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BASIC GEOTECHNICAL PARAMETERS OF BIODRIED WASTE FROM WINTER AND SUMMER PERIOD

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ABSTRACT: One of the possible ways of disposing of municipal solid waste (MSW) is mechanical-biological treatment (MBT), originally developed in Germany with the aim of reducing the amount of biodegradable waste before landfilling. The process consists of a mechanical treatment step in which the waste is mechanically separated to collect recyclable materials, and a biological treatment step in which the waste can be treated by biodrying, composting or digestion of the organic fraction and has several types of outputs (waste fuel, stabilised organic waste, ferrous and non - ferrous metals, and inert waste). Apart from useful products, one part of the waste from the MBT process cannot be used as waste fuel or recyclable material but is still quite rich in organic matter. This type of waste, called the methanogenic fraction, goes to a bioreactor landfill where water is added and recirculated, in order to accelerate or increase the biodegradation of biodried waste, after which biogas is extracted. Bioreactor landfills are equipped with liners and leachate collection systems. Contrary to the usual so-called “dry” landfills, bioreactor landfills will experience faster settlements due to an increased solid waste decomposition rate, and increased pressure due to increased unit weight. Adding water to the waste to increase the biological activity increases the total mass of the waste which can cause an increase in pore pressure. For these reasons, it is necessary to determine the basic geotechnical parameters of waste disposed into bioreactor landfills. This paper presents the established basic geotechnical parameters (moisture content, organic matter content and particle size analysis of waste) and other properties (waste composition, waste classification by form into 1D, 2D and 3D shapes), on samples of the methanogenic fraction with maximum particle size of about 25 mm. Waste samples were taken during the winter (February 2019) and summer (July 2020) periods from the Croatian Waste Management Centre, Marišćina. In order to establish the influence of seasonal variation of waste material the obtained basic geotechnical parameters were compared. The comparison shows small differences which could be attributed to the heterogeneity of the studied waste material. Nevertheless, samples from both time periods are very similar, and therefore they should not cause major differences in plant operation during the year.

Keywords: Biodried waste, Bioreactor landfill, methanogenic fraction, basic geotechnical parameters

1. INTRODUCTION

In accordance with the Waste Framework Directive 2008/98/EC implemented by the Government of the Republic of Croatia, the concept of waste management hierarchy is prescribed in which the most desirable option is waste prevention, and the least desirable option is landfilling. Between these two possibilities, there is a wide range of waste treatment techniques and technologies that can be used as part of a waste management strategy for the recovery and recycling of materials, or the production of energy from waste.

One of the possible ways of disposing of municipal solid waste is mechanical-biological treatment (MBT). MBT technology was developed in Germany with the aim of reducing the amount of biodegradable waste before landfilling (Nelles M. et al., 2012).

The process consists of a mechanical treatment step in which the waste is mechanically separated to collect recyclable material, and a biological treatment step in which the waste can be treated by biodrying, composting, or digestion of the organic fraction, and has several types of outputs (waste fuel, stabilised organic waste, ferrous and non - ferrous metals, and inert waste).

Biodrying is a variant of aerobic decomposition, used in MBT plants for drying and partial stabilisation of municipal solid waste (Velis et al., 2009).

Apart from useful products, one part of the waste from the MBT process cannot be used as waste fuel or recyclable material but is still quite rich in organic matter. This type of waste goes to the bioreactor landfill where water is added and recirculated, in order to accelerate or increase the biodegradation of the biodried waste, after which biogas is extracted.

Bioreactor landfills are equipped with liners and leachate collection systems. Leachate recirculation creates a suitable environment for the rapid microbiological degradation of biodegradable solid waste. One of the most important and critical parameters that affects the biodegradation of municipal solid waste is the moisture content, which can be practically controlled by recirculation (Reinhart and Townsend, 1998).

Contrary to the usual so-called “dry” landfills, bioreactor landfills will experience faster settlement due to increased solid waste decomposition rate and increased pressure due to higher unit weight. Adding water to the waste to increase the biological activity increases the total mass of the waste which can cause an increase in pore pressure. For these reasons, it is necessary to determine the basic geotechnical parameters of waste disposed of in bioreactor landfills.

This paper presents the established basic geotechnical parameters (moisture content, organic matter content and particle size analysis of waste) and other properties (waste composition, waste classification by form into 1D, 2D, 3D), on samples of biodried mixed municipal solid waste. Waste samples were collected during the winter period (February 2019) and during the summer period (July 2020) from the Waste Management Centre Marišćina, Primorje-Gorski Kotar County located in the Viškovo municipality.

2. MATERIALS AND METHODS

2.1 Waste treatment technology in Waste Management Centre Marišćina

Samples of mixed municipal solid waste are subjected to a mechanical treatment step where the waste undergoes sieving, separation, and other processing steps. In this step, the waste is separated into two fractions i.e., a finer (< 200 mm) and a coarser fraction (> 200 mm). The coarser fraction is sent for further mechanical treatment, whereas the finer fraction goes to a biological treatment step. After that, the waste is deposited in concrete chambers in which the moisture content in the material is reduced by a biodrying process i.e., forced ventilation (aeration) for seven to ten days.

In order to obtain as much recovery material as possible, the biodried material is sieved again and subjected to various mechanical refining procedures (sieving, separation of light and heavy materials in an air separator, optical separation of polyvinyl chloride-NIR) in order to separate recyclable materials (plastics, metals, non - ferrous metals). (Sarc et al., 2018)

In this stage of processing, the so-called methanogenic fraction, with maximum particle size of about 25 mm (Figure 1) is separated. This type of material is disposed of in a bioreactor landfill located within the Waste Management Centre Marišćina. After the closure of the bioreactor landfill and recirculation of the leachate, biogas should be produced.

Figure 1. Methanogenic fraction of biodried waste – winter sample

2.2 Sampling and storage

The samples were delivered from the waste treatment plant in the Waste Management Centre Marišćina to the Laboratory for Environmental Engineering of the Faculty of Geotechnical Engineering, in plastic bags from which air was extracted by a hand pump to minimise biodegradation and unpleasant odours during transport of the samples to the laboratory. The sampling of the waste material for winter and summer periods is shown in Figure 2.

a)  b) 

Figure 2. Sampling of the a) winter period sample; b) summer period sample

2.3 Moisture content

Moisture content was determined according to ASTM D 2216 standard for determining soil moisture by measuring mass before and after drying in an oven. Since it is a material rich in organic matter, the temperature in the dryer was 60°C (Figure 3).

Figure 3. Winter waste samples prepared for drying

2.4 Organic matter content

The procedure for measuring the organic matter content was adapted and adopted from ASTM D 2974 standard for Moisture, Ash, and Organic Matter of Peat and Other Organic Soils. A representative sample of 50 g was prepared according to mass percentages shown in Table 1 and Table 2. Each waste component was weighed separately with a laboratory balance and placed in ceramic containers (Figure 4a). The organic matter content of waste samples was determined by ignition in a pre-calibrated furnace at 440°C over a period of 24 h (Figure 4b). Based on the difference in mass before and after the ignition, the percentages by weight of organic matter content were determined.

a)  b) 

Figure 4. a) Weighing of samples with a laboratory balance; b) Ignition in furnace at 440°C

2.5 Waste composition

Representative samples of 30 kg of mechanical-biological treated waste from the summer and winter periods were prepared with the quartering method. The quartering method involves scattering the sample on a solid surface and mixing well. It is then divided into four equal parts by means of a hand tool, of which two diagonally opposite parts are discarded. With the remaining two parts of the sample, the procedure is repeated, until a sufficiently small amount of representative sample is obtained for testing (approximately 1 kg samples in this paper for winter and summer periods). The individual components of the waste were manually separated (Figure 5) and weighed to determine the mass fraction of each waste component for each time period. The part of the waste that could not be identified or separated is a mixture of ingredients and is placed in the category "Unidentified".

Figure 5. Manual separation of fine fraction by waste components

2.6 Particle size analysis

A total of 25 samples for the winter period and 14 samples for the summer period were sieved on a series of sieves as follows: 31.5, 16, 8, 4, 2, 1 and 0.5 mm. The procedure for determining the particle size analysis of waste particles was adopted from ASTM D 422 standard (Particle-Size Analysis of Soils). Waste samples after drying in an oven at 60°C were sieved through a set of sieves as previously described for a minimum of 10 minutes. The masses of individual samples ranged between 231 and 600 g for winter period samples, whereas for summer period samples, the masses ranged between 154 and 330 g.

2.7 Classification of waste samples into 1D, 2D and 3D shapes

The procedure for classifying materials into 1D, 2D and 3D particle sizes was made according to Velkushanova K. (2011b). The detailed procedure is shown below:

a) After the waste was manually sorted according to the composition of paper, plastic, glass, wood, etc. (Table 1 and Table 2), within each component of the waste based on the personal assessment of the researcher, the classification of particles by shape into 1D, 2D and 3D (Figure 8 and Figure 9) was again made manually. A total of two representative waste samples were separated for each time period, after which the mean values were calculated based on the mass percentages (Table 4 and Table 5). In addition, the size frequency of the classified materials mass fractions was calculated (see Table 6) with respect to the mean values of the total separated amounts of studied waste material from Table 4 and Table 5.

b) Unidentified waste was sieved on a 2 mm sieve due to the impossibility of classifying particles according to the shape, and thus separated into a fraction < 2 mm which contributes to the shear strength by friction, and > 2 mm which contributes to the tensile strength according to Velkushanova (2011a). This waste fraction is classified as 0D particle size and is considered to form a “matrix”.

3. RESULTS

3.1 Moisture content

On a series of multiple samples, the moisture content for winter period material ranged from 5.44 to 10.84% with a mean value of 9.60%. For summer period samples, the moisture content ranged from 9.35 to 11.04% with a mean value of 10.13%. When calculating the mean value, the highest and lowest obtained moisture content values were not considered.

It can be seen that the moisture content results of both samples are low, which shows that both waste samples were successfully subjected to the biodrying process.

3.2 Organic matter content

Based on the difference in mass before and after ignition in the furnace at 440°C for 24 h, the percentages by weight of organic matter burned during ignition were determined. The total weight percentage of biodegradable fraction for all components together was 51.6% for the winter period waste sample. For the summer period waste sample, the total weight percentage of biodegradable fraction for all components together was 55.3%.

3.3 Waste composition

Plastic, glass, paper/cardboard, rocks and kitchen waste were found to be the five most common components in the tested samples for the winter and summer periods (Table 1 and Table 2).

Table 1. Mass values and percentages of individually separated components for the methanogenic fraction of studied material – winter period

	Sample 1		Sample 2	
Component	Mass of separated components [g]	Percentage by mass [%]	Mass of separated components [g]	Percentage by mass [%]
Plastic	69	6.36	50	6.49
Textile	2	0.18	2	0.26
Glass	129	11.90	72	9.34
Metals	12	1.11	6	0.78
Paper/cardboard	50	4.61	37	4.80
Wood	13	1.20	9	1.17
Bones/skin	3	0.28	1	0.13
Rocks	29	2.68	22	2.85
Ceramics	1.6	0.15	6	0.78
Rubber	0	0.00	2	0.26
Kitchen waste	34	3.14	9	1.17
Unidentified				
Unidentified >2 mm	475	43.84	317	41.12
Unidentified <2 mm	266	24.55	238	30.87
Total	1083.6	100	771	100

Table 2. Mass values and percentages of individually separated components for the methanogenic fraction of studied material – summer period

	Sample 1		Sample 2	
Component	Mass of separated components [g]	Percentage by mass [%]	Mass of separated components [g]	Percentage by mass [%]
Plastic	73	6.26	47	4.24
Textile	5	0.43	7	0.63
Glass	100	8.58	103.6	9.34
Metals	11	0.94	11	0.99
Paper/cardboard	54	4.63	70	6.31
Wood	80	6.86	40	3.61
Bones/skin	5	0.43	3	0.27
Rocks	100	8.58	14	1.26
Ceramics	7	0.60	10	0.90
Rubber	7	0.60	2	0.18
Kitchen waste	17	1.46	47.4	4.27
Unidentified				
Unidentified >2 mm	369	31.65	439	39.59
Unidentified <2 mm	338	28.99	315	28.40
Total	1166	100	1109	100

Table 3 shows the mean values of two samples per time period of mass percentages of the composition of studied waste material for the winter and summer time periods. The mass percentages are calculated mean values of sample 1 and sample 2 from Table 1 and Table 2, respectively.

Table 3. Mean values of mass percentages of the composition for the methanogenic fraction of biodried waste for winter and summer period

Component	Mass percentages – mean value [%] Winter period	Mass percentages – mean value [%] Summer period
Plastic	6.43	5.25
Textile	0.22	0.53
Glass	10.62	8.96
Metals	0.94	0.97
Paper/cardboard	4.71	5.47
Wood	1.18	5.23
Bones/skin	0.20	0.35
Rocks	2.76	4.92
Ceramics	0.46	0.75
Rubber	0.13	0.39
Kitchen waste	2.15	2.87
Unidentified	-	-
Unidentified >2 mm	42.48	35.62
Unidentified <2 mm	27.71	28.70
Total	100	100

Comparing mean values of mass percentages for the winter and summer waste sample from Table 3, it can be concluded that the summer sample contains significantly more wood and rocks while the other waste components are quite similar. Figure 6 shows the results of the mean values of mass percentages of the composition for both time periods as a graph with corresponding trendline.

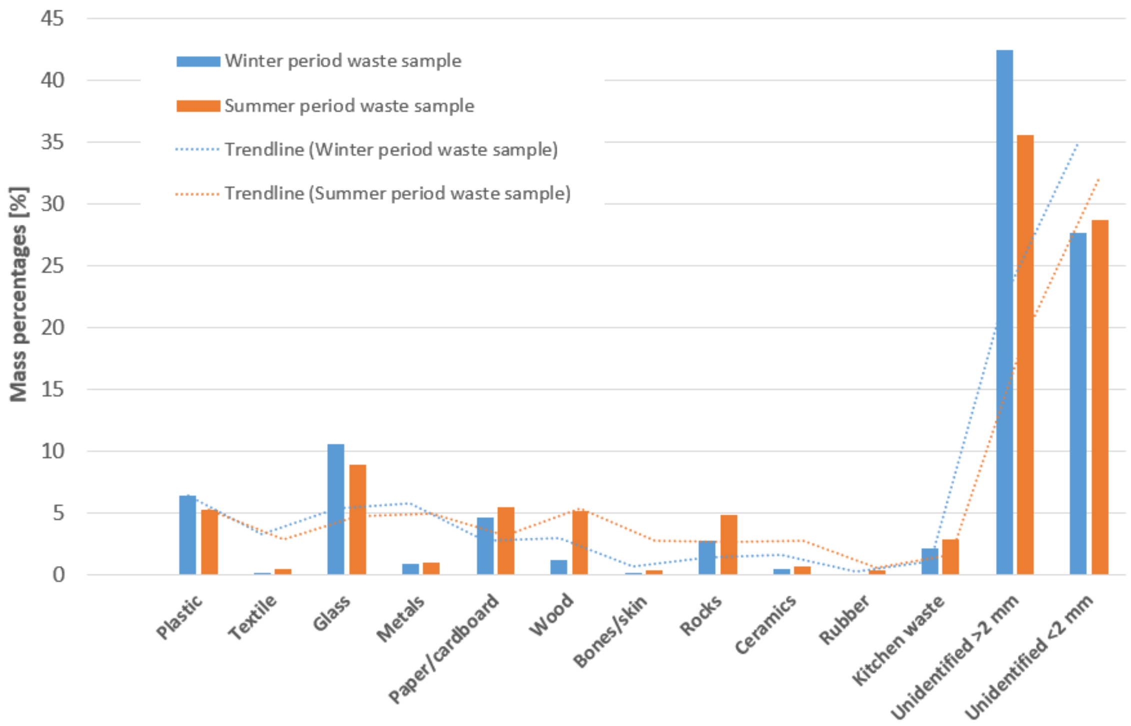

Figure 6. Mean values of mass percentages of waste components

All components, except wood, have a slope resembling the trend line indicating that the waste material sampled during the winter and summer periods is very similar.

3.4 Particle size analysis

The mean value of the particle size distribution curve for the methanogenic fraction for the winter and summer samples from Waste Management Centre Marišćina is shown in Figure 7.

According to the USCS, the waste samples from Waste Management Centre Marišćina can be classified as coarse-grained material. The coefficient of curvature and the coefficient of uniformity for the average particle size distribution curve for the winter sample are Cc = 0.76, and Cu = 15.86, whereas for the summer sample Cc = 1.36, and Cu = 12.49, which means that both summer and winter waste material are well graded materials that can be compacted well.

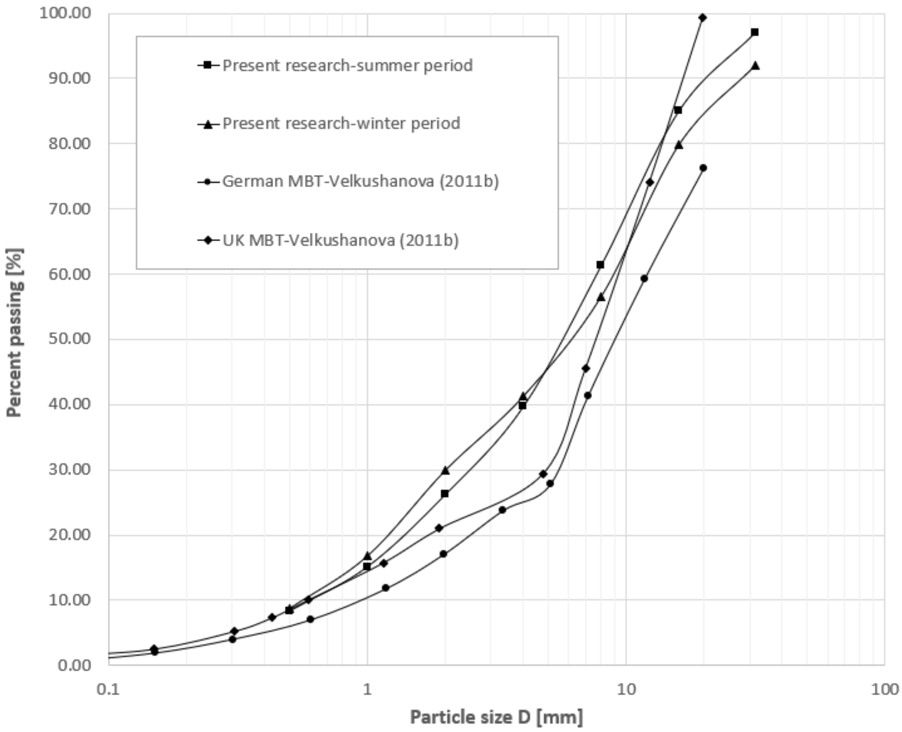

Figure 7. Mean values of granulometric curves of biodried waste for winter and summer period

In addition, two granulometric curves are shown in Figure 7 for UK and German MBT waste material carried out by Velkushanova (2011b). Both materials were subjected to a mechanical and biological (composting) treatment procedure. After the mechanical and biological treatment of UK waste, the maximum particle size was about 20 mm, whereas for the German waste, maximum particle size was about 60 mm.

From Figure 7 it can be concluded that even though both materials were sampled in different time periods, and taking into account that waste is a very inhomogeneus material, the winter and summer waste samples show very similar particle size distribution curves.

3.5 Classification of waste samples into 1D, 2D and 3D shapes

According to Velkushanova K. (2011a), in addition to particle size and type of material, particle dimensions can also affect the mechanical behaviour and formation of voids in the material. For this reason, a classification into 1D, 2D and 3D particle sizes was made on the observed material for the summer and winter periods (Table 4 and Table 5).

1D: fibres, rods and wires - one dimension is more pronounced (longer) due to the typical particle size. Such particles can act as a reinforcement thus increasing the shear strength of the material.

2D: foils and sheets - these particles are flat, have two pronounced dimensions (width and length) and one less pronounced (thickness). They can act favourably on the strength of a material or as elements directing or impeding the flow of fluid through larger accumulations of such material.

3D: bulky particles - these are round particles, pronounced in all three dimensions. Their effect on shear strength and fluid flow direction was characterised as neutral. They can be divided into compressible and incompressible particles. For the purpose of this research, the authors did not make the separation into compressible and incompressible particles.

Velkushanova K. (2011a) also made a classification of 0D particle sizes. These are grains where each dimension is smaller than the minimum significant length. In the present research, these particle sizes are Unidentified > 2 mm and Unidentified < 2 mm (see Table 1). For the winter period waste sample, about 70% of the tested material had too small a particle size (Unidentified < 2 mm and > 2 mm) to be able to determine the exact particle size dimension, whereas for the summer period, about 64% of the tested material was not able to be identified.

Table 4. Mass of winter period waste sample classified according to particle shape (1D, 2D, 3D)

	Mean value-winter period		
	1 D	2 D	3 D
	g	g	g
Plastic	1	52	6.5
Textile	0.05	1.35	0.6
Glass	0	100.5	0
Metals	2.8	1.7	4.5
Paper/cardboard	0	32.3	11
Wood	2	5	4
Bones/skin	0	0.1	1.9
Rocks	0	0	25.5
Ceramics	0	1.3	2.5
Rubber	0	0.3	0.7
Kitchen waste	0	16	5.5
Total mass [g]	5.85	210.55	62.7

Table 5. Mass of summer period waste sample classified according to particle shape (1D, 2D, 3D)

	Mean value-summer period		
	1 D	2 D	3 D
	g	g	g
Plastic	6.7	46.2	7.1
Textile	1.2	1.65	3.15
Glass	11.7	56.9	33.2
Metal	4.3	4.95	1.75
Paper/cardboard	4.5	28.1	29.4
Wood	53	2.65	4.35
Bones/skin	0.45	0.6	2.95
Rocks	0	1	56
Ceramics	0	2.5	6
Rubber	0.65	1.15	2.7
Kitchen waste	3.5	16.6	12.1
Total mass [g]	86	162.3	158.7

For the winter period waste sample, the most frequent 1D particle size dimension in Table 4 is metal, for 2D it's glass, and for 3D particle size, rocks.

The mean value of total mass of sample 1 and sample 2 of separated components in Table 1 is 927.3 g. It follows that of the amount of total classified material, 1D particle size made 0.63% of the sample by mass, 2D made 22.71% of the sample by mass, and 3D made 6.76% of the sample by mass. The rest of 69.90% goes to "Unidentified < 2 mm" and "Unidentified > 2 mm" (0D particle size).

For the summer period waste sample, the most frequent 1D particle size dimension in Table 5 is wood, for 2D it’s glass, and for 3D particle size, rocks.

From a total of 1137.5 g of summer period sample separated (mean value of two separated samples – see Table 2), it follows that 1D particle size made 7.56% of the sample by mass, 2D made 14.27% of the sample by mass and 3D made 13.95% of the sample by mass. The rest of 64.22% goes to “Unidentified < 2 mm” and “Unidentified > 2 mm” (0D particle size).

a) b) c)

Figure 8: a) wood, b) plastic, c) kitchen waste – winter period sample sorted by 1D, 2D and 3D particle shape

a) b) c)

Figure 9: a) textile, b) metal, c) paper/cardboard – summer period sample sorted by 1D, 2D and 3D particle shape

Particle size classification of two MBT waste materials from Germany and UK, carried out by Velkushanova (2011b), is also presented in Table 6 for comparison purposes. The material used in that study was composted. For the present research, 0D particle size refers to percent of Unidentified < 2mm and Unidentified > 2 mm from Table 1, which could not be classified. 0D particle size from Velkushanova (2011a) are particles < 5 mm.

Table 6. Size frequency of the classified materials for present research and Velkushanova (2011b)

Particle size dimension	Present research winter sample [%]	Present research summer sample [%]	German MBT [%]	UK MBT [%]
0D	69.90	64.22	27.0	29.1
1D	0.63	7.56	2.7	3.4
2D	22.71	14.27	23.2	23.3
3D	6.76	13.95	46.8	43.3

1D and 2D particle size can increase the shear strength of the material (particles like sheets, fibre, or strings) or they can impede or divert the flow (2D particle size like sheets), whereas 3D particle size are considered to be neutral on shear strength and flow paths (Velkushanova, 2011a). From Table 6 it can be seen that for the present research, both classified samples have very high amounts of 0D particle size which can form a “matrix” into which the other particles could potentially be embedded (Velkushanova, 2011a).

For the winter period sample, the most prevalent particle size (except 0D) is 2D, followed by 3D. For the summer period sample, the most frequent particle sizes (except 0D) are 2D and 3D with similar percentages.

Based on the size frequency of the classified 1D and 2D particle sizes that can have an influence on flow behaviour, it can be anticipated that materials from both time periods will have an influence to some extent on flow behaviour (recirculation of leachate), and therefore on the normal operation of bioreactor landfill.

4. CONCLUSIONS

This paper shows the established basic geotechnical parameters and other properties such as waste composition, and waste classification by form into 1D, 2D and 3D shapes, of biodried waste material sampled in two different time periods from an MBT plant in Croatia. One biodried waste material was sampled in winter (February 2019) and the other one in summer (July 2020).

The aim of the research was to determine whether there are significant differences in the basic geotechnical and other properties of methanogenic waste from the winter and summer periods, which could consequently affect the mode of operation of the Bioreactor landfill during the year.

Although the test results show small differences, samples from both time periods are very similar and therefore they should not cause major differences in plant operation during the year.

The examined basic geotechnical and other parameters in this paper should contribute to a better understanding of the behaviour of the installed material and increase the capacity of waste material in the form of gas generation potential, which would reduce the total operating costs of the bioreactor landfill and reduce the volume of landfilled waste.

It should be noted that although Croatia is a very popular tourist destination, summer samples may not reflect the true picture of the tourist season due to the pandemic caused by the COVID-19 virus. For this reason, additional research should be conducted when the epidemiological situation improves.

ACKNOWLEDGEMENTS

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