An assessment of potentials for using mechanical processes in municipal solid waste sorting

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Introduction

The dynamic civilization development of the society that forces to adopt consumption-oriented attitudes exerts an inseparable effect on all environmental components. The impacts in their majority have been already recognized, both in respect of its origin and the way of removing their negative effects. Unfortunately, the knowledge and availability of preventive measures not always results in a considerable improvement of environmental components. One of the pro-environmental fields that do not meet the current European standards is the solid waste management sector. The national waste management plant for 2010 [1] lists the following problems regarding the sector:

- Insufficient number of waste recovery and waste treatment plants, including the biodegradable waste
- Low municipal/communal activity in creating trans-communal waste management units
- The technical condition of waste management plants does not meet the legal requirements
- Obstructions or lack of access to systematic waste morphological test results as well as treatment products
- Insufficient environmental awareness of the society.

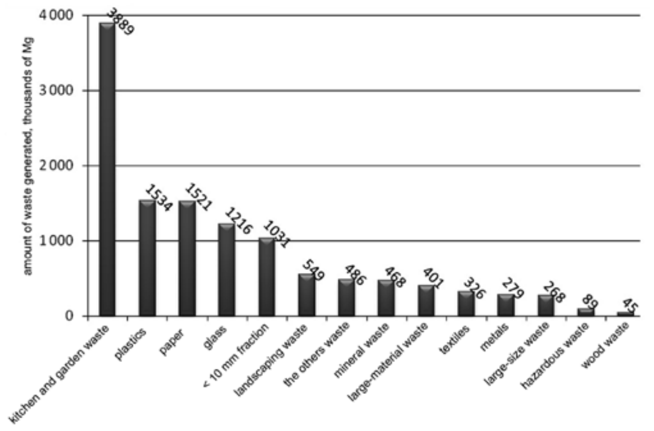

Fig. 1. Structure and amount of municipal waste generated in Poland in 2008 [2]

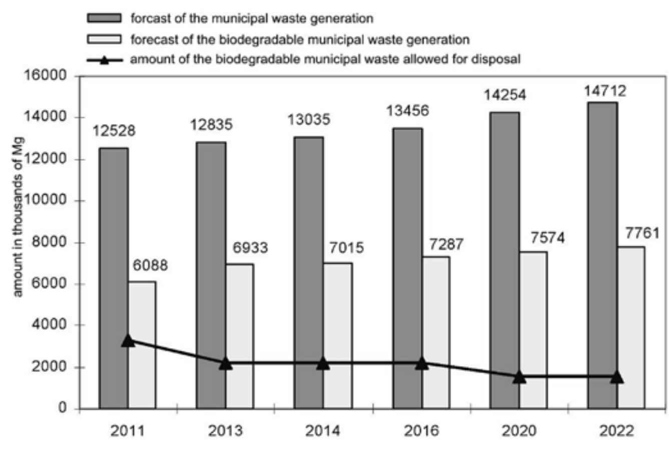

Fig. 2. Forecast for municipal waste to be generated in 2011-2022 [2], thousands of megagrams (Mg)

Apart from technical barriers, an additional problem is the quantitative aspect of Poland's waste management. In 2008 the overall amount of municipal waste generated exceeded the level of 12,100 thousand megagrams (Mg) and was higher by approx.

2,000 Mg than in 2007 [2]. Within the next 10 years, considering the economic and civilization development and legal requirements, we expect that the current trend of raising the amount of municipal waste will be maintained.

According to EU Directive on Waste [3] and the Law on waste [4], as well as taking into account the Decree of 12 June 2007 on criteria and procedures for permitting waste to be dumped at a specific landfill [5], imposing the requirement to avoid the municipal solid waste of which the heat of combustion exceeds 6 MJ/kg of dry weight, the National Waste Management Plan for 2014, sets as a far-reaching objective, developing the system based on the principle of sustainable development (SD), where all hierarchical rules for waste management are met. It means that this is another case when the problem of dumping mixed waste has been emphasized by defining the above-mentioned approach as the worst possible option of waste management.

The above-mentioned plan assumes reducing, by the end of 2014, the weight of municipal waste being dumped, down to the level of 60% of all waste generated. In addition, the municipal originated biodegradable fraction is also expected to be reduced, down to 50% in 2013 and 35% in 2020, in reference to the weight of municipal waste generated in 1995. As a result of the insufficiently developed selective waste collection system, raising the share of recovered municipal waste (both by recycling and energy recuperation) forces to build processing lines necessary to treat mixed waste, functioning within the waste management plants.

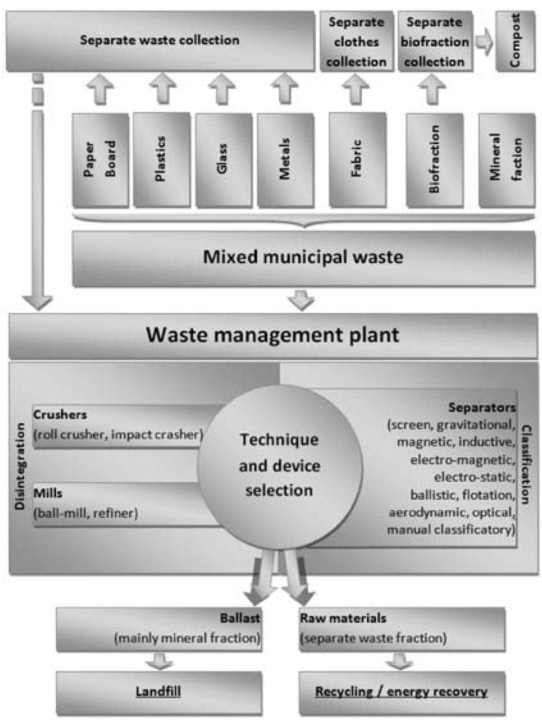

Fig. 3. Waste management system based on waste management plants

In the near future, strategic documents are expected to be followed by intensifying the steps aimed to separate particular fractions from the mixed municipal solid waste stream and deliver them for recovery or specialty treatment. One of the possibilities to achieve this goal is to sort mixed waste at any waste management stage using mechanical process-based waste sorting. Please note that using mechanical processes for sorting mixed municipal waste is just an addition to the suggested waste management system, not a separate processing form that can operate independently. Considering this, installing waste sorting lines in waste management facilities does not allow the waste management system administrators to neglect extensive actions to sort the waste directly where it is generated (it is clearly emphasized in document [2] indicating that selective waste collection (sorting it before disposal), should cover all the Polish population at the latest by 2015). The schematic diagram for waste management system adopting the above-mentioned assumptions is shown in Figure 3.

Waste sorting by mechanical means

Creating highly efficient waste management systems should combine sorting waste at its "source" and the methods of mechanical sorting [8÷10]. To fully analyze the process of mechanical waste sorting, we should be aware that taking into account the strategic legal regulations, they should not create an independent waste treatment form being able to operate independently. The processes of municipal waste mechanical sorting can be classified taking into account a few criteria, such as the process nature, size, the form of final product and the number of fractions obtained simultaneously. In practice, the most frequently used classification takes into consideration the feature that classifies mixed waste into particular fractions or a function fulfilled by each process within the sorting process line located in the solid waste treatment plant. Adopting the above-mentioned division scheme, the following processes can be defined:

Screening processes

The screening methods depend on waste morphology. In waste screeners the following two screen designs are used: flat and drum screens. In both cases the classifying feature is the waste fraction size, however, the very process is carried out using different techniques. The flat ones combine the reciprocating screen movement and linear waste movement (propelled by gravity and/or screen vibrations), while in the case of drum screens, the process is driven by centrifugal force generated by rotation.

Sorting metals and non-ferrous metals

Because of its physical properties it is relatively easy to separate the metal fraction from the mainstream waste. Using the magnetic field (various in nature) in a device or a device group adopting different space/movement configurations (Fig.4) [7, 8, 12] has been proved to be the most efficient method. Some available technologies make it also possible to separate non-ferrous metals [6, 9, 11, 13, 17]. The high efficiency of separating metal fraction from the mixed waste stream allows us to assume that the waste delivered for further treatment is completely free from this fraction, which is one of the aims to build mechanical waste sorting systems.

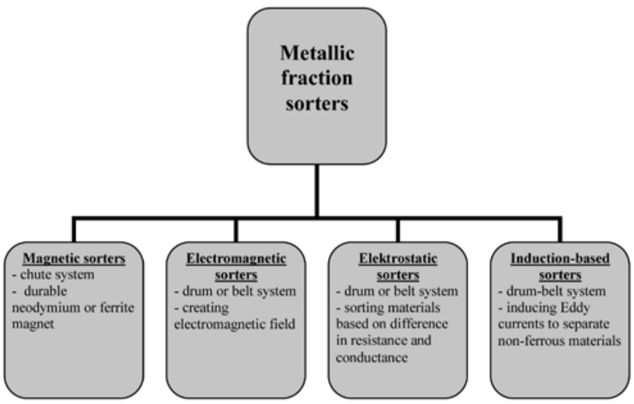

Fig. 4. Division of equipment used to recover metallic fractions from mixed municipal solid waste

Pneumatic and ballistic sorting

The pneumatic sorting is carried out by correlating a compressed air stream and waste density that enables to separate at least two fractions featuring different density values [14]. One of the obvious process advantages is the possibility of defining the separation parameter, being a resultant of gravity and momentum of the particles divided – thanks to this, the pneumatic sorting is a more flexible process that can be used for many waste fractions of raw or partly sorted municipal waste stream. The ballistic sorting is similar in nature, but the process is driven by a rotor, which mechanically throws waste into a sorting chamber.

The process of aerodynamic separation is carried out in aerodynamic separators, while ballistic in ballistic ones. They make it possible to divide waste into two basic groups: lightweight and heavy fraction. The lightweight fraction obtained in the process of aerodynamic sorting includes, e.g. paper, plastic film, plastics, textiles, and delivering it to a ballistic separator facilitates to obtain geometrically unstable fractions like plastic film, paper, textiles.

The heavy fraction remaining after completing aerodynamic and ballistic separation process can be supplied for further treatment or classified as ballast and delivered to a landfill.

Optical sorting process

The optical sorting is supposed to be useful especially when separating the non-metallic fraction. The progress in optoelectronics and computer-based control systems has made it possible to upgrade the process considerably over the last years and to design optical sorters with constantly growing waste sorting efficiency, which in consequence, results in changing economic factors for solid waste processing using optical separation methods.

An optical sorter for any municipal solid waste stream consists of a scanner (detector) using a lamp system and a compressed air system equipped with an air supply for all the equipment used within the process line and the waste air stream recovery.

The most commonly used optical sorting process scanners/detectors are the following:

- NIR (near-infrared detector)
- VIS (visible light detector)
- X-ray (high resolution X-ray detector)
- AAS (atomic absorption spectroscopy detector).

Waste is distributed by a belt conveyor equipped with an advanced speed control system [18]. All the system components are linked with a control system based on a complex algorithm, pre-defined for a given waste fraction. It should be emphasized that the algorithm change can be performed online. For high throughput plants, at unstable waste morphology, for economical reasons it is good to use a multi-scanner system classifying various optical parameters of waste being sorted. The very sorting process is carried out inside the sorter chamber, which, similarly to other belt conveyor based equipment, must ensure thickness optimization and waste layer concentration uniformity within the whole working width of the belt, to eliminate the process of waste item overlapping. The belt working width is determined by the measurement size generated by the scanner or many scanners and the pulse nozzle strip width. The conveyed waste stream is directed to the scanner measurement area located over the belt conveyor. The scanner identifies material properties, including its shape, structure, color, density and spectrum, being necessary for its recognition. Materials with pre-defined properties are pneumatically separated at the belt conveyor end by the pulse nozzle system [19].

Advanced optical sorters adopting the AAS technology, are used in refused derived fuel (RFD) production plants, because they make it possible to separate e.g. only plastics desirable in the fuel (PE, PP, PET), while such plastics as e.g. PVC, containing chloride improper for incineration process, are dumped as ballast at landfills, which is undesirable. Figure 5 presents a schematic diagram of an optical sorter.

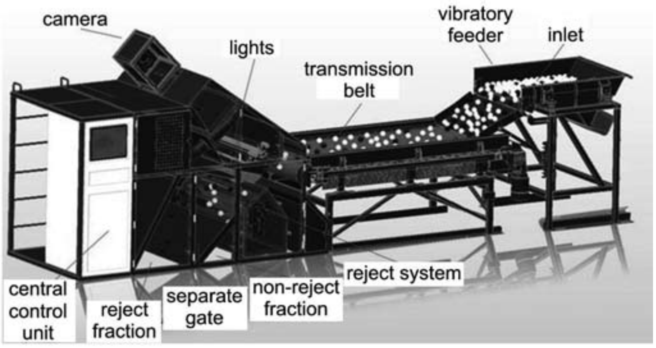

Fig. 5. Optical sorter schematic diagram [20]

Mechanization in the waste sorting plant

To present the potentials of using particular mechanical processes to separate municipal solid waste fractions within a sorting line, a model solid waste management plant has been analyzed for mechanization rate. The selection of machinery for a plant using mechanical processing equipment must meet many criteria and provide operation continuity at a pre-set efficiency level, at the same time, minimizing the need for manual interventions.

The selection of mechanical processes and their parameters, mutual connections between processes depend on the knowledge of morphology, frequency and amounts of waste as well as further processing of fractions recovered. It is worth considering such physical properties as humidity (fully mechanical sorting plant is recommended to treat dry waste), or waste density. Depending on the above-mentioned parameters, the process line will adopt different configurations. The plants can differ not only in equipment used, but also in the number of machines and their sequence within the process line. Only a correct selection of particular sorting line components results in obtaining expected fraction recovery rate from the mixed solid municipal waste. In this aspect, knowing the processes used to obtain particular waste fractions seems to be of critical importance to design and operate solid waste sorting lines. See below for an example of mechanical solid waste sorting plant equipment configuration.

Waste preparation (crushers, mills, perforators)

The profitability of waste transport forces us to use methods to minimize its volume. The process of compacting is carried out at each stage of waste collection, starting from its source, and ending at its final user. These steps should lead to obtaining waste subjected to many compaction stages, which prevents the target recipient from starting direct waste sorting process. Under such conditions, it is necessary to introduce shredding and disintegrating processes. The processes should be carried out until disintegration enabling delivering waste at a constant stream in a square section layer, minimizing its height and providing a constant transverse dimension within the whole process line [6]. Meeting the above-mentioned criteria is extremely important considering the sorting control performed within a complex process line, whose components usually function at various efficiency rates. The shredding process should be divided into initial stage (eliminating effects of transport pressing/compaction) and the main (enabling to obtain a final shredding level). For certain mechanical sorting processes it is necessary to shred waste considerably, that is why the waste should undergo the main shredding stage prior to delivery, where it is, additionally, partly disintegrated to lose its multi-material property [16, 17]. Introducing the few steps of waste shredding intensity provides an opportunity to deliver optimally formed waste to particular process line equipment components. Thanks to combining the processes, shredding is performed simultaneously with screening, e.g. thanks to using sieve screens, it is possible to separate a considerable part of mineral fraction (below 35-40 mm) [15].

Separating into basic fractions (screeners)

The process of sorting into basic fractions in terms of logistics can be facilitated by internal waste conveyance system within the whole sorting plant process line. It is very hard to control the multi-size waste stream, but it also reduces the efficiency of some sorter types (e.g. metallic fractions sorters). To uniform the waste streams it is possible to use e.g. a drum screen to divide raw waste by its size into two basic fractions: fine (delivered to magnetic sorters) and medium (delivered to pneumatic, ballistic and optical sorters).

Sorting ferrous and non-ferrous metals (metal sorters)

As it has been already mentioned, the metal sorting, both ferrous and non-ferrous, is carried out in a highly efficient way using one of many available methods. Unfortunately, to provide a desired division efficiency, the waste stream must cycle a few times to separate the same fraction from each unit stream, for pre-separated or already sorted waste. For this reason metal sorters should be located both at the beginning of the process line, receiving the shredded fraction and following the basic sorting, and in the middle of it, e.g. following the aerodynamic or ballistic sorter.

Pneumatic and ballistic sorting (pneumatic and ballistic sorters)

Pneumatic and ballistic sorters divide the medium size fraction and fine fraction ballast delivered from the metallic fraction sorter. At this stage it is plastic waste that is mainly separated. The ballast fraction often contains some precious mineral material - glass. The lightweight fraction is divided additionally into soft and hard sub-fractions (plastic film separation). Furthermore, the pneumatic and ballistic separators are used to prepare the waste stream from treatment in optical sorters.

Optical sorting (optical sorters)

Depending on requirements for the sorting plant final product it is possible to use different optical sorters (separating particular types or colors of plastics). The sorters being used make it possible to separate both the medium and fine fraction. As a result, the sorter type depends considerably on the process used downstream to recover each fraction. Optical sorters can be used at any point of process line, as the flexibility for selecting a classifying parameter makes it possible to separate many types of materials.

Auxiliary and accessory equipment

The above described equipment should be provided with a complex conveyance (transportation) system, both for raw waste and final products, using majority of methods available (wheel/road transportation, belt bucket elevators/conveyors, pneumatic, chain conveyors) and an advanced control and monitoring system.

Summary

The practice shows that certain equipment types, independently of waste delivered to the sorting plant are always used to separate a particular waste fraction (e.g. metal sorters found in organic recycling facilities, waste sorting lines, RDF production lines). It is mainly due to the high recovery efficiency for each fraction, but also thanks to extremely low sorter operation costs at an average or low sorting efficiency. To meet the rates provided by strategic regulations for waste recovery, each mechanical system for sorting mixed solid municipal waste should be configured based on a detailed functional-use assessment including an extended analysis for waste morphology and chemical composition. As a result, each plant should be designed on an individual basis already at the stage of configuring particular components. This is not about creating dedicated and specific technical solutions for each waste management site, but to develop unambiguous guidelines for particular line components and for optimizing the component selection for the whole and uniform plant. The guidelines need to be confirmed – as it is in other technical sectors – by extensive studies both on a laboratory and industrial scale.

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Chemical Development & Scale-Up in the Fine Chemical and Pharmaceutical Industries
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Chemical process development is generally not taught as part of degree courses in higher education; the conversion of a synthetic route used for making milligram or gram quantities of a chemical into a process for manufacturing multi-kilogram and tonne quantities is typically learnt "on the job" by chemists in industry. For many years, little chemical development work was published in the literature, until the establishment of the Organic Process R & D journal by Dr Trevor Laird (Founder of Scientific Update). Even now, "tricks of the trade" are handed down within individual company organisations, and it can be difficult to gain an awareness of what is involved in chemical development, and of the skills and techniques required to efficiently scale up chemical processes. This three-day course, written and presented by highly experienced process chemists from the pharmaceutical and fine chemical industry, provides a comprehensive overview of this fascinating and important element of the chemical industry. A logical investigative approach to all aspects of chemical development is described, with an abundance of case studies from literature, conferences and private communications. The multi-disciplinary nature of chemical development is emphasised, from the initial interaction with laboratory research scientists to the vital partnership with chemical engineers in the pilot plant and in the production environment. The lectures are interspersed with interactive problem sessions, enabling participants to share in the problem solving and troubleshooting typically experienced during chemical development.

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