Experimental characterization of municipal solid waste bio-drying

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Abstract

The bio-mechanical treatment of Municipal Solid Waste (MSW) has been adopted in Europe either as a pre-treatment before landfilling or as a pre-treatment before combustion. In this frame, the bio-drying process concerns the aerobic bioconversion applied mainly to MSW residual of selective collection. The aim of this process is the exploitation of the biochemical exothermic reactions for the evaporation of the highest amount of the humidity in the waste, with the lowest consumption of organic carbon. The obtained material can be easily refined to produce Refuse Derived Fuel. The present paper reports original assessments of process parameters characterizing the MSW bio-drying. In particular, outputs of a few pilot scale experimental runs have been elaborated in order to assess the following overall process parameters: m^3_{AIR} kg^{-1} of waste, m^3_{AIR} kg^{-1} of consumed volatile solids, m^3_{AIR} kg^{-1} of initial volatile solids, m^3_{AIR} kg^{-1} of organic fraction in the waste. Additionally, the assessed volatile solid dynamics during the bio-drying process are presented. These data are not generally available in the literature. Concerning the organic fraction contents in the waste suitable for bio-drying, usually its application is in the range of about 30-50%. The reasons are: a) lower values can give limited results in term of Lower Heating Value (LHV) increase of the bio-dried material; b) the application to waste with higher organic fraction content has the limitation of starting with very low LHV affecting the final characteristics of the bio-dried material. In this organic fraction range the air flow-rate is significant: it can vary between 6 and 10 m^3/kg_{MSW} that is similar to the off-gas generable from the incineration of the same waste.
Keywords: bio-drying, design, energy, MSW, pre-treatment.

1 Introduction

The bio-mechanical treatment of Municipal Solid Waste (MSW) is an increasing option in Europe either as a pre-treatment before landfilling or as a pre-treatment before combustion. A process suitable for the last case is bio-drying. This process concerns the aerobic bioconversion applied to MSW residual of selective collection. Anyway it can be adopted also for treating MSW as is and contaminated organic fractions (under-sieve from mechanical selection, etc.). The aim of this process is to exploit the biochemical exothermic reactions for the evaporation of most of the initial humidity of the waste, with the lowest consumption of volatile solids. The obtained material can be easily converted in Refuse Derived Fuel (RDF), by a post-refinement with inert separation (European Commission [1]).

In November 2002 a study on the MSW bio-drying process began as a PhD activity in the Power Faculty of the Technical University of Bucharest (Romania). In September 2003 an international scientific collaboration between the Technical University of Bucharest and the University of Trento, Italy, was signed in order to go on with the development of the topic in the frame of a co-supervised doctorate (Rada [2]), as in Trento a bio-drying pilot plant was available at the Environmental and Civil Department of Trento University. This biological reactor was optimized during the PhD research. The reactor was used for several bio-drying runs from 2003 to 2005. The present paper reports original assessments of process parameters characterizing the bio-drying process. These data are not generally available in the literature as they are part of the know-how of the few companies proposing bio-drying (Ragazzi and Rada [3]).

2 Materials and methods

The biological reactor (Figure 1) used for the runs in the University of Trento, Environmental and Civil Department, is an adiabatic box of about 1 m^3 with a leachate collection system.

Figure 1: Bio-reactor used for the experimental runs.

The process air is filtered before entering into a blower. After a further filtration, the process air enters into an electro-valve installed to regulate the flow and, finally, in a flow-meter. After this path, the air is introduced in the biological reactor through a steel diffuser placed at the bottom. The air crosses upwards the waste from the lower part, activating the biological reactions and goes out of the biological reactor from the upper part, to be discharged into the atmosphere (in real scale, an air treatment line must be implemented to guarantee an acceptable environmental impact). When performing a run, the adopted biological reactor is placed on an electronic balance for monitoring the waste mass loss during the bio-drying process. For monitoring the temperature during the bio-drying process, it was decided to place a few temperature probes in different positions: one on the diffuser of the biological reactor (to measure the air temperature at the inlet), one on the piping of discharge (to measure the temperature of the process air at the outlet) and other probes on the vertical (to measure the average temperature of the waste). All these equipments are connected to a data acquisition system.

Starting from the waste characterization of each performed run, the overall composition necessary for the mass and energy balances was assessed. Basing on the performed experimental runs and using the parameters measured during those ones, a bio-drying model (Rada *et al.* [4]) was used. Thanks to energy and mass balances, it can describe the dynamics of the calorific value during the bio-drying process: both for the bio-dried material and for the RDF obtainable after a post-treatment (by separation of glass, metals and inert). By this approach, direct design and management parameters can be taken. The input data of the model are: the initial mass and the material and ultimate composition of waste sent to bio-drying, the amount of air and air temperature at the inlet and outlet of the biological reactor and the weight loss during the bio-drying process.

Several runs have been performed during the overall research in order to be sure about the replicability of the process (Rada *et al.* [5]). In the present paper four representative runs are discussed referring to different organic fraction concentrations. The outputs of the experimental runs have been elaborated in order to assess the following overall process parameters: m^3_{AIR} kg^{-1} of waste, m^3_{AIR} kg^{-1} of consumed volatile solids, m^3_{AIR} kg^{-1} of initial volatile solids, m^3_{AIR} kg^{-1} of organic fraction in the waste. The initial organic fraction concentrations were: 8%, 29%, 50% and 100%. In the first case, the MSW is typical of a region where a very high organic fraction selective collection is performed. The last case was developed in order to study in details the behavior of the organic fraction alone (with no bulky agent). The main management criteria were to keep the process air temperature below 60°C and to guarantee an adequate oxygen supply. No water addition was made.

3 Results and discussion

In Figure 2 the dynamics of the measured air flow for the four runs is presented. A typical lasting of the bio-drying process is 12-14 days (Rada *et al.* [4]), thus the comparison will be made choosing 312 hours as a representative retention time.

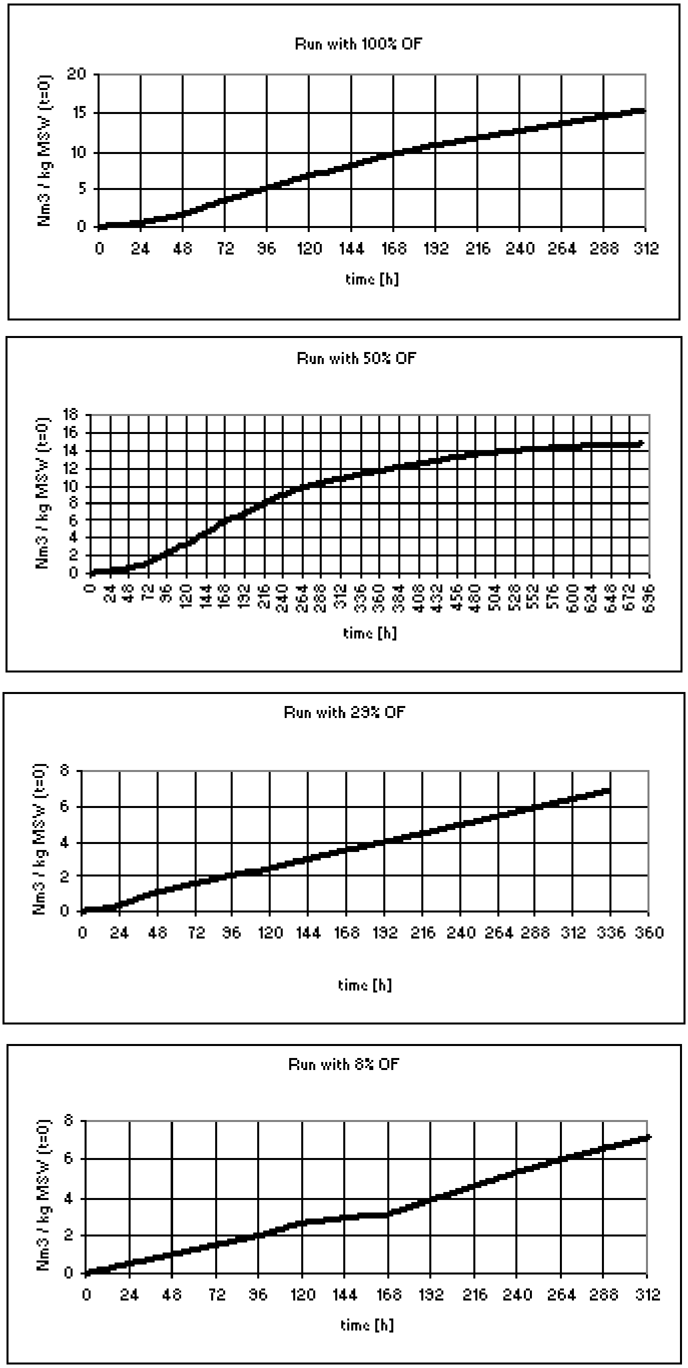

Figure 2: Dynamics of cumulative air flow-rate during four runs.

As shown in Figure 2, the cumulative curves of air flow after 312 hours point out that the process is "air consuming": the values are similar to the one necessary for MSW incineration.

The main consequence of the process is an increase of the Lower Heating Value (LHV), as shown in Figure 3.

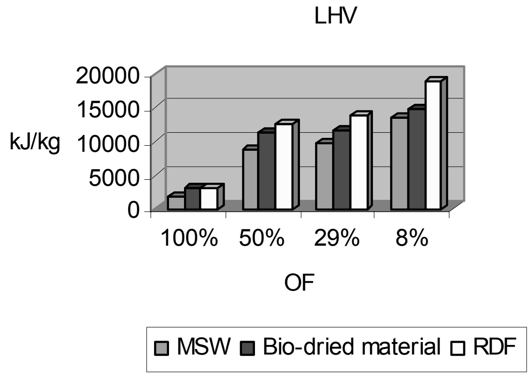

Figure 3: LHV variations assessed from a bio-drying model (Rada [2]).

In the cases of 50% and 29% of organic fraction contents (OF), the LHV changed respectively from 8600 to 12500 kJ/kg and from 9600 to 13700 kJ/kg (there is no energy generation as the biodried mass is lower than the initial one). In order to have higher values an additional post-refinement is necessary (screening) that has the disadvantage of generating residues to be landfilled. On the contrary, the preliminary post-refinement generates only streams of materials to be recycled (glass, metals, inert). The case of 100% of organic fraction content is useful to demonstrate that if the target of a treatment is the production of a good RDF, it is important to apply the strategy only to waste having already a good energy content. The case of 8% of organic fraction content shows as a limited content of putrescible material cannot give significant results in term of LHV increase after bio-drying: only 9%. The post-refinement allows interesting results, but could be directly applied in this care, to the residual MSW avoiding the cost of bio-drying.

The exothermy of the process is a consequence of the volatile solids oxidation. The cited model (Rada *et al.* [4]) allows one to assess the dynamics of the volatile solid consumption as sum of C, H, O, N consumed, as reported in Figure 4. When bio-drying lasts longer than two weeks (see run with 50% org. fraction) the volatile solid consumption slows down. The reason is related to the decrease of the water content in the waste that causes a limiting effect in the process. It must be pointed out that, differently from composting and bio-stabilisation, bio-drying is performed without water addition in order to optimise the energy balance. The consumption of volatile solids in the case of 8% of organic fraction content is very low, but this depends on the unsuitability of bio-drying to the treated waste.

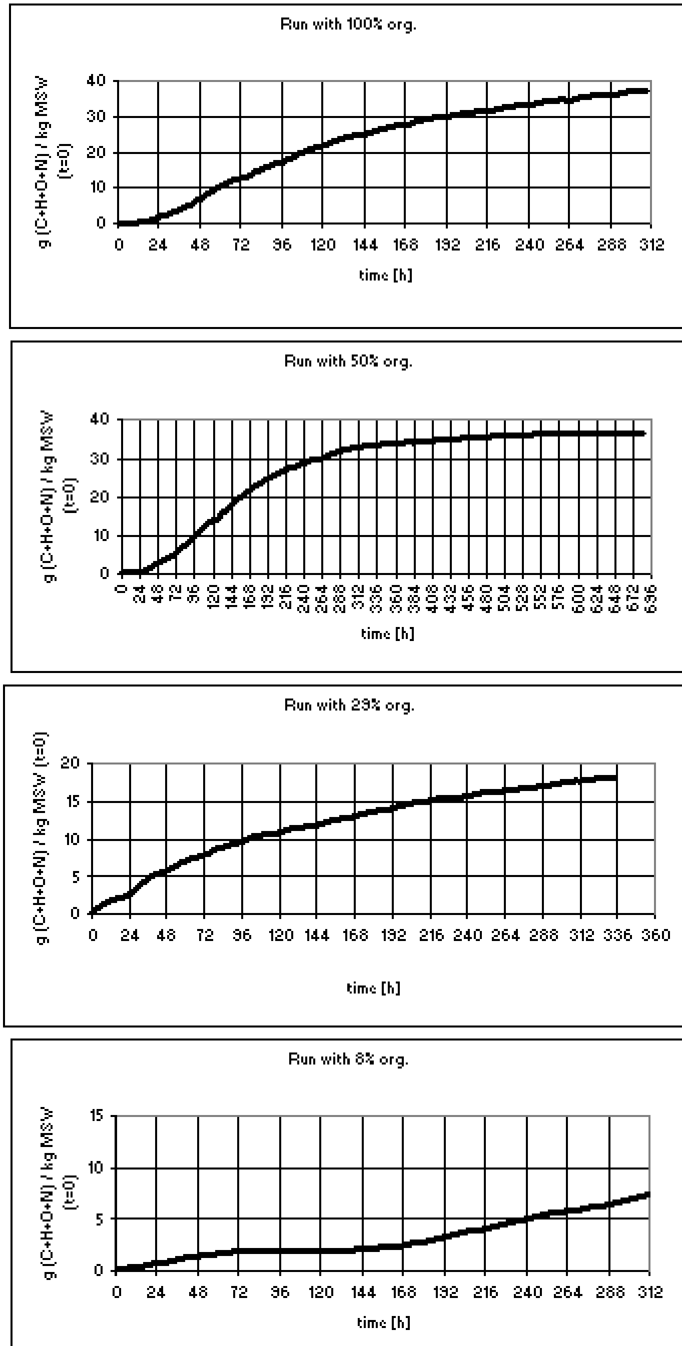

Figure 4: Assessed volatile solids consumption dynamics.

In Tables 1 and 2, some parameters useful for a deeper understanding of bio-drying are reported. The very high values of the ratio $m^3_{AIR}/kg_{\Delta VS}$ demonstrate that the process is not oxygen limited. Indeed the management of the process is based on the regulation of air flow-rate for keeping the temperature lower than 60°C.

The ratio m^3_{AIR}/kg_{VSinit} allows one to make a few considerations:
a) the case of 100% OF shows values double than a typical composting process; the reason is related to the absence, in the studied case, of bulky agent usually added to guarantee an adequate porosity, the bulky agents contributes to the VS amount with slowly biodegradable materials;
b) the remaining cases show values lower than the one of a composting plant; this is a consequence of the lower amount of putrescible volatile solids available in case of MSW bio-drying (see the column $kg_{VSp\ init}/kg_{MSW}$ in Table 2).

The ratio $m^3_{AIR}/kg_{VSp\ init}$ gives an idea of the specific effects of the exothermy of the process: the cases 100% OF, 50% OF and 132% OF show values the same order of magnitude. On the contrary the case of 8% OF was characterised by the highest value. This does not depend on the heat generated from the biochemical oxidation, but to the need of increasing the air flow to see some effects of water removal (Rada [2]): the risk of bio-drying MSW with very low OF content is to operate the plant similarly to a thermal drying with a high air-flow rate (dewatering the waste by physical phenomena and not biological ones).

Table 1: Parameters characterising bio-drying (part 1 of 2).

Run	OF (%)	m^3_{AIR}/kg_{MSW}	$kg_{\Delta VS}/kg_{MSW}$	$m^3_{AIR}/kg_{\Delta VS}$	kg_{VSinit}/kg_{MSW}
1	100%	15.4	0.037	412.7	0.168
2	50%	10.9	0.033	330.8	0.384
3	29%	6.4	0.018	361.7	0.452
4	8%	7.1	0.008	921.0	0.537

Table 2: Parameters characterising bio-drying (part 2 of 2).

Run	OF (%)	m^3_{AIR}/kg_{OF}	kg_{VSinit}/kg_{MSW}	m^3_{AIR}/kg_{VSinit}	$kg_{VSp\ init}/kg_{MSW}$	$m^3_{AIR}/kg_{VSp\ init}$
1	100%	15.42	0.168	91.94	0.168	91.94
2	50%	21.80	0.384	28.42	0.084	129.98
3	29%	22.24	0.452	14.26	0.049	132.48
4	8%	88.87	0.537	13.24	0.013	541.45

4 Conclusions

The results of the international collaboration which supported the presented research have allowed one to have a deeper knowledge of the process both in a country where bio-drying is already performed in real scale (Italy) and in a country where the process was unknown (Romania). Indeed the results of the runs with 29% and 50% of OF can be representative of the behavior of an Italian and Romanian waste respectively. Presently bio-drying is recognized as a process available for waste management (European Commission [1]), but few free research has been developed on it. That makes it important the development of researches, like the one presented, able to generate design and management parameters.

An additional important aspect of the collaboration is the possibility of avoiding the monopolization of the technology in the country where bio-drying has to be introduced. That will allow one to keep low the cost of the process in a country at low income as Romania presently is.

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