Municipal Waste Composition Analysis – Approaches to and Solutions for Czech Waste Management

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Abstract Current trends in European Union waste management (WM) have resulted in the unified European Reference Model on Waste. The European Commission and European Environment Agency commissioned research subjects to develop the model, which covers all 28 EU Member States. Uniform information about municipal waste composition is essential for WM modelling at all territorial administration levels. This paper describes demands for (residual) municipal waste composition analyses in the conditions of Czech WM. Besides legislation and environmental strategies, the main motivation is to assess analyses procedures from the point of view of their economic and technical feasibility. Therefore, the requirements for analyses in a specific purpose context are described, and the main sampling methods are assessed. Typical methods and procedures are identified in the paper. The author's team further develops suggestions to propose optimal and effective waste composition analyses solution for intended purposes in Czech WM context.

Keywords: waste management, municipal waste, waste composition analysis, waste treatment, waste composition analysis methodology.

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1 Introduction

Relevant and comparable information about municipal waste (MW) composition is essential for waste management (WM) business models and plans at all territorial administration levels. Current trends in European Union WM have resulted in visions of the Circular Economy and the unified European Reference Model on Waste. The up-to-date background for MW composition analysis is a document called SWA-Tool (iC consulenten ZT GmbH, 2004), which is not obligatory and does not meet current WM requirements.

Therefore, there is a project under the Ministry of Environment of the Czech Republic, leading to a proposal for a new Czech certified methodology. Brno University of Technology, Institute of Process Engineering is the coordinator of this project. The new methodology should enable not only comparison of values from individual studies, but above all statistical evaluation of the expanding dataset of results and subsequent forecasting. Relevant information about MW composition and quality forecasts of future composition are crucial for the development of relevant models and plans in the field of waste management. These include techno-economical models of MW treatment units (e.g. sorting line, transfer station, energy recovery or waste collection system modelling) and complex business models concerning specific investment in waste management.

Current work corresponds to the beginning of the project and consists mainly of testing individual procedures and analysis options. At the same time, work is under way on the design of a statistical background for the subsequent evaluation of relevant knowledge about the composition of MW in a certain region.

2 Methods

There are several differently detailed and variously demanding methods for analysing the composition of MW and residual MW in particular. An important overview is the paper from Dahlén & Lagerkvist (2008), which provides simple descriptions of methodologies from around the world. The paper presents mainly physical sampling procedures; other, rather outdated procedures are also mentioned. The findings from Dahlén & Lagerkvist (2008) are complemented by data from the UK Defra

(2008) (Annex 5 - Review of Waste Auditing Methodologies), which includes a tabulated overview of methodologies.

In the USA, methods for determining the composition of waste have been under development since the 1960s. The American Society for Testing and Materials (ASTM) method was last updated in 2016 under ASTM D5231-92 (2016).
In Europe, the European Commission seeks to support a vision of what is called the circular economy, as summarized in the Circular Economy Package from the European Commission (2015). Developments in EU waste management are heading towards an unified European Reference Model on Waste (Eunomia Research & Consulting, 2015). This situation will affect the development of new methodologies for MW composition analyses in individual EU member states. The European situation in recent decades is described in the text below.

2.1 European Municipal Waste Composition Analyses Methodics

The SWA-Tool (iC consulenten ZT GmbH, 2004) is a methodology developed as part of a European Commission project. The aim of the methodology is to standardize the procedures used to determine the composition of MMW across EU states. However, this methodology should not become the European standard. The main document is primarily a comprehensive inventory of related knowledge; detailed descriptions are provided in the annexes. These findings are reflected in 24 general recommendations covering all necessary MW composition study parameters, especially the required accuracy of the study; stratification criteria; collection and sorting procedures for samples; and finally, the statistical background for processing the analysis results.

The French MODECOM methodology (Montejo *et al.*, 2011) (Wavrer P., 2008) recommends a minimum of 5 MW collection vehicles for analyses, with at least 2 tons of waste from each. It is recommended to analyse a 500 kg sample by manual sorting and sieving. This methodology does not specify measurement accuracy.

Finnish Nordtest methodology (1995) and Swedish NSR methodology (1997) - while the original 1995 procedures focused on the number and volume of the MW samples and the sampling procedures, the 1997 NSR methodology focused more on characterization of sorted fractions (Dahlén *et al.*, 2007). The sampling takes place from collection vehicles, with subsequent subsampling.

The Dutch RIVM (1995) is an extensive and detailed method demanding both cost and analysis equipment (Cornelissen & Otte, 1993). It combines manual and mechanical procedures.

The Swiss SAEFL methodology (Swiss Agency for the Environment, Forests and Landscape, 2003) uses specific stratification factors: socio-economic factors, geographical location, tourism, seasonality, waste charging system and the effect of separate collection of biowaste. The Swiss method compiled by Maystre & Viret (1995) deals with detailed analysis of waste samples, especially from a chemical point of view. The main objective of this method is to determine the content of heavy metals in residual MW.

In Austria and Germany, there are methodologies at the level of individual Lands and regions. Usually sampling from collection vehicles is used, followed by a procedure for sorted subsample homogenization and separation. Sorting is done manually and with sieves. The output from such analyses is mostly in German, e.g. Kern & Siepenkothen (2010) and Vogel *et al.* (2009). Currently, standardization of procedures and revision of methodology was carried out in Austria in 2017. Sampling from containers is preferred and stratification procedures are established.

In Scotland, Zero Waste Scotland published Guidance on the Methodology for Waste Composition Analysis (Zero Waste Scotland, 2015). Procedures for determining the number of samples are determined according to the required level of study accuracy. Samples for sorting are taken from collection containers. This method, developed in 2006 under the auspices of the Environment Agency of England and Wales (Burnley *et al.*, 2007), deals mainly with stratification parameters that affect the amount and composition of waste.

In Poland in 2006, a report on the "Determination of the methodology for testing the sieve, morphological and chemical composition of municipal waste" (Jędrczak & Szpadt, 2006) was issued to the Polish Ministry of the Environment. The European SWA-Tool procedures (iC consulenten ZT GmbH, 2004) were referenced and commented on.

2.2 Municipal Waste Composition Analysis Methodics in Czech Republic

Most MW composition information is based on studies related to publicly funded projects, where published project results and related publications can be found. In contrast, local studies for smaller municipalities and internal studies for companies operating in the Czech WM often remain unpublished or are mentioned only in references and short reports.

Therefore, the available MW composition data often represents only partial information that is difficult to compare. However, a large part of the Czech studies refers to the methodology established in 2008 under project SP/2f1/132/08 (Benešová *et al.*, 2008), which is based on the results of an extensive analysis of MW composition (12 measurements in each of the three types of buildings per month throughout 2008). Previous Czech methodologies are the "720/2/00" from 2003 and the "VÚMH", which have been developed since the 1970s.

The main characteristics of the SP/2f1/132/08 method from 2008 (Benešová *et al.*, 2008) are as follows:

- The size of the main sample is based on the load of a collection vehicle and should be 6 to 8 t; the sorting sample should be 200 kg (corresponding to a volume of approximately 1 m3);
- Sampling of the analysed (sorted) sub-sample is recommended by "quartation" the sample from the collection wagon;
- Three to four building types are monitored: rural, villa, mixed (housing estate, small town) and housing estate, large town. The size of the collection areas in the individual building types is recommended;
- Waste sorting is based on screening and manual sorting of above-screen fractions. Three levels of classification are monitored; the first level distinguishes 11 components: paper and board and cardboard, plastics, glass, metals, bio-waste, textiles, mineral waste, hazardous waste, combustible waste, electrical equipment, fine fraction;

2.3 State-of-the-art in Municipal Waste Composition Analyses Methodics

The most significant methodological procedures were identified and are described in the text below.

Stratification (stratification layer) is a procedure for establishing a sampling schedule for a specific locality or region in order to obtain representative data in relation to the aim of the analysis. The procedure consists in dividing the target area into several smaller representative groups (stratification layers) for individual types of monitored factors. Samples from individual groups are obtained proportionally according to the ratio of their total representation in the area. Stratification is a prerequisite for proper statistical planning of experimental and measured data evaluation.

Place of sampling within MW treatment:

- A statistical survey or questionnaire is a complementary approach;
- Sampling of households is expected to be inaccurate when the waste producers know about the experiment being conducted;
- Samples from MW collection containers, e.g. volumes of 120, 240 or 1100 litres; this way is recommended by European SWA-Tool (iC consulenten ZT GmbH, 2004);
- Sampling from collection vehicles and subsequent sub-sampling for manual sorting. This is often used in current studies.
- Sample collection at the waste facility, i.e. homogenized samples from the facility waste bunker.

Homogenization of MW samples and **sub-sampling** for sorting - usually, "quartation" is used to reduce the volume of the sorted sub-sample from the total large-volume sample taken. The disadvantage is the gradual reduction of the homogeneity of the sorted volume and thus its representativeness. Other techniques such as machine cutting or milling may also be used; these are used when it is necessary to obtain a very small sample volume for chemical and physical analysis.

Sorting method - for reasons of economy, time and logistics, manual sorting is the method most commonly used. It is also common to use a sieve with a mesh size of about 40 to 20 mm and to thoroughly separate only the oversize waste fraction. Mechanical sorting may have great potential, which is related, for example, to the cost and safety of human labour and the cost of new technologies. Several mechanical sorting methods can be mentioned:

- Sorting with a grate or sieve in a vibrating or drum design;
- Hydraulic and pneumatic sorting;
- Magnetic separators and electrostatic screens are suitable, for example, for separating ferrous and non-ferrous metals from inert materials;
- Optical sorting systems based on the optical identification of materials (different wavelengths, e.g. UV, NIR, X-Ray, laser, microwaves, spectroscopy) and their subsequent mechanical separation (pneumatically, robotic gripper).

The scope and range of monitored components and sorting levels. The first basic level of classification usually consists of 10 to 20 fractions differentiated by material (e.g. plastics, paper, metals or glass), purpose (e.g. electrical waste, food waste, sanitary waste, complex packaging) or other properties (e.g. fine fractions according to the sieves used, hazardous fractions). Lower classification levels often differ significantly between individual analyses and methodological approaches. In general, the agreement between approaches and methods of categorization and studies is questionable for individual methodologies.

Subsequent **laboratory tests** occur occasionally and focus primarily on sorted MW fractions, their energy parameters or the presence of pollutant precursors.

Studies often do not specify **measurement accuracy** when processing measured data. Mean value, median, standard deviation or coefficient of variation can be used to interpret the results of the analysis.

3 Results

Design of the new methodology is in the initial design phase. Current works corresponds to the beginning of the project and consist mainly of testing individual procedures and MW analysis options. At the same time, work is under way on the design of a statistical background for the subsequent evaluation of relevant knowledge about the composition of MW in a certain region. The socio-economic parameters of the region are monitored along with other factors that may affect local MW composition.

These topics, suggestions and practical demands for residual MW composition analyses in Czech conditions were identified based on the first phase of practical tests:

- Samples from MW collection containers, e.g. volumes of 120, 240 or 1100 litres. This way is recommended by European SWA-Tool (iC consulenten ZT GmbH, 2004), and the least impact on the sample during MW collection and transportation is expected (e.g. transfer of moisture content between MW fractions or volume change by pressing);
- Sorting takes place manually; application of screening analyses is discussed. A 40 mm sieve will probably be the most appropriate.
- The first two levels of sorting focused mainly on the material composition of the residual MW mixture and the proportion of packaging materials;
- There will be only recommendations for classification of a third sorting level; this is a possibility for specific aims of individual studies (e.g. studies focused on further treatment and material or energy recovery).
- A possible ash content measurement could be analysed in the winter (heating) season.
- Standard deviations will be part of the results presentation. The methodology will include recommendations for the necessary number of measurements in relation to the accuracy of the analysis.
- Classification of complex, multi-material and contaminated materials will be designed in accordance with the objectives of the methodology, the practical possibilities and the demands of the statistical evaluation.

4 Conclusions

Differently detailed and demanding methods for analysing the composition of MW and residual MW are applicable in the world and in the EU. Data from individual studies can provide varied and difficult to compare information on the composition of MW and especially residual MW, making it difficult to plan the operation of treatment units or complex business models in the field of waste management. Information from a range of countries and regions will gradually be unified in their methodologies, as suggested by development around the European Reference Model of Waste.

A new Czech methodics is proposed by Brno University of Technology, Institute of Process Engineering for the Czech Ministry of Environment. The aim is to offer a methodology that provides basic data for complex statistical processing and enables relevant forecasting of the development of MW composition. In the current working phase at the beginning of the project, demands for residual MW composition analyses in Czech conditions were identified and the first practical tests were carried out.

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