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Research Article

Valorisation of Moroccan Industrial and Municipal Wastes as Alternative Fuel : Determination of Heat Capacity

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2. Keywords

Valorisation; Pyrolysis; Household waste; Heat capacity

1. Abstract

During the last years, Moroccan policy targets new technologies for the treatment and valorisation of municipal Wastes. Among them, incineration and pyrolysis. This is due to the fact that the landfilling is an extensive technology and the waste can be valued partly by production of biogaz.

The faisability study of both incineration and pyrolysis need ratios related to heat capacity for simple and composite alternative fuels. Our work targets valorisation of waste, mainly those used as alternative fuels. Thus, in this paper, we have studied the composition of waste in a statistical way and we have determined the heat capacity of single and composite samples.

That is required for the design of pyrolysers and gasifiers, currently in vogue for waste recovery. Knowledge of heat capaciy value is also requierd for ciment activity when a given waste is used as alternative fuel. This study is the beginning of a more general approach. Where the heat capacity of waste, delivered in bulk and raw will have to be approached. The analysis of the behaviour of the mixtures will be studied in a second step.

3. Introduction

Disposal or recovery of waste is a major challenge for Morocco, as in all countries. This is due to the proliferation of these waste due to population growth and the economy. Disposal of household and similar wastes is currently done exclusively by sanitary land fill, after a pre-sorting to recover a portion, estimated at about 10% [1].

To improve the rate of recovery, government policy encourages production in the controlled landfills of alternative fuels (AF). Their value in energy supply is used by Moroccan cement companies as everywhere in the world. Except that, we do not often mention the value of the heat capacity of each type of waste and especially when they are mixed.

Recently, many companies suggested to municipalities to treat waste by pyrolysis, However information on waste behaviour was not avalable, such as heat capacity o the waste.

Apart from environmental aspects, questionnable and probably surmountable, the economic model of a pyrolysis or incineration treatment is based on the heat capacity of the waste and its moisture content. In Morocco, these data are not available and are used to develop feasibility studies for such industrial units. This, because the heating capacity directly related to the electricity or thermal energy production on which the designer intends to make profitable or at least reduce the costs of treatment.

The objective of this first work is to contribute to the production of these data by measure, on Moroccan waste fractions. The study also looked at other types of industrial waste, which is highly used as biomass

3.1. Experimental

The objective of the work carried out is to measure the heat capacity (HC) of waste and fractions of waste taken in the garbage bin of the Moroccan household. The values of these HC were analyzed in relation to the composition of each waste fraction.

From the measurements made, and according to standard NF-EN-15359 [2], the alternative recovery fuels intended for

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incineration or Co-incineration can be classified, as indicated in the following table (Table 1).

3.2. Tested Materials

The heat capacity value was measured for components of the household waste, namely:

- Paper
- Cardboard
- Plastic
- Vegetables represented by a mixture of carrots, zucchini and potatoes
- The olive pomace
- Sludge from biological waste water treatment plant

3.3. Procedure Followed

The waste selected for the measurements of their heat capacity value has been dried before, by taking the samples to a temperature of 110 °C, in an oven and measuring its weight until it was constant. The heat capacity value is measured using a calorimeter as shown below (Figure 1).

The waste sample is placed in a sealed steel cylinder, called a "calorimetric bomb", with pure oxygen. The water formed during combustion is liquid and vaporizes. The amount of total heat generated by the combustion, called "higher heating value (HHV), is therefore equal to the heat released by the combustion to which must be added the heat necessary for the vaporization of the water.

The amount of heat produced during a combustion is lower than the higher heating value, because the heat of vaporization of the water is not recovered.

The heat capacity is calculated by deducting from the HHV the heat of vaporization of the water. It therefore better characterizes the quantity of energy supplied by the sample considered.

This equation means that the calorific value of the sample is equal to the total mass (mass of water in the tank added to "equivalent mass" which is given by the manufacturer) multiplied by the specific heat of the water multiplied by the difference between the initial temperature and the maximum temperature reached during the experiment, all divided by the mass of the sample.

Reference studies have shown that sample preparation (reduction and then micronization) ensures better reproducibility of the measurements than the direct use of non-micronized aggregates. The tests and the results obtained confirmed the choice of the analytical method and the preparation and sampling protocol.

3.3.1. Size of the Samples Studied: The samples studied have an average size of 0.5 cm. This size was arbitrary choosen medium, however it has no main effect on the HC mesure (Table 2).

3.3.2. Chemical Composition of Waste: Elementary chemicals compositions of waste, mainly sludge and olive pomace were carried out for better analysis of the HC results. Indeed, when the % of moisture is hight, HC measured must be low, and vis versa (Table 2.1).

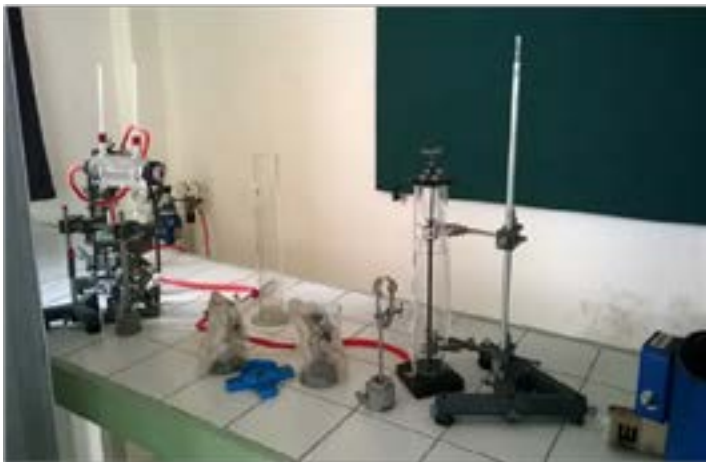

Figure 1: Materials used to measure heat capacity

Table 1: Heat capacity classes according to French Agency ADEME

Statistical measurements	Unit	Classes				
		1	2	3	4	5
Average	MJ/kg	>=25	>=20	>=15	>=10	>=3

Table 2: Samples studied

				
Paper	Cardboard	plastic	olive pomace	Waste treatmet sludge

Table 2.1: Other characterization of sludge from waste water treatment plant

Element	Ppm concentration	Element	Ppm concentration
Mg^{++}	0,30	Na^{+}	150
Zn^{++}	0,30	Ca^{++}	1000
Cu^{++}	0,40	Fe^{++}	2,2
Pb^{++}	0 ,006	K^{+}	0,2
Mn^{++}	0,71	%S	0.04
%Ash	9.2		

4. Results and Discussions

4.1. Sludge

Heat capacity value measured for sludge is close to 3.8 kW/kg. This value is also close to those generaly found in the literature [3, 4].

In addition to the mesure of heat capacity of the sludge, we also mesure the % of as after a combustion at 900°C. The average value found was 9.2%. The value found for the sulfur is low (0.04%) and will not constitue a problem for the combustion, like for heavy metals. Both calcium and natrium represent relatively high percentages in the sludge in comparison with the other chemicals, but calcium represent raw material for ciment industry when the sludge is used in a ciment kiln.

4.2. Olive Pomace

Olive pomace is a waste used by the industry as alternative fuel. Due to its percentage of carbon (52%), and fatty compounds, the heat capacity found was close to 4.4 kW/kg. However, the percentage of sulfur is relatively high (0.12%).

4.3. Potential Recycled Materials From Household Waste

The main components of household that have potentiel heat capacity are plastic, cardboard and paper, in addition to vegetables when they are dried. All these components constitue the so called alternative fuel.

Heat capacities of such separated materials, were measured and reported in the following table. They did not dried except vegetables at 110°C during until their weight was constant.

The obtained result as are in agreement with the well known values. The slightly lower value for cardboard and pape can be explained by their composition in terms of calcium carbonate, which is endothermic decomposition at 900°C.

The value obtained for Vegetables sems to be interesting but the potential energy that they can lead must be balanced by the energy necessary to dry the mater (Table 3).

Table 3: Low heat capacity of components extracted from household waste.

Sample	Heat capacity (kW/kg)
Cardboard	2,4
Paper	2,1
Vegetables	2,78
PET	6

5. Conclusion

The determination of the characteristics of the studied samples shows that low heat capacity of such materials is of great interest for the industrial activity mainly ciment. The samples under study can be used as alternative fuels (AFR) [5, 6]. Since this practice is part of Morocco's environmental policy, it is essential to control the discharges of this combustion and to provide evidence of its economic and environmental viability. This work will be followed by another one that is measuring the heat capacity of the same materials as a mixtures, in ordrer tu analyse how mixing the material can have an impact on their heat capacity.

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