Glass recovery from the unsorted waste stream

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Abstract

The main objective of this work is to study the recovery potential of glass contained in the heavy reject fraction (MBTr) of all of Portugal´s nine MBT plants in full operation in 2018 and in one energy recovery facility. It is observed that the MBTr presents glass contents between 12% and 72%. The granulometric distribution is quite heterogeneous, with the samples presenting 9% to 98% of the particles with a size greater than 5.6mm. The main contaminants found were organic matter, stones, ceramics and bricks. It was estimated that the ten plants studied, annually produce around 111 390 tonnes of glass. The recovery of glass from the MBTr of these facilities would be sufficient to achieve the national packaging glass (PG) recycling goal, imposed by the EU by 2025. The sociodemographic characterization of the regions where the 10 facilities are located and the quality of the service of sorted waste collection were analysed. With the information available, it was not possible to obtain relationships between the quantity of glass present in the MBT_r and the analysed factors.

Keywords: Glass recovery; MBT; characterization of MBT reject, Sociodemographic factors,

1. Introduction

The production, management and treatment of waste is one of the main sources of today´s pollution (UN Environment, 2017). This pollution can manifest itself in several ways, namely, air pollution (due to incineration processes and methane release from landfill and dumpsites), freshwater (generated by heavy metal leaching on landfills and dumpsites as well as from industrial effluent discharge), soil (also resultant from heavy metal leaching and by making changes in the soil use type e.g. by constructing a landfill) and finally marine (either through bioaccumulation and biomagnification of plastics and heavy metals in the food chain or by nutrient release that can ultimately lead to acidification and eutrophication). A full application of the first steps of European "waste hierarchy" (prevention, followed by preparation for re-use and recycling) could avoid irremediable loss of valuable resources and help mitigating and eliminating this source of pollution (CE, 2012).

Portugal, with 44% of glass recycled in 2017 (SPV, 2018), fell short of the 60% target established in the national legislation. The performance of Portugal glass recycling rate is even lower if we consider the EU targets (a total of 70% and 75% of all PG shall be recycled by the years 2025 and 2030 respectively). The low performance can be justified by the diversion of PG to the unsorted waste stream. In 2017, a total of 5.007 million tonnes of Municipal Solid Waste (MSW) were produced in Portugal, being glass 7.27% (weight percentage) of it, which corresponds to 360,504 tonnes (APA, 2018).

Mechanical Biological Treatment (MBT) facilities arise as one of the main options for MSW treatment. MBT main objective is to reduce and stabilize the organic content of the MSW (Barrena et al., 2009; Schu, 2007) as well as the recovery of materials that can then be forwarded to recycling plants (Gallardo et al., 2014). Currently, MBT plants lack processes to recover and recycle PG, which has landfill as its final destination (APA, 2018).

Previous studies have demonstrated the existence of technical solutions to recover PG present in the MBT_r (Dias (2011); Máximo (2013); Dias et al. (2014), Dias et al. (2015a) and Dias et al. (2015b). However, its economic viability depends on the logistics of the treatment and collection of MBT_r. The proposed glass recovery solutions consist on a diagram as described in Dias (2015a). If we consider one glass recovery diagram per MBT plant, the costs associated with optical sorters would strongly affect the economic viability of such process. One way to overcome this barrier is to build a centralized recovery facility that would handle MBT_r from several MBT facilities. However, the geographic dispersion of Portugal´s MBT plants would once again have negative impacts on the economic and environmental viability, mainly due to the costs and emissions associated with waste transport. As proposed by Dias (2015), a possible solution is the use of mobile processing units (MPU) to recover glass form the MBT_r. By integrating a complete recovery diagram, one or several MPUs could potentially overcome the challenges mentioned above.

The main objective of this work is to quantify the glass appearing in the MBT_r of Portugal´s MBT facilities which can ultimately support the development of MPUs.

2. Methodology

The study was carried out in nine of Portugal´s MBT plants and in one energy recovery facility (ER). Two criteria were used to select the facilities: a) full and steady state operation in 2018 and b) the MSW flux entering the MBT plant is higher than 50 000 tonnes per year, as facilities with lower fluxes were considered to have reduced glass recovery potential. The application of the mentioned criteria resulted in a total of 9 MBT plants to be studied. An ER plant was also selected for the study given its high glass recovery potential as described by Jardim (2013).

Fig. 1 shows the geographic location of the facilities under study which are Amarsul-Seixal (AS-S), Amarsul-Setúbal (AS-Set), Braval (BV), Ersuc-Aveiro (ERS-A), Ersuc-Coimbra (ERS-C), Resitejo (RT), Tratolixo (TL), Valnor (VN), Valorlis and Valorsul (VS).

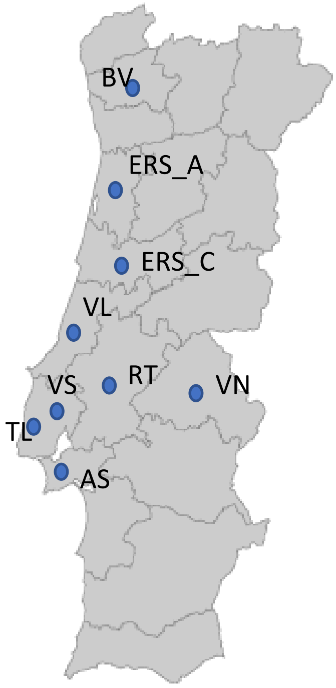

Figure 1 - Geographic location of the studied plants

The sample preparation, particle size analysis and composition methodologies were based on the ones developed in Dias (2011). The experimental proceedings consisted in a total of five steps.

1. Homogenization: The collected samples were carefully mixed with the aid of shovels.

2. Sample division: Application of the manual quartering procedure where non-consecutive squares were removed. Subsequently, the initial sample was divided into four subsamples with approximately equal weight through a Jones Divisor. The 4 subsamples are divided into 3 samples for analysis and one control sample.

3. Drying and Washing: Washing of the subsamples through the use of a hose with water and a rectangular sieve with a 2mm mesh. Drying in an oven at 105º C for approximately 12 hours. Both processes were only performed on some samples.

4. Granulometric analysis: Sieving performed on a mechanical stirrer followed by manual sieving. A series of sieves with decreasing mesh aperture, in geometric progression, was used in order to guarantee the constancy of maximum relative deviations (Cortez and Durão, 1982). The rate of progression used was 2½ and a total of five sieves (22.4, 16.0, 11.2, 8.0, 5.6mm) were used. Dias (2015) observed that the glass content of the below 5.6mm fraction was relatively low so this fraction was discarded from the characterization process.

5. Composition analysis: Each granulometric fraction was subjected to a manual/visual composition analysis in order to classify the different materials present in the MBTr. The classes of materials were chosen based on the characterizations made in Dias (2011). After initial visual analysis of the

sample, it was decided to group the classes brick and ceramics into a single class (since in the fraction +22.4mm and +16mm there were products composed by a mixture of the two materials). The following classes were chosen glass, stones, ceramics + brick, metals, organics and plastic. After manual separation of the materials, these were weighed in a digital scale. The weighing was done for each material and respective granulometric fraction (e.g. weight of glass in the +22.4mm fraction). In the results chapter, organics and plastics were gathered within the same class named "organic + plastic" for all samples.

Table 1 identifies the origin of the collected samples and summarizes the main processing characteristics of the MBT facilities that may influence the MBTr composition. The features are the manual sorting of glass in the initial phase of the mechanical treatment (MT), the mesh of the TMBr output screens and the MT/biological treatment process stage.

Table 1 – Sample origin and main features of the MBT_r

Sample	Plant	Glass sorting	Size	Treatment stage
AS-SF	CVO Seixal	✔	<12mm	Densimetric table
AS-SG	CVO Seixal	✔	<75mm	Inert separator
AS-SC	CVO Seixal	✔	>12mm	Vibrating screen
AS-SetF	CC Setúbal	✖	<12mm	Densimetric table
AS-SetG	CC Setúbal	✖	<75mm	Trommel screen
BV	Braval	✔	-10mm +2mm	Composting
ERS-CP	CITR Coimbra	✖	<70mm	Pulper
ERS-CH	CITR Coimbra	✖	<20mm	Hidrocyclone
ERS-AP	CITR Aveiro	✖	<70mm	Pulper
ERS-AD	CITR Aveiro	✖	<20mm	Grit removal
RT	Resitejo	✖	<10mm	Rotating sieve/drum
TL	CDA Abrunheira	✖	<12mm	Composting
VL-F	Valorlis	✖	-80mm +10mm	Pulper
VL-G	Valorlis	✖	<80mm	Pulper (feeding)
VN	Valnor	✔	<10mm	Composting
VS	Valorsul	✖	<35mm	Rotating sieve

With the intent of identifying possible relations between a set of sociodemographic variables and the glass quantity contained in the MBT_r, it was studied how certain sociodemographic indicators and the quality of the sorted waste collection system can influence the quantity of glass that enters MBT plants. Simple linear regression method and factorial correspondence analysis were used to find possible relations between the exit variable (glass quantity) and the input variables (number of inhabitants per bring bank, proportion of purchasing power *per capita* (%), illiteracy rate (%), quantity of glass packages recovered from the sorted waste stream (kg/inhabitant.year), number of inhabitants per glass container and area covered by each plant/company (km^2)).The selected indicators were the same as those studied by Oliveira et. al (2017), since they were the ones with the greatest influence on recycling rates. The indicators "accessibility of collection systems" and "degree of urbanization" were excluded from the study as the necessary data could not be obtained. The indicator "number of inhabitants per glass container (*vidrão*)" was also chosen, given its possible influence on the amount of glass in the unsorted waste stream.

In the analysis performed it was assumed that the amount of glass present in the MBTr corresponds to the total amount that enters the plants and that the amount of this material is residual in the other flows of the treatment process (compost, refuse or directly sent to landfill). In the case of plants that manually recover the glass during the MT process, the total annual recovered quantity was added to the glass content of the MBT_r.

The factorial correspondence analysis was based on the one performed by Rodrigues et al. (2013). For this analysis the indicator “area” was removed as factorial correspondence analysis requires a high number of samples/number of indicators/variables ratio. The correspondence analysis was generated in the statistical software ANDAD. In the correspondence analysis, the indicators were coded as follows: number of inhabitants per bring bank (h), proportion of purchasing power (p), glass quantity (v), illiteracy rate (e) and quantity of glass packages recovered (r). The plus (+) represents an above average value and a minus sign (-) represents a below average value.

3. Results and discussion

Three analysis were carried out with three subsamples from each plant. Fig.2 shows the cumulative granulometric distribution of all MBTr samples. It is observed that the samples, in terms of their granulometric distribution, can be grouped into three categories. Fine samples contain less than 50% of particles with size greater than 5.6mm. The intermediate samples contain 67% to 76% of the particles with size above 5.6mm. There are also coarse samples with more than 88% of particles with a size greater than 5.6mm. As far as maximum size is concerned, the fine samples have less than 1% of the particles having size larger than 22.4 mm and the intermediate samples contain between 0% and 7% of the particles in the same range. The coarse samples presented a great heterogeneity, with 13% to 69% of the particles with size superior to 22.4mm.

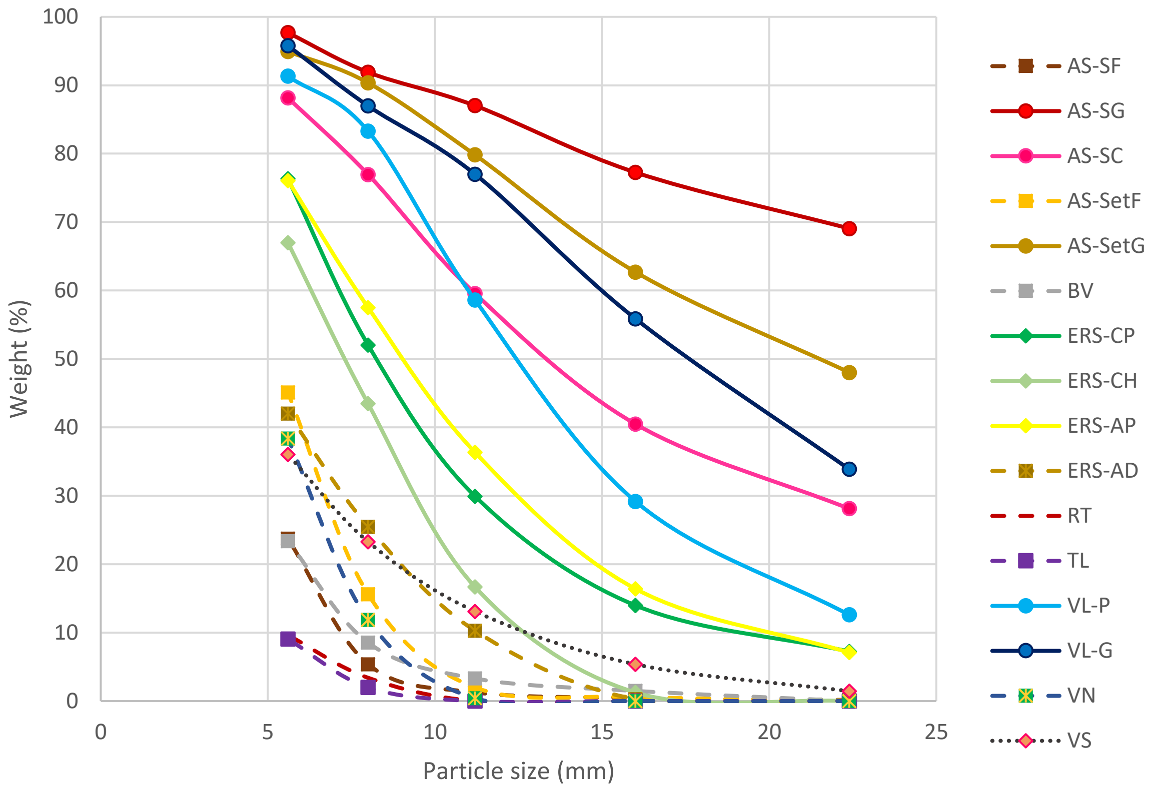

Figure 2 – Cumulative sample size distribution

Fig. 3 summarizes the overall composition of the 16 samples. It was observed that most samples have a glass content of more than 50% and a residual value of other recyclables. The main contaminant found is organic material, also observing considerable levels of stones, ceramics and bricks. The same figure shows that there are a set of samples having an "organic + plastics" content greater than 50%. These are the fine samples BV, RT, VN and the coarse sample AS-SG. In contrast, the ERS-CP, VL-G and VS samples are characterized by low organic and plastic content (<15%). It is observed that the metal percentage is very low in all samples (less than 4%), and the ceramic and brick content ranges from 7% to 21%.

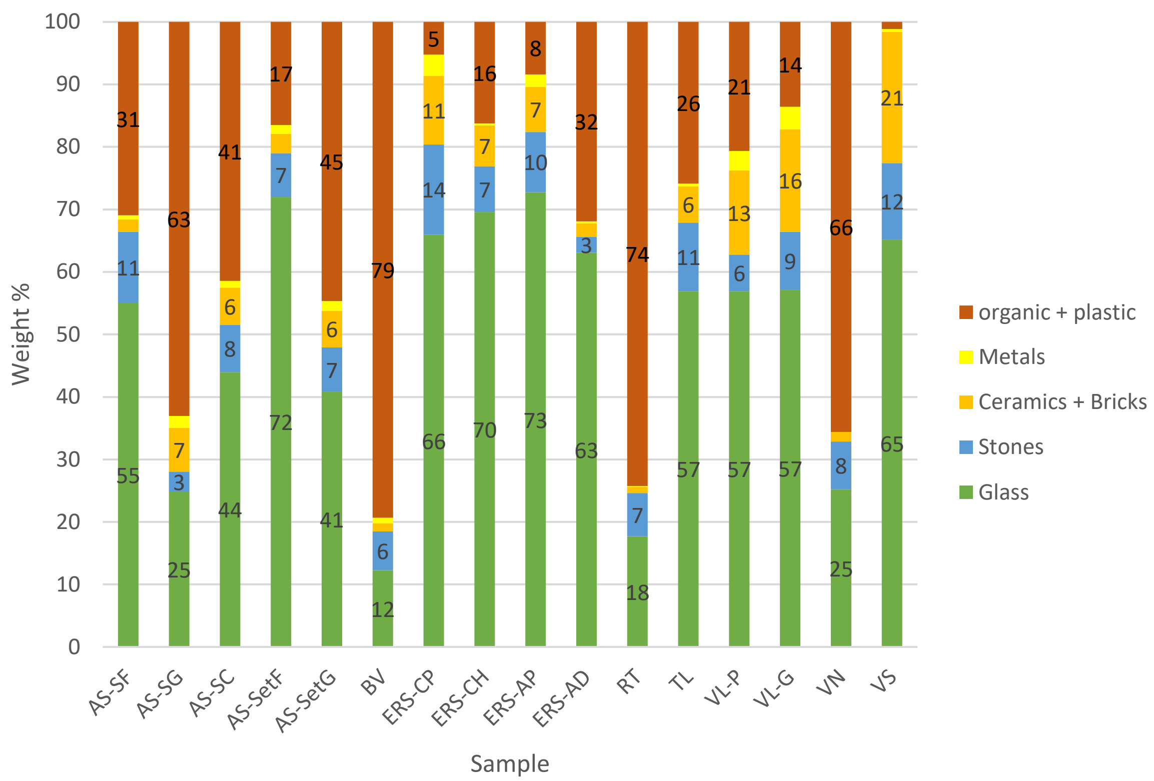

Figure 3 - Composition of each MBTr sample

In Fig. 4 the glass content is presented in ascending order with reference to all of the studied plants: Braval (BV), Resitejo (RT), Valnor (VN), CVO Seixal (AS-S), CC Setúbal (AS-Set), Tratolixo (TL), Valorlis (VL), CITR Aveiro (ERS-A), Valorsul (VS) and CITR Coimbra (ERS-C).

In plants that remove glass at the top of the treatment process (AS-S, BV and VN), a lower glass content is found when compared to pants that do not, with the exception of the RT pant, which does not recover glass in the MT process and presents glass contents similar to MBTs that do so.

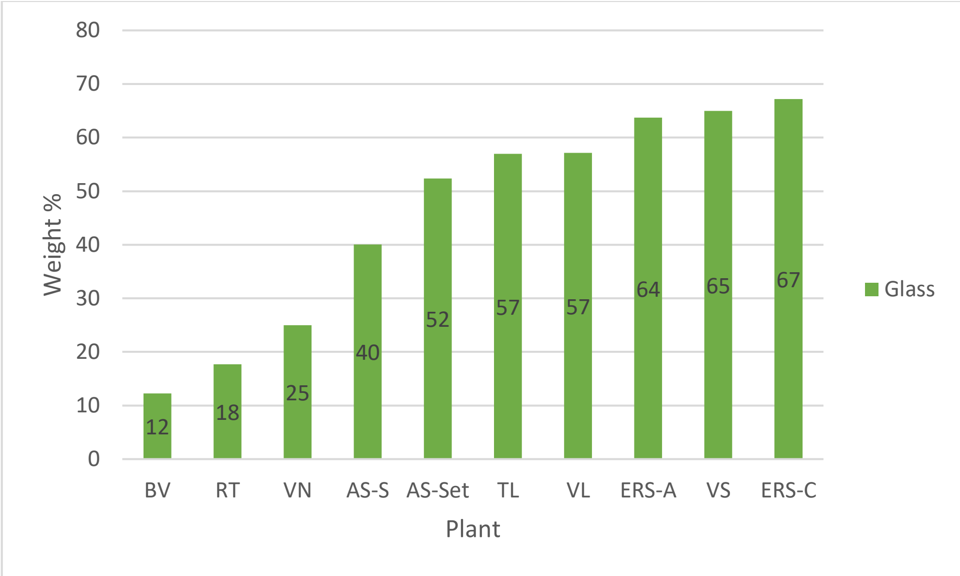

Figure 4 – Glass Weight % per MBT plant

Following the analysis of the glass flow contained in the MBTr regarding contaminants and size distribution, it is necessary to calculate the effective amount of glass present in such product.

Table 2 shows the estimated amount of glass contained in the MBTr of the nine plants studied, as well as in the bottom ash of an EV plant. The plants with the greatest potential for glass recovery are VS, ERS-A and ERS-C. The VN, BV and Amarsul-CC facilities have lower potential for glass recovery, justified by the recovery of the same in the TM process. From the results obtained, it can be concluded that about 46 270 tonnes of glass can be recovered per year from MBT and 149 640 tonnes if Valorsul's EV plant is included.

Table 2 - Glass contained in MBTr produced by the MBT and EV plants under study

Plant	MBTr (t/yr.)	Glass content (%)	Glass contained (t/yr.)
AS-CVO	10 471.0	40	4 396.6
AS-CC	6 696.0	52	3 146.9
BV	3 000.0	12	367.6
ERS-C	17 175.4	67	11 353.5
ERS-A	21 994.2	64	15 648.7
RT	11 128.0	18	1 966.3
TL	9 714.0	57	5 531.5
VL	6 500.0	57	3 707.9
VN	592.0	25	148.0
VS	100 000.0	65	65 119.0
Total	-	-	111 385.8
Total w/o EV	-	-	46 267.0

Linear regression was performed between the glass quantity per inhabitant exit variable and each one of the input variables. No correlation was found between the glass quantity and all of the variables

To understand if the amount of glass present in the unsorted waste stream depends on some of the variables studied, the amount of glass and the factors were projected in the first two planes of correspondence analysis (Fig.5). It is possible to observe that the amount of glass present in the unsorted waste stream is correlated with the quantity of glass containers recovered from the sorted waste stream. However, the behavior is contrary to what should be expected, since, when the amount of glass containers recovered increases, the amount of glass that appears in the unsorted stream also increases. As to the relationship between the variables, it is possible to verify that a higher proportion of purchasing power is associated with a higher level of education and a greater number of inhabitants per bring bank.

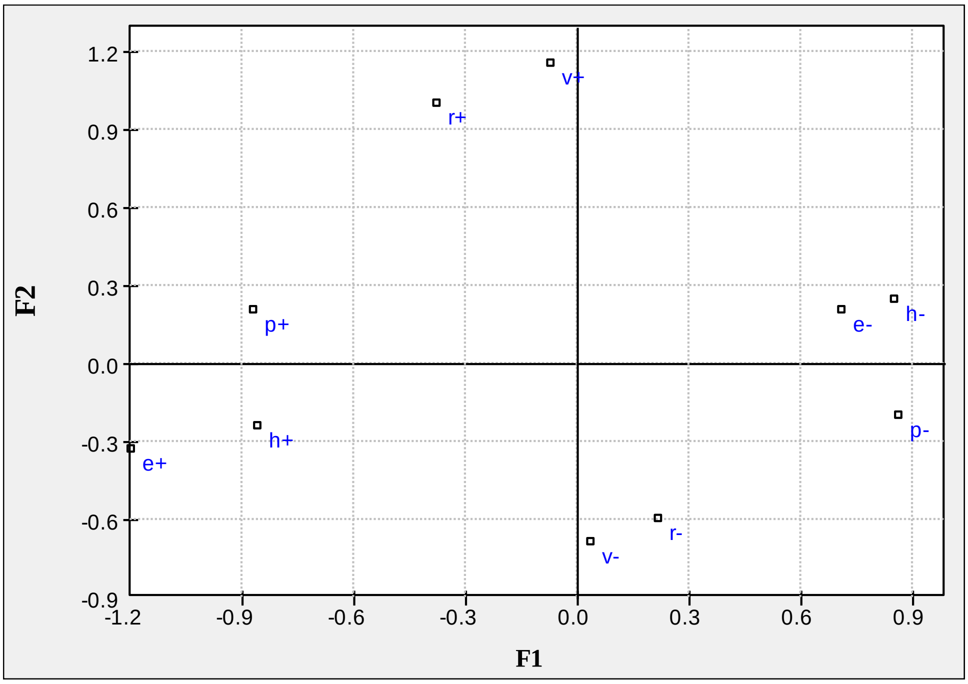

Figure 5 - Correspondence analysis. Representation of input and output variables

4. Conclusion

With this study it was possible to obtain results regarding the granulometric distribution and composition of the MBT_r from nine MBT facilities in Portugal and one EV plant. In relation to the granulometric distribution, it was observed that half of the analysed samples are composed mainly by particles with size inferior to 5.6mm. The glass content ranges from 12% to 67% and strongly, although not exclusively, related to the existence of manual sorting and recovery of such material in the beginning of the MT processes. The most represented contaminants are organic matter, stones, ceramics and bricks.

It is estimated that the ten plants studied produce approximately 111 390 tonnes of glass per year. The comparison between the total glass sent annually to landfill from the studied plants and glass recycling rates in 2018, leads to the conclusion that the recovery and recycling of all of this glass would be enough to meet EU targets by the year 2025 (a total of 70% of all the GP waste produced shall be recycled),

With the information available, it was not possible to obtain relationships between the quantity of glass present in the MBT_r and the sociodemographic indicators studied (number of inhabitants per bring bank, proportion of purchasing power, illiteracy rate, area served by each plant).

The results obtained can be used to develop mobile processing units (MPU) aimed at glass recovery, namely by studying how the composition and size of the MBT_r can affect the efficiency of the MPU.

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