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Volatilization characteristics of solid recovered fuels (SRFs)

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ABSTRACT

The volatilization characteristics of three MSW-derived materials (FO, RT and FL) produced by local waste-management companies were investigated as potential solid recovered fuels (SRFs). FL was prepared from sorted domestic waste and consisted of non-recyclable plastics, refuse paper and biomass. RT and FO were obtained through active hygienization of unsorted MSW and refuse materials from selective waste-collection streams. RT was rich in plastics and had low biomass, whereas FO was mainly biomass and refuse paper. The rate of energy release during volatilization depended on the content of biomass and plastic, especially at a low conversion. Major contaminants had different rates of volatilization. Nitrogen and sulfur tended to accumulate in the charred solid, and were released as SO_2 and nitrous oxides during both the volatilization–combustion stage and the char burning stage. Chlorine release was faster for the fuels rich in plastic waste. According to their ash melting characteristics and slagging indexes (Fs: 1188 °C for FO, 1192 °C for RT and 1234 °C for FL) the three fuels were equivalent to commercial SRFs. The three fuels showed potential as standardized SRF, although it would be desirable to reduce their chlorine content and, in the case of FO, to increase it's heating value.

1. Introduction

The EU directive (2008/98/CE) that regulates the management of municipal solid waste (MSW) has established a hierarchy of treatment that prioritizes waste prevention and reduction, reuse, recycling and recovery, while aiming at minimizing disposal methods that do not contribute to a valorization of MSW such as landfilling. According to this directive the production of energy (i.e., power and useable heat) from processed fractions of MSW that cannot be recycled is an acceptable waste recovery option, given that the plant achieves a threshold value in energy efficiency. Another waste recovery option that offers business opportunities for the waste management companies is to produce the so-called solid recovered fuels (SRF). These are solid fuels obtained from non-hazardous wastes which are used to produce energy in incineration and co-combustion plants, and that must meet quality and classification criteria of the CEN/TS 15359:2006 technical specification [1]. This classification system for SRF is based on economic (heating value), technical (chlorine content) and environmental (mercury content) indicators. SRFs are normally used as substitute fuels in cement kilns and conventional power plants based on fossil fuels such as coal and coke [2]. The advantages and the potential of this substitute fuel have been gradually appreciated and the production of SRF from non-hazardous waste is a growing industry in Europe [3,4]. Further increase in production capacity is expected as more countries adapt their MSW management systems to reduce direct landfilling and conform to the EU directives.

SRF are quite heterogeneous because of different strategies of MSW management, local recycling markets and availability of waste streams, and the different technologies that may be used for SRF formulation [2]. The intrinsic heterogeneity of SRF, the different properties of the conventional fuels with which they are mixed, and the variety of conversion technologies that are available (pulverized fuel combustion, grate firings, fluidized bed combustors, or even gasification processes) [5], make necessary to establish procedures to determine their combustion behavior to anticipate technical and environmental problems that may arise from their utilization [6]. This information is useful not only for the utility-companies and other consumers of the commercially available SRFs, but also for the waste management companies to improve their SRF formulation technologies to render fuels with better performance and market acceptance. In general SRF contain significant amounts of plastics and paper-related materials to attain a high net calorific value (10 to 25 MJ/kg), so they can serve as support fuel and improve ignition, combustion stability and burn out of lower-grade fuels such as biomass, peat or low-rank coals [4]. Key parameters to assess SRF suitability are related to their composition and their volatilization profiles [6]. Concerning composition they may contain high amounts of alkali metals, which form alkali chlorides that promote deposit formation and thus can cause technical problems related to

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slagging, fouling and corrosion on boiler elements exposed to high temperatures. In addition to alkali chlorides heavy metals may form compounds with very low melting points as well, and their presence in SRFs has to be strictly controlled [4]. The proximate analysis of an SRF (volatile matter and fixed carbon), its volatilization profile, the distribution of its energy between the charred residue and its volatile products, the release of alkali metals and trace contaminants during combustion, and the melting characteristics of its ashes, are some key parameters that have to be determined to fully characterize its combustion properties [6].

In this paper we investigated the combustion properties of three MSW-derived fractions that may be useable as SRF. The materials were produced by two MSW management companies as part of their effort to produce standardized SRF in Spain. The chemical composition of the materials was determined following standard analytical methods, and their volatilization and combustion profiles were studied in detail.

2. Experimental

2.1. Fuels

Three different MSW-derived mixed materials that may be considered prototype SRFs have been tested. FL was produced by Sanea (Spain) from mixed domestic waste streams, and had a significant content of non-recyclable post-consumer plastics, waste paper, and biomass. RT and FO are mixed fractions that were produced by Ambiensys (Spain) through their process of active hygienization (GeiserBox®) of unsorted MSW and refuse materials from plants processing selective waste collection streams. RT was rich in plastics and textiles, and had low content of biomass and paper, whereas FO was mainly formed by biomass and waste paper. All materials were ground and sieved to 1 mm using a low-speed rotary cutting mill (Retsch SM-300), operated at a low feeding rate to prevent excessive heating of the samples. When required for analytical purposes, samples were further ground to 250 μm in an ultra-centrifugal mill (Retsch ZM-200).

2.2. Batch pyrolysis

Batch pyrolysis of the fuels was performed in a fully automated LECO TGA-701 thermogravimetric analyzer under nitrogen atmosphere at temperatures of 300, 400 and 500 °C. Several samples of around 1 g of each fuel were placed in ceramic crucibles and dried at 106 °C until constant weight. Then the samples were heated at 5 °C/min until the desired temperature, which was maintained for 7 min, and cooled down to 106 °C under nitrogen. The samples were then collected and stored for further analysis at room temperature in closed vials placed inside a desiccator.

2.3. Analytical methods

All the analyses were performed at least by triplicate, and the uncertainties of the average values were estimated at a 95% probability level. The following standard test methods were applied:

- Proximate analysis of the raw fuels was performed according to the EN-15402 and EN-15403 standard methods [7,8] using a LECO TGA-701 thermogravimetric analyzer.
- Elemental composition (C,H,N) of the raw fuels and the pyrolyzed samples was determined using a LECO Truspec CHN analyzer, according to the EN-15407 standard method [9].
- Heating values were measured following the EN-15400 standard method [10] in an isoperibo LECO AC-600 calorimeter. After each measure the bomb was washed out with a 0.2 M KOH solution to recover sulfur (H_2SO_3) and halogens (HCl and HF), which were measured afterwards by ion chromatography (Dionex ACS 1100) according to the EN-15408 standard method [11].

Table 1
Proximate analysis, elemental composition, heating value and major metals of the different fuels studied in this paper.

Properties	Fuel		
	FL	RT	FO
Proximate analysis (% dry basis)			
Ash	18.2 ± 2.4	9.5 ± 1.5	28.5 ± 0.3
Volatiles	74.8 ± 0.2	88.0 ± 1.5	66.0 ± 0.6
Fixed carbon	7.0 ± 2.2	2.5 ± 0.06	5.5 ± 0.9
Elemental composition (% dry basis)			
Carbon	50.5 ± 0.2	61.6 ± 0.3	40.9 ± 1.3
Hydrogen	7.08 ± 0.07	8.95 ± 0.02	5.5 ± 0.3
Nitrogen	0.96 ± 0.03	0.79 ± 0.02	1.57 ± 0.06
Sulfur	0.22 ± 0.01	0.37 ± 0.06	0.65 ± 0.02
Chlorine	0.65 ± 0.06	0.71 ± 0.12	0.82 ± 0.12
Fluorine	0.011 ± 0.001	0.009 ± 0.002	0.012 ± 0.002
Heating value — LHV (MJ/kg, dry basis)	20.8 ± 0.2	27.3 ± 0.7	15.5 ± 0.6

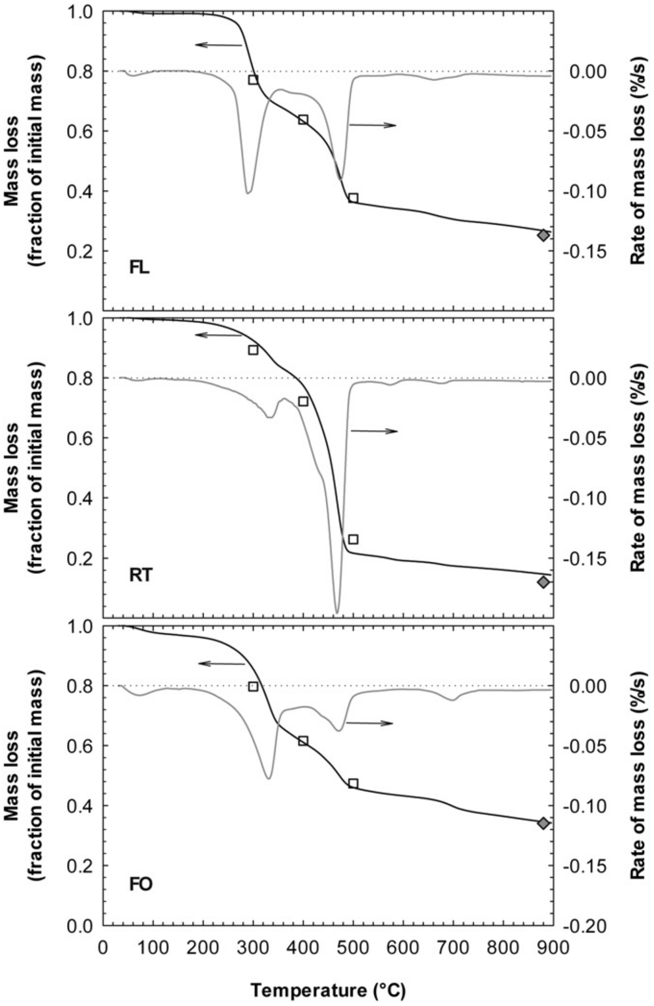

Fig. 1. Volatile release profiles under inert atmosphere of the three materials tested. Continuous lines are TGA/DTG curves. Symbols correspond to the mass loss determined in the batch pyrolysis experiments (□) and the combined content of ash and fixed carbon of each material (◆, Table 1).