recovered. As was demonstrated in the fraction >4 cm in diameter, plastic and paper have a big share of this fraction, which could be utilized as RDF because of its high lower heating value of 24.57 MJ/kg.
3. The fraction with a diameter of <1 cm could be used as a substitute for planting soil after further purification.
4. Given that regional differences in the composition of MSW are observed caused by the various living structures and conditions, no one-size-fits-all solution can be suggested with regard to technologies and the order of sorting.

Acknowledgements

This work was implemented by the project TKP2021-NKTA-21 with support provided by the Ministry of Culture and Innovation of Hungary as well as the National Research, Development and Innovation Fund financed under the 2021 Thematic Excellence Programme.

The authors are grateful to Dél-Kom Nonprofit Kft. and Marcali és Térsége Közszolgáltató Nonprofit Kft. for providing information.

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