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Evaluation of the potential of different high calorific waste fractions for the preparation of solid recovered fuels

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ABSTRACT

Solid recovered fuels constitute a valuable alternative for the management of those non-hazardous waste fractions that cannot be recycled. The main purpose of this research is to assess the suitability of three different wastes from the landfill of the local waste management company (COGERSA), to be used as solid recovered fuels in a cement kiln near their facilities. The wastes analyzed were: End of life vehicles waste, packaging and bulky wastes. The study was carried out in two different periods of the year: November 2013 and April 2014. In order to characterize and classify these wastes as solid recovered fuels, they were separated into homogeneous fractions in order to determine different element components, such as plastics, cellulosic materials, packagings or textile compounds, and the elemental analysis (including chlorine content), heavy metal content and the heating value of each fraction were determined. The lower heating value of the waste fractions on wet basis varies between 10 MJ kg^{-1} and 42 MJ kg^{-1}. One of the packaging wastes presents a very high chlorine content (6.3 wt.%) due to the presence of polyvinylchloride from pipe fragments, being the other wastes below the established limits. Most of the wastes analyzed meet the heavy metals restrictions, except the fine fraction of the end of life vehicles waste. In addition, none of the wastes exceed the mercury limit content, which is one of the parameters considered for the solid recovered fuels classification. A comparison among the experimental higher heating values and empirical models that predict the heating value from the elemental analysis data was carried out. Finally, from the three wastes measured, the fine fraction of the end of life vehicles waste was discarded for its use as solid recovered fuels due to the lower heating value and its high heavy metals content. From the point of view of the heating value, the end of life vehicles waste was the most suitable residue with a lower heating value of 35.89 MJ kg^{-1}, followed by the packaging waste and the bulky waste, respectively. When mixing the wastes studied a global waste was obtained, whose classification as solid recovered fuels was NCV 1 Cl 3 Hg 3. From the empirical models used for calculating higher heating value from elemental content, Scheurer–Kestner was the model that best fit the experimental data corresponding to the wastes collected in November 2013, whereas Chang equation was the most approximate to the experimental heating values for April 2014 fractions. This difference is due to higher chlorine content of the second batch of wastes, since Chang equation is the only one that incorporates the chlorine content.

1. Introduction

The European legislation about waste disposal has established a hierarchy of available technologies for the treatment or management of wastes: prevention, minimization, reuse, recycling, energy recovery and disposal (European Comission, 2008). Under EU policy, recycling of materials is preferable to energy recovery, and landfilling is the last option to be considered. In Europe, 481 kg of waste generated per capita in 2013 (Eurostat, 2013), only 130 kg were recycled, whereas 122 kg were incinerated and 147 kg were landfilled. These data point out the difficulties in the municipal solid waste (MSW) management. Although recyclable fractions such as paper, plastic and glass, and the biodegradable fraction of MSW can be either recycled or used as raw material for biological treatments, not all waste materials can be recycled. Moreover, the material sorting and recycling chains generate a large amount of residues which cannot be recycled and usually go directly to the landfill, although several of these materials present high heating values (Arena and Di Gregorio, 2014; Nasrullah et al., 2014). Waste landfilling presents several drawbacks. Firstly, the great volume of wastes accumulated, which could represent

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2/3 of the initial volume of waste (Montejo et al., 2011), with the subsequent landfill space needings. Secondly, the potential environmental pollution caused either by the methane emissions generated by anaerobic degradation of organic wastes, or the heavy metals leached from the waste of landfill (Sánchez et al., 2009). In addition, landfilling leads to huge loss of material and energy resources. Among the possible alternatives, waste combustion (in specific facilities or in energy-intensive industrial processes) is an option to solve the problems of space and the loss of valuable stuffs. In fact, once the recyclable materials have been recovered, the refuse derived fuel (RDF) or solid recovered fuel (SRF) combustion is an alternative to be considered (Lombardi et al., 2015; Montejo et al., 2011; Rada et al., 2008, 2014; Samolada and Zabaniotou, 2014). The use of fractions of this material as fuel could have several advantages as the decreasing use of landfill, and the replacement of fossil fuels with the corresponding reduction of greenhouse gas emissions (Burnley et al., 2011). The use of wastes as RDF leads to a product which can be burned in a planned plant with higher thermal efficiencies than the obtained in a conventional incineration plant (Burnley et al., 2011). In fact, the production of primary energy coming from waste incineration has shown a continuous increase in the last years (Ruiz Romero et al., 2012). At this point, it has been even demonstrated that these waste-to-energy approaches can have a positive effect in the global economy of a region/country, as demonstrated for the case of Greece in the macro-economic study recently reported (Psomopoulos et al., 2014).

The RDF/SRF generated from non-hazardous waste can come from multiple sources, such as industrial waste, commercial waste, waste from construction and demolition, sewage sludge, and/or MSW (Rada and Andreottola, 2012; Ragazzi and Rada, 2012). In Europe, the mechanical/biological treatment (MBT) is an increasing option for the RDF/SRF production for industrial purposes. The aim of MBT is to minimize the environmental impact associated with landfilling of biodegradable waste and to obtain additional value from waste by recovery of recyclable materials such glass, metals, waste-derived solid fuels fractions (Rada and Andreottola, 2012; Ragazzi and Rada, 2012).

Concerning to the SRF applications, several options for SRF utilization and conversion to energy have been already used or proposed for the future: thermal conversion device, which could include fluidized bed combustion, gasification or pyrolysis, fluidized bed boilers of some gasification plants, co-combustion in coal fired boilers, co-gasification with coal and biomass and co-fuel in cement kilns (Psomopoulos, 2014).

Using SRF in combustion processes in dedicated plants may have several limitations since it is not a zero waste method (resulting ash disposal containing heavy metals), and it is a source of GHG, and furans and dioxins emissions (Samolada and Zabaniotou, 2014). However, using SRF as co-fuel in cement kilns has strengths compared to in comparison to other combustion processes: it is a zero waste method, achieving a reduction in the consumption of conventional fossil fuels with simultaneous material recovery (Samolada and Zabaniotou, 2014). The cement industry, with 30–40% of the total costs due to the energy, is one of the main industrial activities interested in alternative fuels (Tsiliyannis, 2012). Use of SRF in cement kilns effectively contributes to the goals of an Integrated Management Scheme, leading to zero wastes for landfilling. Residual ash, always produced in common combustion units, is effectively incorporated in the cement product. This method has other serious environmental benefits related to the minimization of toxic combustion pollutants (dioxins and furans) due to complete oxidation and to particularly favorable reaction conditions (2000 °C) compared to combustion in dedicated plants usually operated al lower temperatures (Samolada and Zabaniotou, 2014).

SRF can be distinguished from RDF in the fact that it is produced to reach a standard such as CEN/343 (EN 15359). In this way, the European Committee for Standardisation (CEN) has selected as key technical performance indicators of the SRF: lower heating value, residual chlorine content and mercury content (Rada and Andreottola, 2012). The concentration of chlorine in SRF is especially relevant since elevated concentration could create both technical problems and environmental concerns, such as generation of acid gas emissions and formation of polychlorinated dibenzodioxins (PCDDs) (Velis et al., 2012). In order to obtain a waste that can be used as SRF in cement plants, particle size is other of the key parameters. Alternative fuel injection in the main burner of a cement kiln requires that the particle size is less than 10 mm. For use as fuel for injection into precalciner, the particle size should be less than 100 mm, preferably with a two-dimensional geometry.

In this way, COGERSA, waste management Company in Asturias (1 million habitants region in the North of Spain) evaluated the possibility of profiting non-recyclable wastes which are nowadays landfilled. The susceptible residues to be recovered as SRF considered in the present study, were wastes (including mixtures of materials) from mechanical treatment of wastes (List of Wastes, LOW 19 12 12), including wastes not otherwise specified from End-of-life vehicles and their components (LOW 16 01 99), refuse from a sorting plant of municipal packaging waste separately collected (LOW 15 01 06), and refuse from preparation of municipal bulky waste for recycling (LOW 20 03 07). The amounts generated from these wastes in COGERSA facilities (2013) were 17,410 tons of end of live vehicles waste (ELV), 7186 tons of bulky waste and 3277 tons of packaging waste.

The main purpose of this work is to assess the suitability of three non-recyclable wastes generated in our region and, nowadays landfilled, as SRF to be used as co-fuel in a cement kiln near COGERSA facilities. Samples of ELV, bulky, and packaging wastes were taken in two different periods of the years 2013 and 2014 (November 2013 and April 2014), with the aim of including the seasonality as studied variable. For each fraction, both chemical and calorimetric analyses were carried out in order to classify the different wastes from COGERSA as SRF according to the rules established by EN 15359 being the main analyzed parameters, lower heating value (LHV) on wet basis, mercury and chlorine content as shown in Table 1. Likewise, empirical models were applied in order to predict the higher heating values (HHV) of these fractions from chemical composition.

2. Experimental

2.1. Sampling and materials

The samples analyzed in this study from the three selected wastes (ELV, bulky and packaging wastes) were supplied by COGERSA. In order to maintain the representativeness of the industrial samples, sample mass for wastes studied were reduced by the quartering method in COGERSA facilities (Environmental Protection Agency, Ireland, 1996). This method consists in dividing a pile of each waste into four quarters and either pair of opposite corners is removed, repeating this until the desired sample size is obtained. Then, the samples obtained were milled in an industrial milling twice to ensure a particle size below 100 mm (required for use as fuel in cement kilns) and were finally deposited in big bags of 1 m^3. A portion of 5 kg of each waste sample was manually taken by COGERSA workers from big bags before mentioned, and submitted to the laboratory for further analysis. The sampling was carried out in November 2013 and April 2014 and was performed for a week in each occasion. In order to take representative analysis samples of each type of waste, the