

Critical Analysis of High Moisture MSW Bio-drying: The Romanian Case Study

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Kritische Analyse der biologischen Trocknung von Abfällen mit hohem Wassergehalt: Eine rumänische Fallstudie

Abstract

Bio-drying is an aerobic pre-treatment of municipal solid waste that shows its best performances when the waste has a high moisture content. This is a typical characteristics of the waste of low-income countries. The bio-drying process exploits the exothermic reactions developed in the core of the waste thanks to a regulated aeration. The aim is the generation of a material with a higher Lower Heating Value (LHV), using a little part of volatile solids present in the waste. The increase of LHV depends on the water extraction and, if implemented, on the post-refinement treatment aimed to the production of refuse derived fuel. The present paper shows the main results of a co-supervised doctorate research (Italy and Romania) aimed to study the viability of the bio-drying process in both the countries. In the present work the critical analysis of the viability of bio-drying in Romania is presented, based also on experimental data and taking into account the consequences of the recent entrance of Romania in the European Union.

Keywords

Bio-drying, Municipal Solid Waste, Refuse Derived Fuel, Respirometric Index, low income countries.

1 Introduction

The recent EU regulations for a new concept of sanitary landfill point out the importance of bio-stabilisation as an option for landfill pre-treatment. In the sector of bio-mechanical treatments bio-drying shows similar characteristics but does not have to be confused with bio-stabilization. In fact, bio-drying is a process which follows mainly the reduction of municipal solid waste humidity by exothermal reactions of organic substances fermentation from waste. On the contrary, bio-stabilization is a process which has the main aim to obtain a stable waste after the oxidation of organic substances (RADA ET AL., 2005A).

In this frame, a research developed by the University of Trento in collaboration with the Politehnica University of Bucharest has been recently achieved as a result of a co-supervised PhD.

Presently in Romania the municipal solid waste (MSW) is collected as is. In most of the cases MSW is disposed in landfills without pre-treatment. The recent entrance into the European Union (since January 1st 2007) will no longer allow this scenario. New solutions must be implemented taking into account the characteristics of the Romanian MSW and the Romanian economy.

The production of MSW in Romania is growing with a significant increase expected in the next decade as a result of the expected economic development.

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 not suitable for a direct combustion because of the high humidity. 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 developed.

The present paper wants to analyze the advantages and disadvantages of adopting bio-drying as a pre-treatment in areas where the humidity of MSW is high (like in Romania). All the consideration of this paper are based on experimental data.

2 Materials and methods

In Figure 1 the overall method developed for a complete characterization of a MSW referring to bio-drying is presented. The MSW sample was artificially composed in order to simulate the behavior of the Romanian MSW. The reason depends on the fact that an experimental bio-reactor was implemented in the University of Trento and not in the Polithenica University of Bucharest. It has been demonstrated (RADA ET AL., 2005B) that an artificially composed MSW is representative for the study of the dynamics of bio-drying.

This approach is an original way for supporting decision markers and designers who need to know the behavior of bio-drying in their case studies. Under-estimations and over-estimations can causes big troubles in term of waste management. If the capacity of a plant results too low and the new regulations prohibit landfilling, the disposal of the municipal solid waste in excess could be made in emergency. If the capacity of a plant results too high, the cost of the treatment is higher.

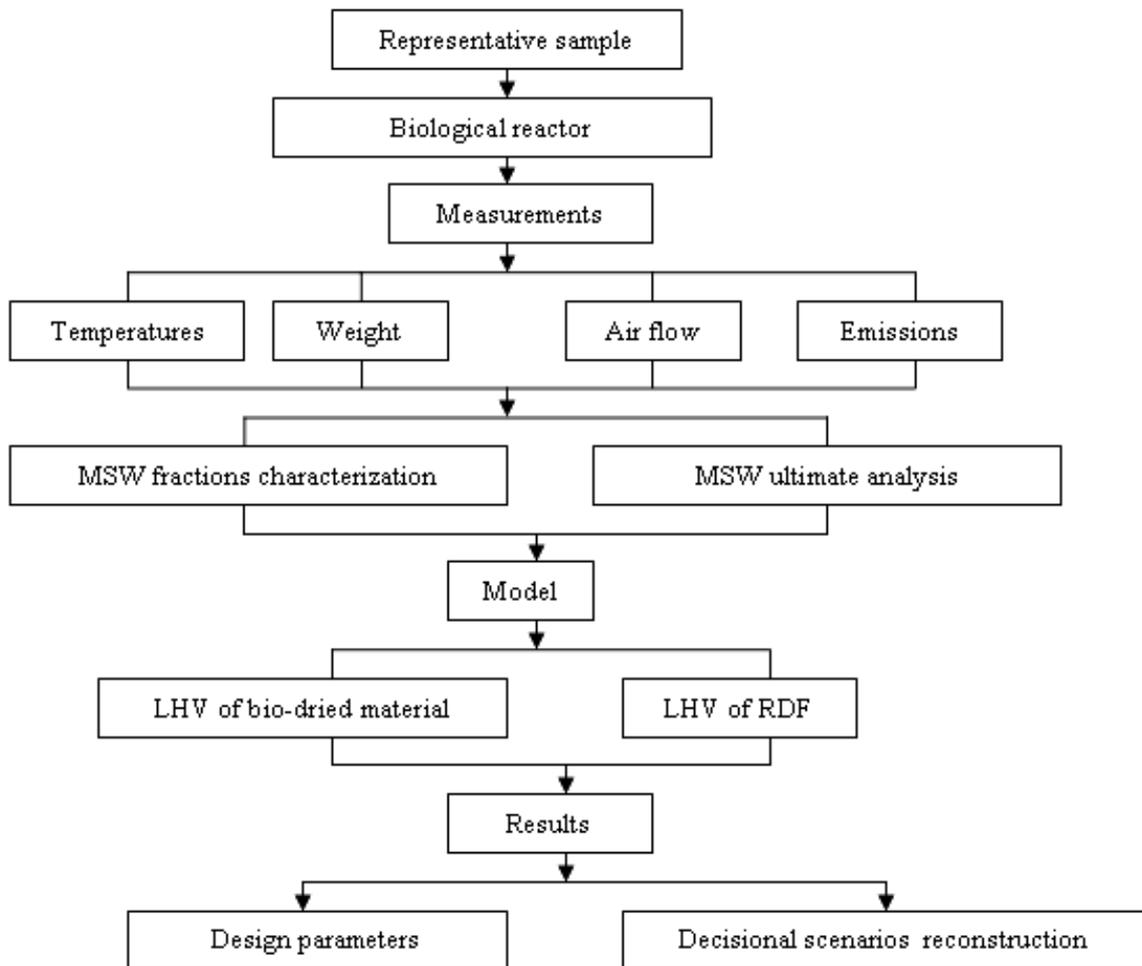


Figure 1 Adopted criteria for MSW characterization referring to bio-drying

2.1 Biological reactor

A pilot scale experimentation with a 1 m³ bio-reactor (Figure 2) has been developed in order to obtain data from bio-drying of a MSW with 50% of humidity. The biological reactor is an adiabatic box. This biological reactor is placed on an electronic balance for monitoring the waste mass loss during the bio-drying process. The process air is sent into the reactor through a steel diffuser, placed at the bottom. For monitoring the temperature during the bio-drying process, five temperature probes are placed inside the reactor, one at the air outlet/inlet and three at different levels. All these equipments are connected to a data acquisition system developed for a good management of the process.



Figure 2 Frontal view of the biological reactor and position of the temperatures probes

2.2 Respirometer

The dynamic respirometer AIR NL developed by the University of Trento is aimed at the measurement in controlled condition of the Oxygen Uptake Rate (OUR) of the organic matrix. The name Respirometer AIR NL (Respirometric Index Analyzer with Not Limiting oxygen), underlines that inside of this instrument a controlled aeration (AIR) in no limiting oxygen conditions (NL) is made. The aim of this instrumentation is to give information regarding the oxygen consumption.

2.3 Modelling

Using the previously presented equipments, a bio-chemical model for the bio-drying process has been developed (RADA ET AL., 2006A) starting from the parameters measured during the experimental runs. The aim was to have an interpretative instrument for the experimental bio-drying curves (to explain the dynamics of the air flow, of the temperature inside the biological reactor and also of the weight loss during the process) for obtaining design parameter for bio-drying plants or for plants that can use the bio-dried material like feedstock.

The bio-chemical model allows assessing the energy parameters (LHV of bio-dried material and RDF) and waste characterization during the process (volatile solids dynamics, humidity).

3 Results

Experimental measurement and modelling results are presented as follows, as a pre-analysis for the study of the viability of bio-drying in Romania.

3.1 Temperature

In Figures 3 data of temperature concerning a run with 50% organic fraction content are reported in order to simulate the behavior of a Romanian-like MSW. This run lasted 30 days, probes 1 and 5 refers to entrance/exit air. The other ones refer to the core of the waste.

What comes from the recorded data is that the temperature in the core of the waste can go over 55°C for 3 days if the organic fraction is enough (8% is too low; 21% is enough for hygienising (RADA ET AL., 2006B)). The air exiting the reactor shows the highest values after the initial lag phase. After a week its value shows a trend towards the values of the entering air. Effects of water evaporation based on energy consumption are clear comparing core temperatures and exiting temperature. Another aspect concerning temperature is the effect of the dimensions of the reactor. The influence of the entering air temperature on the exiting air temperature is clear looking at the fluctuations on the recorded data.

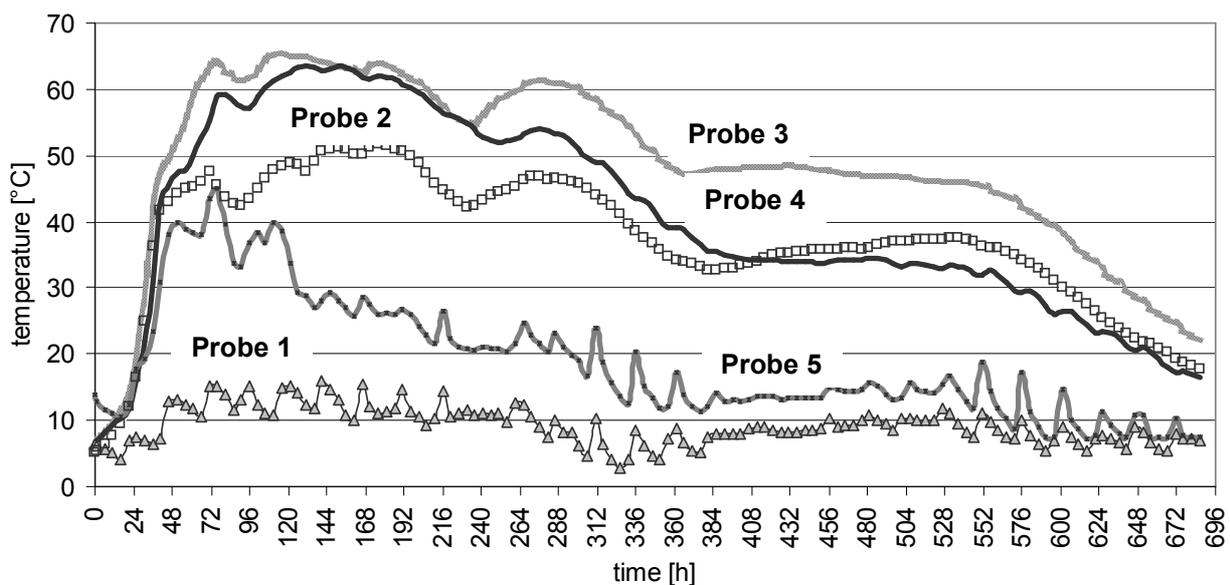


Figure 3 Temperatures dynamic during the process

3.2 Weight loss

Maybe the most important parameter for the characterization of the bio-drying process is the specific weight loss (see Figure 4).

Its value depends on the Volatile Solid consumption and on the water evaporation (reaction water included). Some runs with low organic fraction content showed a condensation phenomenon that gave anomalous data that anyway can be corrected assuming that an optimized process could guarantee a continuous extraction of leachate.

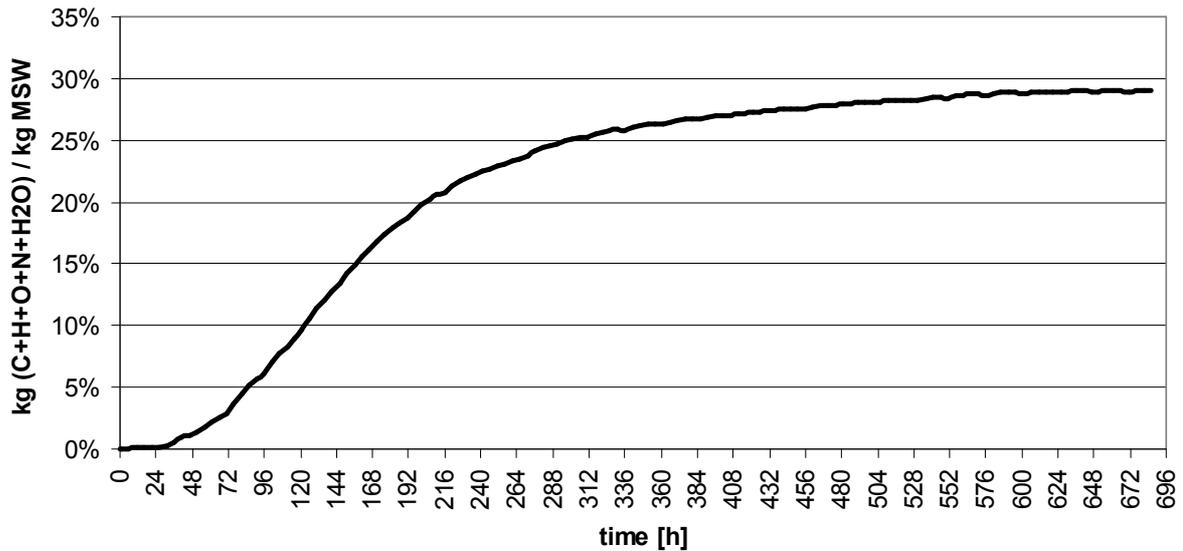


Figure 4 Weight loss dynamic during the process

The importance of the knowledge of weight loss is related to the necessity of data availability for mass balances in Life Cycle Analysis comparisons and design criteria of transport systems. In the first case, the typical information available in the technical literature of the sector is a weight loss of 25% (RADA ET AL., 2006B). A limit of this datum is that it is not possible to generalize the behavior of the process as weight loss depends on the organic fraction content. Anyway it is clear that the characteristics of the present Romanian waste could allow a correct development of bio-drying.

3.3 Volatile solids

Concerning volatile solids consumption, in Figure 5 the dynamics of this parameter is presented; the curve is similar to the one of water loss but the values are significantly lower (as bio-drying develops minimizing the volatile solid consumption). A ratio 1:7 between volatile solid consumed and water removed can be assessed.

For this run it was measured the quantity of volatile solids, in the waste at the beginning and at the end of the run. It was made also a respirometric test for the bio-dried material, for having realistic data concerning the stability of the waste after the bio-drying process.

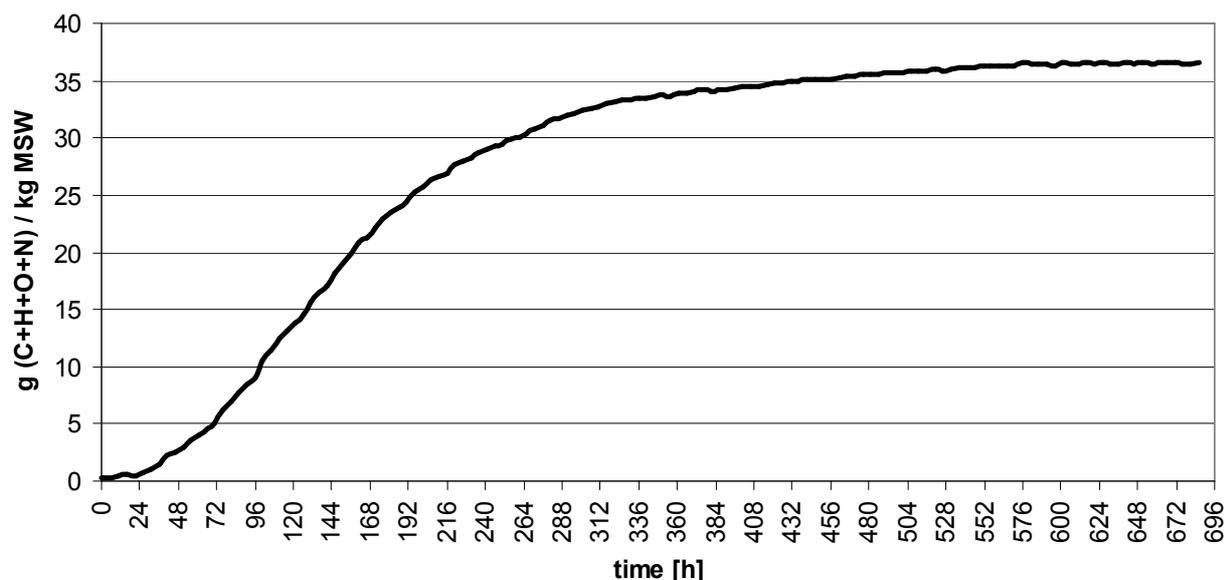


Figure 5 Volatile solids consumption dynamics during the process

A sample of 1 kg, from the initial waste and bio-dried waste after removal of coarse materials was taken for measuring the volatile solid content. The results obtained after the analysis are reported in Table 1. Taking into account the heterogeneity of the treated material, those values can be useful only for a qualitative demonstration of the volatile solid consumption that characterizes the process.

Table 1 Volatile solids present in MSW, bio-dried material and in OFMSW

| | VS/TS [%] |
|--|-----------|
| MSW before bio-drying treatment* | 51.5 |
| MSW after bio-drying treatment (bio-dried material)* | 48.3 |

* after coarse material removal

3.4 Respirometric Index

IR_{24} was calculated as the integral average of data from a 24 hours interval of oxygen consumption. IR_{24} represents the oxygen consumption velocity in the time for unitary weight of organic substance and is expressed in $mg_{O_2} kg^{-1}_{VS} h^{-1}$. In the Figures 6 and 7 the Respirometric Index values, IR and IR_{24} are presented.

The obtained values demonstrate that the stability of the material after processing is partial. The value of those IR s can be considered typical of a bio-drying process.

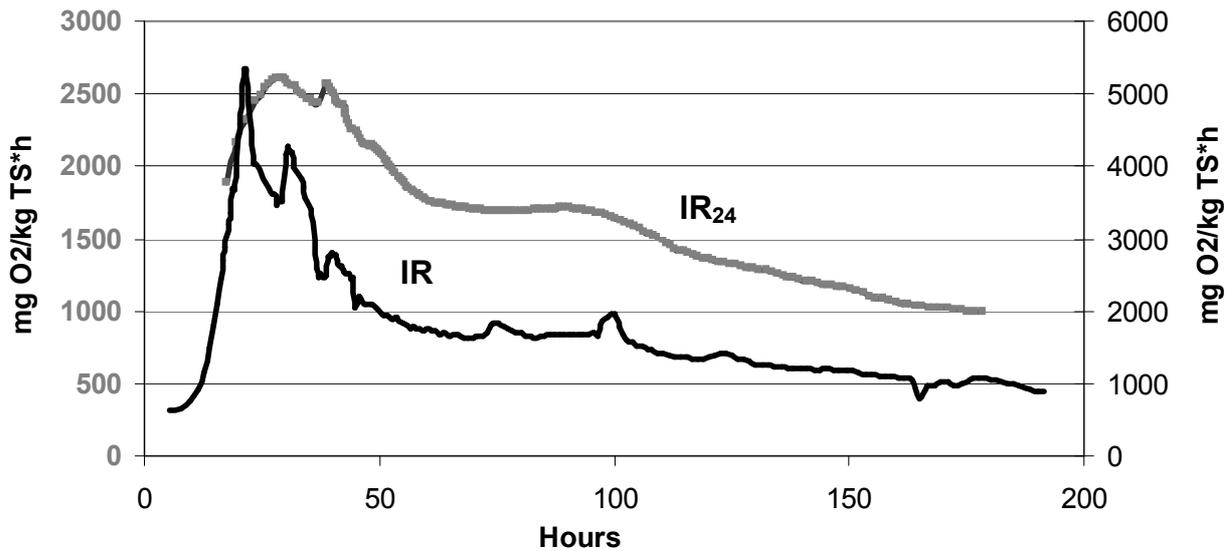


Figure 6 IR and IR₂₄ in the first day

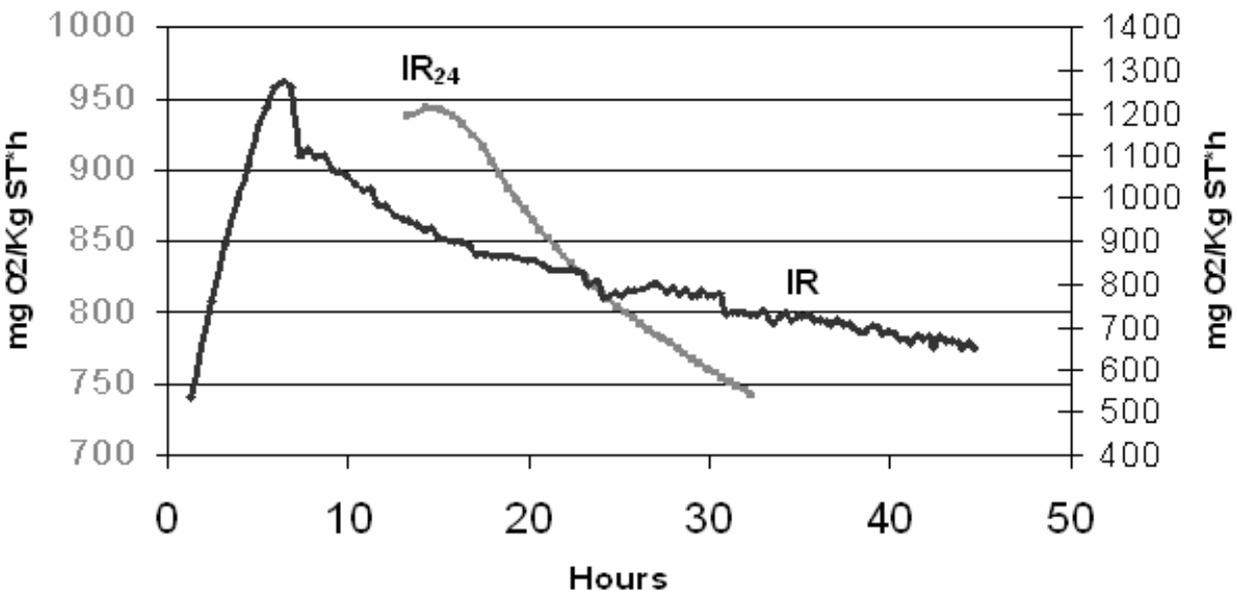


Figure 7 IR and IR₂₄ in the 30th day

3.5 Lower heating value dynamics

Looking at the LHV dynamics showed in Figure 8, it is clear that bio-drying can be a viable option for generating RDF starting from a “poor” waste. However, in the curve presented, the increase of the specific value of LHV, both of bio-dried waste and of RDF, becomes less significant after two weeks.

Concerning the overall energy content of waste, in Figure 8 the loss of energy (from the initial LHV) is reported. This loss (about 2%) is not the only one as bio-drying needs also some electric energy for its operation.

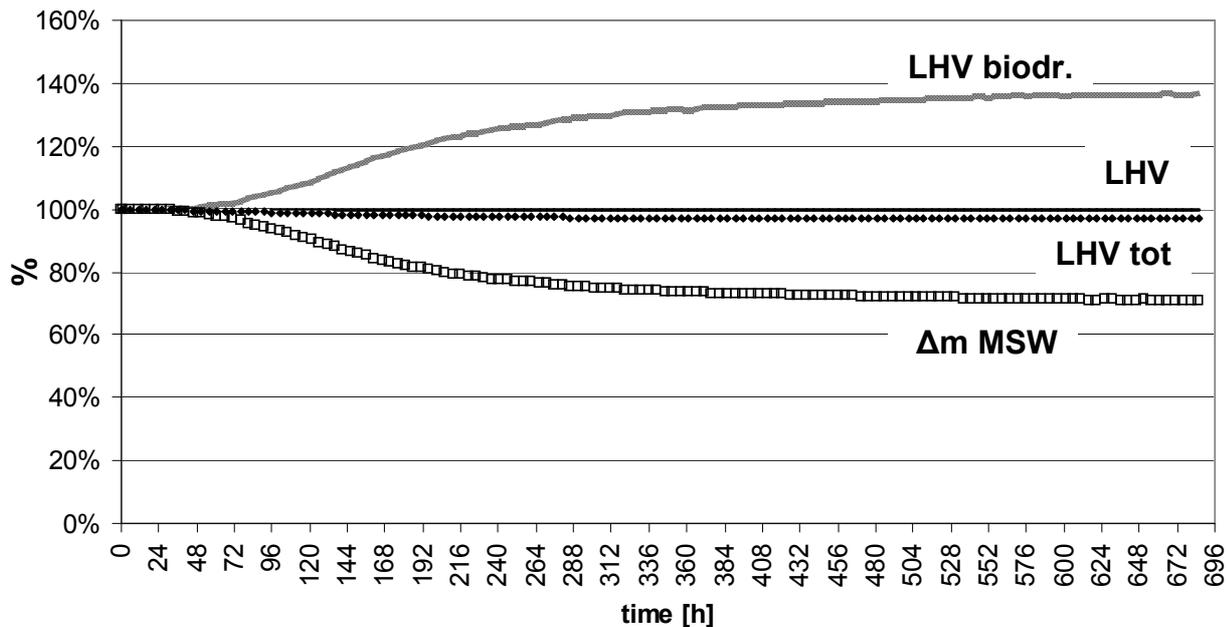


Figure 8 Overall graph of the bio-drying process

4 Discussion

4.1 Critical analysis of the process with Romanian-like MSW

Results showed that:

- The process of bio-drying shows an initial lag phase that delays of about 1 day the full development of the process. The curve of the volatile solids consumption shows a dynamics similar to the one that characterizes the hydrolysis of volatile solids in case of an anaerobic fermentation (ANDREOTTOLA ET AL., 2000). As there is some readily biodegradable substrate even at the beginning of the bio-drying process (as values of the COD in the liquid part of the organic fraction demonstrate (ANDREOTTOLA ET AL., 2000)), the initial lag phase should depend on the lack of microorganisms. Anyway their growth is very fast as demonstrated from the weight loss dynamics of the process.
- The Romanian-like water content of MSW allows to increase the lasting of the bio-drying process up to 4 weeks (usually bio-drying is a proposed for a 2 weeks lasting); as a consequence the level of stabilization can be higher compared to a conventional application (for example like in Italy, where humidity of the MSW could be 20÷30%; experimental data support that consideration).
- Respirometry values point out that the bio-drying process cannot guarantee the level of stability that bio-stabilization can; as a consequence it is important to

study in details the impact of the following landfilling in order to assess its acceptability (another parameter to be considered is also the amount of biodegradable waste landfilled referred to a single inhabitant).

- The increase of LHV obtainable by bio-drying of high moisture MSW can transform a waste unsuitable for combustion to one valuable for it; as a consequence bio-drying in such a scenario can be adopted for flexible strategies of waste management (as a pre-treatment both for landfilling and before energy conversion).

4.2 Critical analysis of the Romanian case

In Romania no selective collection is extensively activated. MSW is disposed of in landfills without pre-treatment. The production of MSW in Romania is growing, being about $300 \text{ kg inh}^{-1} \text{ year}^{-1}$ with a significant increase expected in the next decade. The calorific value is not suitable for a direct combustion because of the high humidity. The present paper shows an alternative strategy to the direct combustion.

Bio-drying could be a temporary strategy before the implementation of a waste-to-energy plant: in a first step, bio-drying could help to decrease the impact of MSW to be landfilled; in a second step, an energetic valorization of the bio-dried (and refined) material could be implemented both in dedicated plants and in co-combustion options.

In Romania an interesting fate of Refuse Derived Fuel from bio-drying could be the co-combustion in cement works. The Authors wish to underline that, before proposing a centralized MSW incinerator, in Romania, it could be important to study the viability of the exploitation of existing combustors. That could be a solution to decrease the capital costs related to a strategy of MSW management (Romania is presently a low-income country). Anyway this alternative pathway must be managed carefully as it must be guaranteed an adequate control of the emissions of co-combustors. Romania has just entered into the European Union, thus the environmental regulation could support the correct management of this practice.

Presently there is no bio-drying plant in Romania. The operation of this process can be managed easily, thus there is no need for a particular formation of technicians.

Apart from the main cities, in Romania the MSW production seems to be decentralized in areas at low density of waste production. To this concern it could be interesting to analyze the viability of small scale innovative solutions like the one presented in a recent conference (RAGAZZI ET AL., 2005): bio-drying could be followed from post-refinement in order to feed a small gasifier coupled with an engine.

Post-refinement can replace the selective collection of some streams of waste (metals, glass). Romania must activate a strategy for selective collection. The adoption of bio-drying could help to keep low the cost of waste collection.

5 Summary

The present paper showed some results of an experimental characterization of Romanian-like MSW treated in a bio-drier. The obtained results showed that the Romanian MSW is suitable for a full developed bio-drying: the waste weight can be reduced as about 25% giving a concentration of the initial energy content that increases the LHV. A small consumption of volatile solids must be taken into account. Electricity consumption must be included in case of energy balances. The implementation of bio-drying could allow the exploitation of existing combustor to be converted for co-combustion. The unsuitability of MSW for direct combustion makes it more interesting this option. An adequate control must be guaranteed in case of co-combustion.

6 Literature

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