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Recyclable waste collection—Increasing ecopoint filling capacity to reduce energy for transportation

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Abstract

Urban waste production is increasing around the world. In the present Covid-19 context, an emergent flow of waste growth, as well as of pollution in general, stems from confinement and the use of protective masks. Although part of the waste is considered commingled, much is recyclable, if properly disposed off. Hence, recycling plays today, more than ever, an extremely important role, not only in terms of pollution prevention, but also from the point of view of the circular economy and of resources use efficiency. Thus, this work is focused on developing an approach to assist in recycling wastes. As a management option, recycling depends on a collective behavior, that relies on individual acts. Therefore, the individual use of plastic/metal compaction systems can help reaching the recycling targets, even as a complement to conventional commingled waste bins. Thus, we present a proposal for a plastic/metal collection station with a built-in compaction element that allows one to compact separated waste, individually, in an easily accessible drawer. Sorting and compaction of waste before collection will then result in a reduction of the number of collection/transportations stops, which will also translate into higher efficiency, reduction of costs, optimization of transported tons/km ratio, and profitability.

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1. Introduction

Our society is one based on consumption, which has contributed heavily to the current and previously unimaginable levels of pollution. Pandemic diseases like Covid-19 have further aggravated an already delicate situation. It is true that, with confinement and the use of disposable protective masks, waste production has increased

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considerably. On the other hand, the need to obtain packed ready to use products for daily consumption, especially food and beverages, is causing a high production of waste, mainly in terms of plastics and metal packaging, which is considered disposable. On the one hand, there was an increase in plastic waste, probably resulting from online purchases and home delivery in plastic packaging, on the other hand, it was also observed an increase in metallic packaging, for drinks and meals, from *take-away* options.

If we were already asking ourselves what to do with so much waste generated daily [1], we are now faced with a situation that leads to a new question: What can we do to properly manage the waste that is increasing exponentially and how can we mitigate the associated impacts?

Of course, one cannot just sit back and wait for the problem to be solved on its own. Municipal solid waste must be treated to avoid environmental problems, which are increasingly serious and harmful to the planet [1], and contribute to climate change. Towards this end, it is mandatory that the rates of waste prevention and reuse of waste products increase, diminishing the need for raw materials and the production of untreated waste [2]. Thus, prevention/ reduction, reusing, and recycling are the first steps towards avoiding the need for elimination and allowing the conversion of waste into raw materials and new finished products. Recycling reduces and rationalizes energy use, the need for big waste treatment facilities and greenhouse gas emissions. This goal of waste elimination reduction can only be achieved through citizen awareness of the need for waste reduction and recycling behaviors [3].

Recycling begins in the mind of every human being, when someone decides to separately dispose off a certain waste material, instead of just throwing it away to the commingled disposal bin. Then, selective collection and transportation to the processing facility where the waste materials are further sorted and depurated are needed to allow waste valorization, while the remaining residual fraction of non-valuable waste (reject) needs to be disposed off in dumps or landfills or incinerated. Thus, separate collection of packaging waste is a common practice in Europe [4], that also impacts on waste management cost [5].

Portugal has one of the lowest recycling rates of packaging waste in Europe, as shown in Fig. 1 [6], so it is necessary to develop strategies that allow its increase, not only to fulfill the goals established and avoid paying fines, but especially to contribute to a more sustainable development.

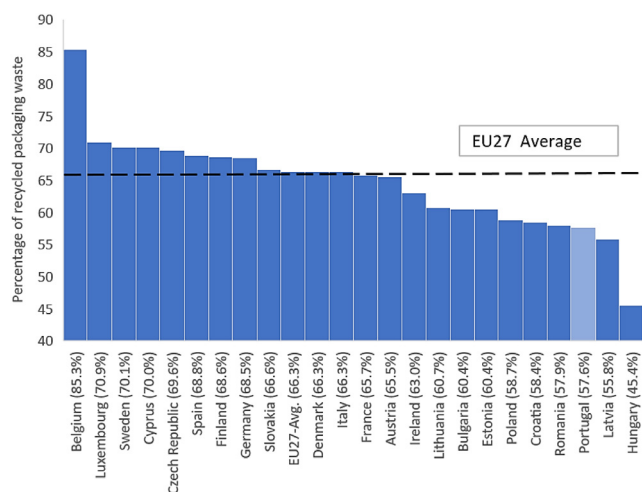


Fig. 1. Recycling rate of packaging waste [6].

In urban areas the collection of recyclable waste is normally carried out in community recycling containers (Fig. 2) or door-to-door, depending on the geographical area. Concerning the community recycling containers, *Cyclea* is the most used drop-off container in Portugal, configured for vertical loading and with a capacity of 1500 liters, for plastic and metal packaging waste (yellow container) or for glass (green container), and of 2500 liters for paper (blue container) [7].

The entire logistics system for collection, storage and processing are the responsibility of the multi-municipal or inter-municipal management system. As such, all investments and costs of the recycling process are centralized.



Fig. 2. Example of drop-off container (*Ecopoint*), *Cyclea*, currently used in most municipalities in Portugal.. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

On the other hand, since the processing costs are fixed, it will be in the waste collection logistics that one must act. An improvement in this sector of activity would involve changing and optimizing routes or reducing the weekly number of rounds.

A bibliographic search using the Scopus database returned few references related with compression devices available for small scale compaction of waste. This includes a study by Xevgenos et al. [8], who proposed an innovative miniature waste separator/compressor, designed and developed for the household source separation of municipal solid waste. Although this approach could result in substantial reduction of the deposited waste, it would probably result in increased cost for individual domestic waste producers, and therefore an intermediate solution, where the compression device is installed in a community waste container would result in reduced costs for the waste producers and simultaneous reduction of transportation costs for the waste collectors.

Thus, in the present work a technological solution was developed, aiming to reduce the collection frequency, increasing the container storage capacity through waste compaction of plastics, and metals packaging, thus contributing to the achievement of the goals established in the Strategic Plan for Municipal Solid Waste (DL 152-D, 2017) [9], General Waste Management Regime (DL 178, 2006) [10], and the European Union for Portugal [11].

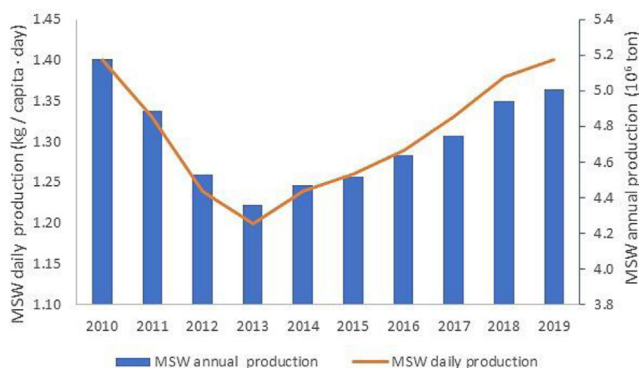


Fig. 3. Production and capitacion of municipal solid waste in mainland Portugal [12].

1.1. Management of municipal solid waste in Portugal

The production of municipal solid waste (MSW) in Portugal has decrease since 2010 with a minimum in 2013 (which was associate to economic crisis), and then has been slowly growing. However, the amount of recyclable waste has not kept up with this evolution, so the amount of recyclable waste produced per inhabitant is still lower than the European average (Fig. 3) [12]. This increase in municipal solid waste is associated to an improvement of

the economic situation, which leads us to believe that the decoupling of waste production from economic growth has not been achieved.

According to data available from the Portuguese Environment Agency (APA), conveyed through the Environmental Status Report [13] the amount of municipal solid waste collected in Portugal for the period 2010 to 2019 was about 5 million tons of waste, in other words, a capitation of 505 kg/(capita-year), which corresponds to a daily production of 1.38 kg per inhabitant in 2018. In 2019 a slight change was observed, with an increase of MSW production to 511 kg/(capita-year), and a daily production of 1.40 kg per inhabitant [12]. However, only 11.29% of the MSW produced is recyclable plastic and metal, as seen in Fig. 4, which seems a good characteristic of the waste produced, due to waste prevention policy.

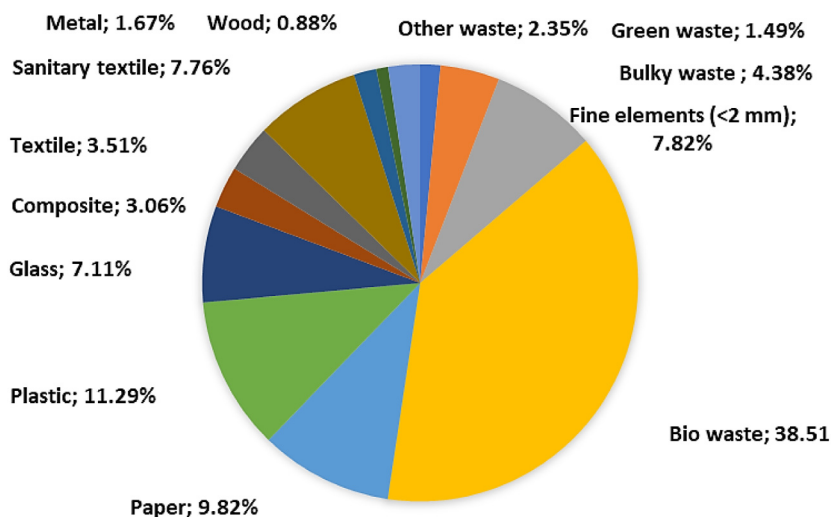


Fig. 4. Physical characterization of municipal solid waste [12].

Yet, the recycling rates have been stable at 11%, for the past 10 years, a trend that goes in the opposite direction to the Community and national strategy for the MSW. This data places Portugal far from achieving the goals established by the European Union which is strongly attributed to insufficient selective domestic collection of recyclable materials.

Additionally, one must keep in mind that the municipal solid waste management involves its collection and transportation before further processing. Regarding collection, it can be distinguished two phases: disposal in (either drop-off or home) containers and collection to transport vehicles, and waste transportation to processing units. The fraction of packaging waste is mostly a light fraction, due to huge voids associated to lack of compaction. Thus, the work presented here is focused on the above-mentioned phases, disposal and subsequent removal, as well as transportation, proposing an improvement to the packaging waste container, that allows for metal/plastic separation and compaction in a single container, which will allow for reduction volume and increase transportation waste mass, that corresponds to lower energy consumption for transportation, while also allows reduction of the need for large mechanical/physical treatment units for plastic/metal separation.

2. Container model developed for metal and plastic packaging

The model presented for the optimization of selective collection rounds involves the change of current metallic and plastic packaging containers. Thus, taking advantage of the current configuration of *Cyclea* containers, a proposal is presented to change the waste collection receptacle, providing not only the deposition of metal and plastic, but also the separation of these two recyclable waste flows. This change aims to replace the traditional collection holes, present on the front face, with a manual compaction system, capable of reducing the volumes of plastic cans and bottles, see Fig. 5.

The compaction unit, placed on one of the sides of the container, has a compaction height that varies between 100 and 345 mm, that is, compaction of plastic bottles from 0.33 L to 2 L and beverages cans with maximum

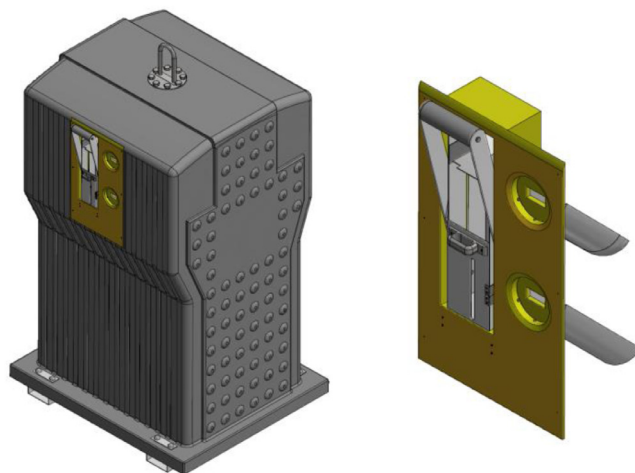


Fig. 5. Proposal of a new *Cyclea* model for the selective collection of metals and plastics in one single container.

diameter 100 mm. Additionally, since this element contains mobile parts, protective measures were taken to avoid the act of compacting with the users' hands inside it. These measures, which are essential for safe operation, were implemented through a small access door that, while not completely closed, prevents compaction. The degree of compaction is visualized by an indicator that, associated with the final position of the lever, shows us the final volume of the pressed object. A requirement for proper operation is that bottles and cans must be open, thus caps must be previously removed.

The selection of the pressed waste material remains the responsibility of the depositor, as the choice of the deposition opening (Fig. 5) always depends on the individual's conscience. The information needed for correct disposal is displayed next to waste disposal receptacle, ensuring the separation of metal and plastic waste in the trash. This form of deposition also prevents waste removal after insertion. The option to rely on the waste owner for its separation was done aiming to reduce the complexity of the system and the need for sensors that would certainly make the whole system also more expensive.

2.1. Selective drawer

In conventional models, the separation of metal and plastic can only be done in the waste treatment phase. In the model that was developed and is presented here, the selection of metals and plastics is made at the receptacle of the container. This separation, under the responsibility of the depositor, is done by means of a selective collection drawer that stores plastic or metal waste with a collection capacity of about 220 L. Each type of waste will be allocated individually on one side of the drawer and deposited directly in containers designated for each type, which will allow removal, by a specialized operator using the drawer method, or by using a crane, as per the current method of operation (Fig. 6).

It must be noted that these approaches to recycling problems shift the action of separating waste products into the deposition phase and, as such, raise the need for awareness of effective recycling of MSW during that same phase. This translates into an indirect benefit, by anticipating the separation phase usually performed in the treatment unit, of part of the waste to be collected, acting as an action that facilitates the recycling process.

It is also noteworthy that the drawer methodology facilitates the extraction of waste, properly separated, and bagged/contained, enhancing the possibility of using transport vehicles with smaller dimensions. This possible reduction in the volume of collection vehicles can allow easier access to urban areas with restricted access, such as historic areas, where narrow streets could hinder the access of conventional vehicles. Where bigger vehicles are allowed to travel, the reduction in transportation costs will be achieved due to less number of travels from collection to treatment units.

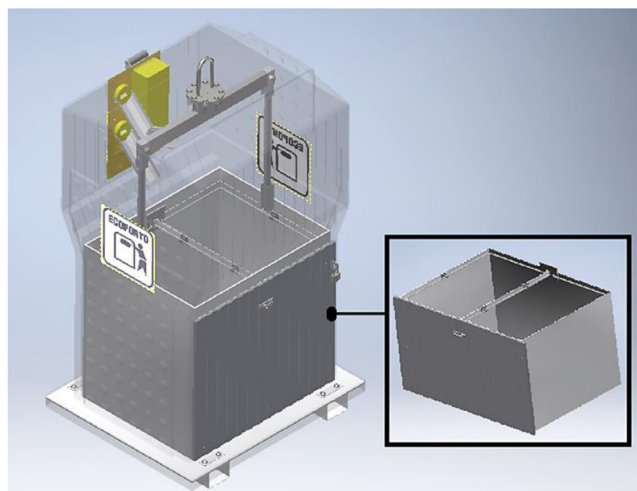


Fig. 6. Waste collection drawer.

2.2. Storage capacity

The use of a drawer, divided into metal and plastic sections, leads to a reduction in the volume of garbage collection. Thus, new *Cyclea's* plastic/metal model would have an effective volume of around 220 L as mentioned above. However, the goal of this proposed collection model will be achieved as more compacted waste is stored, since, for example, a $100 \times 118 \times 0.25$ mm can will occupy much less volume. Plastic/metal compaction leads to a decrease in product volume, so there will be a significant increase in the amount stored in the same volume. This increase can translate into a significant reduction in waste collection rounds with a consequent reduction in transport costs, with the associated reduction of emissions associated not only to transportations but also to avoided compaction within the MSW processing facilities [14,15]. The reduction in energy for compaction is due to the proposed design, where the compression system does not require the use of electric energy, rather being based on mechanical energy provided by the compaction-container user, contrary to the domestic system proposed by Xevgenos et al. [8].

3. Conclusion

The use of plastic/metal recycling units and compactors will optimize the carrying capacity of *Cyclea* containers used in recycling dumps. The approach presented, in addition to considerably increasing the amount of solid waste collected, contributes to increasing the awareness of citizens, as an intervening actor in the recycling process, since they would need to conduct an act of screening at the time of waste deposit.

Another factor that can translate into a profitable management act would be the reduction in the required weekly rounds. In addition to an economic return, this could contribute to the reorganization of routes, not only in terms of accessed pathways, but also in the amount of time spent. It is notoriously a very important contribution to encourage the fulfillment of the goals stipulated by PERSU2020 [16].

On the other hand, in an increasingly “Smart” society, they could migrate to an online connected information system that, using the available network, could transmit information about the amount of product/filling level and estimate the day it could be completed, scheduling collection in advance, optimizing the management of the collection routes, the process itself and, most importantly, making it more efficient, and profitable for the stakeholders involved.

CRediT authorship contribution statement

Adriano A. Santos: Writing – original draft. **António Ferreira da Silva:** Writing – review & editing. **António Gouveia:** Investigation, Formal analysis, Validation. **Nídia Caetano:** Writing – review & editing. **Carlos Felgueiras:** Writing – review & editing.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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