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RECENT DEVELOPMENTS IN LANDFILLING AND BIODEGRADABLE WASTE MANAGEMENT: A CASE STUDY FROM THE CZECH REPUBLIC

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In accordance with EU legislation, the Czech Republic has been progressively implementing stringent regulations for the landfilling of municipal waste. The main reason is to facilitate the transition to circular economy and maximise material and energy utilisation. The aim of this study was to provide insights on biodegradable waste management in Czechia and to monitor changes related to landfilling at two distinct landfill sites in the Czech Republic fulfilling new legislation requirements. The analysis, underpinned by monitoring data on the amount and composition of waste landfilled from 2014 to 2023, has delineated a decline in the proportion of biodegradable waste. This trend aligns with that observed in other European countries. Furthermore, reduced energy production with a decreasing proportion of biodegradable waste in municipal solid waste was confirmed. The study points to the need for improved biodegradable waste separation, and it stands as a case study in the formulation of biodegradable waste strategies.

Keywords: biodegradation; municipal solid waste; landfill gas; cogeneration

European Union has been regulating biodegradable waste management through the Landfill Directive and Waste Framework Directive since 1999. Member states, including the Czech Republic, have been mandated to adopt measures that significantly reduce the landfilling of biodegradable municipal waste to 35% of 1995 levels. Efficient bio-waste management and redirecting of organic materials from landfills bring numerous benefits. It not only diminishes environmental impact but also contributes to resource recovery.

Historically, landfilling was the predominant method for disposing of municipal solid waste, including biodegradable components. However, municipal solid waste (MSW) landfills are recognised as one of the largest sources of human-related greenhouse gas (GHG) emissions consisting of methane and carbon dioxide (Kaza et al., 2018). These gases are produced by decomposing of organic materials inside the landfill body (El-Fadel et al., 1997). Concerning environmental protection, there is a gradual pressure to reduce landfilling of biodegradable wastes and hence reduce the generation of landfill gas, which has an impact on global warming (Sanjuan-Delmás et al., 2021). Landfill gas recovery and utilisation serve as a viable solution to mitigate the adverse environmental impact of landfills. Landfill gas is predominantly composed of methane, a potent greenhouse gas with a significant impact on climate change. When organic waste decomposes in landfills without proper gas management, methane is released into the atmosphere, contributing to global warming and air pollution. However, implementing landfill gas recovery and utilisation systems can significantly reduce methane emissions. Gas recovery involves the extraction of methane from the landfill using gas wells, pipelines, and other collection methods. Instead of allowing the gas to escape into the atmosphere, it is captured and directed towards beneficial use (Ciuła et al., 2023). Nevertheless, landfill gas recovery is not a sustainable solution. The latest Directive 2018/850 imposes restrictions on the landfilling of all waste suitable for recycling or other material or energy recovery and aims to reduce the proportion of municipal waste sent to landfills to 10% (European Union, 2018). To reach all of those ambitious targets of municipal waste landfilling, there is a need to set further incentives to improve the whole bio-waste management. Pivotal targets have been set to divert biodegradable municipal solid waste (BMSW) from landfill and in order to meet them, countries' waste management strategies and policies are changing and developing (Mühle et al., 2010). In response, the Czech Republic has implemented national legislation and strategies aligned with EU directives, focusing on waste prevention and reuse, material and energy recovery, and the safe disposal of waste. Safety and emergency prevention are an important part of operating landfills (Junga et al., 2023). The efforts led to reducing the amount of BMSW going to landfills to 75% of the total weight in 1995 by 2010, 50% by 2013, and 35% by 2020. This shift is not only a legal obligation but also a response to the growing environmental concerns associated with landfilling, such as greenhouse gas emissions, soil and water contamination, and resource deficiency. On the other hand, this transition poses both challenges and opportunities for municipalities, waste management companies, and policymakers, as they navigate towards a more circular economy and sustainable future.

Viewed through the lifecycle analysis, the diversion of organic material from landfill disposal or incineration offers a multitude of environmental and agricultural benefits, extending beyond mere waste reduction. The production of compost from organic waste represents a critical opportunity for enhancing soil quality and agricultural sustainability. The compost utilised as organic fertiliser or soil amendment introduces essential nutrients required for plant growth, improves the soil structure, increases the water retention capacity, and reduces the reliance on fossil-fuel-based fertilisers. The last but not least benefit of BMW diversion is to meet the reduction of carbon dioxide emissions regulation.

An integral part of effective bio-waste management is the collection system. The Czech Republic has developed various collection methodologies to streamline bio-waste segregation from other waste types. These systems are designed to maximise the efficiency of bio-waste processing and recycling.

Therefore, this study aims to monitor and analyse biodegradable waste variations in MSW landfills at two distinct locations in the Czech Republic. By examining these variations alongside existing BMSW management practices, this study endeavours to explore and enhance our comprehension of waste management strategies.

Material and methods

This research involves two municipal waste landfill sites in the Czech Republic. The first landfill (landfill B), situated in the densely populated Central Bohemia Region, is one of the largest in the country and has been in operation since 1994. Since 2014, it has received an average of 221,777 tons of waste annually, with approximately 66,000 tons constituting municipal solid waste. To accommodate its growing capacity, the landfill has undergone several expansions. Its expected closure date is set for 2035. In contrast, the second landfill (landfill F), situated in the South Bohemia Region, has been operating since 2014 and has received an average of 32,000 tons of waste annually, out of which approximately 16,000 tons consist of municipal solid waste.

Both landfills utilise degassing wells, pipelines, and cogeneration units to effectively manage landfill gas, contributing to sustainable waste management practices in the respective regions. The gas management system at each landfill involves the construction of gas wells, which facilitate the discharge of landfill gas into control shafts. From there, the gas is directed through dewatering shafts to the main gas line. Subsequently, the gas is channelled to a gas pumping station and then utilised in the cogeneration unit, where it is burned for energy recovery. The wells are designed using vertical progressively extended PEHD (polyethylene with high density) perforated pipes laid in drainage backfill or as horizontal drains. Gas wells are strategically positioned in sections where municipal waste is disposed as this is where landfill gas is primarily generated.

For the energy recovery from landfill biogas, the landfill B employs two cogeneration units, one with a capacity of 320 kW (TEDOM Cento T300) and the other with a capacity of 600 kW (TEDOM T200). The landfill F utilises a TEDOM Cento T160 SP BIO CHP unit with an output of 160 kW to burn the landfill gas. The landfill gas collection system at the second landfill is similar to that of the first landfill. However, the gas is actively pumped into the cogeneration unit on this landfill. Both landfills have dedicated sections for non-hazardous and hazardous waste, with the waste composition analysis focusing solely on non-hazardous waste.

All quantitative data about municipal waste received by these two landfills between 2014 and 2023 were collected in cooperation with landfill operating company and used for this study. Additionally, data from cogeneration units, continuously measuring electricity production and landfill gas consumption, were examined. The data were processed using MS Excel and program R. Given the non-normal distribution of the data, non-parametric statistical methods were employed throughout the study. This approach ensures robustness and reliability in the findings. The study evaluated the presence of organic material in the total waste and established a correlation with the consumption of landfill gas in the combined heat and power (CHP) unit.

Data used for this analysis:

– Yearly MSW Production (kg): total amount of municipal solid waste accepted by the particular landfill per year.
– Monthly MSW Production (kg): total amount of municipal solid waste accepted by the particular landfill per month.
– Yearly BMSW Production (kg): total amount of biodegradable municipal solid waste in landfill. This entry was calculated by summing the proportion of BMSW present in MSW and other unspecified bio-waste brought to the landfill. The proportion of BMSW was fluctuating every year according to the report of the Czech Statistical Office.
– Monthly BMSW Production (kg): total amount of biodegradable municipal solid waste in landfill each month. This entry was calculated by dividing the yearly volume by 12 months.
– Share: share of BMSW in MSW. This key parameter was used for almost all analyses in this study. This emphasis is attributed to the increasing volume of waste in total, which subsequently led to an apparent rise in bio-waste present in MSW, creating a deceptive impression of an ascending trend in bio-waste. However, the actual share of bio-waste exhibited a declining trend, substantiating the effective diversion of BMSW from landfilling.
– Biogas Production (m^3): biogas produced from MSW in landfill.

Results and discussion

The time-series analysis aimed to examine the trend in BMSW over time. The share of BMSW in MSW was used to show the trend of bio-waste production. In the landfill B, there was a significant decreasing trend in BMSW share despite some fluctuations, as illustrated in Fig. 2a. Concurrently, biogas production exhibited a mildly decreasing development (p-value = 0.035). In contrast, the landfill F (Fig. 2b) displayed almost undetectable significance in both bio-waste amount, which showed a slight decreasing tendency with some fluctuations (p-value = 0.08), and biogas production, which determined no significant changes over the years (p-value > 0.05). The minor significance observed, caused by fluctuations, is associated with the variability in waste received from regions, which can be strongly variable in quality and quantity, depending on many factors, e.g. different operational practices, policy changes, seasonal variables, or rare natural disasters. Despite this, the landfill B with the decreasing trend correlates with the expected outcomes of Czech bio-waste management policies aimed at diverting organic materials from landfills to more sustainable treatment options, such as composting or anaerobic digestion (Wagland et al., 2012).

The correlation analysis between bio-waste and biogas production further underscores the dynamics of waste management. Biogas is produced through the anaerobic fermentation occurring in the presence of biodegradable waste in MSW landfills and may serve as another parameter indicating the volume of bio-waste in landfills. In this instance, the landfill B exhibited a positive correlation, as indicated by a p-value less than 0.05, demonstrating an association between the quantity of bio-waste with biogas production. Concurrently, a reduction in the volume of bio-waste corresponded with a decrease in biogas generation. There are many other factors that may affect the biogas generation, such as total waste amount, moisture, temperature, age of landfill, and biogas capture technology. All these factors need to be considered during any planning or decision-making process.

Building on historical data, a basic prediction analysis using the ARIMA (AutoRegressive Integrated Moving Average) model (Hyndman and Khandakar, 2008) was undertaken for the next 36 months. The findings predicted a continuing decrease in the quantity of bio-waste over the upcoming months at the landfill *F*, with a more pronounced decline observed at the landfill B. The forecasting model suggested a potential continuation of current waste management practices. These projections can help in planning and managing waste and biogas production operations. By anticipating future trends, waste management facilities can optimise their processes and resources. Trends in biogas production forecasts suggest that factors other than just the total waste or bio-waste may be influencing biogas production. This could include the composition of waste, environmental conditions, and the efficiency of biogas generation processes. Understanding these conditions and the fluctuations in bio-waste and biogas production can aid in preparing for the periods of higher or lower activity, although they should be interpreted with caution due to the inherent uncertainties in predictive modelling (Ribić et al., 2019). Further research is required to unravel the complex interplay between waste management practices and biogas production, particularly under different environmental and operational conditions.

The composition of MSW significantly influences the volume and treatment of organic waste. It can be concluded that the amount of organic component in landfill will increase if more MSW is landfilled (Sel et al., 2016). However, the proportion of organic material in landfilled waste should decrease due to Ordinance No. 273/2021 Coll. on details of waste management, even assuming that the amount of MSW will grow in future due to population growth and the change of consumption pattern (Liang et al., 2022). Figure 1 shows that the organic component amount in MSW ranges from 17% to 27% according to Czech Statistical Office. For the years not shown, the composition of MSW is not provided and the same composition as in the previous year is assumed.

In EU, bio-waste constitutes 30–40% of MSW (with variations from 18% up to 60%) (European Commission, 2023). Under the EU's Waste Framework Directive, it was compulsory for all the member states to initiate separate collection of bio-waste by 1st January 2024 (European Commission and Directorate-General for Environment, 2023). In its report from June 2023, the Commission has identified member states that are potentially at risk of not achieving the 2025 targets for preparing municipal waste for re-use and recycling and the 2035 landfilling target. Only nine member states including Czechia are on course to fulfil the targets. Given this scenario, it is crucial for member states to intensify their focus on deploying efficient bio-waste collection strategies. This is fundamental not only to attain these demanding goals but also to further the development of circular economy throughout Europe. As the deadline passed, many municipalities are likely to adopt more cost-effective models to meet the minimum standard of separate collection of organic waste. The prevalent choice often includes the use of large curb side containers

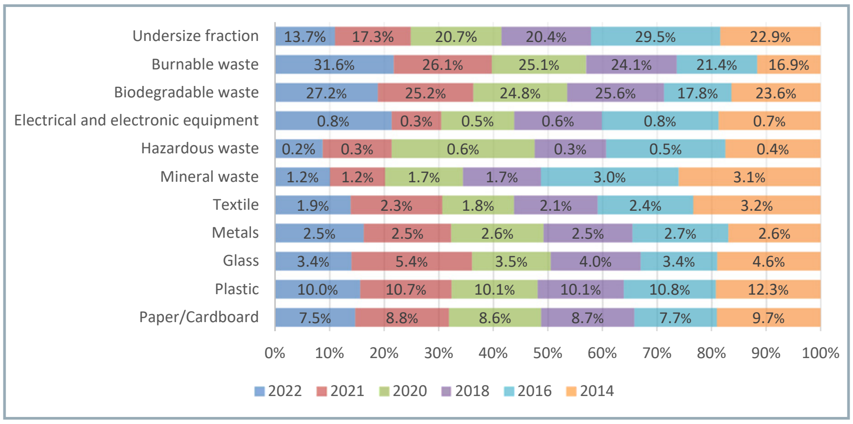

Fig. 1 Changes in the composition of MSW over year with bio-waste share

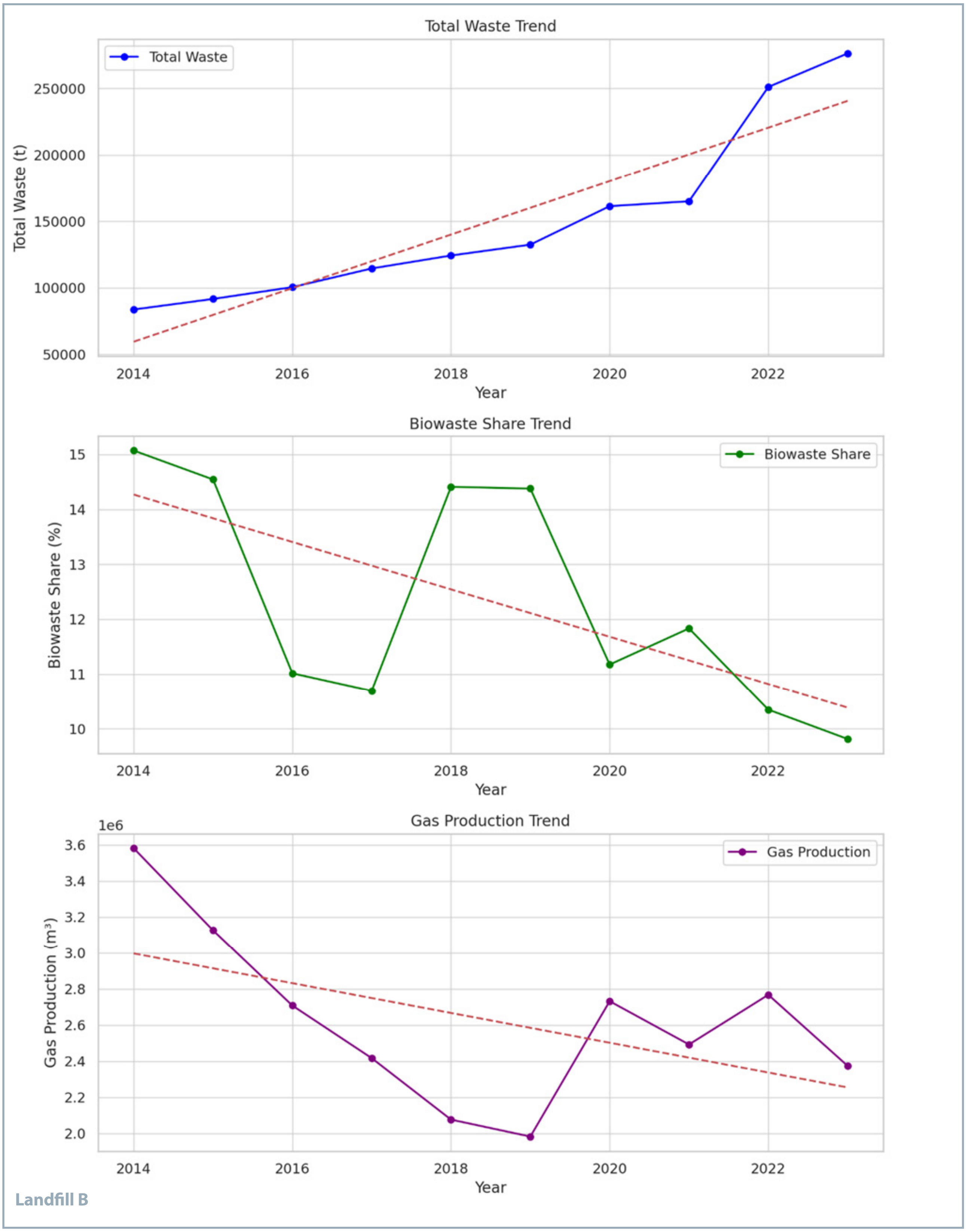

Fig. 2a Trends in total municipal waste, biodegradable waste share, and the volume of biogas production in landfill B

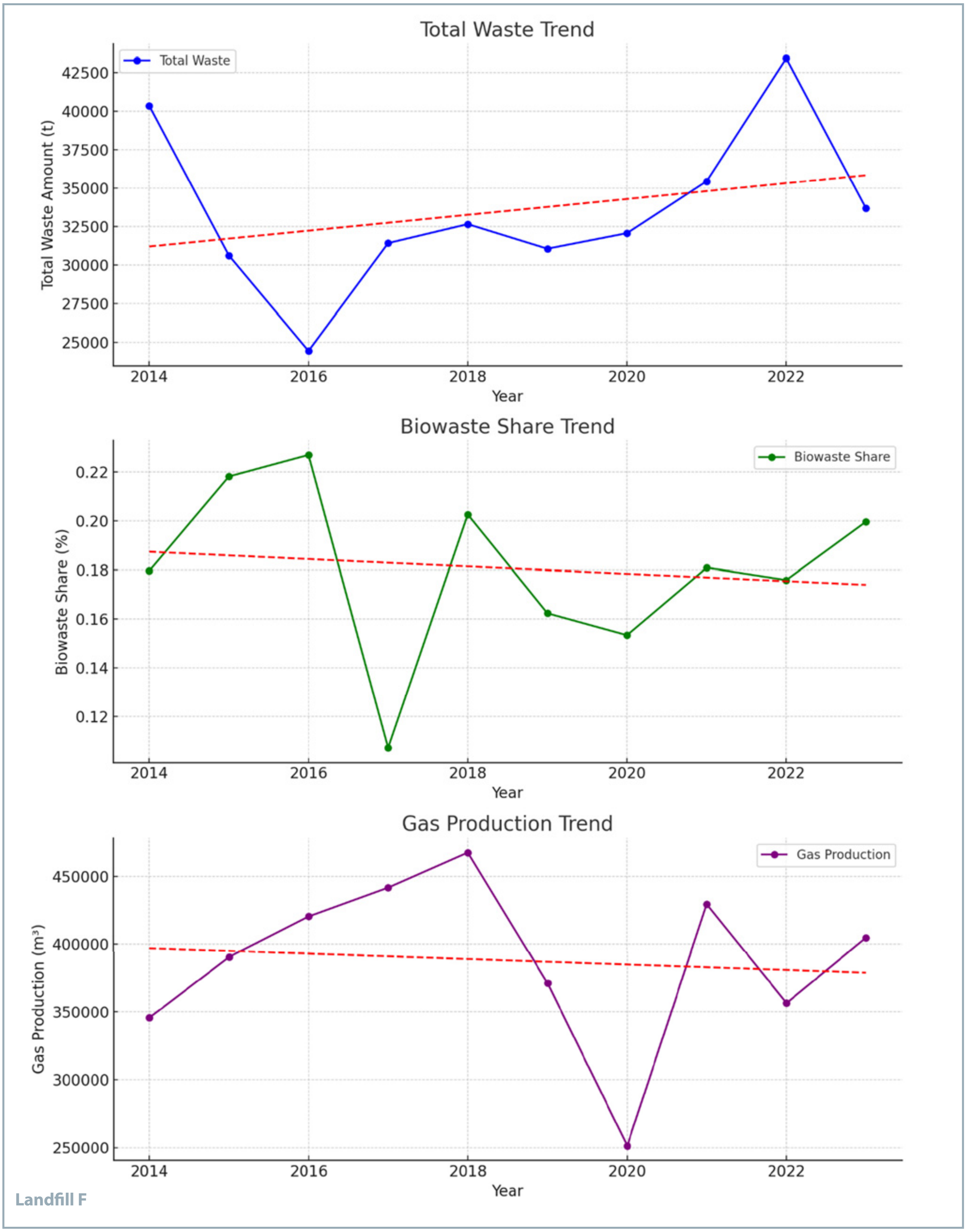

Fig. 2b Trends in total municipal waste, biodegradable waste share, and the volume of biogas production in landfill F

or bins, which some municipalities prefer due to their relative ease of implementation and lower costs (Wanderley et al., 2022).

The method of collection should align with municipality's capabilities. Typically, the most cost-effective method is accumulating organic wastes in high-capacity containers at collection yards. When municipalities place large-capacity containers in public spaces, they must consider the costs of handling and transporting these containers and the potential contamination of waste with unwanted substances.

It is worth mentioning that there's a tendency for residents with access to bio-waste bins to stop home composting and discard all bio-waste into these bins. Experience shows that the amount of BMSW collected in this way rapidly increases, with some cases reporting up to 100 kg of bio-waste per inhabitant per year (EKO-KOM, 2023a). With efficient sorting, the frequency of mixed waste collection could potentially be reduced to once every two weeks. Increased costs of bio-waste collection and system operation can be offset by reduced costs of MSW collection, transportation, and landfill fees.

There is an emphasis on the role of public participation and awareness in effective waste management. According to studies focused on bio-waste collection (Friege and Eger, 2022; Závodská et al., 2014), a targeted, regular, and repeated education for raising public awareness is essential, and different target groups should be identified and addressed by using different information channels to reach as many citizens as possible because citizens' participation in separation of bio-waste is a strong precondition for an effective and successful recycling scheme (Malamis et al., 2017). Continuous evaluation of the project and publication of results, such as the amount of bio-waste sorted and the benefits for citizens and the municipality, are essential.

In the Czech Republic, bio-waste constitutes the second most significant component of municipal solid waste and is currently one of the most debated waste types. If bio-waste is not collected separately, it ends up in incinerator or landfill with other MSW, where its potential is not adequately exploited (EKO-KOM, 2023b). The Czech Republic has implemented well-designed separate collection systems for BMSW, particularly in urban areas. These systems have been effective in decreasing the amount of biodegradable waste in the overall MSW stream (Chotovinský and Altmann, 2018). Already since 2015, the Czech Republic has implemented a mandatory separate collection of biodegradable municipal waste of plant origin in municipalities, at least during the period from 1st April to 31st October (Decree No. 321/2014 Coll.). The obligation to ensure year-round collection was introduced in 2019 (Decree No. 210/2018 Coll.). The obligation to provide facilities for the separate collection of biodegradable municipal waste is also considered fulfilled if the municipality has established a system of community composting for all plant residues from the maintenance of green areas (parks, forest parks, urban greenery) and gardens. Community composting is primarily seen as a preventive measure, not as a BMSW treatment method.

In the Czech context, the competence, responsibility, and administration of waste systems are delegated to municipalities. Consequently, these local authorities strive to prevent waste generation rather than landfill to reduce the burden on the municipal budget. Waste charge levied to residents must cover the costs of all waste management services, including public awareness activities. Citizens are obliged to separate bio-waste and other waste fractions from the residual waste (Hřebíček et al., 2017). To motivate citizens to separate at source, residual waste bins are usually charged at a much higher rate than bio-waste bins. However, too high differences in fees between organic and residual waste encourage incorrect sorting. For example, in PAYT system (Pay As You Throw), people pay for the amount of MSW they throw away. In order to minimise the waste, some residents try to burn the waste before throwing it away in order to reduce its weight, or in another case, to dump it in an illegal dump, i.e. littering. Moreover, there was a similar effect observed in a motivation system, where the citizens are rewarded for sorting bio-waste by a fee discount. People may dispose MSW into bins of bio-waste with the aim of increasing the weight. Therefore, visual inspections before collection should be conducted by collectors, and penalties in the case of repeated violations must be set effectively (Friege and Eger, 2022).

Despite the potential misuse mentioned above, the motivational system is still considered an effective mechanism for sorting bio-waste and generally all recyclable components of municipal waste. The first Czech system MESOH (Motivational and Register System for Waste Management) was devised in 2012 and it combines motivation and waste register in one. The core of the MESOH system lies in the implementation of a D2D (door-to-door) collection system, i.e. households have containers for sorted waste collection directly at their homes like mixed waste thus far. The reduction in the attendance distance enhancing convenience to residents results in both an increase in the quantity and an improvement in the purity of the sorted waste (Rousta et al., 2015). On average, bio-waste collected via local collection points has a higher share of contaminants than the door-to-door system. In highly populated areas, door-to-door collection is more optimal and cost effective, but living space may not allow for storage of several waste streams. Underground containers can be an option in city centres but require intensified follow-up to improve the quality of collected fractions. Collection systems must be set up in accordance with the type of bio-waste that the system will accept. For example, collection equipment and the frequency of collection of kitchen waste should be designed to minimise the risk of odour. The collection frequency of bio-waste significantly influences the effectiveness of separate waste sorting and helps address biodegradation issues like odours, flies, and leaks, ultimately improving the user experience. During the winter months, the frequency of waste collection may also be reduced due to lower production of bio-waste in households.

The motivational part of this system rewards citizens for waste sorting and reducing MSW by offering discounts on waste disposal fees. This approach encourages residents to handle their waste more responsibly and leading to an increase in the production of sorted waste. Consequently, this typically results in reduced costs for the collection of mixed municipal waste for municipalities. The system may also remunerate citizens for waste prevention measures, such as home composting or vermicomposting (Evans, 2001). The home composting system is considered the most cost-effective bio-waste management option for the municipality, as the costs are related only to the information campaign or contributions for the purchase of composters. In rural areas, home composting can often be easily implemented and the recovered nutrients can be used locally (Stejskal et al., 2017). If citizens do not wish to compost at home, community composting (collection at a composting site) is a viable alternative for managing bio-waste from households and gardens.

The promotion of home composting via communication campaigns reduces the publicly collected waste volume and costs in both rural and urban areas. Communication and new digital applications can reduce food waste by providing practical information on how to plan food purchases, store food, and utilise leftovers.

The practice of separating bio-waste at the generation point is essential for diverting BMSW from landfills, which is a key objective in minimising environmental impact and maximising resource recovery (Panaretou et al., 2021).

Conclusion

Current EU legislation requires a gradual reduction in the proportion of biological components disposed of in landfills, coupled with an emphasis on achieving the maximum material and energy recovery. In European Union, various projects and systems for bio-waste management are integrated into broader waste management strategies and numerous pilot projects are being carried out at municipal or city levels.

This study provides pivotal understanding of the dynamics of bio-waste management and landfilling practices in the Czech Republic. Despite existing gaps in the collection and utilisation of bio-waste, a noticeable improvement is observed through separate waste collection and recycling. As Czechia continues to evolve its waste management practices, findings from this research serve as a crucial basis for policymaking and strategic development, contributing to the sustainable waste management and environmental conservation.

The Czech model of BMSW management demonstrates a comprehensive approach that integrates effective collection and separation systems, anaerobic digestion for biogas production, and public education and participation. Establishing a uniform bio-waste management system that would be applicable to all cities and municipalities is not feasible. However, this model can serve as a benchmark for other countries looking to improve their waste management practices, particularly in the context of increasing environmental concerns and the need for sustainable waste solutions.

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References

CIUŁA, J. – KOWALSKI, S. – GENEROWICZ, A. – BARBUSIŃSKI, K. – MATUSZAK, Z. – GASKA, K. 2023. Analysis of energy generation efficiency and reliability of a cogeneration unit powered by biogas. In Energies, vol. 16, no. 5, article no. 2180. DOI: https://doi.org/10.3390/en16052180

Czech Republic. Decree No. 321/2014 Coll. on the extent and method of provision of separate collection of components of municipal wastes.

Czech Republic. Decree No. 210/2018 Coll. on the extent and method of provision of separate collection of components of municipal wastes.

EKO-KOM. 2023a. Efficiency of sorted waste collection in municipal systems between 2018 and 2022. Available at: https://www.ekokom.cz/vyteznosti-trideneho-sberu-v-letech-2018-2022-v-systemu-eko-kom/

EKO-KOM. 2023b. Results of municipal solid waste analysis in 2022. Available at: https://www.ekokom.cz/vysledky-rozboru-smesneho-komunalniho-odpadu-z-obci-v-roce-2022/

EL-FADEL, M. – FINDIKAKIS, A. N. – LECKIE, J. O. 1997. Environmental impacts of solid waste landfilling. In Journal of Environmental Management, vol. 50, no.1, pp. 1–25. DOI: https://doi.org/10.1006/jema.1995.0131

European Commission. 2023. Recycling of biowaste. Eurostat. Available at: http://data.europa.eu/88u/dataset/d2ja6lfsx1pw8prkuxpka

European Union. Directive (EU) 2018/850 of the European Parliament and of the Council of 30 May 2018 amending Directive 1999/31/EC on the landfill of waste.

European Commission and Directorate-General for Environment. 2023. Waste Early Warning Report 2023.

EVANS, G. 2001. Biowaste and Biological Waste Treatment. London : James & James Science Publishers Ltd, 216 pp. ISBN 1902916085

FRIEGE, H. – EGER, Y. 2022. Best practice for bio-waste collection as a prerequisite for high-quality compost. In Waste Management & Research, vol. 40, no. 1, pp. 104–110. DOI: https://doi.org/10.1177/0734242X211033714

HŘEBÍČEK, J. – KALINA, J. – VANĚČEK, M. 2017. Model of biowaste separation of household waste. Case study of the city of Brno. In Waste Forum 2017, no. 4, pp. 223–236.

HYNDMAN, R. J. – KHANDAKAR, Y. 2008. Automatic time series forecasting: The forecast package for R. In Journal of Statistical Software, vol. 27, no. 3, pp. 1–22. DOI: https://doi.org/10.18637/jss.v027.i03

CHOTOVINSKÝ, O. – ALTMANN, V. 2018. A comparative case study of the efficiency of collection systems for paper and biodegradable municipal solid waste. In Agronomy Research, vol. 16, no. S1, pp. 997–1009. DOI: https://doi.org/10.15159/AR.18.106

JUNGA, P. – TRÁVNÍČEK, P. – SUCHÝ, P. – KOTEK, L. – VÍTĚZ, T. 2023. Analysis of emergency situations at municipal solid waste landfills. In Journal of Material Cycles and Waste Management, vol. 25, pp. 288–301. DOI: https://doi.org/10.1007/s10163-022-01532-4

KAZA, S. – YAO, L. C. – BHADA TATA, P. – VAN WOERDEN, F. – MARTIN, T. M. R. – SERRONA, K. R. B. – THAKUR, R. – POP, F. – HAYASHI, S. – SOLORZANO, G. – ALENCASTRO LARIOS, N. – SELENE – POVEDA, R. A. – ISMAIL, A. 2018. What a waste 2.0: A global snapshot of solid waste management to 2050. World Bank Group. Report no. 132827, vol. 1. ISBN 978-1-4648-1329-0

LIANG, X. – KURNIAWAN, T. A. – GOH, H. H. – ZHANG, D. – DAI, W. – LIU, H. – GOH, K. C. – OTHMAN, M. H. D. 2022. Conversion of landfilled waste-to-electricity (WTE) for energy efficiency improvement in Shenzhen (China): A strategy to contribute to resource recovery of unused methane for generating renewable energy on-site. In Journal of Cleaner Production, vol. 369, article no. 133078. DOI: https://doi.org/10.1016/j.jclepro.2022.133078

MALAMIS, D. – BOURKA, A. – STAMATOPOULOU, E. – MOUSTAKAS, K. – SKIADI, O. – LOIZIDOU, M. 2017. Study and assessment of segregated biowaste composting: The case study of Attica municipalities. In Journal of Environmental Management, vol. 203, no. 2, pp. 664–669.
DOI: https://doi.org/10.1016/j.jenvman.2016.09.070

MÜHLE, S. – BALSAM, I. – CHEESEMAN, C. R. 2010. Comparison of carbon emissions associated with municipal solid waste management in Germany and the UK. In Resources, Conservation and Recycling, vol. 54, no. 11, pp. 793–801.
DOI: https://doi.org/10.1016/j.resconrec.2009.12.009

ORDINANCE No. 273/2021 Coll. on details of waste management.

PANARETOU, V. – TSOUTI, CH. – MOUSTAKAS, K. – MALAMIS, D. – MAI, S. – BARAMPOUTI, E. M. – LOIZIDOU, M. 2021. Chapter three – Food waste generation and collection. In WONG, J. – KAUR, G. – TAHERZADEH, M. – PANDEY, A. – LASARIDI, K. (Ed.). Current Developments in Biotechnology and Bioengineering. Elsevier, pp. 43–105. ISBN 978-0-12-819148-4.
DOI: https://doi.org/10.1016/B978-0-12-819148-4.00003-8

RIBIĆ, B. – PEZO, L. – SINCIĆ, D. – LONČAR, B. – VOCA, N. 2019. Predictive model for municipal waste generation using artificial neural networks – Case study City of Zagreb, Croatia. In International Journal of Energy Research, vol. 43, no. 11, pp. 5701–5713.
DOI: https://doi.org/10.1002/er.4632

ROUSTA, K. – BOLTON, K. – LUNDIN, M. – DAHLÉN, L. 2015. Quantitative assessment of distance to collection point and improved sorting information on source separation of household waste. In Waste Management, vol. 40, pp. 22–30.
DOI: https://doi.org/10.1016/j.wasman.2015.03.005

SANJUAN-DELMÁS, D. – TAELMAN, S. E. – ARLATI, A. – OBERSTEG, A. – VÉR, C. – ÓVÁRI, Á. – TONINI, D. – DEWULF, J. 2021. Sustainability assessment of organic waste management in three EU cities: Analysing stakeholder-based solutions. In Waste Management, vol. 132, pp. 44–55.
DOI: https://doi.org/10.1016/j.wasman.2021.07.013

SEL, İ. – ÇAKMAKCI, M. – ÖZKAYA, B. – SUPHI ALTAN, H. 2016. Case study on prediction of remaining methane potential of landfilled municipal solid waste by statistical analysis of waste composition data. In Waste Management, vol. 56, pp. 310–317.
DOI: https://doi.org/10.1016/j.wasman.2016.07.023

STEJSKAL, B. – MALSOVÁ, A. – BÁREKOVÁ, A. 2017. Comparison of family house and apartment households bio-waste production and composition. In Waste Forum, no. 4, pp. 237–243.

WAGLAND, S. T. – VELTRE, F. – LONGHURST, P. J. 2012. Development of an image-based analysis method to determine the physical composition of a mixed waste material. In Waste Management, vol. 32, no. 2, pp. 245–248.
DOI: https://doi.org/10.1016/j.wasman.2011.09.019

WANDERLEY, T. – MCQUIBBAN, J. – MÖRSEN, T. 2022. How to best collect bio-waste: Guidance for municipalities on the best performing methods to separately collect bio-waste. Zero Waste Europe. Available at: https://zerowastecities.eu/wp-content/uploads/2022/11/How-to-best-collect-bio-waste-EN-Final.pdf

ZÁVODSKÁ, A. – BENEŠOVÁ, L. – SMYTH, B. – MORRISSEY, A. J. 2014. A comparison of biodegradable municipal waste (BMW) management strategies in Ireland and the Czech Republic and the lessons learned. In Resources, Conservation and Recycling, vol. 92, pp. 136–144.
DOI: https://doi.org/10.1016/j.resconrec.2014.09.007