THERMAL TREATMENT OPTIONS FOR THE ROMANIAN MUNICIPAL SOLID WASTE: ENERGY BALANCES

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ABSTRACT

In Romania the impact of waste on the environment has increased at an alarming rate during the past decades also because of an inadequate management of the generated waste. One of the thermal options that can better this situation is based on the concept of municipal solid waste bio-drying pre-treatment in order to open to a group of solutions alternative to direct combustion for energy recovery. This paper presents the results of energy balances based on the average characteristics of the Romanian municipal solid waste. Interesting results could be obtained exploiting existing industrial plants that could partially substitute conventional fuels by refuse derived fuel. One of the problem of this strategy is the potential generation of residues to be landfilled when a high quality fuel must be generated. The lower heating value obtainable by bio-drying and simplified post-treatment can overcome 15 MJ/kg while an additional post-treatment can allow reaching values higher than 20 MJ/kg.

KEYWORDS: bio-drying, energy, MSW, RDF, thermal treatments.

INTRODUCTION

In Romania, as well as in other countries, the impact of waste on the environment has increased at an alarming rate during the past 20 years. The inappropriate management of this problem has caused soil, subsoil and groundwater contamination, fugitive emissions of methane and toxic gases, with direct impact on the public health.

From the energetic point of view, municipal solid waste (MSW) is equal to a fossil fuel because it contents oxidable material (especially carbon and hydrogen) which can free energy quantified as calorific power. This energy can be utilized

for heat and/or electricity generation.

Energy from waste is an alternative source and is also a secure energy supply because the waste generation is a steady by-product of human and industrial activities and can have a positive impact on climate changes because using this option the overall greenhouse gas emissions are reduced and the uncontrolled emissions from waste disposed in landfill can be avoided.

Romania is recently entered into the EU (January 1st 2007), thus it must re-organize its municipal solid waste sector taking into account the EU principles regarding MSW prevention and reuse/recycling before final disposal. Presently in Romania most of the MSW is collected as is. In most of the cases MSW is disposed of in landfills without pre-treatment. However, some experiences regarding the selective collection of sellable materials are implemented in some cities of Romania and also sanitary landfills are under construction. There is no Waste-To-Energy plant for MSW in Romania in spite of the need of electricity generation. One of the reasons is related to the characteristics of MSW: the calorific value is often not suitable for a direct combustion because of the high moisture. There are a high number of cement works and thermal power plants potentially available for co-combustion. In spite of that, the sector of refuse derived fuel (RDF) co-combustion is not yet fully developed.

The regulation frame in Romania is in a fast evolution, driving to a substantial modification to the present waste management system, with important consequences at local level for land planning. With the Governmental Decree 162/2002 (landfilling of biodegradable waste) it was pointed out the necessity of reducing the quantity of biodegradable waste disposed of. The target is that by the year 2013 the annual amount of biodegradable waste that will be landfilled must decrease down to 2.4 million tons, representing 50% of the total amount produced in 1995. Also by the year 2013 recovery rates of useful materials from waste packaging are set (for recycling or incineration with energy recovery): 60% for paper or cardboard, 22.5% for plastics, 60% for glass, 50% for metals and 15% for wood.

For these reasons, in this paper some scenarios were considered for recovering energy from MSW, keeping in account the best available technologies and considering the bio-drying process utilized after a grinding process.

METHODS

The Romanian MSW (Figure 1) has been considered not suitable for direct combustion as the percentage of organic faction in the waste represents about 50% (Apostol et al., 2010) thus its Lower Heating Value (LHV) can be low.

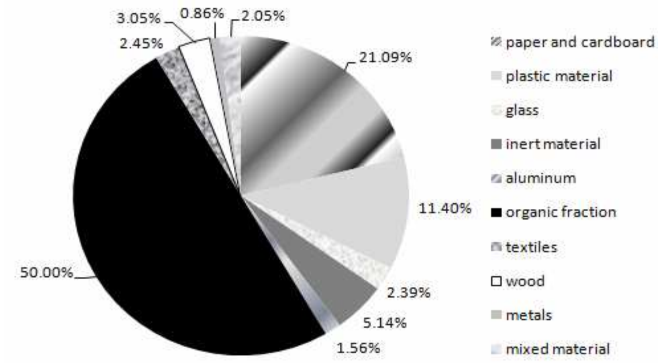

Figure 1. Romanian MSW composition

The production of MSW in Romania is growing, being about 300 kg inh^{-1} $year^{-1}$ with a significant increase expected in the next decade.

Bio-drying is a short-time process of aerobic bioconversion, applied mainly to MSW as is and to MSW residual of selective collection. The aim of this process is the exploitation of the exothermic reactions for the evaporation of the highest part of the moisture in the waste with the lowest conversion of organic carbon. No water addition is required (and must be avoided).

Bio-dried material is the product obtained after bio-drying process and which can be used to obtain RDF (Refuse Derived Fuel) after inert separation (incombustible materials separation). An additional refining stage can increase the quality of the obtainable RDF, named RDF of high quality (RDF_Q), but can also generate a secondary stream of wasted material to be landfilled.

Taking into account the MSW situation and the EU principles, the following MSW treatment scenarios are proposed in this paper in order to have energy recovery form MSW:

- Bio-drying and combustion on grate / fluid bed + Steam Power Cycle
- Bio-drying + RDF / RDF_Q + Co-combustion in Thermal Power Plant
- Bio-drying +RDF / RDF_Q + gasification+ turbo-gas / integrated system

The calorific value of MSW, bio-dried material, RDF and RDF_Q were calculated taking into account a biochemical model (Rada et al., 2007). In particular the model reconstructs the composition of the bio-dried waste through a process balance taking into account the mass, the biochemical reactions stoichiometry and the available energy, resulting at the end a determined mathematical system that has as input the quantity of water, carbon, hydrogen, oxygen and nitrogen contained in the initial mass of MSW and as output the amount of water, carbon, hydrogen, oxygen and nitrogen consumed/removed during the bio-drying process.

For the mass balance it was taken into account all the pre-treatments before and after the bio-drying process and also all the combinations of inert separation (with or without a pelletization units, that is a device aimed to improve the characteristics of homogeneity of the generated RDF).

For calculating the mass balance (Rada, 2005), for the equipments utilized for mass loss the following hypotheses were made:

- the bio-drying efficiency is supposed 25% as mass loss;
- the magnetization recovery is supposed 3% of the MSW mass in input;
- the magnetic induction recovery is supposed 3%;
- the glass recovery is supposed 8%;
- the other inert separation is supposed 5%;
- internal consumption of bio-drying is supposed 5%;
- the screening treatment separation is supposed 10%;
- energy process loss is supposed 5%;
- energy loss due to RDF production is supposed 10%.

For pre-treatment specific consumption for each equipment utilized the following hypotheses have been made (Rada, 2005):

- there are three types of grinding (with shears multi-shaft, mono-shaft, bi-shaft) and the consumption goes from 7 to 15 kWh/t. For the calculations it was utilized a value of 11 kWh/t;
- a value for bio-drying is 50 kWh/t;
- there are two different types of magnets: permanent and electromagnet, with consumption from 0.2÷0.4 to 0.6÷1 kWh/t. For the calculations it was utilized an electromagnet for middle/high flows with a middle consumption of 0.3 kWh/t;
- for the separation with an induced magnetization it is utilized one with consumption from 0.7-1.2 kWh/t and it was assumed for the calculations 0.95 kWh/t;
- the consumption for the equipment for glass and other inert separation is from 1÷3 kWh/t, and for the calculations it was assumed 2 kWh/t;
- the consumption for the equipment for densifying was assumed 20 kWh/t;
- the consumption for the screening equipment was assumed 1 kWh/t.

The conversion efficiency value (net values) used for the development of the research was considered similar with the ones proposed by Consonni et al., 2002 and 2008; Arena et al ., 2005, De Stefanis 1999)

- combustion on grate : 20%
- combustion on fluid bed : 21%
- gasification+ turbo-gas : 30%
- co-combustion in Thermal Power Plant : 32%
- gasification+ integrated system : 47%

RESULTS AND DISCUSSION

The electric energy for the systems in kWh/t_{in} and in kWh/t_{MSW} and total net generated for each scenario were calculated starting from electric energy efficiency and using calorific values from the mass balance and values of total energetic consumption for all the stages.

The pre-treatments increase the calorific value of the "fuel" but also reduce its mass, therefore the quantity of MSW that could be sent to Waste to Energy plants is reduced.

The loss of weight due the varied phases of the process of pre-treatments have been estimated in function of the elementary analysis of the waste. The mass reduction is mainly owed to the bio-drying process (25% of overall mass loss, with 33 g_{VS}/kg_{MSW} consumed as result of the biochemical process) that decreases the water content and also to the treatments of recovery of iron, glass and other inactive material. In our case the mass balance points out a significant decrease of the stream to be thermally treated:

- MSW to RDF: 58% as output
- MSW to RDF_Q : 43% as output

Taking into account the hypotheses presented above results :

- a consumption of 11 kWh/t_{MSW} for the pre-treatment of the MSW as is, due entirely to the grinding stage;
- a consumption of 76 kWh/t_{MSW} for obtaining the bio-dried material (slight differences could depend on the patented process adopted);
- a consumption of 79.5 kWh/t_{MSW} and respectively 91.3 kWh/t_{MSW} for obtaining the RDF and the RDF_Q.

For the calculation of the calorific value it was hypothesized that the energy content of MSW as is (100% of the mass) is concentrated in the mass of treated waste sent to combustion. Subsequently a 5% loss of bio-drying process has been considered and another 10% loss for the RDF production process. In Table 1 the LHV resulting from bio-chemical model before and after bio-drying process of these scenarios are presented.

Table 1. LHV for the MSW as is, bio-dried material and RDF

Scenarios	LHV [kJ/kg]
MSW as is	8,621
Bio-dried	11,273
RDF	15,394
RDF-Q	21,026

The calorific value for Romanian MSW has been considered for the proposed scenarios about 8 MJ/kg_{MSW} (Rada et al.,2010) but its value could be lower as the existing literature is controversial. The MSW (Figure 1) refers to the composition of waste from a big Romanian city. Of course this composition is different for rural areas were the percentage of organic fraction is bigger than 50%.

The increase of LHV for the MSW to bio-dried material and to RDF (obtained from the bio-dried material without inert, glass and metals) and RDF_Q is significant. However the quantity of produced electric energy is tightly correlated to the calorific value of the components of the MSW used and to the efficiency of conversion in electric energy of the considered scenarios (Tables 2 and 3).

Table 2. Net energy in gasification options

Energy production				
	Electric energy production			Net energy generated
	kJ/kg_{in}	$kWh/kg_{treated\ waste}$	$kWh/kg_{treated\ MSW}$	$kWh/kg_{treated\ MSW}$
Gasification + Turbo-gas plant (30% conversion efficiency)				
RDF	15,394	1.10	0.61	**0.53**
RDF_Q	21,026	1.50	0.61	**0.52**
Gasification + Integrated system (47% conversion efficiency)				
RDF	15,394	1.72	0.96	**0.88**
RDF_Q	21,026	2.96	0.96	**0.87**

Table 3. Net energy in combustion options

Energy production				
	Electric energy production			Net energy generated
	kJ/kg_{in}	$kWh/kg_{treated\ waste}$	$kWh/kg_{treated\ MSW}$	$kWh/kg_{treated\ MSW}$
Combustion on grate (20% conversion efficiency)				
Bio-dried	11,494	0.61	0.45	**0.38**
Combustion on fluid bed (21% conversion efficiency)				
RDF	15,394	0.77	0.43	**0.35**
RDF_Q	21,026	1.05	0.43	**0.34**
Co-combustion in thermal power plant (32% conversion efficiency)				
RDF	15,394	1.17	0.66	**0.58**
RDF_Q	21,026	1.60	0.66	**0.56**

From the analysis of the results, the Integrated System represents the technology most effective in function of physical characteristics of the waste, thanks to the elevated efficiency guaranteed by the combination of a turbo-gas plant integrated with a steam power cycle, but the use of a hybrid fuel as "syngas + methane", in such plant, it is an option not yet applied in real scale. Also in the case of the Integrated Systems, as hybrid fuel is used "RDF + coal".

A very satisfactory result is gotten by the co-combustion in thermal power plant that has reached some notable productions in all the analyzed cases and for the Romanian MSW represents the better solution after the Integrated System option.

CONCLUSIONS

For the optimization of energy balance it is important to plan the waste management in order to avoid densification (generally used in order to facilitate the transportation): that means that it is important to have a local production and consumption of RDF. The metal and inert removal does not cost a lot of energy; however it is important to verify if a market for the selected material exists.

The incineration of the MSW as is, also thanks to its diffusion, represents a valid technology, only in the case of a high efficiency of selected collection.

Gasification results a technology particularly effective if the derived fuel (syngas) is sent into a Turbo-gas or in Integrated Systems that could give very high electric energy productions.

The use of hybrid fuels, sent in thermal power plants for the production of electric energy (co-combustion in central thermal power plants or Integrated Systems), results particularly effective.

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