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Energy Recovery of Reject Fraction of Municipal Solid Waste Resulting from the Mechanical-Biological Treatment Plants

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In the order of 2/3 of MSW (Municipal Solid Waste) generated in Europe are disposed on landfills after mechanical and biological treatments. Composition of this reject from 10 MBT (Mechanical-Biological Treatment) plants in the area of Castilla y León, Spain, has been studied during two years and gross caloric value of each fraction has been measured in a calorimeter system IKA C200. Attending to the obtained results, this fraction is mainly composed by combustible materials such as paper and plastics (above 50 %), textiles (8.65 %) or cellulose (5.76%) and organic matter by 23.71 %. Finally, net caloric value of this fraction (22,802 J/g) can be compared with some widely used fuels.

1. Introduction

More than 258 Mt of municipal solid waste (MSW) is generated in Europe every year. Waste management policy in the European Union follows a three hierarchically ordered strategy options; primary emphasis is focused on waste prevention, followed by promotion of recovery (i.e. recycling, reuse and energy recovery) and lastly by disposal of waste.

Following these criteria hundreds of waste treatment plants (mechanical-biological treatment plants or MBT plants) have been installed in Europe in the last decades. In these facilities the organic fraction of MSW is removed and stabilized by means of biological treatments (composting or anaerobic digestion) and recyclable materials such as paper, plastic containers, cans, etc., are recovered as far as possible.

The rest, known as reject fraction, represents 2/3 of the initial amount of waste, and is usually disposed on landfills (De Araújo et al., 2008). With the purpose of solving the consequent problems of space, incineration of the reject fraction with energy recovery has been suggested.

Incineration can reduce the waste volume up to 95 % although is not a very popular process. Nevertheless, the more stringent requirements on air pollution can be controlled using correctly the existing technology (Porteous, 2001). Japan is the country

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with the highest number of waste incineration plants followed by the European Union, mainly France, and the United States.
According to previous works on integrated waste management, MSW have a high caloric value allowing the incineration with great energy recovery (Consonni et al., 2005).
However, none studies of the caloric value of the reject fraction are available in the literature. Accounting for the current management strategies, incineration should be done once recovered recyclable materials, i.e. to reject fraction from MBT plants. Considering the high performance on material recovery reached in these facilities, composition of reject fraction could be very different from MSW before the treatment as well as energy production.
The aim of this work is, therefore, to investigate the caloric value of reject fraction in order to study the process effectiveness. For this purpose, the unknown composition of this fraction, named Refuse Derived Fuel when is used for incineration, has been determined.

2. Materials and Methods

Experiments were performed by triplicate on 18 different Refuse Derived Fuel samples collected in 10 MBT plants sited in the area of Castilla y León, Spain. Visits were conducted in different seasons and working days (excluding Mondays since MSW are not collected on Sundays).
Approximately 1,000 kg were taken by mechanical shoveling at the end of the material recovery process carried out in these plants.
Samples were spread to form a circle and divided into quarters, two opposite sectors were taken and a new circle was formed which was again divided into quarters; the final sample (approximately 250 kg) was composed of two opposite sectors once more.

In order to determine the Refuse Derived Fuel composition, these samples were manually sorted and weighed *in situ*.
Because the Spanish or European standard methodology has not been established, waste materials present in Refuse Derived Fuel fraction were divided into 19 categories:

- Biodegradable matter (mainly food waste) usually named organic matter
- Paper and cardboard
- Plastics, divided into:
  - (a) HDPE,
  - (b) LDPE
  - (c) ET
  - (d) PVC
  - (e) and mix
- Glass
- Ferrous metals
- Non ferrous metals
- Cellulose

- Tetrabricks
- Textiles (used clothes)
- Wood
- Rubber
- Batteries
- Garden waste
- Electronics
- Building waste

For the gross caloric value determination, 3 samples of each category were taken from each MBT plant. Moisture was measured by the weight lost after oven drying at 105 ºC for 24 h or at 70 ºC for five days in the case of plastics, cellulose and tetrabricks. After drying, approximately 1 g sample was prepared and inserted into a calorimeter system IKA C200, analyses were carried out by triplicate.

3. Results and Discussion

Results obtained in the characterization of 18 different samples of Refuse Derived Fuel from MBT plants are summarized in the second column of Table 1.
Percentage data are shown as the average of weight percentage from each category ± the standard deviation. Caloric values obtained for combustible materials from the Refuse Derived Fuel fraction appear in the third column with the same format; these results are in concordance with other values previously available in literature (Tchobanoglous, 1993).

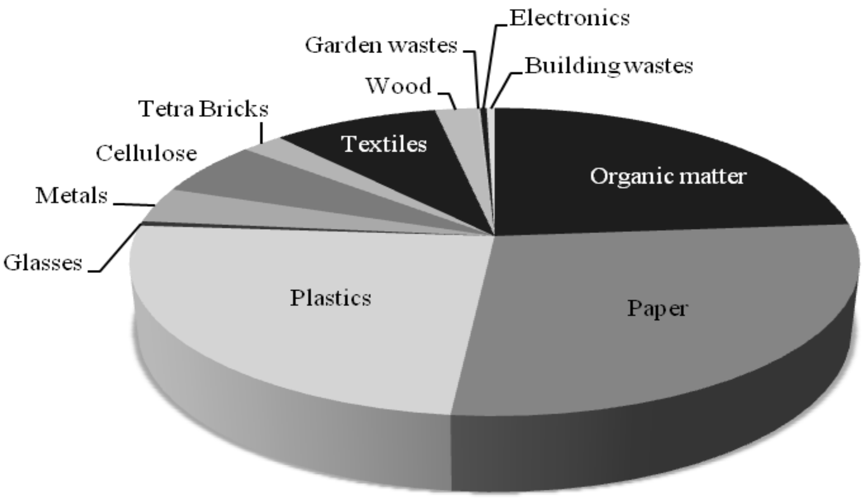

Figure 1: Composition of Refuse Derived Fuel

Table 1: Weight percentage and caloric value of each fraction from Refuse Derived Fuel.

Categories	*Percentage (%)*	*Caloric Value (J/g)*
Organic matter	23.71 ± 7.84	14,905.0 ± 57.1
Paper	27.91 ± 4.73	14,739.9 ± 2654.7
Plastics	24.50 ± 4.25	
HDPE	0.99 ± 0.73	45,670.4 ± 443.6
PET	1.87 ± 0.85	22,995.0 ± 16.1
LDPE	10.93 ± 3.29	41,269.5 ± 3,043.3
Mix	10.62 ± 3.41	41,203.8 ± 2,820.9
PVC	0.08 ± 0.19	
Glass	0.48 ± 0.45	
Ferrous metals	3.10 ± 1.99	
Non ferrous metals	0.61 ± 0.51	
Cellulose	5.76 ± 2.33	45 552.0 ± 84.6
Tetrabricks	2.16 ± 1.77	23 557.1 ± 154.5
Textiles	8.65 ± 3.76	21 298.2 ± 5 226.0
Wood	2.18 ± 1.37	18 825.0 ± 20.3
Rubber	0.03 ± 0.10	
Batteries	0.00 ± 0.00	
Garden wastes	0.14 ± 0.37	
Electronics	0.34 ± 0.50	
Building wastes	0.48 ± 0.45	

Refuse Derived Fuel contains organic matter, paper, and plastics as main components, approximately 1/4 each one (Figure 1). Attending to the obtained results, valuable information about recycling and effectiveness of waste management can be extracted.

Once known the present real composition of Refuse Derived Fuel, gross caloric value has been calculated from individual values of each combustible fraction. Materials with caloric values above 40000 J/g such as high or low density polyethylene (HDPE and LDPE), mix plastics and cellulose are widely present in Refuse Derived Fuel. Low density polyethylene always will be present in large proportions since is used in garbage bags. In a lower level with caloric values around 20000 J/g, materials like tetrabricks and textiles represent 2.16 % and 8.65% respectively, wood appears in low proportion 2.18 % contributing with 18,825 J/g as well as polyethylene terephthalate (PET) with 1.87 % and 23000 J/g. Finally, the lowest caloric value (15,000 J/g approximately) corresponds to paper and organic matter which both constitute the half of Refuse Derived Fuel fraction.

On the other hand, non-combustible materials appear in low proportions. Metals percentage (mainly cans) does not reach 4 % and glass less than 1%, proving the high performance of mechanical recovery carried out by magnets in the MBT plants.
During the experiment at least one battery was found in each of the samples although, because of its small size is not showed in the weight percentages. Ashes produced in the incineration process by these non-combustible materials are disposed in a security dump, however according to this work a large amount is not expected.
In addition, dioxins and furans should not arise since presence of halogenated compounds in this fraction is practically void as shown by the percentage of polyvinyl chloride (PVC).
The net caloric value for Refuse Derived Fuel fraction is 22,802 J/g, approximately twice than caloric value of MSW before mechanical-biological treatment, 10,600 J/g according to Porteous (2005). Moreover, Refused Derived Fuel caloric value is higher than values of some types of wood such as pine, 20,583 J/g, or ilex, 18,475 J/g (Vignote and Martínez, 2006) hence, incineration of Refused Derived Fuel could be a profitable process from energy standpoint under these conditions.
Furthermore, an increase in the energy recovery can be achieved by improvement in removal system of the organic matter as this fraction usually contains 50 % moisture. Despite of the mechanical removing that takes place in MBT plants by means of trommel screens (Richard, 1992), it still appears in Refused Derived Fuel high proportions but, if this fraction is deposited in landfills may violate the European Directive 1999/31/CE about biodegradable wastes.
Since organic matter is non-source separated in the area under study, the performance of recovery systems in MBT plants should be increased.

4. Conclusions

Attending to the obtained results after analyzing 18 different samples of Refused Derived Fuel from 10 MBT plants of the region of Castilla y León, some conclusions can be extracted. Average composition of Refused Derived Fuel shows a high percentage, above 50 %, of combustible materials such as paper or plastics.
Considering the high calorific value of these components, final value for Refused Derived Fuel is higher than some types of wood and similar to fuels currently used in biomass boilers. Incineration with energy recovery performed under safety conditions can be a viable strategy to reduce the amount of waste deposited in landfills.

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