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Role of Organic Fraction MSW Selective Collection as Indirect Landfill Pre-treatment

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Abstract
According to the recent regulations, raw Municipal Solid Waste (MSW) will no longer be landfilled in the European Union. Pre-treatments such as bio-stabilization (and even incineration) can decrease the impact of material to be landfilled.

In order to decrease the cost of MSW management, in regions where a highly efficient selective collection is adopted there are proposals for renouncing to a pre-treatment when the organic fraction in the residual waste is below a limit value. In other cases a simplified pre-treatment is proposed.

The present paper makes a critical analysis of these two approaches. Considerations are also based on the experimental characterization of MSW with low organic fraction content. To this concern a pilot scale bio-reactor has been used in order to characterise the biological activity of the waste.

Real residual MSW at low of organic fraction content (as a consequence of the selective collection of the region) has been aerated without and with water addition in order to study its reactivity.

Results showed that even if the organic fraction content is low, the residual putrescibility of the waste gives a respirometric index value not negligible, before and after simplified pre-treatments. Moreover, a complete bio-stabilization consumes in practice all the volatile solids present in the organic fraction of MSW; on the contrary the decrease of organic fraction content decreases, but cannot put to zero, the volatile solids of the organic fraction; as a consequence the indirect effect of selective collection cannot be equal to bio-stabilization.

A balance of the readily biodegradable volatile solids in terms of kg inhabitant^{-1} year^{-1} gives a more clear idea of the impact on the environment of the landfilling of MSW at low organic fraction content.

1 Introduction
Modern management of Municipal Solid Waste (MSW) must minimise the adoption of landfilling. According to recent regulations, raw Municipal Solid Waste will be no longer landfilled in the European Union countries (however the imple-

mentation of this scenario will be different from country to country). Pre-treatments as bio-stabilization (and even incineration) will decrease the impact of material to be landfilled but will increase the MSW management costs if compared to scenarios with direct landfilling of MSW.

In order to decrease the cost of MSW management, in regions where a highly efficient selective collection is adopted there are proposals for renouncing to a pre-treatment when the organic fraction in the residual waste is below a limit. In Italy, for instance, a few regions set a limit of 20%.

The present paper gives a contribution to the understanding of this approach. Considerations are based both on theoretical balances and on experimental characterization of MSW with low organic fraction content. To this concern a pilot scale bio-reactor has been used in order to characterise the biological activity of waste (residual MSW at low of organic fraction content as a consequence of the selective collection of the region).

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. 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 guar-

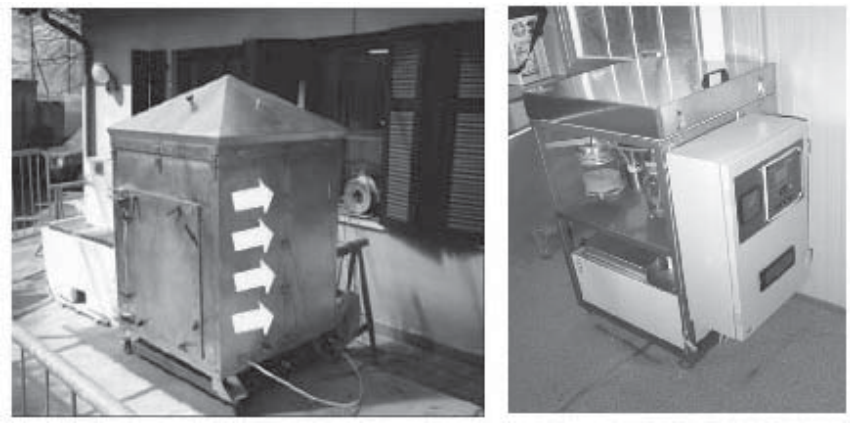


Fig 1: Bio-reactor (left) and respirometer (right) used for the experimental runs

antee 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 process. For monitoring the temperature during the 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 run performed, the overall composition necessary for the mass and energy balances was assessed. Based on the performed experimental runs and using the parameters measured during those ones, a biological model (Ragazzi et al., 2006) was used. Thanks to energy and mass balances, it can describe the dynamics of the calorific value and of the volatile solid consumption during the process. The input data of the model are: the initial mass and the material and ultimate composition of waste sent to the biological treatment, the amount of air and air temperature at the inlet and outlet of the biological reactor, the water addition (if any) and the weight loss during the process.

Additional information on the waste has been generated by the use of a dynamic respirometer adopted at the University of Trento (Andreottola et al., 2005) shown in Figure 1.

In the present paper a few representative runs are discussed referring to low organic fraction concentrations. The main management criteria were to keep the process air temperature below 60°C and to guarantee an adequate oxygen supply.

The initial organic fraction concentration of the first run was about 20%. In this case, the MSW was taken from an Italian region where it has been proposed a direct landfilling of residual MSW when the organic fraction content is kept below 20% thanks to a selective collection strategy. The experimental run lasted about two weeks and had the aim to check if a soft strategy of organic fraction selective collection gives a residual waste that can be landfilled after a short process as bio-drying is.

The initial organic fraction concentration of the second run was 8%. In this case, the MSW was taken from an area of an Italian region where a very high organic fraction selective collection is performed. The experimental run lasted two weeks and had the aim to check if a short process as bio-drying is, can substitute bio-stabilization before landfilling in case of very low organic content in the residual MSW (thanks to the effect of selective collection).

The obtained results will be used to understand if there is a percentage of organic fraction below that it is reasonable to go directly to landfill.

3 Results and discussion

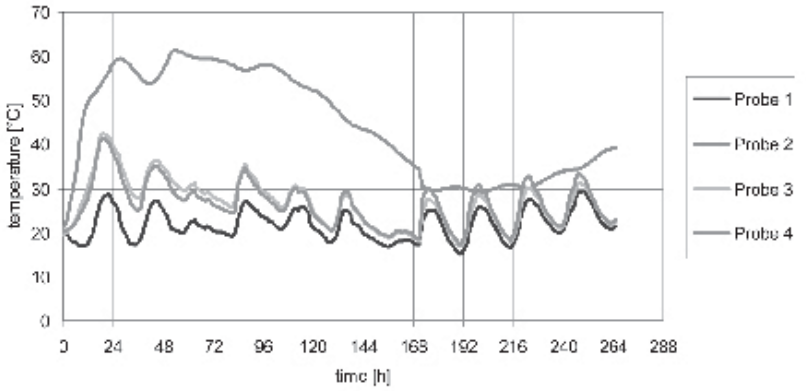


Fig. 2: Temperature dynamics before re-humidification

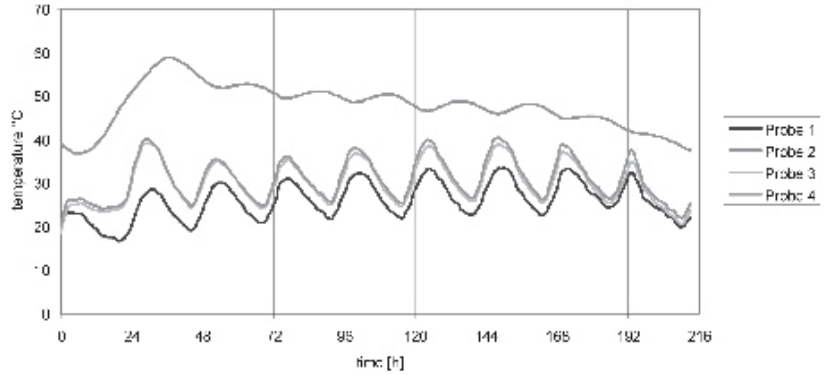


Fig. 3: Temperature dynamics after re-humidification

As mentioned above, a run with about 20% of organic fraction was performed in two steps in order to analyze the goodness of the strategy that set at 20% the limit for avoiding pre-treatment. The experimentation was developed in order to verify if after a simplified pre-treatment the residual MSW is suitable for landfilling.

In Figures 2, 3, 4 and 5 some measured parameters are presented for step I (bio-drying) and step II (bio-stabilization). Bio-stabilization has been activated adding water. 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 re-humidification was obtained adding the amount

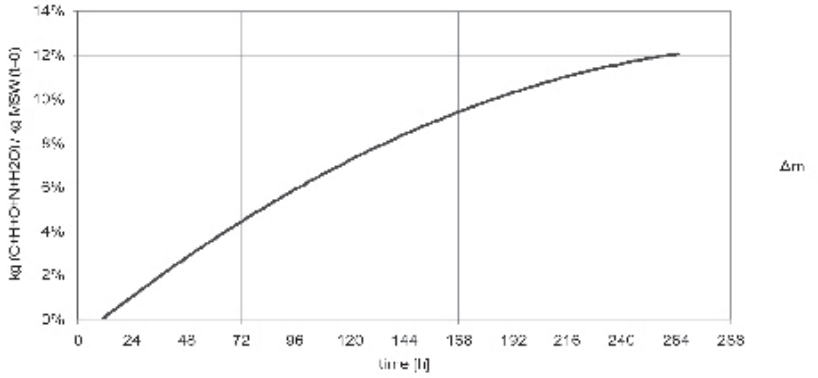


Fig. 4: Mass loss dynamics before re-humidification

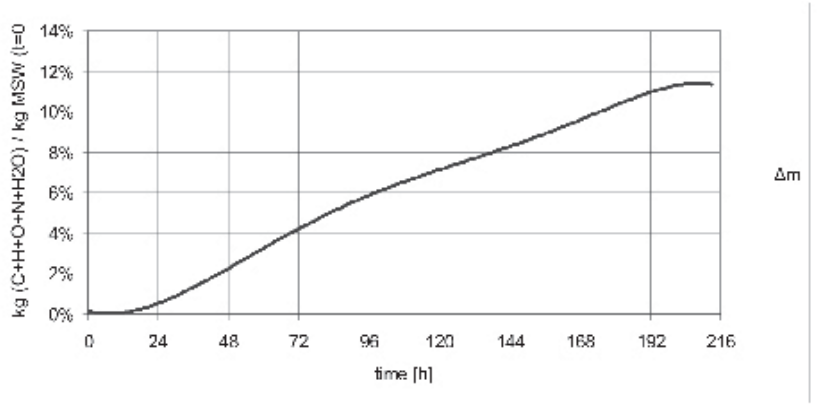


Fig. 5: Mass loss dynamics after re-humidification

of water loss. As the area of the bio-reactor measures about 1 m^2, the water addition simulated an event of only 11 mm of rain (that means a light rain event). In Figure 2 and 3, probe 1 shows temperature values of air entering the reactor. Probe 2 shows temperature values in the core of waste. Probe 3 and 4 give 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 demonstrated 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 a MSW

with 20% of organic fraction. Concerning temperatures of probes 1,3,4 the cyclic dynamics can be explained through the day – night fluctuations of the ambient air temperature.

In Figures 4 and 5 the dynamics of mass loss is presented. It can be seen that 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 about 6% for the second step.

The application of the bio-chemical model (Rada et al., 2005b) allowed reconstructing 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 and the water addition effects on mass balances.

Water addition has an important meaning in term of significance of the process: the specific LHV increases progressively before water addition giving to the biological process the possibility to generate a product useful for energy recovery; the risk is to have a final product with a LHV higher than 13,000 MJ kg^{-1} that is unsuitable for landfilling according to the EU principles. 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^{-1} at the beginning of step 1 (residual MSW), 14,211 MJ kg^{-1} at the end of step 1 (bio-dried material), 11,633 MJ kg^{-1} at the beginning of step 2 (as effect of water addition), and 13,107 MJ kg^{-1} at the end of step 2. That means, LHV resulted critical also after the second step. Additionally it must be pointed out that if the target is to generate a Refuse Derived Fuel it is important to set a post-treatment in order to increase the LHV.

In Figures 6 and 7 the VS consumption during bio-drying and bio-stabilization are shown (Rada et al., 2005a, c), (Rada et al., 2006). Comparing 3 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 demonstration that the waste can be easily reactivated. From the practical point of view, it is not reasonable to hypothesize that the landfilled waste will not be in contact with water as the closing of a landfill sector is not immediate.

Thus simple pre-treatment cannot fully solve the requirements for a landfillable waste.

A following question had to be answered: a lower organic fraction content makes possible a simplified pre-treatment? For that reason a 8% OF run was performed. The cited model allowed assessing the dynamics of the volatile solid consumption as sum of C, H, O, N consumed also for the 8% case (Figure 8). When bio-drying lasts longer than two weeks 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

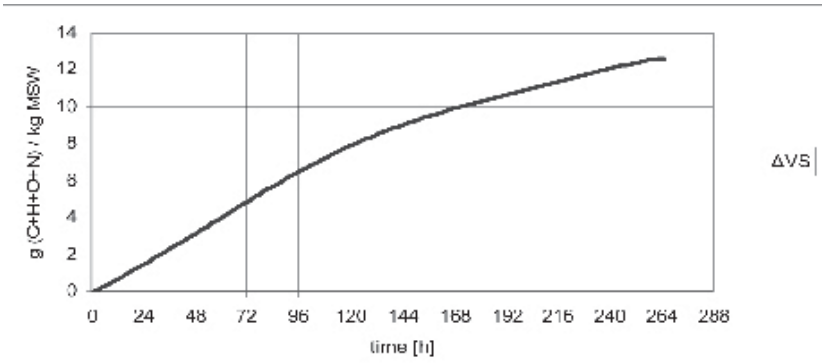


Fig. 6: Volatile solids dynamics before re-humidification

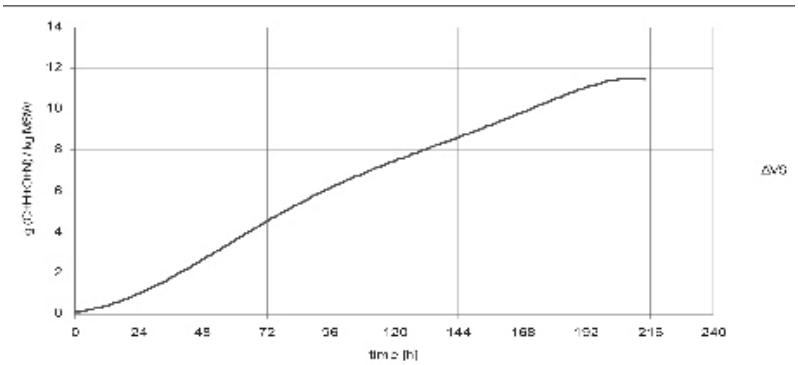


Fig. 7: Volatile solids dynamics after re-humidification

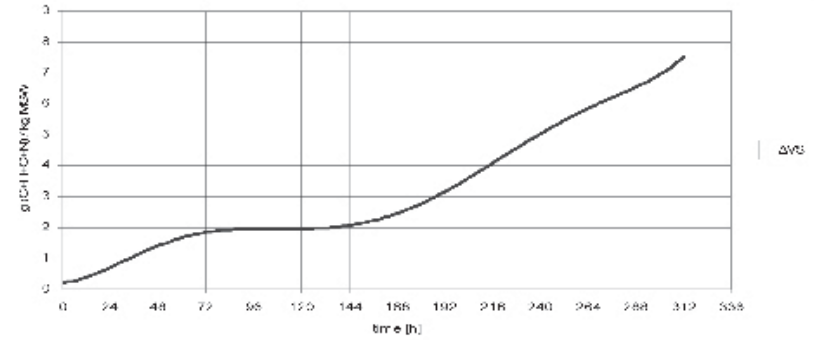


Fig. 8: Volatile solids dynamics during the run with 8% OF

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.

A volatile solids balance in the residual MSW before and after the treatment pointed out that the initial amount of (putrescible) VS was 19g_{VS} and the final one 12 g_{VS} .That means about 50% of the potential reactivity compared to case 1 obtained in two weeks (only by bio-drying). If the respirometric index is assessed referring to VS, the putrescibility of the final material can strongly affect its value. A balance of the readily biodegradable volatile solids in terms of kg inhabitant^{-1} year^{-1} gives a more clear idea of the impact on the environment of the landfilling of MSW at low organic fraction content. In Italy the latest Waste Management Plans set targets for instance as 175 kg inhabitant^{-1} year^{-1} of material to be landfilled. In reality, it could be interesting to set a target for the readily biodegradable volatile solids that keep in the residual MSW, as its value (that can be assumed equal to the VS of the organic fraction) gives a more direct idea of the impact of the future landfills.

In Italy the value for the index of respiration is less stringent than the one asked for German plants aimed to bio-stabilization (Rada et al., 2005a). 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. Results of the performed tests showed that the respirometric index can be reduced about of a factor 2.5 if bio-drying is performed without limitations. Considering the respirometric index that characterize a raw residual MSW (for instance 5000 mgO_2 kg_{TS}^{-1} h^{-1}) in case of conventional selective collection, it is clear that the necessary pre-treatment should last longer.

4 Conclusion

A complete bio-stabilization, in practice, consumes all the volatile solids present in the organic fraction of MSW; on the contrary the decrease of organic fraction content decreases, but cannot totally eliminate the volatile solids of the organic fraction; as a consequence the indirect effect of selective collection cannot be equal to bio-stabilization. Partial results can be obtained with bio-drying.

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