

Municipal waste management model with the use of optical sorting elements

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Introduction

The current situation on the waste management market forces all business and public entities to sort waste. The strict limits imposed on municipal waste deposited on landfills makes the processes of waste sorting and recycling of specific fractions of the produced waste the key element of waste management system. The most frequent method of waste sorting is sorting at the source, i.e. separate gathering of specific waste fraction directly by the entity producing the waste. Another method involves transferring mixed waste to specialised plants equipped with appropriate devices to sort waste into fractions (automatically or manually). At the moment, depending on the logistic capabilities, the morphological composition and volume of waste, as well as the expected quality of recycled resources, both methods are combined and complement each other [1]. A comprehensive amendment to the legal basis has proven to be essential for unification of the waste management system in Poland. The amended Act on the Maintenance of the Municipality in Clean and Orderly Fashion [3] significantly changes the approach to waste management approach in Poland. The nature of the changes is fundamental, therefore requiring amendment to strategic documents of the waste sector, i.a. the 2014 National Waste Management Plan [4]. As set forth in the document, the key entity responsible for waste treatment and achieving the assumed rate of recycling of municipal waste collected in the municipality or union of municipalities is the Waste Management Company (ZZO). Pursuant to the amendment to the Act [3], the territory of Poland has been divided into Waste Management Regions where this function is to be performed by Regional Municipal Waste Treatment Installations (RIPOK). Act [3] provides a clear definition of the regional installation (RIPOK) as the waste management company with capacity sufficient for accepting and treating waste from areas with at least 120,000 residents, compliant with the requirements of the best available technique or technology, providing the services of waste thermal treatment, or:

- mechanical and biological treatment of mixed municipal waste and separating fractions eligible for complete or partial recycling from the municipal waste mixture
- selective treatment of collected green waste and other biowaste, and manufacturing from said waste a product with fertilising properties, or plant growth stimulators, compliant with requirements set forth in separate laws and regulations
- landfilling waste produced in the process of mechanical and biological treatment of mixed municipal waste and residues from sorting municipal waste, providing landfilling capacity allowing the RIPOK to accept waste for a period not shorter than 15 years and in volumes not smaller than the volume of waste produced in the installation for mechanical and biological treatment of mixed municipal waste.

Amendments to the Act [3] resonate through the entire waste management system in Poland. From this perspective, the key change

is providing the local governments with clear legal basis for specifying the responsibilities of entities that produce waste, the compliance with which shall be enforced to the same extent as with other legal duties. Thus, an efficient administrative tool has been created which, through controlling the waste trade, favours the development of waste management system based on advanced technologies for large-scale production of tradable fractions from mixed municipal waste. Such legal basis will provide the operators of regional installations with easier access to large waste streams, necessary for the correct operation of the installation. The current absence of guarantees on the volumes of waste delivered to specific treatment installations is a major obstacle for investments in this sector. Therefore, the provisions introduced in the amendment to the Act [3] regulate the capability of directing waste streams in local governments, thus providing the investors with a kind of guarantee of exclusive use of waste volumes collected in the given waste management region. Considering the estimated value of the municipal waste treatment market in Poland, amounting to approx. PLN 5 billion/year [5], it should be noted that the new provisions create favourable conditions for the development of this sector.

Municipal waste management models

Working towards executing the legal obligations concerning waste management, it is worth employing the hierarchy of activities proposed by environmental management systems. The models are universal for all environment-related investments. However, they are particularly important for investments operating in the conditions of market competition. The proposed hierarchical problem analysis model (Fig. 1) is helpful in providing the right direction for the waste management in the economic entity, or in the local government.



Fig. 1. Model hierarchy of activities in developing a waste management system

This model recommends that at the first stage of development of waste management system a thorough analysis of the current state be performed. The analysis should be based on all available methods (legal, normative, calculative and measurement) to allow correct positioning within the waste management system of all components, i.e. selective collection, transport, regional installations, etc., and adjusting them to local conditions. Only after conducting such analysis can steps be taken to plan the strategy of waste management system operation in the given region.

The second proposed stage in the hierarchical model of actions taken during the planning phase of the waste management system is selecting the appropriate strategy for the system. It is a key stage for the preliminary activities, as it decides on the further method of handling waste. Thus, it is correlated to the type of waste treatment technology to be applied. It is also proposed that factors taken into consideration on this stage include the following, together with the defined short- and long-term variability coefficients:

- waste volume
- waste type
- character of the region (industrialised, rural, tourist)
- landscape and type of urbanisation
- ecological awareness of the local community
- thermal neutralisation capabilities
- internal use of waste capabilities
- demand for resources obtained from the waste
- capabilities of implementing technologies using the recycled resources in the region.

Given the broad scope of activities assigned to this stage in the model, the choice of technology, apparatus and equipment for the installation will be the final stage of development of the new waste management system. The key factor here is the ability to identify the optimal correlation between the quantitative and qualitative waste parameters and the best available treatment technology. Only proper correlation of all indicated parameters will enable the achievement of objectives defined in the previously developed waste management strategy. The prerequisite for achieving those objectives is the appropriate development of next level of the system, i.e. system management. It is the final stage before the deployment of the waste management system. The aspect of management is situated on top of the waste management system hierarchy, thus becoming its most essential component. The subordinate stages include managing design and construction, waste management system launch and managing proper operation of the waste management system.

Regional municipal waste treatment installation

The morphological composition of municipal waste and the resulting diversity of physical and chemical properties require dividing the sorting process into several sub-processes. Together, the sub-processes create a comprehensive waste sorting program which allows obtaining specific basic fractions. The fractions are then transferred for recycling, composting of the biodegradable fraction or landfilling (mainly mineral fractions), respectively.

Both composting and landfilling depend on the sorting processes which is the crucial element of the proposed municipal waste management system. Figure 2 illustrates the currently employed techniques of separation of mixed municipal waste. The simplest method of separating municipal waste into fraction is manual sorting in sorting cabins, often combined with techniques of mechanical waste separation (a frequent combination includes sorting cabins and separators of ferrous and non-ferrous metals or optical separators). Systems of this type have been classified as combined waste sorting systems [2]. Due to the relatively undeveloped system of sorting waste at the source and society's

low ecological awareness in terms of waste sorting in Poland, such combination of techniques proves very efficient in our country. The sorting cabin technique is based on the manual work of the operator who classifies waste visually according to specific properties. Sorting cabins can operate in positive or negative sorting mode. Positive sorting consists in identifying the desired properties in the waste, while negative sorting eliminates ballast without the specific properties. Negative sorting is characterised by higher efficiency than the positive one, although at the cost of quality of the obtained resources. On the other hand, positive sorting guarantees high quality of the product, but at the cost of efficiency [2]. Sorting cabins are also characterised by high flexibility since the operator may interpret the given property being classified at various levels of detail (e.g. he may identify the glass fraction in general, or more precisely, according to colour). This is a major advantage, as it enables quick, cost-free adjustment of the sorting line to changing waste parameters or demand for recycled resources.

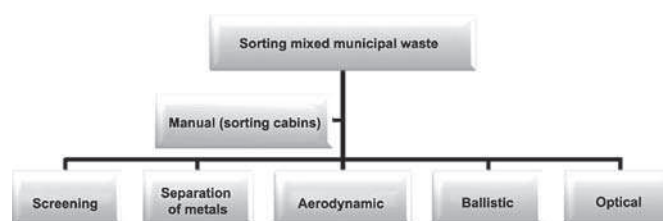


Fig. 2. Sorting techniques of mixed municipal waste

A further development of the sorting cabins are the optical sorting systems where the operator's eyes are replaced with the electronic signal from detectors that identify various types, structures and functions of waste. Those systems are employed in waste treatment plants and according to the amendment to the Act [3], they are to be used more and more frequently by the Regional Municipal Waste Treatment Installations. Optical separators are the most advanced technique of separation of mixed municipal waste fractions at the moment. The principle of operation is based on the identification of changes of radiation reflected from the given waste fraction. Optical separators comprise the emitter-detector system and a sorting factor (usually compressed air or mechanical follower), directing identified fractions into appropriate chambers (Fig. 3). Structural parameters are selected mainly in accordance with the detector type and thus the type of radiation responsible for identifying the fractions. The most frequently used detectors include near-infrared (NIR) and visible light (VIS) detectors. Less popular are high-resolution x-ray (RTG) and atomic absorption spectroscopy (AAS) detectors. Detectors may be used individually or in combinations, thus increasing the flexibility and efficiency of detection (Fig. 4).

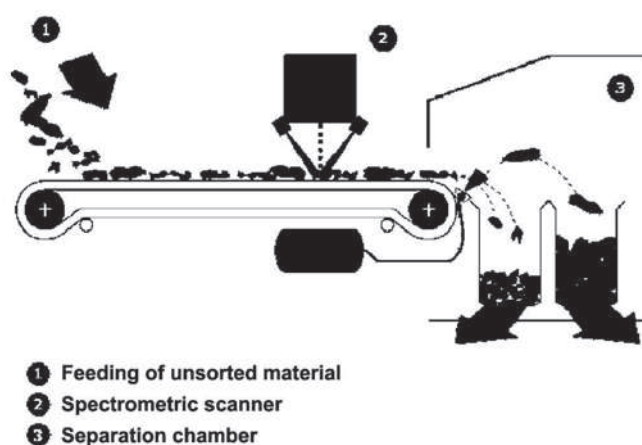


Fig. 3. Principle of operation of the optical detector [7]

CHOOSING STANDARD PACKAGES FOR SPECIFIC APPLICATIONS		MODELS			
		A	B	C	D
Sorting POLYMERS	Sorting e.g. juice boxes, PE, PP, PS, PVC, PET, EPS, ABS, according to material type	•	•	•	•
Separating mixed PAPER	Separating paper from the stream of mixed input materials	•	•	•	•
RDF	Producing RDF fraction, with additional separation of stone/wood		•		•
Sorting construction waste	Sorting organic/inorganic materials		•		•
Sorting PET/PE	Sorting PET/PE according to colour, e.g. light blue, transparent, etc.			•	•
Cleaning WOOD	Producing fractions of clean wood/chipboard by eliminating painted and coated wood			•	•
PAPER PLUS	Producing clean deinking fraction			•	•
Separating METALS	Separating all metals			Optional: EM detector	
MULTIFUNCTION	Up to FIVE packages in ONE device		•	•	•
SPECIAL APPLICATIONS	Upon request	•	•	•	•

Fig. 4. Detector configuration for optical separators [7]

An example of application of the system of optical separation of mixed municipal waste fractions can be found in Zakład Gospodarki Komunalnej SA (Municipal Management Company) in Bielsko-Biała which in the years 2009-2012 has implemented the project "Construction of comprehensive waste management system for the city of Bielsko-Biała and municipalities of Bielsko-Biała district" [6]. The total cost of the project is approx. PLN 85.5 million, with approx. PLN 55.2 million of co-financing from the Cohesion Fund. Under the project, aside from the construction of 2nd sector of the waste landfill, as well as shutdown and reclamation of the old landfill site, also the design and construction of a Waste Management Company in Bielsko-Biała Lipnik is planned, together with infrastructure and hardware, including i.a. the sorting plant for mixed and selectively collected municipal waste, with the capacity of 70,000 Mg/year. The system will comprise:

- a sorting cabin (preliminary waste sorting with cleaning the selectively collected waste)
- rotary wedge wire screen for separating the mineral fraction,
- ferrous and non-ferrous metals separators
- optical separators (7 pcs.) for separating plastic fractions (PET, PE, PP), papers, Tetra-Pack packagings and energy fraction (component for production of refuse-derived fuel – RDF)
- automatic baler.

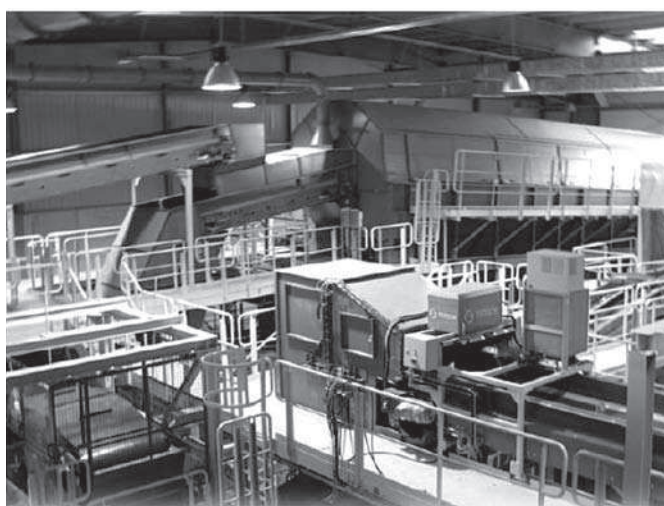


Fig. 5. Installation for sorting mixed municipal waste with the use of optical separators [6]

With the investment, Zakład Gospodarki Komunalnej SA in Bielsko-Biała has reached the recycling rate stipulated by law and achieved a significant ecological effect (reduction in waste deposited on the landfill by 60%, increase in the volume of biodegradable waste transferred to composting plant by 42.5%, reduction in waste mass after composting by 30%, increase in recycling rate of recyclable resources by 21.5%). Furthermore, implementing the mechanical waste sorting based on optical techniques enabled the automatic separation of the energy fraction for producing alternative fuel (RDF).

Summary

Interdisciplinary growth of environmental engineering, utilising even the complex solutions from the field of electronics or mechatronics, has led to the development of technologies which enable comprehensive management of all fractions of mixed municipal waste. The efficiency of those technologies depends on a multi-faceted correlation of the given region's character with the chosen waste sorting techniques. The available models of management for this type of enterprise, both at the stages of planning and operation, support the decision-making processes and facilitate the operation of the investment on an open market. At the same time, the opportunity to observe individual cases of comprehensive approach to developing a modern waste management system (not only in other European countries, but also in Poland) is of paramount importance. Learning how similar problems were solved by other regions is the easiest way to achieve the objectives set forth in the waste management strategy.

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