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Research article

# Characterization of SRF from MBT plants: Influence of the input waste and of the processing technologies

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ABSTRACT

Mechanical and biological treatments are the widespread treatments of mixed waste and organic waste in order to enable recovering recyclable materials from MSW. However, a large portion of mixed waste ends up as rejects, which can provide a remarkable energy content. Rejects can therefore become a solid recovered fuel (SRF) for incineration or co-incineration plants that meet the classification and specification requirements laid down in standard CEN/TS 15359 (2012). In this work, different flows of reject have been studied and identified, and different rejects have been characterized. The most important differences exist between rejects from the stages of recovery of recyclable materials and rejects from the stages of compost/bio-stabilized matter refinement. Rejects are composed mainly of combustible material, with low S, C and Hg contents, although rejects from the material recovery stage have a higher chlorine content than the others, due to their higher plastics content. Nevertheless, rejects from the material recovery stage have the most favourable SRF class code. Therefore, to take advantage of the fuel contained in the SRF it is necessary to examine the different reject flows from MSW treatment plants separately in order to improve the quality of SRF obtained from rejects.



## 1. Introduction

In recent years, the objectives of developed countries regarding waste are focused on reducing the volume and the maximum exploitation of the resources in waste. By doing so, the amount of MSW sent to landfills can be minimized. With this in mind, the current European regulations on waste are fostering a better exploitation of MSW by means of separate collection systems of different materials (glass, paper, cardboard, used oils, packaging, biowaste, etc.) in order to recycle them. In this sense, the regulations about waste are based on a waste hierarchy, where recycling is given priority over energy recovery, and energy recovery is prioritized over landfill [1].

Mechanical-biological treatment (MBT) is the most widespread form of processing for mixed waste [2], which stabilizes organic matter by means of the bio-stabilization process. Furthermore, this treatment can recover recyclable materials. However, a large portion of mixed waste ends up being rejected and taken to landfills or to energy recovery [3,4]. For example, in Spain, 48% of mixed waste is treated at MBT plants [5]. The percentage of the reject fraction respect to the total flow which fed to MBT plants is 63%, and the 95% of the reject generated in them is taken to landfills (the other 5% is taken to energy recovery) [5]. This reject can have a remarkable energy content, above all if the mixed waste has a high calorific value [6], so it could be considered as combustible residues. Thus, mixed waste can become solid recovered fuel (SRF) and accordingly a better use of the mixed waste is achieved [7].

The European Union (UE) regulations define SRF as solid fuels prepared from non-hazardous waste after being treated, to be utilized for energy recovery in incineration or co-incineration plants and meeting the classification and specification requirements laid down in the standard CEN/TS 15359 (2012). In order to produce SRF it is necessary to remove non-combustible material from the reject and then it must be milled, dried and, in some cases, pelletized [8,9]. Additionally, from the point of view of incineration efficiency, fuels from reject are better than fuels from MSW [10].

In the UE the amount of SRF produced from MSW with a high calorific value is about 12 million tonnes per year [11]. In addition, the SRF production from MSW is increasing year after year, on the one hand, due to the growing interest of the energy industries sector in the supply of a cheaper alternative fuel and, on the other hand, due to the construction of new MBT plants in many countries [7]. Between 2005 and 2011, the number of these plants in Europe is reported to have increased with

*Abbreviations:* CM, combustible material; DTG, differential thermogravimetric analysis; MBT-1, plant 1 of mechanical biological treatment; MBT-2, plant 2 of mechanical biological treatment; BWC-3, plant 3 of biowaste composting; NMC, no combustible material; RAB1, reject from pre-matured bio-waste refinement; RAB2, reject from bio-stabilized material refinement; RAC1, reject from compost primary refinement; RAC2, reject from compost secondary refinement; RRA, reject from automatic material recovery; RRM, reject from manual material recovery; TG, thermogravimetric analysis; d/w, dry weight; w/w, wet weight.

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60%, to >330, and a total treatment capacity of around 33 million tonnes [12].

These SRF, as an alternative fuel, involve a primary energy saving and are used mainly in power generation facilities, co-generation plants and heat-demanding processes [11,13,14]. Co-firing in cement kilns appears to be the most suitable option, since SRF can be used without affecting the quality of the final product [15]. On the other hand, environmentally speaking, the energy valorisation of reject is considered a partially renewable source of energy that reduces the emission of greenhouse gases [16], as the carbon dioxide released by firing the biodegradable fraction of MSW is not taken into account in the assessment of greenhouse gas emissions [17]. In consequence, the use of SRF provides better results than non-renewable fuels in terms of greenhouse gas emissions [7,18–21].

Notwithstanding, in MBT plants there are several treatment stages and each of them generates a different type of reject. Their composition and properties are different, and therefore their use as a fuel and their valorisation alternatives may differ. Moreover, their characteristics depend firstly, on the layout and design of the MBT plants [22] secondly, on the composition of the MSW [23] and thirdly, on the MSW management strategies of the area [24]. Because of these concerns, it is necessary to perform a suitable characterization of the different flows of reject in MBT plants in order to plan alternatives focused on the energetic valorisation so as to minimize the environmental impact, and to diminish the consumption of natural resources and costs [16].

In this regard, Nithikul, Karthikeyan, and Visvanathan [25] established that reject from stages prior to the biological treatment have a higher potential to become SRF, and its main use would be in cement kilns. Moreover, Bessi et al. [6] and Di Lonardo et al. [24] determined that reject flows from MBT plants could be used as an SRF following the specification requirements laid down in the standard CEN/TS 15359 (2012), but with a wide range of different qualities.

Furthermore, the thermal behaviour of rejects must also be taken into account [26], since this can help avoid technical and environmental problems that may arise during their use [27]. Sever Akdağ, Atimtay, and Sanin [28] compared the combustion of two samples of SRF from different MBT plants with coal and petroleum coke by a thermogravimetric analysis. Their TGA results showed that the combustion mechanisms of volatile matters in RDF samples are complicated than the samples of char. In coal and petroleum coke combustion, the constituents of the fuel decomposes in solid-phase at the char combustion; however, in RDF combustion, the decomposition occurs at early stages of the combustion in gas phase due to the low fixed-carbon and high volatile matter content of RDF [28]. Otero et al. [29] compared several types of biowaste (including the organic fraction of MSW) with coal and polyethylene terephthalate (PET) waste. Both studies showed different combustion mechanisms for each material, which makes their study and analysis essential.

The main goal of the present work is therefore to determine the influence of the process of generating reject on the manufacture and final quality of SRF. To this end, different reject flows were studied in three Spanish MBT plants in order to analyse the physical, chemical and thermal properties of SRF. The research has been divided into three main parts: firstly, the sampling of different reject flows was performed. Secondly, physical and chemical properties were determined, following specification requirements, and, thirdly, the combustion profile and the thermal decomposition profile were studied by means of thermogravimetric analysis (TGA).

## 2. Material and methods

### 2.1. Description of MBT plants

In this subsection, the main characteristics of three MBT plants are described.

The MBT-1 plant has a capacity to treat 120,000 t/year of mixed waste. In this plant recyclable materials (plastic, paper-cardboard, glass and metal) are recovered by mechanical means such as sieves, magnetic separators and Eddy-current separator or by means of near-infrared (NIR) separators for the different plastic types. Biowaste is bio-stabilized in piles within a closed building (Fig. 1). As a result, a flow of recovered material, other of bulky material, a flow of bio-stabilized material and three streams of reject are obtained. One of them comes from the material recovery process, and two of them come from the process of bio-stabilized matter refinement. Process losses (gas emission and liquid) represent 30% of the incoming material. Fig. 1 shows the percentage of the different output flows respect to incoming material. In this plant, the reject flow from the process of automatic recovery (RRA) by pneumatic separation was analysed.

The MBT-2 plant has a capacity to treat 120,000 t/year of mixed waste. Recyclable materials are recovered by mechanical and manual means (plastic, paper-cardboard, glass and metal). Biowaste is bio-stabilized within tunnels (Fig. 2). After waste has been treated, recovered materials, bio-stabilized material and three reject flows are obtained. One of them comes from the recovery stage and two from the biological stage: refinement of pre-matured biowaste and refinement of bio-stabilized material. Process losses (liquid and gas emissions) represent 43% of the incoming material. Fig. 2 shows the percentage of the different output flows with respect to the incoming material. In this plant, the reject flow from manual and mechanical recovery (RRM), the reject from the refinement of pre-matured biowaste (RAB1), and the reject from the bio-stabilized biowaste (RAB2) were analysed. The refinement of the pre-matured biowaste is obtained in the trommel (30 mm) and corresponds to the gross fraction. The refinement of bio-stabilized waste is obtained by means of densimetric separation.

The MBT-1 and MBT-2 plants receive mixed waste from cities where separate collection systems are divided into four fractions: light packaging (plastic, metal and bricks), glass, paper-cardboard, and mixed waste.

The BWC-3 plant has a capacity to treat 36,000 t/year of biowaste. This facility receives biowaste from cities where separate collection systems are divided into five fractions: biowaste, light packaging, glass, paper-cardboard, and mixed waste. The mechanical stage eliminates non-desirable waste from pre-matured biowaste (Fig. 3). Biowaste is composted in an open shed. As resulting material there is a small flow of recovered metals, a compost flow, which is used as an organic fertilizer, and two flows from the refinement of compost: one of them from the primary refinement, which includes the non-desirable materials, and another from the secondary refinement of compost.

Process losses (liquid and gas emissions) represent 39% of the incoming material. Fig. 3 shows the percentage of the different output flows with respect to the incoming material. In this plant, the reject flow from the primary refinement of compost (RAC1) and the secondary refinement of compost (RAC2) were analysed.

### 2.2. Sampling and physical characterization

Sampling and physical characterization of rejects were performed from May to July 2013. The methodology employed for the six flows of reject is described in the following.

First, a representative sample (250 kg) of the reject flow was taken. To do so, 20 kg/h were taken for 12 h. Then, the material was mixed and homogenized on a clean smooth surface. After that, the sample was quartered to obtain a final sample of around 30 kg, which was transported to the laboratory.

Physical characterization consisted in determining moisture and composition. Moisture was determined by drying the material in an oven at 105 °C (standard CEN/TS 15414-3 (2011)). Moreover, two main fractions were classified in terms of physical composition: combustible and non-combustible. The non-combustible material (NCM) was composed of inert, glass, metals and hazardous waste. The remaining materials constituted the combustible material fraction (CM).