Detailed Sampling Protocol for the Analysis of Residual Municipal Solid Wastes

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Abstract

For the application of advanced waste management options the qualitative features of the generating municipal solid wastes have to be known. The most important information is the material composition. If the process engineering design of a RMSW processing plant is our aim, the knowledge of the material composition of many discrete RMSW size fractions is necessary. There are standards for MSW sampling in many countries (SWA-Tool, LAGA PN 98, ASTM D5231, NF X30-413, MSZ 21420 parts 28 and 29). There are similarities and differences among the standards, but they generally aim to examine only the material composition, not the material composition of many discrete size fractions. Authors developed a detailed sampling protocol by the further development of the French MODECOM methodology. By this new protocol two RMSW sampling campaigns were carried out in 2017/18 in Hungary, where 224 waste collecting vehicles were sampled and analysed. Sampling was stratified according to the type of the waste source and the population. Some detailed features, such as the packaging material content of all material components and size fractions and different types of food wastes were also measured.

Keywords: Residual municipal solid wastes (RMSW), average sample, sampling stratification, material components – size fractions.

Introduction and literature survey

Modern lifestyle results in significant municipal waste generation and even developed countries have to take the long-term generation of residual municipal solid wastes (RMSW) into account, because even with the application of a sophisticated selective collection system there are still large amounts of residual materials that have to be non-selectively collected and handled (Aich and Ghosh 2016). The social, natural and economic features of local communities are quite diverse; therefore, beneficial managing options for the RMSW materials might be specific to a particular community (Hanc et al. 2011; Montejo et al. 2011). As a consequence the analytical methods might be different all around the globe, but it is sure that the first step before any waste managing option design is the analysis. The first European MSW sampling standard was probably the French NF X30-413 Standard derived from the MODECOM methodology. The MODECOM methodology was developed on the basis of Gy's (1979) sampling theory. This method is based on collecting vehicles sampling. Another generally applied method is the so called SWA-Tool developed by a European project consortium. Weichgrebe et al. (2017) carried out a detailed RMSW sampling campaign in

West-Zone Bangalore, India on the basis of the SWA-Tool and the German Standard LAGA PN 98. AbdAlqader and Hamad (2012) carried out a RMSW campaign in Gaza Strip based on the previous version of the ASTM D5231 Standard. These standards give guidelines about the stratification of the examined population, the substance of sampling (e.g. collecting vehicles or collecting bins, etc.), the number and quantity of single and mixed (average) samples, the sorting and screening protocol, the sorted material categories and sub-categories, the taking and preparation of sub-samples for drying and chemical analysis and so on. The comparison of the results of the different methods is difficult, because of the different definitions of the methods and terms. For example each mentioned protocol defines the so called "fine" material category, but the size differs (<20 mm in NF X30-413, <14 mm according to Weichgrebe et al. (2017), <10 mm in SWA-Tool, etc.). However, there is a common feature of the mentioned MSW analytical standards that their main aim is the determination of the material composition, namely the determination of the mass concentrations of the specified material categories and the production of laboratory analytical samples for laboratory measurements. Generally they do not aim the measurement of the material categories as function of many discrete particle sizes; however this detailed composition is necessary for waste processing technological design.

The current Hungarian Standards MSZ 21420 Parts: 28 and 29 regarding the analysis of municipal solid wastes were introduced in 2005. The Hungarian Standards are based on Gy's sampling theory and the MODECOM methodology (Gy, 1979), but details were tailored to the Hungarian situation in 2005. Waste collecting vehicles can be selected for sampling. The raw sample in a vehicle characterises the sector (lot or stratum), namely the area from where the waste had been collected. The total unloaded waste has to be put over by a ~250 litres volume bucket loader. Randomly 10 increments (single samples) have to be selected and mixed together forming the gross (averaged or simply the average) sample. By this way the minimal mass of the average sample of MSW is 500 kg comprising ten 50 kg single samples (MSZ 21420-28). The flowsheet of the standard average sample preparation is shown in Figure 1 (MSZ 21420-29).

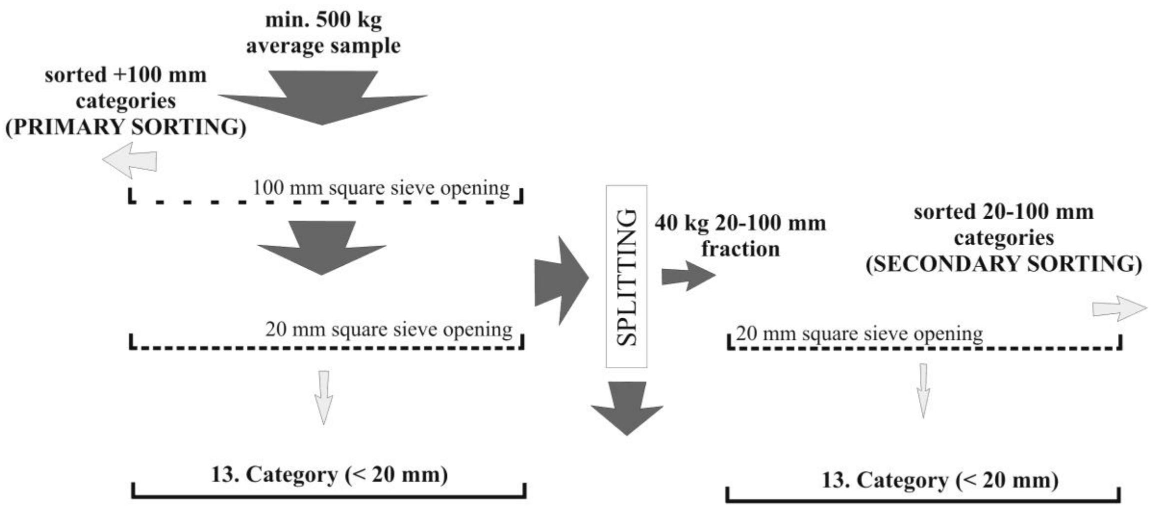

Figure 1. Sampling protocol according to Hungarian Standards MSZ 21420 Parts: 28 and 29.

There is a simplified option as well in the Hungarian standards for the average samples taking. The waste collecting vehicle downloads the waste into a longitudinal strip and a min. ~3 m^3 volume bucket loader takes the average sample in a full cross section, in crosswise direction.

Materials and methods

The Hungarian Standards MSZ 21420 Parts: 28 and 29 regarding the analysis of municipal solid wastes were introduced in 2005 and since then considerable changes on waste management had happened. More than 3000 old landfills had been closed and re-cultivated and only a few but modern and big regional landfills and waste processing plants had been built. As a consequence there are machines, such as mobile drum sieves everywhere available for the MSW analysis. Another consequence, that the waste is transported into regional plants, therefore the analysis can be carried out in one spot for a complete region. The food content and the packaging materials content of the residual municipal solid wastes are requiring more and more attention recently. A very important issue, namely more detailed information about the MSW composition for many discrete particle size fractions is necessary for advanced technological design. All these arguments made the improvement of the standard sampling protocol to be important; therefore the protocol of the average sample processing had been significantly improved. Figure 2 shows the designed flowsheet for the new average sample preparation.

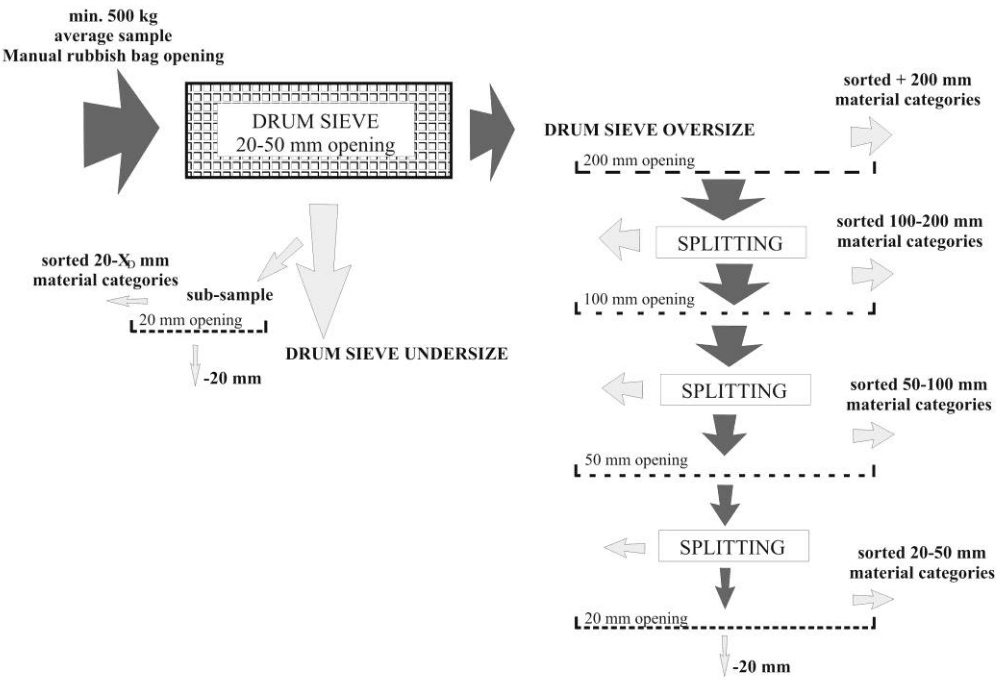

Figure 2. The applied new protocol for the average sample preparation.

The application of a drum sieve machine is beneficial because it loosens the material and the dirty fine fractions are removed and the safety of sorting workers and the accuracy of sorting are increasing. The mass of the total drum sieve undersize (<XD) fraction was measured by an appropriate scale. A min. 10 kg sub-sample was taken from this material stream at the drop-off end of the belt conveyor. This 10 kg <40 mm subsample was sieved at 20 mm and the 20–XD mm fraction was hand sorted.

Figure 3. Drum sieving of the average sample.

200 mm

100 mm

50 mm

20 mm

Figure 4. Sorting on the sorting sieves.

The total drum sieve oversize (>X_D) fraction of the average sample was processed as follows. The sample was gradually sieved and hand sorted simultaneously from coarser into finer particle sizes. Simple 1.2×1.2 m sieve frames were used; the applied square openings of the sieves were 200, 100, 50 and 20 mm. This is a so called "2" sieve series, where the width of size fractions practically doubles. The sorted material components and their numbering are shown below. The developed sampling protocol is flexible because after each sieve the mass of the undersize fraction can be reduced by sample splitting. According to the sample nomogram calculated by Gy, the minimal mass of the processed sample is 63 kg on the 50 mm sieve and 4 kg on the 20 mm sieve only. This protocol ensures the necessary masses for the sorting of each sieve, therefore it is fast and accurate.

The applied material categories and sub-categories and their numbering during the campaigns were as the followings.

1. BIOLOGICALLY DEGRADABLE WASTES
    - 1a. eatable food waste. Everything that was intended for human consumption, independently from its state during sorting. E.g. the eatable part of a banana separately.
    - 1b. non-eatable part of food. E.g. the banana peel separately, eggshell, etc.
    - 1c. non-dismantled food waste, eatable and non-eatable together (mixed) E.g. complete banana, apple, nut of which core cannot be dismantled.
    - 1d. other biologically degradable, garden wastes, flowers, grass, leaves, etc.
2. PAPERS
    newspapers, magazines, envelopes, packaging papers, etc.
3. CARDBOARDS
    flat and corrugated cardboards, packaging cardboards, etc.
4. COMPOSITES
    multilayer packaging materials, laminated materials, tetrabrik, composite milk, fruit juices packaging, etc.
5. TEXTILES
    clothes, rags, cottons, linens, bedclothes, textile packaging materials, synthetic textiles, etc.
6. HYGIENIC WASTES
    other hygienic clothes, diapers, tampons, tissues, etc.
7. PLASTICS
    - 7a. 2D, 2 dimensional plastics, foils, nylons, etc.
    - 7b. PET, materials marked with the PET symbol
    - 7c. 3D, all the other 3 dimensional plastics
8. OTHER NON-CATEGORISED COMBUSTIBLES
    wood, leather, bones, shoes, wallets, etc.
9. GLASSES
10. METALS
    - 10a. Fe, iron metals including stainless steels
    - 10b. Al, aluminium.
    - 10c. Cu, copper

11. OTHER NON-CATEGORISED NON-COMBUSTIBLES (INERT)
    other non-categorised non-combustible inert materials, stones, ashes, ceramics, bricks, construction debris, etc.
12. HAZARDOUS
    batteries, aerosol sprays, pesticides and their packaging’s, plant protection products and their packaging’s, paints, acryl, medicines and their packaging, motor oils and their packaging’s, other special medical wastes, syringes, etc.
13. FINE FRACTION (< 20 mm)
14. EXTRANEOUS MATERIALS
    all the materials, that should not have to be thrown into MSW, mainly electric and electronical equipment.

The dry substance composition was measured by drying of the given quantities of each category in a heated chamber at 105 °C until mass equilibrium. The necessary minimal masses for dry matter and chemical analyses are 20 kg of the Bio (1); 4.5 kg of the Fine (13) and 2 kg of all other material categories. The given mass for dry substance content measurements was taken from the sorted 20-50 mm, 50-100 mm and 100-200 mm size fractions evenly for the 1 to 12 material categories. Sub-samples from the sorted +200 mm size fractions were not taken. The < 20 mm fine fractions (13) were analysed for TOC as well by an ELEMENTAR Vario TOC device.

Results and discussion

Samplings were carried out from October 2017 to May 2018. A regional waste management centre was selected from each of the seven EU statistical regions of Hungary, and at a time 17 RMSW (residual municipal solid wastes) collecting vehicles were sampled. Altogether 224 vehicles had been sampled. The selectively collected MSW streams were not sampled, but the main features of the selective collection (collection area of each RMSW collecting vehicle – called sector, the collected waste streams, their collection frequency, method, containers, etc.) were reported by the public service waste management companies.

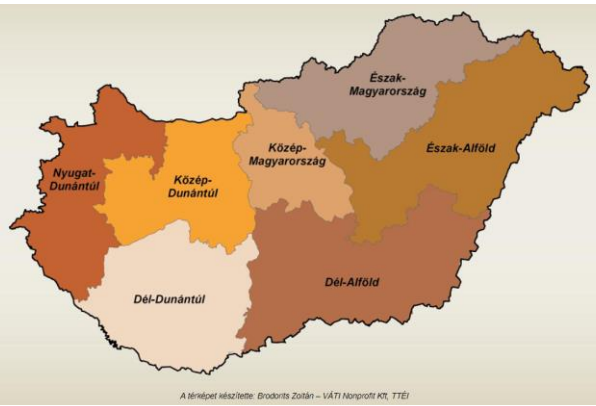

Figure 5. NUTS EU statistical regions of Hungary.

During the campaigns, the standards (MSZ 21420 Parts: 28 and 29) were applied for the preparation of sampling, selection of the vehicles and sectors, average samples taking and measuring of the dry matter content and TOC. The measured results have been evaluated and the wet and dry material compositions of the winter and spring campaigns have been calculated for every examined municipality, regions and the total country. Measured composition results were averaged by the weighting methods (stratification) on the basis of the number of inhabitants of municipalities described in the standards.

Some key parameters had been defined as follows. The **total food waste content** is the sum of the material sub-categories 1a- eatable food waste, 1b- non-eatable food waste and 1c- non-dismantled (eatable and non-eatable were found together). The **eatable food waste content** is the material sub-category 1a. In addition to the 1- biologically decomposable standard material category sorted during the campaigns a new parameter has been also introduced called **biologically decomposable material content**. The residual material fraction of the average (gross) sample processing is the so called 13- fine (<20 mm) material category (fraction). This high concentration fraction contains biologically decomposable materials, therefore TOC (total organic carbon) tests were carried out on the mixed fine fractions of each of the examined municipality. The **biologically decomposable material content** was calculated as the sum of the mass concentration of the sorted 1- biologically decomposable material category plus the TOC times the concentration of the 13- fine fraction. The **total packaging material content** was determined during the processing of the average sample by the applied method described earlier. The **potential secondary raw materials content** was calculated as the sum of the mass concentrations of the 2- papers, 3- cardboards, 4- composites, 7- plastics, 9- glasses and 10- metals material categories.

Results of samplings were evaluated first at municipality level. The type (family houses area, block of flats area, non-household source) and number of the inhabitants of each sector (area where from a collecting vehicle collects MSW) were determined. The municipality level evaluation was calculated as the weighted average on the basis of the number of inhabitants of the sectors. The distributions of some discrete municipality size categories of the examined counties were calculated on the basis of the 2016 data of the Hungarian Central Statistical Office. A given county represented the corresponding region; therefore regional waste compositions were calculated as the weighted average on the basis of the number of inhabitants of the municipalities. The final results, the country level tables were calculated as the weighted average on the basis of the number of inhabitants of the regions. Because of text limitation, tables are not shown here. Only the defined key parameters (dry substance distribution described by mass concentrations) are shown in Table 1 and 2.

Table 1. Key parameters of the 2018 winter RMSW campaign.

	Central-Hungary	North-Hungary	Northern Great Plain	Southern Trans-danubia	Central Trans-danubia	Southern Great Plain	Western Trans-danubia	**Hungary**
Total food waste content [%]	14.1	15.5	10.9	13.9	10.5	7.7	7.2	**11.9**
Eatable food waste content [%]	9.1	3.8	4.0	4.1	5.4	2.2	4.6	**5.5**
Biologically decomposable materials content [%]	21.1	26.2	21.1	26.8	23.4	16.3	20.3	**20.8**
Total packaging materials content [%]	34.6	28.6	31.8	23.8	32.4	23.1	27.8	**30.1**
Potential secondary raw materials content [%]	41.3	33.9	40.1	31.3	42.2	35.5	39.9	**31.6**
TOC of 13. fine fraction [%]	18.5	18.2	29.8	19.0	27.8	16.1	16.9	**17.3**

Table 2. Key parameters of the 2018 spring RMSW campaign.

	Central-Hungary	North-Hungary	Northern Great Plain	Southern Trans-danubia	Central Trans-danubia	Southern Great Plain	Western Trans-danubia	**Hungary**
Total food waste content [%]	11.2	5.6	14.9	14.2	8.1	5.7	15.5	**10.8**
Eatable food waste content [%]	7.8	3.7	3.3	5.9	4.7	2.4	5.7	**5.2**
Biologically decomposable materials content [%]	19.9	21.1	25.2	26.9	33.0	28.0	23.6	**23.4**
Total packaging materials content [%]	35.3	24.6	32.0	23.1	23.5	21.3	26.0	**28.4**
Potential secondary raw materials content [%]	47.8	38.4	38.9	36.6	31.2	28.6	43.1	**31.9**
TOC of 13. fine fraction [%]	27.5	19.7	26.1	29.7	30.2	25.9	30.3	**22.6**

Conclusion

Since the introduction of the Hungarian MSW sampling standards in 2005 the waste management have been significantly improved in Hungary, therefore two validation campaigns, - a winter and a spring time - have been carried out from October 2017 to May 2018. A significantly improved average sample preparing protocol have been applied. According to the standard protocol the mass of each sample portion is measured during the feed into analysis. According to the new protocol everything is weighted after processing. After some initial confusion among sampling experts, - because of this different strategy – the new protocol was successfully applied and results with low margin of errors have been achieved.

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