



University of Pannonia
Doctoral School of Chemistry and Environmental Sciences

**Innovative technological developments to divert municipal solid waste from
landfills and increase waste recovery rates –
supporting the circular economy**

DOCTORAL (PHD) THESIS

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Introduction

Since the Industrial Revolution, the functioning of modern societies has been determined by continuous economic growth and technological development, which has resulted in significant environmental burden. The ever-growing population, the intensive extraction and use of raw materials, and the transformation of production and consumption habits pose serious challenges. The previous linear economic model, in which materials follow the “extraction-production-consumption-waste” path, has proven to be unsustainable in the long term, as it depletes resources and produces ever-increasing amounts of waste. The circular economic model, on the other hand, is an approach in which materials remain in the economic cycle and are reused, thus minimizing the need for landfilling. In order to achieve the above goals, international strategies have been formulated, where the emphasis is on prevention, but other options (reuse, recycling, energy recovery) are also available to minimize landfilling – as an avoidable practice – and to eliminate it in the long term.

The aim of my research work is to examine the possibilities for modernizing and developing waste management, with a particular focus on minimizing landfilling. For this, I have developed and examined various technological solutions and systems that can contribute to achieving the national waste management goals, especially the target of a landfill rate below 10% by 2035.

During my work, I designed a mechanical and biological waste treatment technology to reduce the proportion of mixed collected municipal waste going to landfill. In addition, I developed an innovative complementary technology for the utilization of biodegradable waste, which was granted utility model protection. I also examined the efficiency of deposit-based redemption systems (DRS), with particular attention to the willingness to use the system and the collection infrastructure. Finally, I created a modular simulator system that provides the opportunity to model and optimize waste treatment technologies.

The results of the thesis may contribute to the development of waste management, the implementation of the circular economy in Hungary, and the development of more sustainable, resource-efficient waste management strategies.

Methods used

The complex approach required a similar complexity in terms of the methods used. The methods I used in my research on various landfills are as follows:

- The design of mechanical and biological waste treatment systems is based on the examination of market needs and fuel criteria. For this, I used foreign (German and Austrian) practical experience, as well as domestic research and experiments. During the design, I determined the quality parameters and appropriate technological solutions taking into account the needs of the domestic receiving market, I got acquainted with the latest available tools and equipment, while also taking into account the limitations of financial resources.
- In order to utilize the biodegradable (B) fraction with a new method, I determined the separation points and the necessary technological steps. I provided the technological equipment on a factory scale for the tests. I examined the waste fraction produced in this way using standard methods of waste analysis. Manual sorting and NIR optical sorting equipment were also available for the examination of the stabilized waste. The fuel was qualified based on a standard, which was carried out based on the parameters of heat of combustion, moisture content and chlorine content. During the measurements, I used an air-mixing drying cabinet, a calorimeter and a chlorine analyser.
- Hungary introduced a deposit refund system (DRS) for glass, PET and aluminium cans from 1st of July 2024. I conducted an online survey in the summer of 2020 to examine its public acceptance, in which 20,430 respondents participated. During the analysis, 16 explanatory and 23 explanatory variables were defined, and then I examined their relationship using statistical methods with the aim of using the results to help decision-makers in the effective design of the return system.
- I used a simulation solution to review waste management technologies and examine the effects of changes in the changing waste composition. The model I developed has a modular structure, thus enabling the individual examination of technological steps and the validation of data, helping to optimize existing technologies and supporting the design of new systems. I used expert questionnaires for the simulation, and reduced the uncertainty arising from the lack of measurements with Monte Carlo simulation. The results obtained using this method help to optimize existing technologies and support the design of new systems.

Theses

- I. According to the quantitative and qualitative composition of mixed household waste collected in the North Balaton Region:
 - I designed a modern, robust mechanical and biological waste treatment facility capable of treating 140,000 tons of MSW, which can flexibly meet the changing needs of the Hungarian alternative fuel market by producing two types of products (14-16 MJ/kg, 18-22 MJ/kg);
 - After the design, I supervised the construction and test run, which ensured that the expected parameters were met during the design and construction phases.

- II. I identified the energy potential of the approximately 60-70,000 tons/year of “B” fraction generated in the 120,000 tons/year capacity MBH plant operated in the North Balaton Waste Management System. I designed a new technology that is suitable for the production of an additional approximately 18-20,000 tons/year of RDF/SRF fuel. The technology has received utility model protection.

- III. Prior to the legislative changes in Hungary, I conducted a 24-question questionnaire survey regarding the acceptance of the introduction of the DRS system. From the analysis of the data of 20,430 people, I found that
 - based on the analysis of correlations, the introduction of the DRS system has a *raison d'être* in Hungary;
 - individuals' demographic characteristics and environmental attitudes both influence the use of the planned new DRS system, however, education does not significantly influence the willingness to do so;
 - Even at the lowest available fee (10-20 HUF), there is a significant willingness to use it, which increases as the fee increases;
 - Women with higher education living in the city are most open to the system;
 - For the sake of efficiency, it is necessary to primarily ensure placement in shopping centers and larger stores.

- IV. I have developed a modular simulator system, which allows for the economical design of waste sorting technologies that can be adapted to quantitative and qualitative conditions. In connection with the model sorting technology I examined, I ran the optimal 3000 cycles and found that the median of the recovery percentage results obtained by simulation was in all cases within the intervals given by the experts, thus validating the tool I developed.

Publication list

Publications related to theses

- Sarkady, A., Egedy, A., Kurdi, R., & Tóth, E. (2024). Towards a Circular Economy—Changing Needs and Solutions for Waste Management Systems. *Hungarian Journal of Industry and Chemistry*, 52(1), 45-53.
- Bárkányi, Á., Egedy, A., Sarkady, A., Kurdi, R., & Abonyi, J. (2022). Expert-Based Modular Simulator for Municipal Waste Processing Technology Design. *Sustainability*, 14(24), 16403.
- Boros, A., Kurdi, R., Lukács, Z. P., Sarkady, A., & Banász, Z. (2021). Opinion of the Hungarian population on the reform of beverage packaging deposit-refund system. *Sustainability*, 13(11), 6373.
- Sarkady, R. Kurdi (2015) Waste To Energy In Hungary: New Trends In The North-Balaton Regional Waste Management System Of Hungary In: Al-Kayiem H H, Brebbia C A, Zubir S S (szerk.) *Energy and Sustainability V: Special Contributions*. Konferencia helye, ideje: Kuala Lumpur, Malajzia, 2014.12.16-2014.12.18. Southampton; Boston: WIT Press, 2015. pp. 287-294. (ISBN:978-1-78466-095-6)
- A Sarkady, R Kurdi, B Morvai, Cs Leitól (2015) Diverting Muncipal Solid Waste from Landfill: New Methods in Hungarian Waste Management, In: Al-Kayiem H H, Brebbia C A, Zubir S S (szerk.) *Energy and Sustainability V: Special Contributions*. Konferencia helye, ideje: Kuala Lumpur, Malajzia, 2014.12.16-2014.12.18. Southampton; Boston: WIT Press, 2015. pp. 303-314. (ISBN:978-1-78466-095-6) .
- Sarkady, A., Kurdi, R., & Rédey, Á. (2014). RDF—refuse derived fuel, possibilities in the North-Balaton Regional waste management system. *Pollack Periodica*, 9(Supplement-1), 23-30.
- Sarkady, A., Yuzhakova, T., Dióssy, L., Kurdi, R., & Rédey, Á. (2013). NEW TRENDS IN COMMUNAL WASTE MANAGEMENT AT THE REGIONAL LEVEL: WASTE TREATMENT PLANTS IN HUNGARY AND PRACTICAL APPLICATIONS. *Environmental Engineering & Management Journal (EEMJ)*, 12(8).
- Sarkady, A., Dióssy, L., Yuzhakova, T., Kurdi, R., Utasi, A., & Rédey, Á. (2013). INDUSTRIAL AND COMMUNAL SUSTAINABLE WASTE MANAGEMENT IN HUNGARY. *Environmental Engineering & Management Journal (EEMJ)*, 12(8).

Utility model protection

File nr.: 137139-3046 EV/E/MGP Használati mintaoltalmi bejelentés száma: U2300217
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Submission: Attila Sarkady, Róbert Kurdi, László Kertai

Other publications

- Rózsenberszki, T., Koók, L., Bakonyi, P., Nemestóthy, N., Logroño, W., Pérez, M., Urquizo, G., Recalde, C., Kurdi, R., Sarkady, A. (2017). Municipal waste liquor treatment via bioelectrochemical and fermentation (H₂+ CH₄) processes: Assessment of various technological sequences. *Chemosphere*, 171, 692-701.
- Rózsenberszki, T., Koók, L., Hutvágner, D., Nemestóthy, N., Bélafi-Bakó, K., Bakonyi, P., Kurdi, R., Sarkady, A. (2015). Comparison of anaerobic degradation processes for bioenergy generation from liquid fraction of pressed solid waste. *Waste and biomass valorization*, 6, 465-473.

Conference presentation with appearance:

- Sarkady Attila, Egedy Attila, Kurdi Róbert: Úton a körforgásos gazdaság felé - változó igények és megoldási javaslatok a hulladékgazdálkodási rendszerek kapcsán– Előadás MŰSZAKI KÉMIAI NAPOK Veszprém, Veszprém 2023. április 18-20.
- Sarkady Attila, Bárkányi Ágnes, Egedy Attila, Kurdi Róbert: Moduláris szimulátor fejlesztése a települési csomagolási hulladék feldolgozási technológiájához– Előadás MŰSZAKI KÉMIAI NAPOK Veszprém, 2022. április
- Sarkady, A. Hulladékgazdálkodási projekt az Észak-balatoni térségben „HULLADÉKBÓL HASZON” szakmai konferencia Innovatív megoldások a hulladékgazdálkodásban 2012. június 5. kedd, 09:30 Pannon Egyetem Veszprém, Egyetem u. 10. Konferenciaterem (B épület, 2. em.)

Poster

- J. Bobek-Nagy, E. Tóth, F. Róbert, K. Berta, A. Sarkady R. Kurdi „OFMSW as a potential secondary raw material for chemical recycling” – August 27, 2023, 15th European Congress on Catalysis. Prague, Czech Republic
- Sarkady, A. Szent-Györgyi Albert Konferencia “Szelektív hulladékválogatás technológiai műveleteinek moduláris szimulációja” - 2021. április 17. Poszter csatorna