MSW Bio-Drying And Bio-Stabilization: An Experimental Comparison

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EXECUTIVE SUMMARY

In the field of the aerobic processes for the treatment of Municipal Solid Waste, a distinction must be made between bio-stabilization and bio-drying:

1. Bio-stabilization: treatment of aerobic bioconversion applied to MSW as is, to MSW residual of selective collection, or to contaminated organic fractions (under-sieve from mechanical selection, etc.) with the aim of generating a stabilized organic fraction suitable to be landfilled or used for capping operations during the cultivation of the sanitary landfill.

2. Bio-drying: treatment of aerobic bioconversion is applied to the same fractions. The final product is aimed to the use as Refuse Derived Fuel (RDF), after inert separation, or to thermal disposal in authorized plants according to Dir. 2000/76/CE.

Both of the processes adopt an aeration of the mass of waste. Anyway, targets are different: in the case of bio-stabilization (long-time process) the aim is the highest conversion of organic carbon, while for bio-drying (short-time process) the aim is the exploitation of the exothermic reactions for the evaporation of the highest part of the humidity in the waste, with the lowest conversion of organic carbon.

For studying in details the two processes, some experimental runs have been performed using a pilot plant at the Trento University (Italy). The system allows an on-line control of air flow and the recording of the weight loss.

The present paper shows the results of a pilot scale experimentation on bio-drying / bio-stabilization of Municipal Solid Waste. After a first step of bio-drying the waste was re-humidified without mixing in order to simulate the effect of rain on bio-dried material (in Italy bio-drying has been proposed also as a pre-treatment before landfilling). The obtained results demonstrated that the stabilization from bio-drying is only partial.

Basing on the performed experimental runs, an original bio-chemical model was used. 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 post-treatment. By this approach direct design and management parameters can be taken. The bio-stabilization modeling takes into account the water addition.

Concerning measurements, the temperature in the core of the treated waste demonstrated that the water addition after bio-drying reactivated the process. The weight loss in the second step was still significant.

According to the results of the application of the bio-drying model, the water loss resulted 11.2% out of 12.4% of the overall weight loss (difference is attributed to volatile solids conversion).
The volatile solid conversion rate was similar comparing the end of the first step and the beginning of the second one.

The Lower Heating Value of waste increases during bio-drying but showed an obvious fall as a consequence of the water addition.

If bio-stabilization were used as a pre-treatment before combustion in place of bio-drying, the energy consumption for pre-treatment would be higher and the available energy in the mass to be burnt would be lower.

Literature data (from the same research group) demonstrate that the time required for an effective bio-stabilization is very longer than the time for bio-drying.

INTRODUCTION

The latest UE policy on waste management recommends the recycling of material, energy recovery and waste treatment before landfilling. For this reason the biological processes as bio-stabilization and bio-drying represent an increasing option used either as a pre-treatment before landfilling or as a pre-treatment before combustion. In the field of aerobic processes a distinction must be made between bio-stabilization and bio-drying:

- **Bio-stabilization**: treatment of aerobic bioconversion applied to Municipal Solid Waste as is, to MSW residual of selective collection, or to contaminated organic fractions (under-sieve from mechanical selection, etc.) with the aim of generating a stabilized organic fraction suitable to be landfilled or used for capping operations during the cultivation of the sanitary landfill.

- **Bio-drying**: treatment of aerobic bioconversion is applied to the same fractions. The final product is aimed to the use as Refuse Derived Fuel (RDF), after inert separation, or to thermal disposal in authorized plants according to Dir. 2000/76/CE.

Both of the processes adopt aeration into the mass of waste, but with different targets: in the case of bio-stabilization (long-time process) the aim is the highest conversion of organic carbon, while for bio-drying (short-time process) the aim is the exploitation of the exothermic reactions for the evaporation of the highest part of the humidity in the waste, with the lowest conversion of organic carbon. A graphical explanation of the two processes regarding the details of the behavior of humidity, volatile solids (VS) and non-volatile solids is presented in Figure 1. The VS consumption strongly depends on the lasting of the treatment and on the initial organic matter content (Figure 1 refers to a high initial organic matter content).

![Figure 1. MSW behavior during bio-drying and bio-stabilization](image-url)
In table 1 the main parameters indicated in the Italian Decree 372/99, article 3, for describing these processes are presented. As explained in the present paper, there are many more differences than the role of humidity, pointed out in table 1.

**Table 1. Parameters of bio-stabilization and bio-drying process**

<table>
<thead>
<tr>
<th>Parameters of process</th>
<th>Bio-stabilization</th>
<th>Bio-drying</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maximal temperature (°C)</td>
<td>70</td>
<td>70</td>
</tr>
<tr>
<td>Minimal temperature (°C) (&gt;3days)</td>
<td>55</td>
<td>55</td>
</tr>
<tr>
<td>Humidity (%)</td>
<td>&gt;50%</td>
<td>Not significant</td>
</tr>
<tr>
<td>Oxygen (% v/v)</td>
<td>&gt;10%</td>
<td>&gt;10%</td>
</tr>
<tr>
<td>Specific weight (t/m³)</td>
<td>&lt;0.7</td>
<td>&lt;0.7</td>
</tr>
</tbody>
</table>

An important factor for the correct management of this biological aerobic process is to know the real biological stability obtained after those ones. Biological stability is the state where, even if the conditions optimal for the development of aerobic microbial activity are guaranteed, the biodegradation process is significantly slowed down. That means that a significant part of VS must be degraded. The most important factors for these two processes are the MSW composition (the nutritive elements, the C/N ratio, temperature and free oxygen availability).

In order to contribute to the research in the field of biological treatment of MSW, an agreement between the University of Trento (Italy) and the Technical University of Bucharest (Romania), concerning a three years co-supervised PhD research regarding bio-drying/bio-stabilization, was signed in winter 2002.

**MATERIALS AND METHODS**

The biological reactor (Figure 2) used for the runs at the Trento University, Environmental and Civil Department, is an adiabatic box of about 1 m³ with a condensate collection system. The necessary air is filtered with a dust filter before entering into a blower. After a further filtering, the process air enters into an electro-valve installed to regulate the flow and, subsequently, in the flow-meter. After these paths the air is introduced in the biological reactors through a steel diffuser placed at the bottom. The air flow crosses upward the waste from the lower part, activating the biological reactions and goes out of the biological reactor from the upper part. Finally, after having crossed the system, the process air is discharged into the atmosphere. 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.

*Figure 2. Bio-reactor used for the experimental runs*
For monitoring the temperature during the bio-drying process, it was decided to place a few temperature probes: one on the diffuser of the biological reactor (to measure the air temperature at the entrance), one on the piping of discharge (to measure the temperature of the process air at the exit) 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 a town with a high selective collection, the overall composition necessary for the model was assessed. In Figure 3 some details on the MSW fractions are presented.

For the bio-drying run (step 1) and bio-stabilization run (step 2) the same waste was used. For the bio-stabilization run it was used the waste obtained after bio-drying adding a known amount of water without mixing. Mixing was avoided to characterize the process in case of rain on the bio-dried material (in Italy bio-drying has been proposed also as a pre-treatment before landfilling).

![Figure 3. MSW characterization Step 1 (percent of fractions)](image)

Basing on the performed experimental runs and using the parameters measured during those ones, an original bio-chemical model was used. 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 post-treatment. By this approach direct design and management parameters can be taken. Details on this bio-drying model are available in (Rada et al. 2005a). The input data of the model are: the initial mass and the material and ultimate composition of waste sent to bio-drying, the quantity of air and air temperature at the entrance and exit of the biological reactor and the weight loss during the bio-drying process. In the present paper a modified version has been used to simulate the bio-stabilization process. The modifications concern the reassessment of the waste composition after water addition when bio-drying is followed by a bio-stabilization step.

RESULTS AND DISCUSSION

In Figures 4a,b and 5a,b some measured parameters are presented for step I (bio-drying) and step II (bio-stabilization). Bio-stabilization has been activated adding only a part of the water loss. The bio-drying run started with 104.70 kg and ended with 91.71 kg. According to the results of the application of the bio-drying model, the water loss was 11.2% out of 12.4% of overall weight loss (difference is attributed to volatile solids conversion). A partial re-humidification was obtained adding 2.65 kg of water. As the area of the bio-reactor
measures about 1 m², the water addition simulate an event of only 3 mm of rain (that means a light rain event). The aim was to check the waste reactivity in case of bio-drying were used as pre-treatment before landfilling or as a system for a temporary storing of waste before conversion to energy.

In Figure 4a and 4b the Probe n.1 shows temperature values of air entering the reactor. Probe 2 shows the temperature values in the core of waste. Probe 3 and 4 give the temperature values after contact with waste. The temperature values resulted higher than 55°C for more than 3 days confirming the correct management of the run. The initial increase demonstrate that the process has a lag phase of about 1 day (no inoculum is required). The water addition dropped down the air temperature in the core (from 40°C to 30°C) but the residual putrescibility caused a following increase. That confirms that the 11 days are not enough to stabilize the waste. Concerning temperatures of probes 1,3,4 the cyclic dynamics can be explained through the day – night fluctuations of the ambient air temperature.

![Figure 4a. Temperature dynamics before re-humidification](image1)

![Figure 4b. Temperature dynamics after re-humidification](image2)
In Figures 5a and 5b the dynamics of mass loss is presented. The scale of the two Figures is different, anyway the weight loss following the re-humidification turns to higher values. If we consider the values of the last four days for step 1 and 2, we can see that at the end of the first step the weight loss resulted about 3% while 7% for the second step.

![Figure 5a. Mass loss dynamics before re-humidification](image)

**Figure 5a. Mass loss dynamics before re-humidification**

![Figure 5b. Mass loss dynamics after re-humidification](image)

**Figure 5b. Mass loss dynamics after re-humidification**

The application of the bio-chemical model allowed to reconstruct the waste composition at the end of the bio-drying step, taking into account the volatile solids loss (C, H, O, N), the humidity loss, the water addition effects on mass balances. In Figure 6 the composition at the beginning of step 2 is presented. The volatile solids loss has been attributed to the organic fraction as this one is the more putrescible. As a simplification the water addiction has been attributed to the same fraction.
The water addition has an important meaning in term of significance of the process: the specific LHV increases progressively before water addition (Figure 7) giving to the biological process the possibility to generate a product useful for energy recovery; the water addition, on the contrary, has an opposite aim; indeed step 2 can be considered only for stabilization purposes. The LHV changes as following: 12.479 MJ/kg at the beginning of step 1 (residual MSW), 14.211 MJ/kg at the end of step 2 (bio-dries material), 13.736 MJ/kg at the beginning of step 2 (as effect of water addition), and 14.808 MJ/kg at the end of step 2. It is clear that an optimization of the biological process, if aimed to energy recovery, cannot accept a water addition.

In Figure 8 the removal of water during the bio-drying step is reported. Values of Figure 8 refer to the real water content decrease, as the biochemical process causes a generation of additional water from the oxidation of Hydrogen in volatile solids. This additional water is extracted through the same air flow that guarantees the decrease of the initial water content. The Authors checked that, during the process, the characteristics of the air kept suitable for de-humidification without condensation on the mass of waste.
In Figures 9a and b the VS consumption during bio-drying and bio-stabilization are shown. The first step is aimed to convert VS as low as possible in order to keep the combustible fraction in the waste. On the contrary, the second step must convert VS as high as possible in order to stabilize the organic fraction in the waste. Comparing 4 days, the rate of VS conversion in the second step resulted almost double than the rate in the final period of the first step. This is a clear consequence of the different targets of the two processes.
In Italy the value for the index of respiration is less stringent than the one asked for German plants aimed to bio-stabilization (Wiener et al, 2003). As a consequence design criteria, management criteria and costs can change significantly. If a bio-drying process were considered sufficient for a bio-stabilization, the lasting of treatment could be of two weeks, but for obtaining the requested characteristics of bio-stabilized material according to the most stringent regulations, the lasting should increase to a few months.

At the University of Trento a pilot experience was developed before the experimentation reported in the present paper (Rada et al. 2005b). The aim was the assessment of the level of bio-stabilization through the use on a respirometric index during a run lasted longer than 2 months. Figure 10 shows that the difference can be of one order of magnitude comparing the initial and the final values. Apart from the respirometric index values reported in Figure 10, a direct demonstration of the necessity of long times for bio-stabilization is given in Figure 11: an addition of water after 2, 4, 7 weeks in a run with MSW with high organic content (46,5%) (Rada et al, 2005b) caused always the reactivation of the process. In figure 9 data about IR values demonstrate that bio-stabilization needs times longer than bio-drying.
In Romania (expected entrance in EU in 2007), there is an increasing attention from managers and decision makers to follow a sustainable approach to waste management and to integrate strategies that will produce the best viable option. Presently in Romania MSW is collected as is: no selective collection is activated, apart from few pilot experiences. Generally MSW is then disposed of in uncontrolled landfills. The production of MSW in Romania is presently about 285 kg inh⁻¹ year⁻¹. A significant increase is expected with consequencies also on MSW composition. There is no Waste to Energy plants 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 generally not suitable for a direct combustion because of its high humidity. The present research will be useful for a correct introduction of these processes in this country.

CONCLUSION

As explained in the present paper, bio-stabilization and bio-drying are two different processes. A bio-stabilization plant could be converted in bio-drying plant if the one stream option is adopted. On the contrary the bio-drying process needs smaller plants and lower energy consumption. The present method for a direct study of bio-drying – bio-stabilization supports the choice of design parameters. Anyway, first of all a good MSW characterization is required.

ACKNOWLEDGEMENTS

The author thanks Mr. Lorenzo Fabbri, Mr. Alessio Franzinelli and Mr. Luca Rossato for the support in the management of the experimentation.

REFERENCES