The Secret of the Black Bins: Results of Physical Analyses of Mixed Municipal Solid Waste in the Czech Republic in 2018 – 2022

Soňa Klepek JONÁŠOVÁ[1], Bedřich MOLDAN[1], Lukáš ZEDEK[2], Vratislav ŽABKA[2], Tereza VÁLKOVÁ[3], Shuran ZHAO[4], Petr NOVOTNÝ[5]

[1] Faculty of Humanities, Charles University, Pátkova 2137/5, 182 00 Prague 8, Czech Republic, e-mail: sona.jonasova@gmail.com, bedrich.moldan@czp.cuni.cz
[2] Faculty of Mechatronics Informatics and Interdisciplinary Studies, Technical University of Liberec, Studentská 1402/2, 461 17 Liberec 1, Czech Republic, e-mail: vratislav.zabka@tul.cz, lukas.zedek@tul.cz
[3] Faculty of Social Studies, Masaryk University, Joštova 218/10, 602 00 Brno, Czech Republic, e-mail: terezaa.valkova@gmail.com
[4] Faculty of Engineering, Czech University of Life Sciences Prague, Kamýcká 129, 165 00 Praha - Suchdol, Czech Republic, e-mail: zhao@tf.czu.cz
[5] Institut cirkulární ekonomiky, z.ú., Purkyňova 648/125, 612 00 Brno – Medlánky, Česká republika, e-mail: petr.novotny@incien.org

Summary

This paper presents a comprehensive analysis of mixed municipal solid waste (MMSW) based on material composition conducted in Czech municipalities between 2018 and 2022. The study identifies key trends in mixed municipal waste generation, evaluates the efficiency of waste separation at source, and highlights the potential for improving municipal waste management practices. The findings reveal that a significant proportion of MMSW consists of recyclable fractions (65.6%). The largest share is represented by biodegradable waste (33.6%), followed by plastics (8.8%), textiles (6.5%) and paper waste (6 %). Trend analysis revealed a gradual decline in composite packaging materials, plastics and textiles, whereas a slight uptick in biodegradable waste indicated limited availability of separate collection systems in municipalities. These findings emphasize the need for better waste sorting systems and educational initiatives. On the other hand it yet suggests that the existing fee structure and collection infrastructure do not sufficiently alter household behaviour, resulting in substantial losses of valuable materials and energy. Wider adoption of pay-as-you-throw schemes, expansion of door-to-door biodegradable waste collection, and introduction of deposit-return systems for high-value packaging materials are therefore recommended. Finally, it is proposed that municipalities incorporate regular physical MMSW analyses into strategic planning to enable continuous assessment of the effectiveness of implemented measures.

Keywords: *municipal solid waste, physical waste analysis, waste management, circular economy, waste sorting*

1. Introduction

Municipal solid waste (MSW) management plays a crucial role in achieving sustainability goals and transitioning to a circular economy. Physical waste composition analyses provide essential data for evaluating the efficiency of waste sorting systems and identifying improvement areas. Previous studies on waste management in the Czech Republic and other European countries indicate that a large fraction of MMSW consists of biodegradable and recyclable materials, which are often not properly sorted and end up in landfills.

The following issue manifests at both the beginning and end of supply and value chains. On the input side, a key factor is the intensive extraction of primary raw materials, which is associated not only with significant environmental burdens, but also particularly in recent years with increasing economic uncertainty due to rising commodity prices.

On the output side, the persistent challenge lies in the generation of mixed, unrecycled, and further unutilised waste. Despite the availability of alternative waste management methods, landfilling remains the most commonly employed approach, both in the Czech Republic and in many EU countries. This results in the irreversible loss of valuable and often hard-to-obtain resources, except in cases where landfill mining is pursued — a highly limited and infrequently applied strategy with negligible material recovery at present.

1.1. What can be deduced from physical analyses of waste?

Physical waste analyses offer unique insights into consumer behaviour and help identify trends in waste generation. For example, in recent years, several European countries have seen an increase in the share of electronic waste in municipal solid waste, with particular attention drawn to emerging waste types such as electronic cigarettes and batteries.

Another key benefit of these analyses is the ability to pinpoint materials that are not being effectively captured by current sorting systems. In the Czech Republic, for instance, waste composition studies have revealed that significant amounts of recyclable plastics and paper still end up in residual waste, despite the wide availability of collection containers[1]. An important insight into the composition of mixed municipal waste is also provided by the company EKO-KOM, which conducts analyses at 160 locations every two years. Beyond environmental considerations, physical analyses can also enhance the economic efficiency of waste management. In Italy[2], for example, collection logistics were adjusted based on analysis results, leading to a reduction in operational costs.

1.2. Municipal Solid Waste Composition in the Czech Republic

In the Czech Republic, the responsibility for waste management falls primarily on municipalities rather than individual households. This is because Czech law mandates that municipalities are responsible for organising and ensuring the collection, transportation, and disposal of municipal waste, which includes waste generated by households. The relevant legislation is Law No. 541/2020 Coll. Waste Act, which clearly defines the role of municipalities as waste managers within their jurisdictions. They are also required to designate facilities for the separate collection of various waste fractions, including hazardous waste, paper, plastics, glass, metals, biodegradable waste, used edible oils and fats, and beginning 1st January 2025, textiles. Furthermore, municipalities must publish, at least annually and in a format accessible remotely (e.g. via the municipal website), detailed information on the scope and methods of separate waste collection, the amounts collected, the management of municipal waste, prevention and minimization measures, as well as the associated operational costs of the waste management system. Moreover, the Act establishes recycling targets for recyclable municipal waste: at least 60% by 2025, 65% by 2030, and 70% by 2035. These targets form part of the broader national Waste Management Plan (Plán odpadového hospodářství České republiky), embedding the principles of circular economy into local waste policy.

Landfilling remains a significant issue in the Czech Republic. While the overall landfill rate across all waste streams stands at 13 %, the situation is markedly more critical in the domain of municipal waste, where approximately 45 % of the total 5.8 mil. tonnes generated are landfilled, substantially exceeding the EU average of 23 %. The total volume of waste designated for disposal in 2022 amounted to 769 million tonnes. This category includes waste deposited in landfills, incinerated without energy recovery, or disposed of by methods such as deep-well injection or surface impoundment.[3]

1.3. Situation of Municipal Solid Waste Composition across Europe

In recent years, the European Union has adopted several strategic documents highlighting the importance of detailed waste composition monitoring. The European Green Deal sets ambitious goals for waste reduction and the promotion of recycling[4]. Complementing this, the Circular Economy Action Plan introduces concrete measures, including requirements for more detailed waste analyses to inform the development of future waste management policies[5].

According to Eurostat (2023), approximately 225 million tonnes of municipal waste were generated in the European Union in 2022, of which only 48 % was recycled[6]. Detailed physical waste composition analyses provide valuable insights into which waste fractions are not being effectively collected. These findings can inform improvements in waste management practices, such as expanding collection infrastructure or implementing targeted public awareness campaigns. For example, Estonian studies have revealed that despite established source-separation schemes, a substantial amount of plastics and biodegradable waste still ends up in the mixed municipal waste stream. This study has used such analyses to identify gaps in its collection systems and to guide efforts aimed at increasing recycling efficiency.[7]

The availability and frequency of physical waste composition analyses across Europe vary significantly. While some countries (such as Austria, Germany, and Denmark) regularly publish the results of detailed studies on municipal solid waste, others provide only limited data.

Across Europe, mixed waste analyses serve as an essential tool for evaluating the effectiveness of separate collection programmes, identifying weaknesses in collection infrastructure, and supporting the circular economy objectives set by the European Union. For example, in Austria[8], physical waste composition analysis is a common foundation for formulating waste minimisation strategies and enhancing recycling rates.

In Germany[9], study found that nearly 40% of this mixed waste consists of organic waste (mainly kitchen and garden waste), 32.6% is residual waste (e.g., hygiene products and ash), and 27.6% consists of still-recoverable dry materials such as plastics, paper, or glass. Special attention was given to hazardous waste (e.g., batteries), which is still found in small amounts in household waste. The study recommends improving public communication, expanding return and collection services, and implementing a mandatory nationwide system for organic waste collection in order to improve waste separation and reduce the overall volume of waste.

Similarly, in Greece, waste composition studies have been instrumental in revising national waste management legislation. The analyses highlighted deficiencies in waste collection infrastructure and the need for more effective recycling measures[10]. A study conducted in Crete identified three dominant waste biodegradable, paper, and plastics, which together constituted approximately 76% of total MSW. Putrescible waste alone represented 39%, while plastics and paper accounted for 17% and 20%, respectively. The share of glass (7%) was also notable, primarily consisting of disposable (non-refillable) bottles. In tourist-heavy areas such as Hersonisos and Malia, the proportion of glass rose to 18% during the autumn season[11].

As another example, in Estonia, SEI Tallinn completed a national waste composition study in 2020. The findings suggest that the composition of mixed municipal waste has remained relatively stable over the past decade. Compared to the 2012 study, the proportion of biodegradable waste has remained largely unchanged, while the share of plastics, paper, and cardboard has increased. Packaging waste now constitutes 32% of the MMSW. On average, biodegradable waste accounts for 32% of the MSW, primarily in the form of kitchen and food waste. These results are used to assess the performance of current collection and recycling systems and to identify areas for improvement[12].

On the other hand, Slovakia[13] presents a similarly concerning picture of up to 78% of the analysed mixed waste was theoretically recyclable. The largest fraction consisted of biodegradable kitchen waste. A localized analysis in the Košice region and a comprehensive 2020 survey of 31 municipalities, biodegradable waste consistently emerges as the predominant fraction, collectively accounting for nearly 40 % of the MSW stream, with 254% of planted-based biodegradable waste and 13.7% of kitchen waste [14]. Across the composition analysis in Slovakia, packaging waste accounts for roughly one quarter of the

MMSW mass, of which plastics are the single largest fraction. In Košice (urban) and Poproč (rural), packaging represented 24% and 29%, respectively[15]. While the average share of municipal waste ending up in landfills across the European Union is around 24 percent, Slovakia significantly exceeds this figure, with approximately 40 percent of its municipal waste still being landfilled. The share of waste being landfilled has been decreasing only marginally in recent years. In 2022, Slovakia's households sent approximately 1.1 mil. tonnes of waste to landfills - just 200,000 tonnes more than a decade earlier. In addition to household waste, around 16 percent of other waste types also end up in landfills[16].

The European Union's Waste Framework Directive mandates increased recycling rates and the reduction of landfill disposal, placing additional responsibility on municipalities to improve waste management strategies. In response, Czech municipalities have been conducting physical waste analyses to gain insights into waste composition and optimize waste collection systems. This paper presents a summary of such analyses conducted between 2018 and 2022, highlighting key trends and challenges in waste management.

This article presents the findings of over 50 physical analyses of mixed municipal waste conducted in the Czech Republic, thereby contributing valuable data to fill existing gaps regarding waste composition across Europe. These analyses focus on changes in waste composition over the past decade and enable the tracking of key trends in waste generation, such as the decline in plastic and textile waste and the increase in biodegradable waste, the latter attributed to improvements in source separation infrastructure.

2. Materials and Methods

Physical waste analyses represent a vital tool in waste management, providing essential data for the improvement of recycling systems, the optimisation of collection networks, and the identification of emerging waste streams. These analyses are increasingly integrated into the environmental policies of European countries, not only in response to the EU's recycling targets, but also due to their economic and strategic benefits.

This study was designed to analyse the physical composition of MMSW among Czech municipalities, with a specific focus on household waste remaining after the separation of all recyclable fractions of municipal waste. This analysis was intended to provide information about which recyclable or non-recyclable waste fractions are present in MMSW samples and in what quantities, aiming to determine the share of individual fractions present in MMSW and evaluate the potential for improving MMSW separation. The proposed methodology standardizes the analytical procedure, ensuring comparability and reproducibility of results across locations and periods. This analytical procedure can be used for determining the composition not only of MMSW but also of other types of municipal waste, e.g. determining the composition of biodegradable municipal waste (BMW) produced in households.

The methodology was developed in accordance with the Methodological Instruction for Waste Sampling of the Ministry of Environment (2008) and the Ministry-certified Methodology for Determining the Composition of MSW (2021), with modifications to the classification of individual MSW fractions to enhance the clarity of results and their interpretation and to align with the specific objectives of this analysis. These modifications primarily concerned more detailed classification of certain MSW fractions that were not sufficiently distinguished in the original methodology, such as the detailed division of biodegradable or plastic waste.

The study design incorporated a comprehensive approach to deliver a detailed characterisation of the physical composition of MMSW (mixed municipal solid waste), quantifying the proportional contribution of each fraction to the overall amount of the residual waste. Analysis combined manual sorting of representative waste samples with sieve analysis, which utilized a 40 x 40 mm mesh sieve. MMSW underwent a complete material analysis, including the undersize (< 40 mm) fractions. Statistical methods were employed to analyse relationships between population characteristics and waste composition, enabling robust data interpretation and identification of significant trends.

2.1. Description of Sampled Waste and Municipalities

The subject of analysis is mixed municipal solid waste remaining after the separation of all recyclable fractions of municipal waste, classified as Mixed Municipal Waste under catalogue number 20 03 01 “směsné komunální odpady” in the Czech Waste Catalogue. Thus, the composition of the MMSW mainly consists of polluted packaging, kitchen waste, and general mixed waste.

A representative sample consisted of a predetermined amount of MMSW for which the material composition analysis was conducted. The research encompassed a total of 50 waste composition analyses carried out between 2018 and 2022 across 38 Czech municipalities with significant variation in population size. For these analyses, municipalities with populations up to 49,999 inhabitants were selected, reflecting the predominant small-scale settlement structure characteristic of the Czech Republic. By excluding only the largest cities exceeding 50,000 inhabitants, the analysis captures the diverse spectrum of predominantly rural and small-town settlement patterns that define the Czech territorial structure, while maintaining focus on communities where local governance dynamics and citizen participation patterns differ significantly from those in major urban centers. In several municipalities, analyses were conducted repeatedly in different years and seasons to capture potential temporal variations in waste composition, which explains the higher number of analyses compared to the number of municipalities. This approach also allowed for a more robust dataset reflecting both geographic and temporal diversity within the Czech Republic.

2.2. Sampling Procedure

The sampling process required close cooperation with local authorities who provided essential support. The site selection and positioning method for the representative sample for field analysis were determined based on local conditions, current weather, and the needs of the sampling group. The site chosen considered the time and financial costs of preparation and execution of the analysis. The area designated for analysis was clearly marked and secured against unauthorized entry. A tarp placed both under and over the sampled material prevented waste leakage. An ideal location for analysis is a waste collection center (WCC), usually located within or near the municipality, facilitating the transportation of the representative sample. These sites are usually fenced and secured, allowing temporary restricted access during the survey period. Utilizing WCCs is advantageous as municipalities typically manage them, simplifying necessary arrangements and organizational logistics.

Sampling events were scheduled to coincide with regular MMSW collection days. Based on agreements with municipalities and waste collection companies, a set of MMSW batches (approximately 1 ton) collected from residential buildings were delivered to the designated research site immediately after collection by municipal technical services. From this batch, representative samples of 500 kg were compiled. Representative samples were constructed from individual sub-samples randomly collected from different layers and sections of the delivered waste batch, ensuring random data selection conditions. The collected samples typically represented MMSW production in households over a period of 1 – 2 weeks, depending on the collection frequency in the given locality. It is important to note that the survey was always conducted without prior notification to citizens, in order to preserve the authenticity of their normal waste production behaviour and obtain a realistic picture of MMSW composition unaffected by the ongoing investigation.

2.3. Pre-sampling Preparation and Safety Measures

Prior to each sampling event, the number of personnel involved in the analysis (samplers) was set at 4 – 6 workers per analysis. All samplers underwent thorough training on hygiene and safety principles that needed to be maintained throughout the survey. Given that workers come into contact with potentially hazardous substances during MMSW handling, it was essential to handle samples with increased caution.

Sanitary facilities (toilet with running water and disinfectant) and a first-aid kit equipped for minor injury treatment were always available at the analysis site. Workers were equipped with necessary protective equipment throughout the duration of the analysis, including long, cut-resistant gloves, protective glasses, face shields, respirators, work clothing, work coveralls, rubber boots, head coverings, and reflective vests indicating ongoing research.

The following tools were always available during analysis: rakes, brooms, shovels, knives, scissors, brushes, sturdy large-volume bags (50 l) for waste sorting, digital scales for determining the weight of individual fractions, and a set of sieves. Sieves were used to separate the undersized fraction from other MMSW fractions, using combinations of sieves with mesh size 40 × 40 mm.

Strict hygiene protocols were emphasized throughout the survey. Workers were prohibited from consuming food or drink during analysis. Breaks for refreshments and fluid replenishment were scheduled at predetermined intervals and only after proper hand washing and disinfection. Upon completion of work, thorough body disinfection was performed, and all used protective equipment was deposited at the collection yard for disposal.

2.4. Waste Sampling Methodology

The methodology followed the official Methodological Instruction for Waste Sampling of the Ministry of Environment (2008) and the Ministry-certified Methodology for Determining the Composition of MSW (2021). Modifications were introduced to enable a more detailed breakdown of individual MSW fractions and to improve the clarity of results in relation to municipal waste management practices. These adjustments allowed for a clear identification of material streams with the high potential for separate collection and recycling.

The waste sampling was always commenced in the morning, following a standardized methodology to ensure consistency and accuracy. The representative MMSW sample, after being deposited in the designated area, was manually sorted into 12 categories and detailed subcategories according to waste types, as different types of plastics and paper, metals or container glasses. Each waste fraction was placed into 50-liter plastic bags before being weighed to determine the mass balance of the individual waste fractions. The monitored indicator was the weight of individually sorted MSW fractions contained in the waste samples. For each material group, the total weight and its proportion of the total sample weight were determined separately.

A Solid Bench bridge weighing device with a capacity of up to 150 kg and an accuracy of 0.05 kg was used to weigh individual fractions. Weighing was carried out continuously after filling each collection bag, and the total weight of individual fractions was determined by summing the weights of the partial collection bags and recorded in the prepared protocol. The entire analysis was carefully photographically documented to enable retrospective verification of the correctness of the procedure and possible additional evaluation of the sorted fractions. After sorting and weighing were completed, all analysed waste was emptied into pre-prepared collection containers for proper disposal by municipal services. No laboratory samples were required for this particular study, as the analysis focused solely on the composition and weight distribution of municipal waste fractions.

The results of this waste analysis provide insight into the composition of municipal waste and potential opportunities for improved waste management and separation strategies. The findings support municipal decision-making regarding future waste reduction measures and the elimination of hazardous and critical waste fractions.

2.5. Classification System for Waste Fractions

The physical waste analysis classified the collected waste into distinct fractions based on their recyclability and material composition, reflecting the final categorization scheme applied in the study. Waste was divided into two primary categories: non-recyclable waste and recyclable waste. The non-recyclable fraction included mixed municipal solid waste (MMSW) and miscellaneous waste (MW) as other residual waste including hazardous waste or infectious waste that could not be assigned to recyclable categories. The recyclable fraction encompassed biodegradable waste (BIO), which includes both plant- and animal-based organic materials; plastic waste; textile waste; paper waste; glass waste; metal waste; waste from electrical and electronic equipment (WEEE); composite packaging materials (CPM); treated wood waste (WW) and batteries and accumulators (BaA). Each fraction was quantified as a share of the total waste composition, enabling further evaluation of material recovery potential and contamination levels. Batteries and accumulators were identified but not present in the analysed samples.

Figure 1: The physical analysis, captured by unmanned aerial vehicle, offering a comprehensive view of the manual sorting of MMSW, 2023

2.6. Statistical Analysis

For statistical evaluation, the proportions of individual waste fractions (e.g., plastic, paper, glass, metal) were analysed based on manual sorting of mixed municipal waste samples collected from 38 selected cities. Prior to analysis, the data were cleaned to remove errors and extreme values, standardized, and converted into a machine-readable format suitable for processing in the R programming environment (version 4.5.0)[17].

The statistical analysis focused on identifying potential relationships between waste composition, time of sampling, and the population size of municipalities. To estimate temporal trends in the time series, several regression approaches were applied:

- Classical linear regression model (LM) – baseline estimation assuming homoskedasticity and independence of errors.
- Robust linear model (RLM) – downweights the influence of outliers by weighting observations according to residuals, producing estimates less sensitive to extreme values.
- Linear model with cluster-robust standard errors – accounts for potential non-independence of observations due to repeated measurements within the same municipality. Standard errors were adjusted using a cluster-robust approach (sandwich estimator) with CR2 correction, clustering by municipality.
- Linear mixed-effects model (LMM) – includes municipality-level random intercepts to account for the hierarchical structure of the data and unobserved heterogeneity between municipalities.

Model assumptions, including the normality of residuals and homoscedasticity, i.e., that the variance of the error terms is constant across all levels of the independent variables, were evaluated using diagnostic plots[18]. In case of potential violations of model assumptions, robust regression was applied using the rlm function from the MASS package in R19. This method reduces the influence of outliers and non-constant variance by iteratively reweighting observations, offering more reliable estimates in the presence of heteroskedasticity or non-normal residuals. To further account for intra-group correlation and potential violations of the independence assumption across observational units, cluster-robust standard errors were computed. Specifically, the vcovCR() function with the CR2 estimator was used to correct the standard errors for clustering at the municipal level[20]. Results were presented asregression curves or point estimates with confidence intervals to highlight systematic temporal changes in the composition of the waste samples. Visualizations were created using the ggplot221 package in R, based on pre-computed model predictions.

Temporal trends in the proportion of waste types were assessed using linear mixed-effects models implemented via the lmer function from the lme4 package in R[22]. In these models, the proportion (pW) for each waste category was expressed as a function of time (date), with a random intercept for municipality (muni) to account for unobserved heterogeneity and the hierarchical structure of the data. Estimation was performed using restricted maximum likelihood (REML), which provides unbiased estimates of variance components under normality assumptions[23].

3. Results

The physical waste analyses were conducted over a five-year period from 2018 to 2022, with a total of 50 samplings from 38 Czech municipalities (Fig. 2). The municipalities ranged in population from 547 to 49,705 inhabitants, representing the characteristic fragmented settlement structure of the Czech Republic. The population distribution of the 38 studied municipalities demonstrated positive skewness, with the mean population (6,557.5 inhabitants) being higher than the median (3,567 inhabitants). This disparity indicates that while the majority of municipalities were small communities, a few larger municipalities approaching the 10,000 inhabitant limit pulled the mean upward. The median provides a more representative measure of the typical municipality in the sample, demonstrating that most waste composition analyses were conducted in smaller Czech municipalities, which reflects the general pattern of Czech municipal demographics characterized by numerous small communities.

The number of analyses increased notably from 4 in 2018 to a peak of 19 in 2019, followed by a decline to 7 in 2020 (influenced by COVID-19 pandemic restrictions). On average, 10 analyses were performed annually. Fig. 3 masks the substantial year-to-year variation. Seasonal distribution revealed a strong bias toward spring and autumn sampling, which together accounted for 58 % of all analyses. Summer and winter periods were mildly underrepresented due to the weather conditions. This seasonal pattern reflects practical considerations such as weather conditions and accessibility for waste sorting activities.

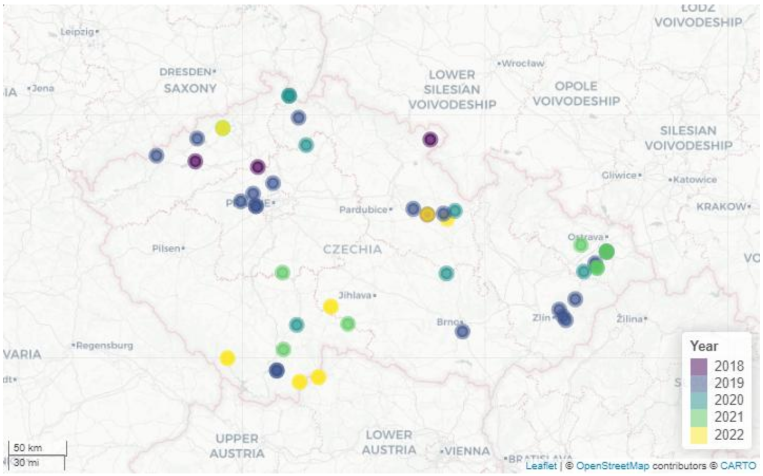

Figure 2: Geographical distribution of analysis sites in the Czech Republic, 2018 – 2022

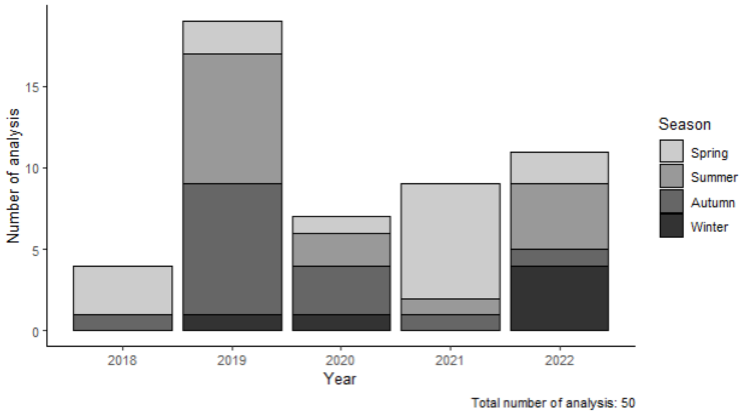

Figure 3: Temporal distribution of analyses conducted in 2018 – 2022 categorized by season

Waste samples contained MMSW from households, with each sample weighing an average of 500 kg. MMSW fractions were identified and manually sorted into 12 categories and subcategories. As a result of the study, the average composition of the waste samples was determined. The category of non-recyclable waste included waste fractions that could not be further materially utilized, encompassing hazardous waste, infectious waste, sub-sieve fraction, and residual mixed waste that cannot be recycled or reused. The average proportion of materially non-recyclable waste in municipalities amounted to 34.44% of total MMSW amount, while recyclable waste comprised 65.56 % (Tab. 1).

The comprehensive analysis revealed highly heterogeneity in waste composition. Biodegradable waste constituted the largest proportion in waste samples with an average rate of 33.62%, consisting of compostable and non-compostable fractions. Given the significant share of biodegradable waste in MMSW and its environmental impact, this waste category was further subdivided. The compostable biowaste was further categorized into biodegradable waste originating from gardens, parks, and urban greenery, and kitchen waste of plant origin. Non-compostable biodegradable waste predominantly comprises materials of animal origin, including meat residues, bones, eggs, and food products that have undergone thermal or other forms of processing. Besides biowaste, the next most numerically represented recyclable fractions in the MMSW samples was plastic waste with a share of 8.84%, followed by paper fraction representing 5.93% of total MMSW weight and textile waste comprising 6.46%.

Non-recyclable MMSW fractions, which should theoretically constitute the predominant portion of the waste sample, actually occupied slightly over one-third of the total waste samples, with 29.23 % comprising MMSW and an additional 5.21 % consisting of miscellaneous waste. Although residual MSW represents the second-highest proportion in the physical waste analysis, its representation was surprisingly low, particularly considering that the analysed MMSW sample represented residual waste following the separation of all recyclable fractions. The sample should theoretically consist of a large percentage of non-recyclable mixed waste, while recyclable waste should appear in minimal quantities after sorting (Fig. 4).

Table 1: Average percentage share of waste fractions in MMSW

Utilization	Waste Type	Share [%]
Non-recyclable waste 34.44 %	Mixed municipal solid waste (MMSW)	29.23
	Miscellaneous waste (MW)	5.21
Recyclable waste 65.56 %	Biodegradable waste (BIO)	33.62
	Plastic waste (PL)	8.84
	Textile waste (TE)	6.46
	Paper waste (PA)	5.93
	Glass waste (GL)	5.06
	Metal waste (ME)	2.73
	Waste from electrical and electronic equipment (WEEE)	1.17
	Composite packaging materials (CPM)	0.96
	Wood waste (WW)	0.79
	Batteries and accumulators (BaA)	0.00

Note: A three-tiered color-coding system is applied to categorize constituent materials based on their proportional representation in the waste stream: Red (>15 %); Orange (5-15 %); Blue (<5 %)

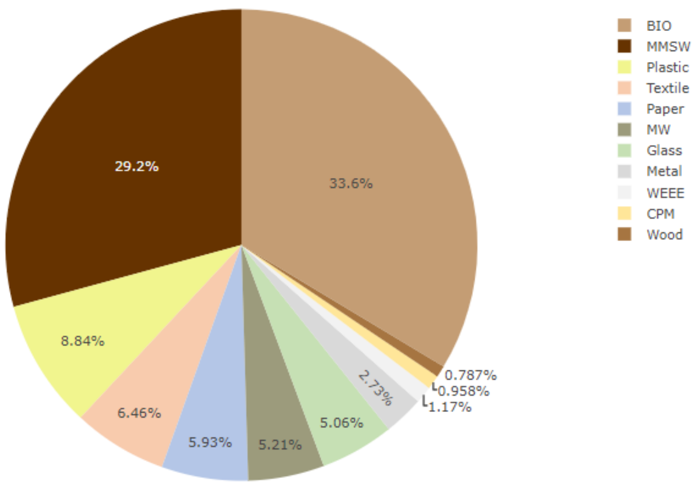

Figure 4: Proportional representation of individual waste fractions in samples of MMSW. Abbreviations: BIO: biodegradable waste; MMSW: Mixed municipal solid waste; MW: Miscellaneous waste; WEEE: Waste from electrical and electronic equipment; CPM: Composite packaging materials, 2018 – 2022

The physical analyses results reveal considerable heterogeneity in MMSW composition and variability in the proportions of individual fractions identified across the monitored Czech municipalities. This diversity may be attributed to several factors influencing waste characteristics and composition in Czech municipalities. One primary factor is the varying effectiveness of waste sorting systems implemented across different municipalities. Some municipalities have established efficient waste sorting systems with extensive collection container networks, frequent collection schedules, and adequate public awareness. These municipalities may exhibit lower proportions of recyclable fractions in MMSW. Conversely, municipalities with less developed waste sorting infrastructure can be expected to show higher representation of potentially recyclable fractions in MMSW. Beyond these primary factors, additional variables may influence waste composition, including seasonal fluctuations in waste production (e.g., higher biodegradable waste production during summer months), local economic conditions affecting consumption patterns, and regional specificities (recreational areas) [24, 25, 26, 27, 28].

The statistical analysis included an experiment examining relationships between the proportions of waste fractions present in MMSW samples, the time of sampling, and the population size of individual municipalities, using 3 regression approaches: classical linear model, robust linear model, and the linear model with cluster-robust standard errors. These results were compared in terms of standard errors, statistical significance, and trend direction. Overall, the direction and magnitude of estimated trends were consistent, while significance levels were appropriately adjusted for within-municipality correlation.

Among the tested waste types, plastics, beverage cartons, and textile waste demonstrated declining trends over time, suggesting improving sorting practices for these waste categories in municipalities. In contrast, biodegradable waste exhibited an increasing trend, indicating a growing share of this waste type in MMSW. Mixed municipal waste demonstrated only a minimal increase, resembling stable development (Fig. 5). These results confirm effective sorting of plastic waste, beverage cartons, and textile waste. However, attention must be focused on reducing biodegradable waste quantities, improving its sorting, or preferably preventing its generation through home composting initiatives.

Comparison of the robust and classical linear models indicated that estimates were generally similar. However, the robust model often yielded a lower residual standard error, confirming its resistance to the influence of outliers. A notable difference was observed for the plastic fraction, where the robust model estimated a slight decline over time, whereas the model with cluster-robust standard errors suggested almost no change. This discrepancy illustrates the potential impact of outliers on trend estimation.

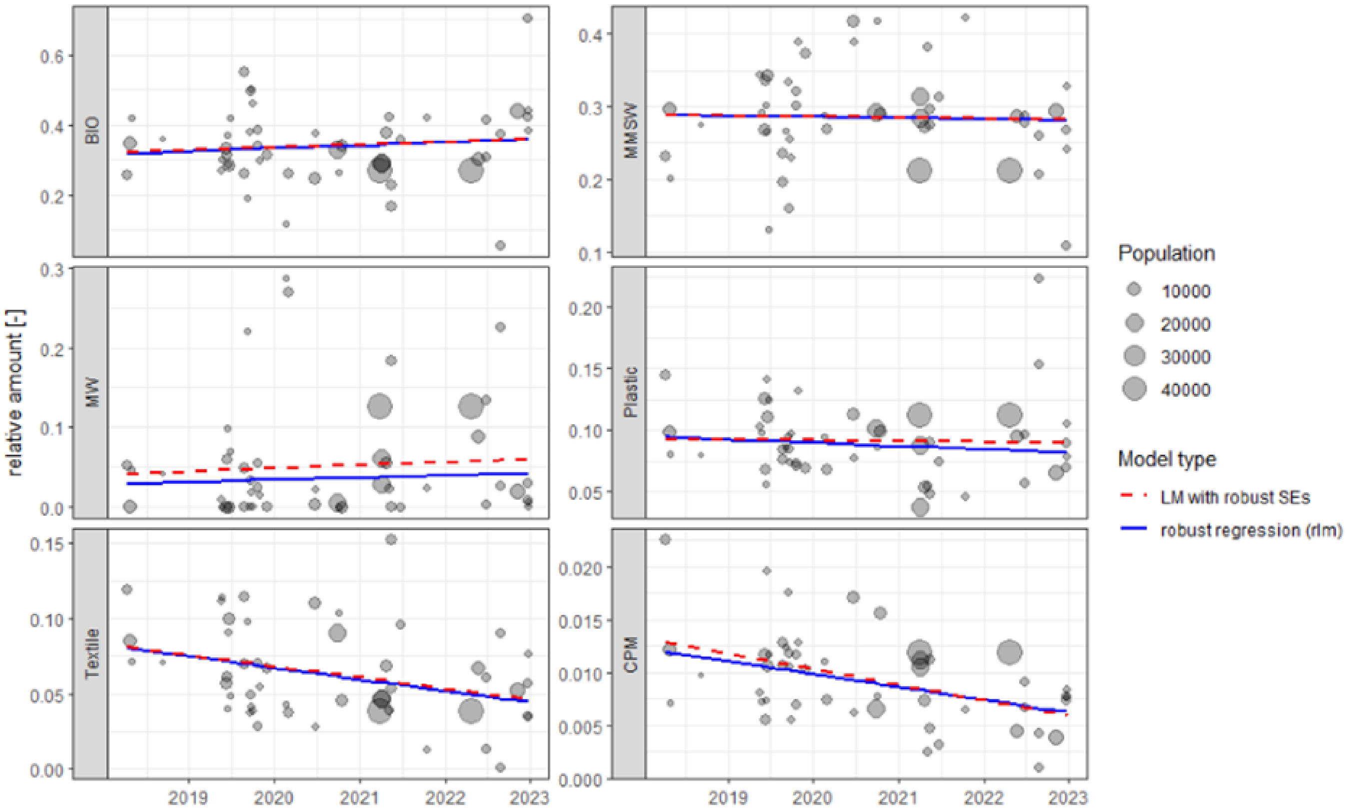

Figure 5: Temporal analysis of key MSW fractions across Czech municipalities (2018 – 2022), scaled by population size. Abbreviations: BIO: biodegradable waste; MMSW: Mixed municipal solid waste; MW: Miscellaneous waste; CPM: Composite packaging materials. 2025

An additional mixed-effects model was used to better account for the impact of repeated measurements from the same municipalities, with selected key results shown below:

Biodegradable waste (BIO): The analysis employed a linear mixed-effects model (lmer) with municipality-level random intercepts to account for variation between groups. The fixed effect for time (date) was positive but not statistically significant ($\beta = 2.07e{-5}$, $t = 0.66$). Most of the variance was captured by the residual component (SD = 0.0978), but the random intercept for municipality also showed notable variability (SD = 0.0464), suggesting differences in baseline levels across municipalities. The proportion of BIO in MMSW was additionally tested for temporal and seasonal patterns using a linear mixed-effects model because of its seasonal characteristics. Fixed effects included date (as a continuous time variable), season (categorical: Spring [ref], Summer, Autumn, Winter), and a random intercept for each municipality to account for between-group variability (n = 38). The fixed effect of time was small and not statistically significant ($\beta = 1.35e{-5}$, $t = 0.41$), indicating no consistent linear trend over time. Seasonal effects showed some variation: compared to spring (reference category), the share of biowaste was higher in autumn ($\beta = 0.075$, $t = 1.84$) and winter ($\beta = 0.088$, $t = 1.59$), though these estimates were not statistically significant at conventional thresholds. Random effects indicated modest between-municipality variability (SD = 0.043), with the majority of variance explained by residual variation (SD = 0.097). Overall, the model suggests a possible seasonal pattern, with higher proportions of BIO in autumn and winter, and no clear time trend. However, due to the limited sample size (n = 50) and uneven seasonal coverage, these results should be interpreted with caution.

Plastics: A slight negative trend over time was detected ($\beta = -5.29e{-6}$), accompanied by a small but non-zero municipality-level variance (SD = 0.0237). The residual variance (SD = 0.0212) was of similar magnitude, indicating that both individual- and group-level components contributed modestly to the overall variability.

Textile: The model estimated a negative time effect (β = −2.00e−5), suggesting a possible decline over time. Municipality-level variance was zero, indicating highly similar baseline levels across municipalities. Residual variation (SD = 0.0303) accounted for all observed differences.

Composite packaging materials: A slight negative time trend was observed (β = −4.49e−6), with minimal variation attributable to municipalities (SD = 0.0034). The residual component was also relatively small (SD = 0.0021), suggesting limited overall variability in this waste type.

MMSW: The model indicated a negligible positive time trend (β = 4.85e−7), suggesting virtually no change over time. Variability between municipalities was modest (SD = 0.0421), while the residual variance remained the dominant source of variation (SD = 0.0548). These results point to temporal stability in this waste type.

Miscellaneous waste: A small positive time effect was identified (β = 1.08e−5), while the municipality-level random effect variance was estimated at zero, indicating no detectable between-group variability. The residual standard deviation was 0.0734, implying that variation occurred primarily at the individual observation level.

Across all waste fractions, the effect of time was small and in many cases statistically non-significant, indicating relative stability in composition over small municipalities and the observed period. For recyclable fractions such as textiles and plastics, slight negative trends were observed, which indicates a reduction of these materials in the MMSW waste stream and suggest a gradual improvement in source separation, possibly influenced by policy measures such as the upcoming mandatory textile collection in 2025 and the expansion of multi-material collection systems. This is a positive development, as lower proportions of recyclable materials in MMSW reflect more effective diversion from disposal and better system performance. In contrast, biodegradable waste showed no statistically significant reduction, remaining the largest single component of residual waste, which points to persistent shortcomings in its separate collection. Variability between municipalities was notable for certain fractions, such as biodegradable waste, plastics, and MMSW, implying that local conditions, including settlement size, infrastructure availability, and collection systems (e.g. frequency) play a role in determining outcomes. In contrast, fractions with zero municipality-level variance (e.g., textiles and metals) appear more homogeneous nationwide, with observed changes driven primarily by temporal factors rather than local factors. Overall, the results indicate that while targeted municipalities with up to 49 999 inhabitants show modest signs of progress in certain material streams, substantial amounts of recyclable materials remain in MMSW, indicating that targeted, locally adapted interventions are still needed. Extending such analyses to larger municipalities will be essential to fully understand national waste composition dynamics and to design interventions that are effective across diverse settlement types.

4. Discussion

The physical analyses of MMSW conducted in 38 Czech municipalities up to 49 999 inhabitants between 2018 and 2022 reveal a surprisingly large quantity of recyclable materials still found in residual black-bin waste, with several key trends: a consistently high share of biodegradable waste and a modest decline in beverage cartons, textiles, and plastics. These findings underscore both systemic shortcomings and strategic opportunities for improvement.

The finding that 65.56% of MMSW consists of recyclable fractions requires interpretation that goes beyond a purely technical reading of the data. The substantial presence of high-value materials such as PET bottles, paper, and textiles in MMSW highlights systemic inefficiencies rather than solely methodological artefacts. The measured inefficiency of the system is not influenced by the methodology, as the adopted approach allows only minimal room for inaccuracies, unlike the methodology used by the Ministry of the Environment, which does not separate fine fractions and instead incorporates them into MMSW, despite the fact that fine fractions may contain a considerable share of biodegradable material.

Analyses were carried out in several municipalities with diverse waste management systems, taking into account factors such as the distance to collection points, the type of housing (multi-unit versus single-family dwellings), and other relevant variables. The reported outcomes represent a weighted average of all analyses conducted. The findings reveal a significant inefficiency within the current waste management system, which relies primarily on voluntary citizen participation and gradual public education. The presence of 65.6% recyclable components in residual waste may be interpreted as an approximate upper limit of the effectiveness of such a system. Further intensification of waste separation efforts, in the absence of additional motivational instruments, is unlikely to lead to substantial improvements.

The observed decline in beverage cartons and textiles over time can likely be attributed to intensified source separation efforts: in the case of textiles, as a preparatory response to the mandatory textile collection starting in 2025; and for beverage cartons, due to the increasing adoption of multi-material collection systems (e.g., plastics, metals, and cartons combined). This trend highlights that where concrete interventions combine **convenient infrastructure** with **systemic incentives**, behavioral shifts among residents are achievable.

However, the persistently high proportion of biodegradable waste — averaging 33.62% — remains a major concern. Although biodegradable waste constitutes the single largest waste fraction by both weight and volume, its separate collection is clearly insufficient. This situation has significant environmental implications, such as methane generation in landfills, and represents a missed opportunity for the production of biogas, compost, or digestate. The findings clearly indicate that the current system in small towns is ineffective: **most residents pay a flat-rate waste fee**, meaning their behavior has no impact on costs, and **collection containers for sorted waste are often farther away than residual bins**, reducing the convenience of source separation. In municipalities with maximum inhabitants up to 49 999, waste management services operate with limited budgets, which can result in less frequent collections, fewer container locations, and lower investment in public awareness campaigns. Seasonal fluctuations, such as increased population during holiday periods, can further strain existing collection systems and exacerbate inefficiencies in waste separation.

One of the key contributions of this study lies in its ability to quantify these patterns across time and location. Without adequate motivation — whether financial (e.g., discounts, PAYT schemes, deposit-return systems) or ergonomic (e.g., proximity and usability of bins) — behavioral change is unlikely. Moreover, according to annual reports from authorized packaging company EKO-KOM[29], about 20 – 30% of households still do not engage in waste sorting at all, or do so insufficiently, highlighting a significant untapped potential for improving source separation directly at the source. The fact that over 65% of residual waste still consists of recyclable materials indicates that existing measures in small municipalities are insufficient. There is an urgent need to redesign the system to be convenient, motivational, and economically fair.

Behavioural and social aspects further amplify these effects. Established disposal habits, limited awareness of the economic and environmental value of recyclables, and perceived inconvenience in transporting sorted materials to bring points all contribute to recyclable leakage into residual streams. Seasonal and situational factors – such as garden waste peaks, tourist influxes, or limited storage space in multi-unit housing – may also temporarily increase the share of recyclable fractions in black-bin waste.

These findings indicate that the high proportion of recyclable materials in residual waste is not simply a measure of technical recovery potential, but a reflection of the interplay between collection infrastructure, economic incentives, and household behaviour. Incorporating such behavioural and service-related parameters into future waste composition studies would enable a more accurate assessment of systemic efficiency and support the design of targeted interventions, such as improved container accessibility, PAYT implementation, or deposit-return systems for high-value packaging.

The data presented can be used not only to optimize local collection networks but also to inform **national policy interventions**. For instance, introducing deposit-return schemes for PET bottles and aluminum cans – materials with high market value and volumetric impal – would address key leakage points. Likewise, **door-to-door collection of biodegradable waste** should be prioritized, drawing inspiration from proven international practices. The study also notes that certain fractions (e.g., e-waste, composite materials) remain underrepresented, which may reflect not only analytical methodology but also low consumer engagement in specialized waste sorting.

Future research should delve deeper into the **motivational factors influencing household waste behavior**, the effect of container proximity, pricing models, and seasonal waste generation. Additionally, it would be beneficial to integrate physical waste composition data with **municipal sorting performance metrics**, thereby enabling a more holistic understanding of system efficiency. The results of physical waste analysis can be effectively used for several key purposes. They provide a basis for designing and optimising strategies aimed at increasing the rate of sorting recyclable and recoverable waste. Additionally, such data can support the adjustment of legislative measures related to waste management at the regional or national levels. Furthermore, the findings can help municipalities to set priorities for investment in local waste processing infrastructure.

5. Conclusion

This study presents a comprehensive analysis of the physical composition of mixed municipal solid waste (MMSW) in the Czech Republic, based on 50 standardized sampling campaigns conducted between 2018 and 2022 across 38 municipalities (inhabitants < 49 999). The results offer a detailed, data-driven insight into waste generation patterns and the efficiency of existing waste separation systems mainly in small Czech municipalities.

Key Findings:

The analysis reveals that **biodegradable waste constitutes the largest single component**, accounting on average for **33.62%** of total MMSW. This is followed by plastic waste (**8.84%**), textiles (**6.46%**), and paper (**5.93%**). Non-recyclable waste makes up **34.44%** of the total, a surprisingly low proportion given that the sampled waste represents residual streams after source separation. This suggests significant inefficiencies in waste sorting practices.

Temporal trend analysis identifies **statistically significant reductions** in the shares of **beverage cartons, textiles, and plastics** in the residual waste stream, indicating modest improvements in source separation for these categories. Conversely, the **share of biodegradable waste has slightly increased over time**, a finding that is both unexpected and concerning, given the availability of composting infrastructure in many municipalities. The composition of residual waste thus remains relatively stable in structure but suboptimal in performance, particularly with respect to organic waste management.

Interpretation and Implications:

These findings highlight critical systemic shortcomings in the Czech waste management over small up to medium-size areas. While improvements in the separation of some recyclable streams are observable, the persistent presence of biodegradable waste and other recoverable materials in MMSW suggests that **neither current infrastructure nor incentive structures are sufficient**. The flat-rate payment system, coupled with suboptimal accessibility of sorting infrastructure (i.e., containers located farther than residual bins), contributes to a lack of behavioral change among residents.

The study also confirms the **high material recovery potential** embedded within residual waste — 65.56 % of the analysed waste could be recovered or recycled. Particularly from a resource economics perspective, the presence of PET bottles and aluminum cans in residual waste represents a **significant loss of marketable materials**.

Recommendations for Practice and Policy:

The data advocate for a shift toward more **personalized and motivational waste management models**, such as:

- **PAYT (Pay-As-You-Throw) systems** to link behavior with cost;
- **Door-to-door collection schemes**, especially for bio-waste;
- **Deposit-return systems** for high-value packaging materials;
- Targeted communication strategies backed by behavioral insights and data.

From a policy perspective, these results reinforce the urgency of moving beyond infrastructural expansion and toward **systemic redesign that prioritizes motivation, convenience, and economic feedback loops**.

While this study provides valuable insights into waste composition across a wide geographic range in Czechia, the sampled municipalities all had populations below 49,999 inhabitants. Extending physical waste composition analyses to medium-sized towns and large municipalities is essential for building a comprehensive national dataset. Such an expansion would capture the influence of higher population density, diverse socio-economic conditions, and different waste management systems, enabling more accurate generalizations and the design of targeted, scalable policy interventions.

In conclusion, althoughthe Czech Republic has made measurable progress in waste separation, this analysis confirms that the **status quo is insufficient to meet EU circular economy targets** or to meaningfully reduce landfill rates. If biodegradable waste and high-value recyclables continue to leak into residual streams, both environmental and

Physical waste composition analyses – standardized, repeated, and scaled—should be embedded as a regular diagnostic tool for evidence-based municipal and national policy planning.

Acknowledgements

A special thanks to Professor Bedřich Moldan for his help with the formulation of research questions, as well as with focusing attention on the most essential aspects of the research in the field of circular economy, waste management focused specifically on textiles.

Literature

1. EKO-KOM: Výsledky rozborů směsného komunálního odpadu z obcí v roce 2022. EKO-KOM, 2022. https://www.ekokom.cz/vysledky-rozboru-smesneho-komunalniho-odpadu-z-obci-v-roce-2022/
2. ISPRA: Urban Waste Report – Italy. ISPRA, 2023. https://www.isprambiente.gov.it/files2023/pubblicazioni/rapporti/rapportorifiutiurbani_ed-2022_n-381-bis_versionedati-di-sintesi_en_05_04_2023-1.pdf
3. Eurostat: Municipal waste statistics, Eurostat, 2023. https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Municipal_waste_statistics
4. European Commission The European Green Deal. European Commission, 2019. https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:52019DC0640
5. European Commission: Circular Economy Action Plan. European Comission, 2020 https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A52020DC0098
6. Eurostat: Municipal waste statistics. Eurostat, 2023. https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Municipal_waste_statistics
7. World Bank: Baseline Review of Estonian Municipal Solid Waste Management System. 2021. https://documents1.worldbank.org/curated/en/911911637048755678/pdf/Baseline-Review-of-Estonian-Municipal-Solid-Waste-Management-System.pdf
8. Eurofins: Abfallanalytik – Methoden und Anwendungen. 2024. https://www.eurofins.at/umwelt/umwelt-oesterreich/boden-und-feststoffe/abfallanalytik/
9. Dornbusch, Heinz-Josef, et kol.: Factsheet zur UBA-Studie "Vergleichende Analyse von Siedlungsrestabfällen aus repräsentativen Regionen in Deutschland zur Bestimmung des Anteils an Problemstoffen und verwertbaren Materialien". 2020. Vergleichende Analyse von

Siedlungsrestabfällen aus repräsentativen Regionen in Deutschland zur Bestimmung des Anteils an Problemstoffen und verwertbaren Materialien | Umweltbundesamt

10. YPEN: Waste Composition Analysis in Greece. 2024. https://ypen.gov.gr/wp-content/uploads/2024/07/Final-Report_WCA_JMD114218_%CE%95%CE%9D.pdf
11. Gidarakos, Evangalos; Havas, G. and Ntzamilis, Panagiotis: Municipal solid waste composition determination supporting the integrated solid waste management system in the island of Crete. Waste Management, 2006, 26(6): 688 – 679. DOI: 10.1016/j.wasman.2005.07.018
12. Jani, Yahya; Kriipsalu, Mait; Pehme, Kaur-Mikk; Burlakovs, Juris: Composition of Waste at an Early EU-Landfill of Torma in Estonia. Iranian Journal of Energy and Environment, 2017, 8(2): 112 – 117. DOI:10.5829/ijee.2017.08.02.03
13. Enviroportal (2023): Analýza komunálneho odpadu ukazuje, že na Slovensku máme stále problém s triedením. Dostupné z: https://www.enviroportal.sk/clanok/analyza-komunalneho-odpadu-ukazuje-ze-na-slovensku-mame-stale-problem-s-triedenim
14. Ilko, Ivan; Peterková, Viera: Analysis of mixed municipal waste in selected municipalities and towns in Slovakia. Waste Forum, 2023, 4: 264 – 273
15. Takáčová, Zita; Vindt, Tomáš; Havlík, Tomáš; Kvokačka, Jozef: Analysis of the material composition of mixed municipal solid waste in the Košice region of the Slovak Republic. Environmental Engineering and Management Journal, 2018, 17 (4): 969 – 976. DOI: 10.30638/eemj.2018.097
16. Darmovzal, Petr: Slovensko bude stavět nové spalovny komunálního odpadu. MZV ČR, 2023. https://mzv.gov.cz/bratislava/cz/obchod_a_ekonomika/slovensko_bude_stavet_nove_spalovny.htm
17. R Core Team: R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria, 2024. https://www.R-project.org/
18. Wooldridge, J. M. Econometric Analysis of Cross Section and Panel Data. 2010. MIT Press
19. Venables, W. N., & Ripley, B. D. Modern Applied Statistics with S. 2002. Springer.
20. Arellano, M. Computing robust standard errors for within-groups estimators. Oxford Bulletin of Economics and Statistics, 1987. 49(4), 431 – 434
21. Wickham, Hadley: ggplot2: Elegant Graphics for Data Analysis. Springer-Verlag New York, 2016.
22. Bates, D., Mächler, M., Bolker, B., & Walker, S. Fitting Linear Mixed-Effects Models Using lme4. Journal of Statistical Software, 2015. 67(1), 1 – 48. https://doi.org/10.18637/jss.v067.i01
23. Patterson, H. D., & Thompson, R. Recovery of inter-block information when block sizes are unequal. Biometrika, 1971. 58(3), 545–554. https://doi.org/10.1093/biomet/58.3.545
24. Abylkhani, B., Guney, M., Aiymbetov, B. et al. Detailed municipal solid waste composition analysis for Nur-Sultan City, Kazakhstan with implications for sustainable waste management in Central Asia. Environ Sci Pollut Res, 2021. 28, 24406 – 24418.https://doi.org/10.1007/s11356-020-08431-x
25. Denafas, G., Ruzgas, T., Martuzevičius, D., Shmarin, S., Hoffmann, M., Mykhaylenko, V., Ogorodnik, S., Romanov, M., Neguliaeva, E., Chusov, A., Turkadze, T., Bochoidze, I., & Ludwig, C.: Seasonal variation of municipal solid waste generation and composition in four East European cities. Resources, Conservation and Recycling, 2014, 89, 22 – 30. https://doi.org/10.1016/j.resconrec.2014.06.001
26. Edjabou, M. E., Jensen, M. B., Götze, R., Pivnenko, K., Petersen, C., Scheutz, C., & Astrup, T. F.: Municipal solid waste composition: Sampling methodology, statistical analyses, and case study evaluation. Waste Management, 2021, 36, 12 – 23. https://doi.org/10.1016/j.wasman.2014.11.009
27. Palovčík, J., Jadrný, J., Smejkalová, V. et al. Evaluation of properties and composition of the mixed municipal waste fine fraction, the case study of Czech Republic. J Mater Cycles Waste Manag 25, 550 – 564, 2023. https://doi.org/10.1007/s10163-022-01534-2
28. Parfitt J, Griffiths P, Reid T. Guidance on the methodology for waste composition analysis. Zero Waste Scotland, Stirling, Scotland. 2013. https://www.zerowastescotland.org.uk/content/guidance-methodology-waste-composition-analysis-0. Accessed 5 Oct 2022
29. EKO-KOM: Výroční shrnutí. 2025. https://www.ekos.ekokom.cz/d/a9ee0/1085-ekokom_vyrocni_shrnuti_2024_cz_final_small.pdf

Tajemství černých popelnic. Výsledky fyzických analýz směsného komunálního odpadu v letech 2018 – 2022

Soňa Klepek JONÁŠOVÁ[1], Bedřich MOLDAN[1], Lukáš ZEDEK[2], Vratislav ŽABKA[2], Tereza VÁLKOVÁ[3], Shuran ZHAO[4], Petr NOVOTNÝ[5]

[1] Fakulta humanitních studií, Univerzita Karlova, Pátkova 2137/5, 182 00 Praha 8, Česká republika, e-mail: sona.jonasova@gmail.com, bedrich.moldan@czp.cuni.cz
[2] Fakulta mechatroniky, informatiky a mezioborových studií, Technická univerzita v Liberci, Studentská 1402/2, 461 17 Liberec 1, Česká republika, e-mail: vratislav.zabka@tul.cz, lukas.zedek@tul.cz
[3] Fakulta sociálních studií, Masarykova univerzita, Joštova 218/10, 602 00 Brno, Česká republika, e-mail: terezaa.valkova@gmail.com
[4] Technická fakulta, Česká zemědělská univerzita v Praze, Kamýcká 129, 165 00 Praha – Suchdol, Česká republika, e-mail: zhao@tf.czu.cz
[5] Institut cirkulární ekonomiky, z.ú., Purkyňova 648/125, 612 00 Brno – Medlánky, Česká republika, e-mail: petr.novotny@incien.org

Abstrakt

Tento článek představuje komplexní analýzu směsného komunálního odpadu (SKO) na základě fyzických rozborů jeho složení, které byly provedeny v českých obcích v letech 2018 až 2022. Studie identifikuje klíčové trendy v produkci odpadu, hodnotí efektivitu třídění a upozorňuje na potenciál zlepšení v oblasti nakládání s komunálním odpadem. Výsledky ukazují, že významnou část SKO tvoří biologicky rozložitelné a recyklovatelné materiály, což zdůrazňuje potřebu kvalitnějších systémů třídění a osvětových aktivit na podporu recyklace. Použitá metodika vychází ze standardizovaných postupů vzorkování a dat shromažďovaných po dobu deseti let.

Klíčová slova: *směsný komunální odpad, fyzická analýza odpadu, odpadové hospodářství, cirkulární ekonomika, efektivita třídění odpadu.*