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# Research underpinning the design of an optical sorting plant

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## ABSTRACT

In the sorting plant examined during the research, the sorting of the selectively collected mixed packaging waste is done by hand. Studies were performed on the quantitative changes of the waste stream entering and leaving the sorting plant, the composition properties according to the particle size, and lastly the number of pickings. The amount of incoming waste has increased linearly over the years. The sizes preferred by the optical separators were the guideline during the measurements. Sixty per centage of all incoming waste falls in the ideal range of 70–350 mm, 20% in the range of <70 mm and 20% in the range of >350 mm. Because there are significant differences in composition and quantities as the seasons and months alternate, these results provide important information for engineers designing a mechanized technology.

## KEYWORDS

packaging waste, household waste, selective collection, manual sorting, optical sorting

## 1. INTRODUCTION

One of the main challenges for the current circular economy policy of the European Union (EU) is to increase the rate of recycling packaging. The EU has set a target of recycling at least 65% by weight of all packaging waste by 31 December 2025 at the latest and at least 70% by weight by 31 December 2030 at the latest [1]. Manufacturers of various products have the biggest role in the generation of packaging waste, as the packaging they produce goes to waste collection after the product is put to use, but they tend to think that once the product reaches consumers, the fate of packaging is no longer their problem [2].

The next essential element of the circular economic model of packaging waste is the proper management of the waste generated. The most common method of preparation for recycling in Europe is sorting. Today, there are many ways to do this, from manual sorting to fully mechanized sorting technologies using countless machine types [3–5]. The capacity of a manual sorting facility is affected by the number and performance of the workforce. In Hungary, the processing of the current amount of waste is already a problem for many sorting plants; more problems will arise from the expected increase of the packaging waste, the congestion in the plants, and the unsuitable collection methods. Therefore, it is necessary to start working on mechanized developments and expansions now, so the sorting of selectively collected packaging waste succeeds in the coming years to meet EU recycling targets [6–8].

To apply the sorting technologies effectively, it is essential to pay due attention to the long-term and cost-effective operation as early as in the design phase [9]. This requires accurate knowledge of the exact quantity and composition of the waste entering the plant, and it is essential to take into account the quantitative and qualitative changes in the waste trends [10]. Due to the characteristics of the incoming material, several factors influence the efficiency of the technology. Divergent wastes can become tangled and jammed at transfer

points and dispatch points, but they can also cause jams in sieves and shredders. Therefore, in all cases, it is worthwhile to prefer technologies with real-time monitoring devices, as easier detection can also lead to faster troubleshooting [11]. There was an attempt in Hungary to combine the advantages of several separators in one device. This separator is a combination of three widely used machines: a magnetic separator, an eddy current separator, and two types of airflow separators. The equipment eliminates the need for conveyor belts and feeders between separate machines, thus minimizing the possibility of jams [12].

The incoming wastes quality and quantity have changed over the years. It is not enough to assess the current conditions, but also the possibilities for the future using the results of previous years needs to be outlined and considered. Research and analysis provide the basis for making decisions about the redesign of existing manual sorting plants. It also assists in the selection of efficient machine technology, the equipment to be used, such as ballistic separators, Near-Infrared (NIR) sorters, and other machines for sorting packaging materials from selective collection by the public.

## 2. MATERIALS AND METHODS

The data come from the sorting plant of the Pécs-Kökenyi Regional Waste Management Center, where manual sorting of selectively collected mixed packaging waste from households takes place. The incoming material arrives in the plant from curbside mixed packaging collection and public collection points broken down into paper and plastic fractions. Glass waste is collected separately from the public collection points, which was not separately addressed during the research.

The selectively collected packaging waste is sorted according to waste types and then transported to the recyclers for treatment. Much of the sorting is done by hand in two cabins in parallel, completed with a drum screen and two magnetic metal separators. During manual sorting, the workers separate the material mixed on the sorting belt into the following types of materials: mixed paper, cardboard, beverage cartons, PolyEthylene Terephthalate (PET), Low-Density PolyEthylene (LDPE), High-Density PolyEthylene (HDPE), mixed plastic, aluminum, iron, glass, and impurities. The separated waste is sent to processors and recyclers in bales.

### 2.1. Examination of quantitative and qualitative changes

In the first phase of the research, changes in the amount of selectively collected waste from the start of the operation to the present day were observed (from 2015 to 2019). The development of the collected and sorted quantities, the effects of the seasons on them was examined and people's selective waste collection habits were concluded. Based on the data recorded in the sorting plant, the quantitative

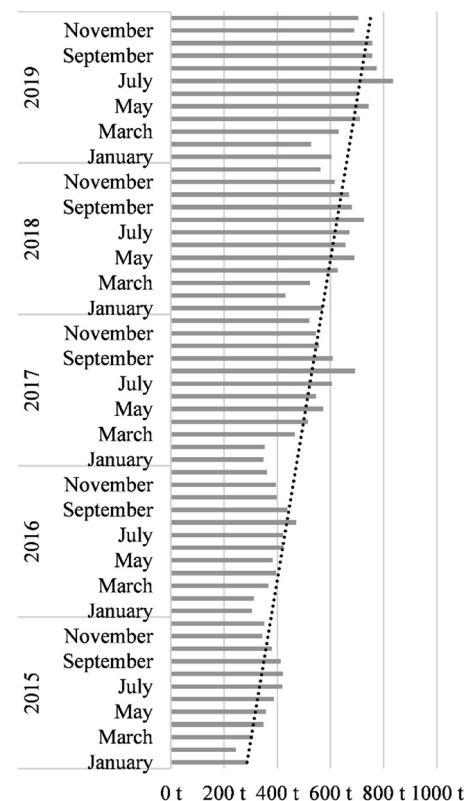


Fig. 1. Quantity of material entering the sorting plant by month in tones

changes of each material type over time in different seasons were analyzed. Quantities of substances were obtained daily, and then these datasets were aggregated into monthly and seasonal quantities.

### 2.2. Examination of size distribution and internal composition

In the second stage, the size and material composition of the incoming waste were examined. Twelve samples were taken in 3 months (from January to March 2020) from material received during the previous day as an average of several increments. During the measurement, the samples were separated manually by size into the following fractions: <70, 70–350, and >350 mm. Each size fraction was divided into further fractions according to the types of the materials. The determination of size limits for the separation was based on the ideal size range of optical sorting equipment.

### 2.3. Examination of pickings

During the third phase of the research, the picking rates of the selection staff for 14 days (from January to February 2020) were examined. Three times 15 min a day in two shifts on two parallel sorting belts, in a total of 6 time zones in one day were observed. The intervals were chosen to take into account the beginning, end, and breaks between work hours, so that representative samples at the beginning, middle, and end of the shifts were obtained as well. During sorting, a

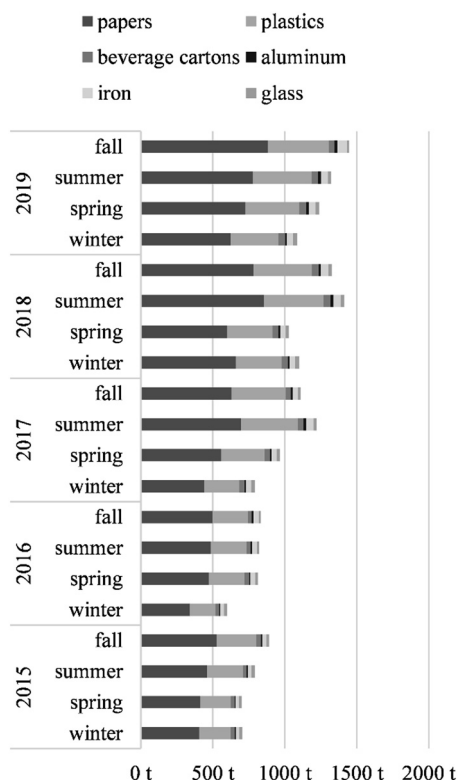


Fig. 2. Quantity of sorted recyclable materials per season in tonnes

person stands between two drop zones. They either throw the picked-up material into the drop zones or put it in bags, depending on the material type. The speed of the sorting belt was  $0.3 \text{ m s}^{-1}$  in each cabin.

### 3. RESULTS AND DISCUSSION

#### 3.1. Examination of quantitative and qualitative changes

Incoming volume changes cyclically with the seasons (Fig. 1). However, in addition to the increase in the amount of recyclable material, the amount of impurities has also increased. Recyclable materials removed from the sorting belt include mixed paper, cardboard, beverage cartons, PET, LDPE, HDPE, mixed plastic, aluminum, iron, and glass. Although the latter is collected as useful material, according to the collection rules, it should not be thrown into mixed recycling bins, so it is stored separately. Hazardous and electronic waste is also removed from the sorting belt by hand, as these are impurities. Sorting residue and small particle size waste separated by drum screen were also included in this fraction.

Paper (mixed paper and cardboard) and plastic (PET, LDPE, HDPE, and mixed plastic) are present in the processed material in the largest quantities. The amount of other recyclable materials is an order of magnitude smaller than that of paper and plastic (Fig. 2). Paper accounts for 60% of the sorted recyclable material and plastic for 30%.

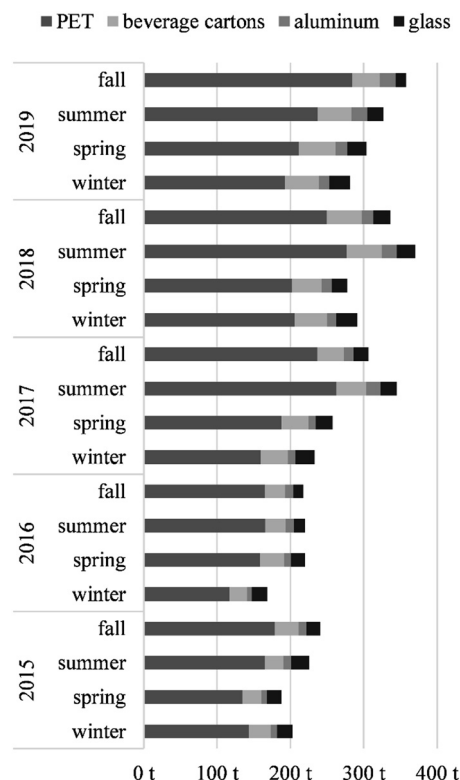


Fig. 3. Quantities of materials used to package beverages by season in tonnes

The remaining 10% is beverage carton, aluminum, iron, and glass.

Observing the number of materials used for beverage packaging, PET is collected in the largest amount. The warm weather has a prominent effect on this type of material, in which case 20–40% more is sorted. Aluminum shows similar trends, with 40–60% more sorting of this material in warm weather compared to cold weather. In contrast, the sorted amount of glass is higher in cold weather, with an average 20% increase compared to warm weather. The beverage carton does not show significant differences in terms of seasons (Fig. 3).

#### 3.2. Examination of size distribution and internal composition

It can be stated that 60% of the incoming waste falls within the preferred size range of 70–350 mm for optical separators, while nearly 20% is larger and nearly 20% is smaller than this range. Larger wastes should be separated by hand and smaller ones by a ballistic separator or a drum sieve, to increase the sorting efficiency of the NIR sorters, and other machines for sorting packaging materials from selective collection by the public.

More than half of the >350 mm fraction is cardboard waste and nearly 10% is LDPE film. Both are frequently used packaging materials for larger products. In both 70–350 mm fraction, almost equal amounts of mixed paper, beverage cartons, metals, LDPE, and HDPE plastics and glass were

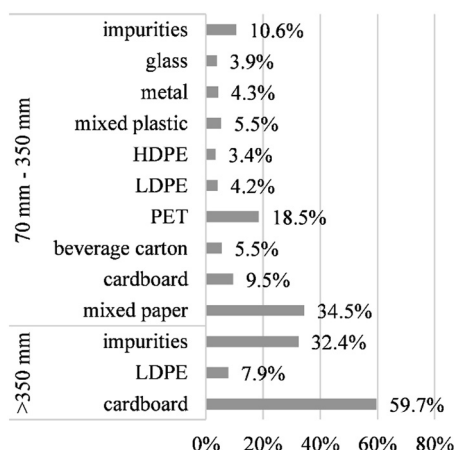


Fig. 4. Ratio of material composition by size in weight per weight percent

found, at around 4–5%. It was twice as much for cardboard and impurities with 9–10%, four times for PET with 20% and seven times as much as for mixed paper with 35%, compared to the first-mentioned fractions (Fig. 4).

For all sorted cardboards, the size distribution shows a 40–60% distribution between the 70–350 mm and >350 mm fractions, while the opposite is true for LDPE. This also means that cardboard is preferred when packaging large products. Impurities are found in almost equal proportions in the two fractions (Fig. 5).

### 3.3. Examination of pickings

The proportions of materials thrown into the drop zones and placed in the bags are on average 80 and 20%. There is no significant difference between the cabins, the right and left sorters, or the time of day in the picking ratio of the materials placed in the drop zones and the bags (Fig. 6).

LDPE, beverage cartons, mixed plastics, aluminum, and hazardous materials get sorted into bags. Two of these are also taken into the drop zone: LDPE and beverage cartons to maximize the quantities sorted. Only mixed paper, cardboard, and HDPE plastic get taken into the drop zone. Mixed plastic and aluminum get only picked in bags, as practical experience has shown that the amount, they can collect in one shift does not justify a separate drop zone. The

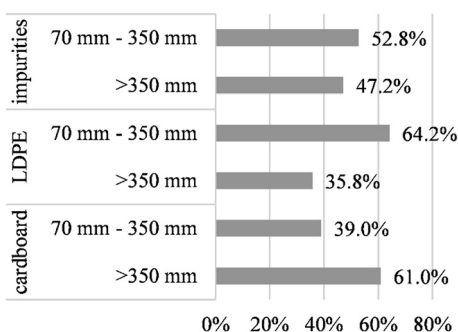


Fig. 5. Ratio of size by material types in weight per weight percent

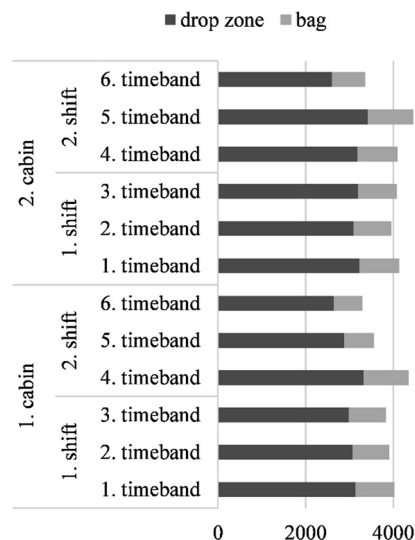


Fig. 6. Number of pickings per cabin, time of day, in the assigned timebands

sorting residue is transferred to a mechanical-biological treatment plant, so it is important to separate other contaminants as well. These materials can endanger the operation of the technology or be problematic in terms of combustion, some of which are inflammable or explosive. Forty one percentage of the number of pickings per hour is made by sorting PET bottles and 21% by sorting mixed paper, which together accounts for almost two thirds of the pickings. LDPE gives a significant number of pickings with 14%, cardboard is at 6%, aluminum and beverage carton are 3–3%, mixed plastic is 2%, plus unfortunately 10% impurities.

In general, the first 5 timebands do not show a significant difference, however in the 6th timeband the number of picking decreases significantly. This is the timeband spent working at the latest in the evening. Workers are probably the most tired at this time, so their reaction time is extended, which can contribute to fewer pickings.

## 4. CONCLUSION

From the quantities of material, it can be stated that the highest quantities enter the sorting plant in summer and autumn, and less is collected in the colder months compared to the rest of the year. The properties of selectively collected mixed packaging waste from households and as well as the seasonal effects combined with the effect of increasing quantities require the modification of manual sorting plants and the use of efficient machine pre-sorting systems.

Seventy percentage of the material entering the sorting plant is recyclable and 30% is non-recyclable. Sixty percentage of the material entering the sorting plant is in size fraction from 70 to 350 mm and 20–20% is in size fraction <70 mm and >350 mm. It can be stated that without pre-treatment, only 60% of the incoming material stream is

suitable for machine pre-sorting, which can be increased by shredding the 20% of fraction larger than 350 mm. The remaining 20% (which is smaller than 70 mm) is not suitable for either machine or manual sorting.

Sixty percentage of the 70–350 mm fraction is made up of mixed paper, PET and cardboard. In the >350 mm fraction, only cardboard and LDPE appear among the recyclable materials, which again account for 60% of the fraction. Examined together with the number of pickings per hour, it can be stated that 41% of them are provided by PET bottles, 21% by mixed paper, 14% by LDPE foil and another 14% by other recoverable materials.

From this data, the technology can be designed, the type and number of machine equipment required for the selection of each type of material can be determined, including the number and capacity of the NIR equipment to be used and the capacity and throughput of the ballistic separator.

## ACKNOWLEDGMENTS

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