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Packaging glass contained in the heavy residual fraction refused by Portuguese Mechanical and Biological Treatment plants

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ABSTRACT

Mechanical and Biological Treatment (MBT) is an important strategy to manage Municipal Solid Waste (MSW) in Europe. The presence of recyclable materials on MSW depends on different factors such as inefficiencies in the Municipal Solid Waste collecting schemes and to the low level of citizenship environmental education. Among other products, MBT plants produce a residual fraction, named here as heavy residual fraction, that contains a significant amount of packaging glass which in Portugal is currently landfilled. This material is not recycled because it is heavily contaminated with other materials, preventing its processing in Material Recovery Facilities (MRF).

In this paper the characterization, including particle size and composition, of the residual fraction of six Portuguese MBT plants is presented. The relevant variables that determine the heavy residual fraction characteristics were identified. It was observed that the MBTr particle size distribution is different and depends mainly on the place on the flowsheet where the MBTr exits the process, which is determined by the type of biological process and by the aperture of the last screen where the product passes through. The content in glass varies from 33 to 83%. These values are mainly related with the upstream glass sorting and with the efficiency of the recovery of the organic fraction which is the glass main contaminant. The second main contaminant is "stones".

The quantity of glass contained in this product in all the plants that will be in operation in Portugal in 2014 was estimated. The work shows that if all the 48,000 of glass could be recovered the Portuguese recycling rate would increase by 4.4%.

1. Introduction

In Portugal, as in many other countries, selective deposition and collection of specific streams of waste like packaging, green waste, waste from electrical and electronic equipment, etc., are common practices. Therefore, the undifferentiated stream – Municipal Solid Waste (MSW) should be almost solely constituted by organics with a very minor content of a mixture of different items and materials for which there is no specific recycling stream today in place. Nevertheless, in some cases, a considerable amount of recyclable packaging waste, as defined by the directive 75/442/EEC, ends up in the MSW – and this happens mostly because recycling is highly dependent on the community effort (Halvorsen, 2012).

The characteristics and also the quantity of MSW depend of different factors, such as standard of living and environmental education (Dong et al., 2003). In Europe, the landfill directive (Directive 1999/31/EC), the landfill taxes and the targets regarding packaging waste (such as wood, plastic, metal, paper and cardboard, and glass) established by Directive 2004/12/EC on Packaging and Packaging Waste are the main tools to push the companies and citizens to reuse and recycle materials (WRAP, 2008).

The recycling not only reduces the quantity of raw materials used but it minimizes the quantity of waste landfilled too with consequent economic saving with landfilling, increases the lifespan of landfill and reduces the soil, water and air contamination. It is clear that all the chain generates a cost but the extended producer responsibility (EPR) principle helps to support recycling and also encourages the industry to recover packaging waste (Da Cruz et al., 2012).

Portugal, with 59.66% of glass recycling rate in 2011 (FEVE, 2013), almost attained the EU target for glass (60%), although this value is still below the European average – 69.59% (FEVE, 2013). On the other hand, Portugal did not attain the national targets established on the Strategic Plan for MSW (PERSU) for 2011. The target was 227,060 tonnes of glass while actually only 210,422 tonnes were collected (APA, 2013). Regarding the deposition of glass outside the specific stream, in 2011 according to the Environmental Portuguese Agency 5.8% of Portuguese MSW is glass (APA, 2013).

In Portugal in the same year, 59% of the domestic waste was landfilled, 21% was incinerated, 9% was sent to recycling and 11%

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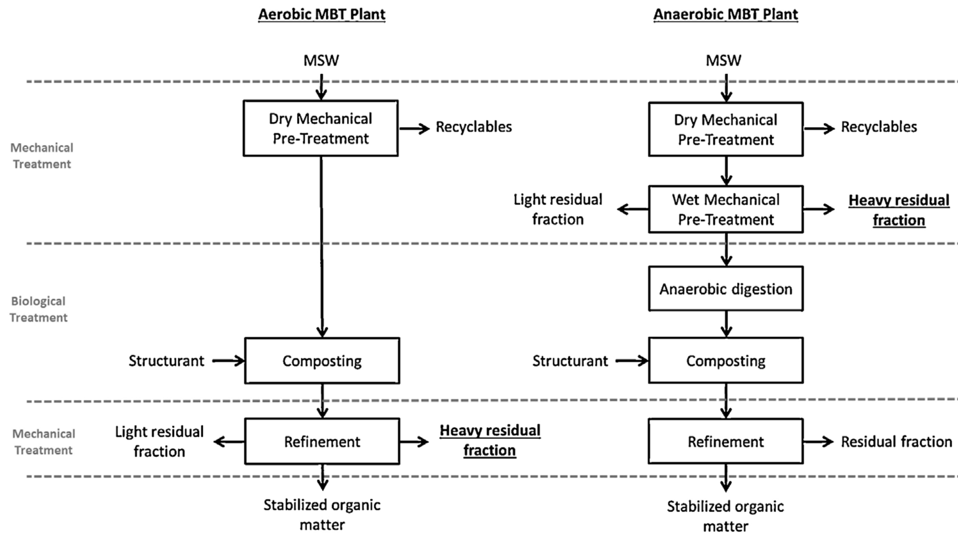

Fig. 1. Simplified flowsheets of solids in anaerobic and aerobic MBT plant types.

was sent to Mechanical and Biological Treatment (MBT) plants (APA, 2013). MBT is an important strategy used in Europe to treat MSW, mainly to minimize the quantity of biodegradables landfilled (Lornage et al., 2007; Montejo et al., 2010; Pires et al., 2011; Tintner et al., 2010; Vellini and Savioli, 2009). In what concerns MSW, in Portugal, there has been a great effort in the construction of MBT plants. While in 2012 only 6 MBT plants were in operation, in 2014, 8 other will be operating.

The biological process in the MBT plants can be aerobic or anaerobic (the stabilization of organic matter occurs in the presence or absence of oxygen, respectively). There are two main flows in a MBT facility, named as upstream, which is the feeding of the process (MSW or selective collection of organic waste), and downstream, which is the final product, such as biogas, compost, air emissions, residual fraction, leachates and recyclables. The recovery of recyclable materials in the MBT facilities that treat MSW highly depends on the existence of a market for each material. Besides the benefits collected from selling recyclables, important costs related with final disposal and negative impacts are avoided (Massarutto et al., 2011).

In the process of organic fraction decontamination there are two main solid waste streams. The light residual fraction, which is mainly composed by plastic film and paper, in some cases, is used to produce Refuse Derived Fuel (RDF). The heavy residual fraction (MBTr), represented in bold and underlined in Fig. 1, is mainly composed by inert materials, mainly glass, being currently landfilled because there is no viable technology for its recovery.

It was observed in the analysis of one Portuguese plant (TRATOLIXO) that the MBTr is mainly composed by packaging glass (Dias et al., 2011). It was found that it is composed by a significant percentage of glass (83%) being the organic matter and stones the other main components with about 7%. This MBTr presented a moisture content of 4% and the particle size did not exceed 10 mm.

Nevertheless, up to now the packaging glass occurring in MBTr is not recycled in Portugal because the glass content is lower than the specifications imposed by the plants that decontaminate the selectively collected packaging glass for recycling – Material Recovery Facilities (MRF). Even when the content in organics is low, the organic contamination of glass particles, which have a small size reduces the efficiency of optical sorting process which is commonly used in the glass MRF (VIDROCICLO, 2011).

Dias and Carvalho (2012) developed a simple and cheap process based on the difference in particle shape able to upgrade the content in glass of MBTr. Using a sample of MBTr from one MBT plant they showed, that it is possible to concentrate the glass by removing almost 60% of the stones, the main and most problematic contaminant due to its circularity that decreases the efficiency of the optical sorting currently used in MRF. Approximately 80% of the glass was recovered in the final concentrated product (Dias et al., 2011).

So, the objective in recovering the packaging glass present in MBTr is not only to help to increase the glass recycling rate, but also to avoid the cost of landfilling it. Besides, the value of the recyclables materials such as glass and also the existence of an economic incentive from Green-Dot System, a common practice in Europe as a result of the EPR (Extended Producer Responsibility) principle,

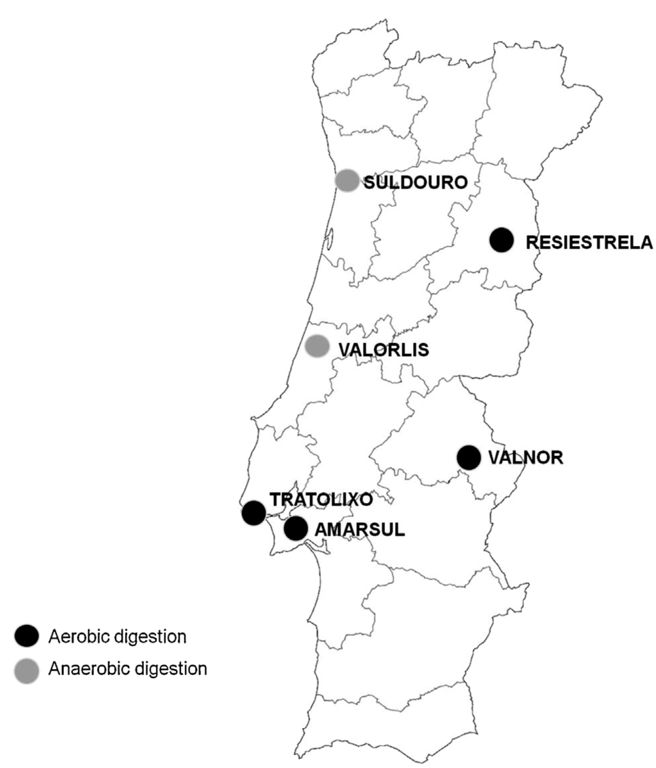

Fig. 2. Localization of the Portuguese MBT plants treating MSW in 2012.

must be taken into account. For the packaging glass recovered from selective deposition this value is around 35 to 60 Euros per tonne (depending on its quality), while, in the case of household glass packaging waste recovered in composting plants the incentive is 5 Euros per tonne (SPV, 2012).

The present study was carried out to quantify the glass appearing in the MBTr, in order to evaluate the relevance of the application of a process to recover this glass. The first step for such a study is to find out the constraints associated with the real quantity and characteristics of the MBTr. This paper describes a characterization study undertook with samples of the MBTr of all the six Portuguese MBT plants in operation in 2012 that feed the process with mixed MSW, aiming at the evaluation of the quantity of packaging glass that appears in this stream. The data from TRATOLIXO plant presented in this paper were obtained by Dias et al. (2011).

In the present study, plants fed with green or organic waste were not considered, because a preliminary analysis showed that the quantity of recyclable materials present in the MBTr from these plants is negligible.

In Section 2 a brief analysis of the flowsheets and processes of the plants is made. In Section 3 the characterization of the samples of MBTr collected in the plants is presented and related with technical main features of each plant. The annual flow of glass present in MBTr is quantified in Section 4. Section 5 presents the challenges for recovery and recycling of packaging glass from this outflow and, finally, the Section 6 presents the conclusions of the study.

2. Portuguese MBT plants treating MSW in operation in 2012. Processing main features

The MBT plants under study were – AMARSUL, RESIESTRELA, SULDOURO, TRATOLIXO, VALNOR and VALORLIS. Their localization is shown in Fig. 2.

The characteristics of the MBT plants are summarized in Table 1. A careful analysis showed that the following features have the major effects in the MBTr characteristics: the existence of glass sorting before biological treatment; the aperture of the last screen whereby the MBTr passes through (outputscreen aperture), the screen product where MBTr is recovered (underscreen or overscreen) and the output stage of MBTr (Wet Mechanical Pre-Treatment or refinement). All the screens have circular holes except in TRATOLIXO plant where they are rectangular. The structurant, normally constituted by wood sawdust or tree branch from tree pruning, when added has the objective of controlling the humidity and also to allow the flow of air between the particles. It has a possible effect on the content of organic matter grade and on the MBTr moisture content since this material absorbs moisture and provides moisture to the MBTr. However, the addition of this material in the anaerobic process (in the case of the SULDOURO and VALORLIS plants) does not influence the characteristics of the MBTr, since this is removed before the addition.

The heavy residual fraction, in the anaerobic plants (VALORLIS and SULDOURO), is removed in the pulper (BTA technology). This equipment includes a sieve to retain the heavy residual fraction separating this material from organic fraction. The screen has a 5 mm aperture in SULDOURO and a 10 mm aperture in VALORLIS.

3. Characterization of the MBTr from 5 Portuguese MBT plants

3.1. Materials and methods

The methodologies employed for sample preparation, moisture content determination and particle size and composition analysis were based in the ones developed in Dias et al. (2011).

3.1.1. Sample preparation and moisture content determination

The samples used in the study (one per plant), weighing 35–60 kg, were collected by the local staff of the plants. The sampling process was made using the appropriate standards and the representativeness was assured by the plants staff. Each analysis was repeated 2 times.

At the laboratory the samples were firstly carefully homogenized with a shovel (Fig. 3A) and divided in sub-samples using a Jones splitter (Fig. 3B). For samples with particles with size over 16 mm the splitting was made by the method of manual quartering division (Fig. 3C and D). The sub-samples weighted between 1 and 3 kg depending on the particle size.

The moisture content was measured in accordance with the CEN/TS 15414-1:2006 by drying all samples in a stabilized oven at 105 °C. The moisture content was determined in at least 3 sub-samples after the reception of the samples in the laboratory and they were dried for further characterization. It should be pointed out that the values of the moisture content are only indicative because it could not be completely controlled during all the time elapsed from the sample collection until reception in the laboratory.

3.1.2. Particle size and composition analysis

Firstly, a complete particle size analysis was carried out with 3 sub-samples. Then, a composition analysis by particle size fraction, using manual sorting of the different materials, was performed also with the 3 sub-samples.

Fritsch Analysette 3 Spartan apparatus and the DIN 4188 sieving series with 16.0, 11.2, 8.0, 5.6, 4.0 and 2.8 mm aperture were used (Fig. 3E) to determine the particle size distribution.

The composition of each size fraction was determined manually by sorting the different materials (Fig. 3F). After a preliminary visual analysis the following classification was selected: plastic, metal (including ferrous and non-ferrous), glass, ceramic, brick, stones and "others". This class is composed mainly by organic matter and materials that are difficult to be identified. In what concerns glass, due to the small particle size, it was not possible to visually discriminate between packaging glass and other types of glass.

In fractions with particle size above 2.8 mm, the materials can be clearly visually distinguished. In few cases when the exact identification of the materials could not be made the item was classified as "others". The materials in the particle size fraction bellow 2.8 mm are mostly composed by a mixture of items of unidentifiable materials, with very high percentage of organic matter and dust, so all this particle size fraction was classified as "others".

3.2. Results and discussion

The results presented in this section are the average values obtained with the 3 sub-samples. Statistical significance was measured by the coefficient of variation that was always significantly lower than 50%, thus the results are statistically significant (Afonso and Nunes, 2011).

3.2.1. Moisture content

The average moisture content of each plant sample is shown in Table 2.

The RESIESTRELA and TRATOLIXO samples exhibit lower moisture contents than the other samples. This is probably due to the fact that these two aerobic plants are the only ones where the addition of structurant material does not occur (see Table 1).

In all the other plants, structurant material is added. Nevertheless, in the two plants with anaerobic treatment (SULDOURO and VALORLIS) the MBTr is removed in the pulper before the structurant material is fed (see Fig. 1 and Table 1). Therefore the high moisture content in those two cases is not due to the presence of this

Table 1
Main features of the MBT processes relevant for MBTr characteristics.

Plant	Glass sorting	Output screen aperture (mm): fraction[a]	Output stage	Structurant addition
AMARSUL	–	12: u/s	Refinement	Yes
RESIESTRELA	–	30: u/s	Refinement	–
SULDOURO	–	5: o/s	Wet Mechanical – Pre-treatment	Yes
TRATOLIXO	–	20 × 7[b]: u/s	Refinement	–
VALNOR	Yes	6 and 12[c]: 6–12 mm	Refinement	Yes
VALORLIS	–	10: o/s	Wet Mechanical – Pre-treatment	Yes

[a] Product where MBTr is recovered: u/s, underscreen; o/s, overscreen.
[b] Rectangular aperture width × length.
[c] Existence of two screens.

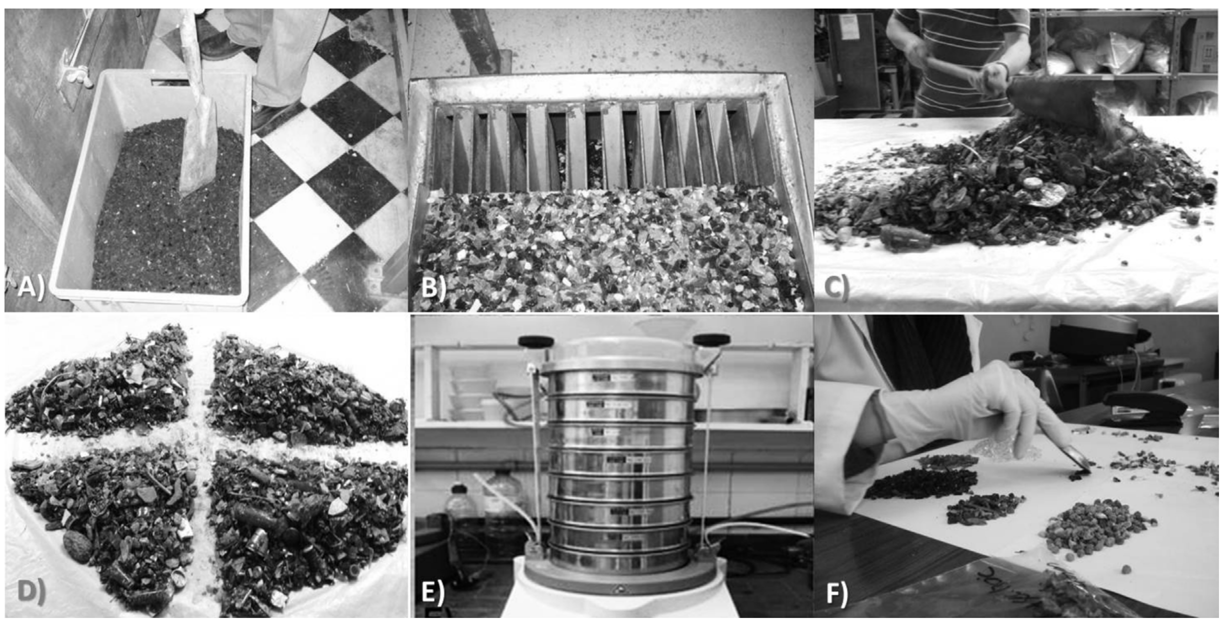

Fig. 3. Samples preparation. (A) Homogenization; (B) sample division; (C) homogenization of large particles sample; (D) division of large particles sample; (E) sieving and (F) composition analysis.

material. The wet mechanical treatment process includes a pulper followed by a screw to separate solids from the liquid.

3.2.2. Particle size

Fig. 4 shows the particle size distribution of the MBTr samples. As can be seen there are three groups of samples. The coarser ones, those from VALORLIS (VL) and SULDOURO (SD), have similar distributions, with about 50% of the material over 16 mm. The finer samples, from AMARSUL (AS) and VALNOR (VN), also present very similar distributions, which are almost completely finer than 5.6 mm. The other two samples, from RESIESTRELA (RE) and TRATOLIXO (TL), have intermediate particle size distribution, with most particles over 5.6 mm. The correspondent curves are quite different in shape as well.

As previously mentioned, the inert residual fraction of the anaerobic digestion plants, VALORLIS and SULDOURO, is removed early in the process, while in the aerobic plants, AMARSUL, RESIESTRELA, TRATOLIXO and SULDOURO, this product is removed only at the end of the process. Furthermore MBTr of VALORLIS and SULDOURO plants is the overscreen while in the others there is an upper limit superimposed by the screen mesh. So, in these cases the particles are subject to stronger fragmentation and attrition, and this is reflected in their finer particle size distributions. Fig. 5 shows pictures of the three types of products.

On the other hand, the particle size distributions are in accordance with the screen aperture of the screens where MBTr exits the process. There are, however, two exceptions. Although the MBTr of VALNOR should be 6–12 mm particle size fraction (see

Table 2
Average moisture content of the MBTr samples.

Plant	Moisture content (%)	Coefficient of variation (%)
AMARSUL	13.05	1.16
RESIESTRELA	2.92	12.20
SULDOURO	12.95	8.4
TRATOLIXO	3.45	–
VALNOR	22.33	2.0
VALORLIS	12.00	–

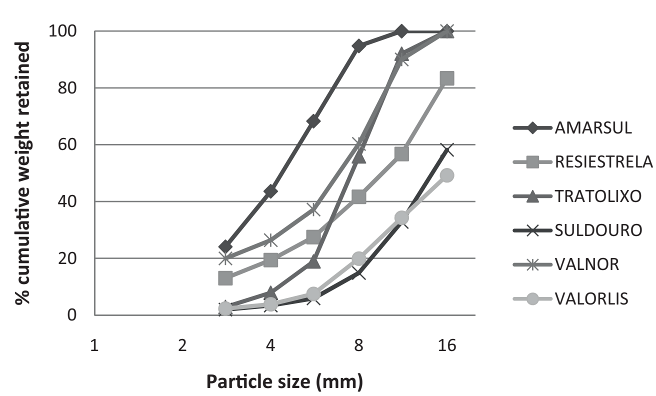

Fig. 4. MBTr samples size distribution.

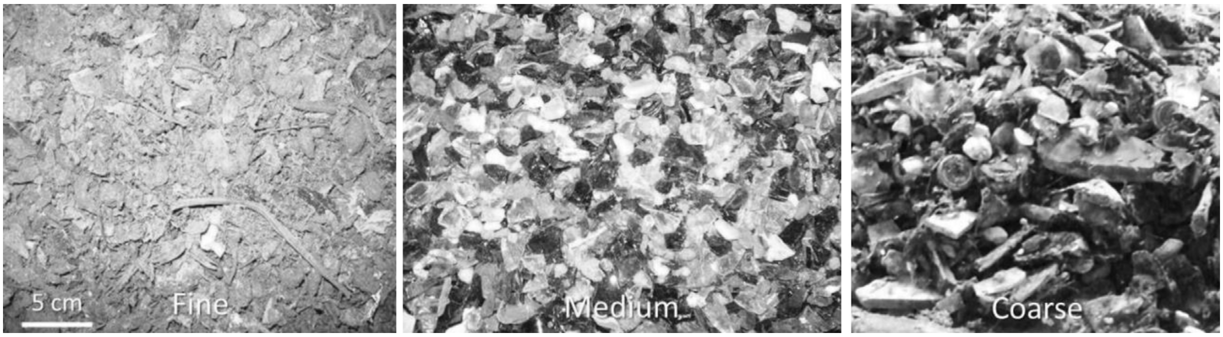

Fig. 5. Pictures of MBTr samples of different grain sizes.

Table 1), more than 60% of the sample exhibited particle size below 5.6 mm. This is probably due to the agglomeration of the particles that occurs in the industrial process caused by the high moisture content (see Table 2) preventing them to pass through the under screen causing screening inefficiencies. In the particle size analysis, made in the laboratory, the agglomeration disappeared and the fineness of the product showed up. On contrary, the VALORLIS sample exhibits approximately 25% of undersize material in the over screen. Two possible causes for this are the screen inefficiency (e.g. clogging) or screen under sizing.

Table 3
Glass contained in MBTr produced by the MBT plants in operation in 2012.

MBT plants	MBTr (t)	Glass content (%)	Glass contained (t)
AMARSUL	1488.6	41.0	609.7
RESIESTRELA	N.a.	53.3	N.a.
TRATOLIXO	3962.5	56.7	2246.0
VALNOR	7843.6	82.9	6500.0
SULDOURO	12423.0	33.2	4122.0
VALORLIS	5647.0	58.3	3294.5
TOTAL	31364.7		16772.1

3.2.3. *Composition*

Fig. 6 summarizes the overall composition of the six samples. For a clearer visualization, ceramics, plastics, brick and metal were aggregated in one class, named as CPBM, since the content in these materials is very low in all samples.

All the samples, with the exception of the one from VALNOR, exhibit a very high content in glass, while the content in other recyclable materials is only vestigial. The main contaminants are the "stone" and "others" classes and, in the case of SULDOURO, the CPBM too.

The MBTr from TRATOLIXO presents the highest content in glass, while the VALNOR sample is the one with the lowest. The other samples are intermediate in terms of glass content. It is observed that the higher the content in glass, the lower the content in "others".

The fairly low glass content in the VALNOR and AMARSUL samples compared with the other samples is due to their high content in organic matter ("others") (probably due to the addiction of structurant material) and also, in the case of the VALNOR plant, to the existence of glass sorting.

Despite the inexistence of structurant material and low moisture content, the RESIESTRELA sample has a quite higher content of organics and a lower content in glass than the one from TRATOLIXO. A probable reason for this is the different screen apertures.

In both anaerobic plants (SULDOURO and VALORLIS), the efficiency of organic matter separation is evident, since this type of material constitutes a lower percentage of the MBTr composition. This is probably due to the high efficiency of disintegration of organic matter in the wet mechanical pre-treatment, which easily passes through the sieve screen aperture of pulpers.

In order to analyze in which fraction the materials are concentrated, Figs. 7–9 show the composition, respectively in glass, stones and "other" of the 6 samples by particle size fraction. It should be highlighted that the overall composition was determined taking into account that, as referred, the −2.8 mm fraction was classified as "others" because it is composed mostly by organic matter, sand and dust.

It is observed that the glass content increases with particle size (excluding the fraction over 16 mm) and the opposite occurs with the "stones" class. The "others" content is higher in the fine particle size fraction (below 4 mm).

4. Quantification of packaging glass occurring in MBTr in Portuguese plants

Table 3 shows the quantity of glass contained in the MBTr in the Portuguese plants in operation in 2012 calculated by considering the glass content obtained in the characterization carried out (Fig. 6) and the most recent available values of the amount of MBTr sent to landfill. Only five of the six plants in the study could supply the exact values of the annual amount of MBTr sent to landfill. RESIESTRELA does not measure the MBTr flow rate.

In view of the results in Table 3, it can be anticipated that, if all the glass sent to landfill (16,772 t) could be recovered, the quantity of glass sent to recycling would increase from 210,422 t, the quantity recycled in 2011, to 227,194 t. This value would be enough to achieve the PERSU targets. This would also mean an increase of 4,4% in the recycling recycling taxes that would approximate Portugal to the European average glass recycling rate.

It is expected that in 2014 eight new plants will be in operation to process mixed MSW in Portugal. Today, there are no reliable data that can be used to predict the quantity of glass that will appear in the heavy residual fraction of these new MBT plants. Yet, an approximate value can be calculated by considering the nominal capacity of the new plants (Table 4) and the actual figures obtained in plants operating in 2012.

As can be seen in Table 4, considering the "actual plant feed (%)" and the plant nominal capacity, all the plants in operation in 2012 worked under or over the nominal capacity. Nevertheless, the six plants worked, in average, at nearly 79.2% of the nominal capacity. If this same ratio could be used, in 2014, about 1,300,000 tonnes of MSW would feed the 14 plants in operation.

Considering that the ratio "glass contained in MBTr" (16,772 t)/"MBT feed" (439,147 t) in Tables 3 and 4 would be the same in 2014, the 1,300,000 tonnes of MBT feed in 2014 would then lead to more than 48,000 tonnes of glass appearing in the MBTr.

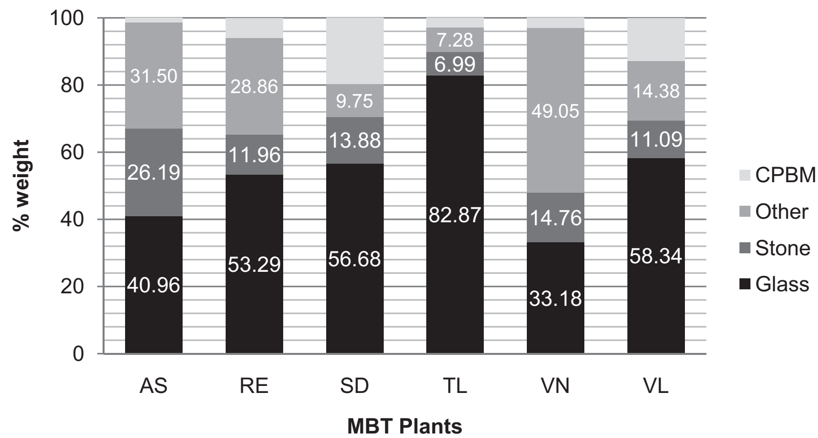

Fig. 6. Composition on glass, stones, "others" and CPBM of each MBTr sample.

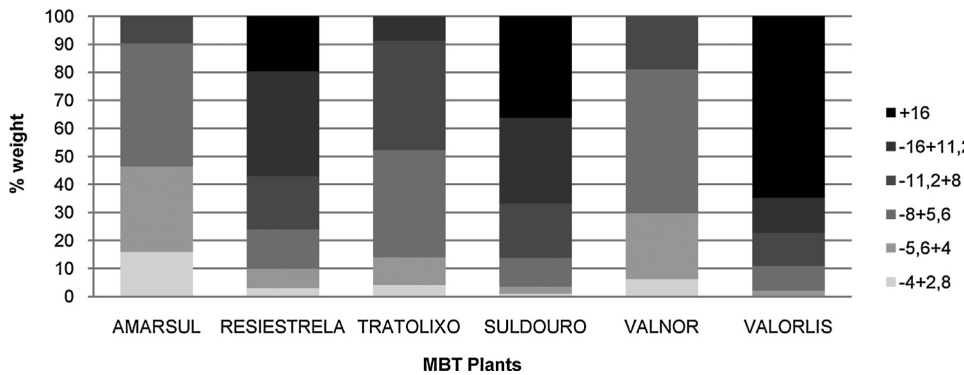

Fig. 7. Glass particle size distribution.

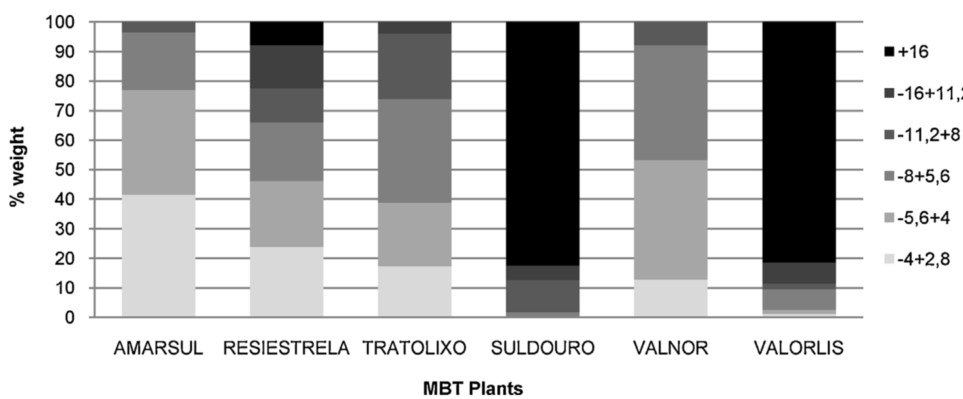

Fig. 8. Stones particle size distribution.

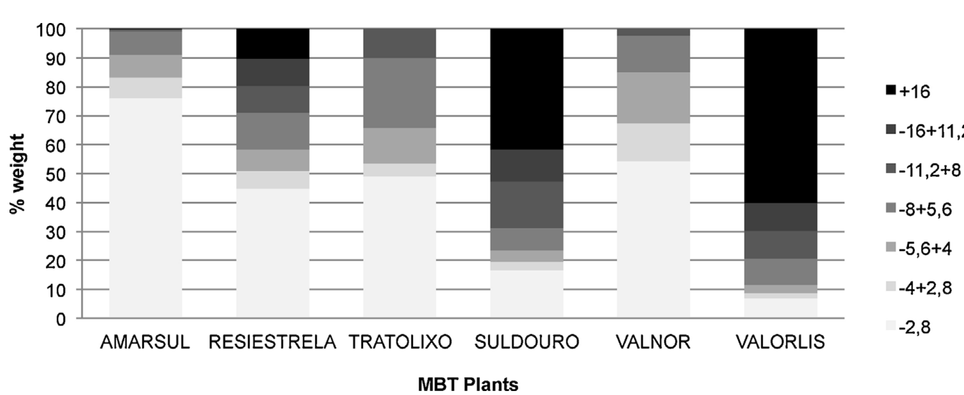

Fig. 9. "Others" particle size distribution.

Table 4
Nominal capacity of Portuguese MBT plants that will be in operation in 2014 and current MSW feed values registered for the plants in operation in 2012.

Plants	Nominal capacity (t/year)	Actual plant feed (t/year)	Feed/capacity ratio[a] (%)
AMARSUL	50,000	42,652.0	85.3
AMBILITAL	65,000	–	–
BRAVAL	100,000	–	–
ERSUC 1	180,000	–	–
ERSUC 2	180,000	–	–
GESAMB	113,000	–	–
RESIDUOS DO NORDESTE	55,000	–	–
RESIESTRELA	150,000	50,000.0[b]	33.3
RESINORTE	180,000	–	–
RESITEJO	100,000	–	–
SULDOURO	50,000	23,781.1	47.6
TRATOLIXO Tr.[c]	–	153,894.1	76.9
TRATOLIXO Ab.	200,000	–	–
VALNOR	100,000	131,504.1	131.5
VALORLIS	50,000	37,316.0	74.6
TOTAL	1,573,000	439,147.3	

[a] Ratio between the "actual plant feed" and the "nominal capacity".
[b] Value of 2011 (one year before the year of sample collection).
[c] MBT plant that will be closed before 2014; in 2012 the nominal capacity was 150,000 t.

These results show how important is to consider a further processing stage to process MBTr to attain the adequate characteristics for recycling.

5. Challenges for recovery and recycling packaging glass from MBTr

Glass from the MBTr product exhibits potential to be used as a secondary raw material in the glass industry, in the melting process and in the production of new glass containers. Its use, together with the glass selectively collected, could have a positive environmental impact in the replacement of raw materials used in the manufacturing process (Vellini and Savioli, 2009). This allows considerable energy savings (in the extraction and transport of raw materials and the blast furnace for smelting) as well as savings on raw materials (resource depletion). Moreover recycling reduces the amount of waste to be sent to the landfills.

To be used for this purpose it must, however, comply with the quality requirements of the glass MRF. To improve the quality of glass waste sent to the MRF, based on these facilities, the Portuguese Green Dot Company stipulates some specifications for glass cullet from selective collection, which are shown in Table 5.

The present study showed that MBTr, as it is, is not accepted by glass MRFs due to the high level of contaminants (see Fig. 6). Nevertheless, the amount of glass sent today to landfill is very high so the processing of this product should be considered.

Current technological and economic challenges are related with the efficiency of the currently used decontamination processes. It is known that the higher the target for the final product quality desired, the higher the costs involved (CAPEX, operational costs, etc.) and the lower the amount of the enriched glass product obtained. Due to the similar properties of glass and other inert contaminants, state of the art technology is based in the optical sorting. However this process is quite inefficient when the contamination level is high and the particle size is small.

Taking in account the particle size limitations and regarding Figs. 7–9 that show that glass concentrates on the +5.6 mm fraction and stones and "others" on the −5.6 mm fraction in the majority of plants, a screening process using an aperture of around 5.6 mm can produce a product with increased glass content. Table 6 shows glass, stones and "others" content and recovery of glass after the application of a screening with 5.6 mm aperture.

Comparing the data from Fig. 6 with Table 6 it can be observed that the glass grade increases when the −5.6 mm fraction is eliminated. The glass in the fraction +5.6 mm represents most part of the glass contained in the MBTr (53.61–97.87%). However, the content of stones and "others" is still significant, therefore other processes should be applied to eliminate these contaminants.

Regarding the separation of glass based in the shape of particles, the literature is sparse. Beunder developed a rotary cone, which exploits the difference in particle rolling or slipping. However, in tests conducted with glass they were not successful because a large part of the glass that has been trapped by the walls of the cone was lost (Beunder et al., 2002).

Bonifazi developed image analysis techniques in order to improve the technology of decontamination of glass (Bonifazi, 2000). However, this sophisticated technology was still "blind" with respect to the ceramic glass (highly heat-resistant); another study was carried out, with the conclusion that the largest difficulty was to separate the amber ceramic glass (Bonifazi and Serranti, 2006). Thus, separating the ceramic glass became a challenge.

The Binder Company, through the merger of a UV sensor with a digital camera, developed the an equipment named Clarity that analyzes information in the ultra-violet wavelengths, that allows

Table 5
SPV specifications for glass cullet.

Materials		Content (%)
Product	Glass cullet	≥98.00
Contaminants	Infusible with dimensions ≤40 mm	≤0.05
	Ferrous metals	≤0.75
	Non-ferrous metals	≤0.20
	Organic matters	≤0.50

Table 6
Material content and recovery of glass in the particle size fraction over 5.6 mm.

MBT plants	Material content (%)			Recovery of glass (%)
	Glass	Stone	Others	
AMARSUL	69.46	19.02	8.90	53.61
RESIESTRELA	66.52	8.91	16.67	90.01
SULDOURO	70.34	10.00	4.72	96.93
TRATOLIXO	87.83	5.27	3.62	85.90
VALNOR	58.52	17.34	18.24	70.21
VALORLIS	59.24	11.16	16.56	97.87

the identification and removal of ceramic glass (Binder+Co., 2012). The optical sensors efficiency decreases sharply with the decrease in particle size and also with the contamination level. Furthermore, the equipment is quite inefficient in the elimination of stones (the main contaminant in Portuguese MBTr) due to the unpredictable trajectories of round particles that fall in front of the sensors.

As referred before, previous studies showed, at a laboratory scale, that it is possible to upgrade MBTr in glass by removing stones. Dias and Carvalho (2012) developed simple and cheap equipment, the RecGlass, which is inspired in the "vanner" equipment, exploiting in this case the difference in shape of particles. With this equipment, it was possible to concentrate the glass by removing almost 80% of the stones, the main contaminant, with a recovery of approximately 80% of glass in the final concentrated product.

The characteristics (particle size, composition and moisture content) of MBTr are superimposed by the flow sheet, technical parameters and efficiency of the equipment. Therefore, changes in the MBT processes can modify heavy residual fractions characteristics, which could allow the recovery of glass. Nevertheless other improvements should to be done in order to comply with the specifications of MRFs. This is a current research that must be considered in the future.

6. Conclusions

MBT plants that process mixed MSW produce an inert residual fraction (MBTr) composed mainly by packaging glass. This material cannot be recycled as it is because it does not attain an adequate quality determined by Material Recycling Facilities, mainly due to the high contamination with other materials.

In the present paper, the particle size distribution and composition of the MBTr of the six plants in operation in 2012 in Portugal is presented. It was observed that the glass content ranges 33–83% and the main contaminants are the stones (7–26%) and "others", constituted mainly by organic materials (7–49%). The particle size distribution is variable. In the finer samples 80% of the material has a particle size below approximately 7 mm, while in the coarsest 80% of the material has a particle size over 10 mm. Both composition and particle size distribution are directly related with the upstream processing flowsheet.

The glass contained in the MBTr of all the six plants in operation in 2012 was quantified and, based in the nominal capacity of the eight new plants that will be operating in 2014, it was estimated that in this year, about 48,000 tonnes of glass will appear in MBTr.

The high amount of glass that will be sent to landfill shows how important is to make efforts in the development and improvement of processes and equipment to recover this material for recycling. Based in the characterization study, it was shown that with simple and cheap processes like organics elimination and screening the product could be significantly upgraded in glass. Nevertheless, the elimination of stones is today a challenge and a subject of research.

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