Modelling of Landfilling Acceptance of Residue from Refused Derived Fuel Generation

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Modellierung des Deponierungsverhalten von Restabfall aus der Sekundärbrennstoffproduktion

Abstract

The European Union policy on waste management recommends the recycling of material, energy recovery and waste treatment before landfilling. In the latest years it can be seen that the waste pre-treatment plants before combustion were more and more adopted. The production of waste derived fuel is generally based on mechanical biological treatment plants (MBT). The present paper deals with modelling MBT plants where either bio-drying or bio-stabilization are the core of the system. The importance of this work is related to the lack of tools for decision makers that must compare the one stream and two streams options. The biological stability and process modelling is based on the experimental results of an international research recently achieved. In the present work the different characteristics of the refuses to be landfilled in the case of one stream and two stream options are presented.

Keywords

Municipal Solid Waste, Refuse Derived Fuel, Respirometric Index, Lower Heating Value, one stream process, two stream process, bio-drying, bio-stabilization

1 Introduction

The introduction of Landfill Directive (1999/31/CE) in the European countries caused significant restrictions in landfilling of biodegradable material (“Respiration Activity after four days below 10 mg O_2 g^{-1} dry matter or a Dynamic Respiration Index below 1.000 mg O_2 kg VS^{-1} h^{-1}”) and also put a limit for the lower heating value (LHV) of the landfilled material (< 13.000 kJ kg^{-1}) (EC, 2001).

For this reasons, waste pre-treatment have been more and more adopted before landfilling but also before combustion. In this way it is more easy to separate the recyclable material from the pre-treated waste and to managed and to decide the final use of each fractions derived from the initial municipal solid waste (MSW).

The production of waste derived fuel (RDF) is more and more based on mechanical biological treatment plants (MBT). Its utilization is viewed in the European countries as a strategic component of an integrated waste management policy because in this way the quantity of the biodegradable materials that could arrive in a landfill is reduced.

The aim of these MBT plants varies depending on the kind of waste: organic fraction of MSW separated at the source can be converted in compost in composting plants; residual MSW after selective collection can be treated either in one stream bio-drying plants (the aim is the exploitation of the exothermic reactions for the evaporation of the highest part of the humidity in the waste), or in two streams bio-stabilization plants (the aim is the highest conversion of organic carbon with higher volatile solids consumption) to generate, respectively, RDF alone (no initial screening stage is adopted in this case) and RDF in parallel with stabilized organic fraction (SOF) to be used for remediation activities (RAGAZZI 2004; RADA ET AL., 2005A).

In this frame, the biological process modelling is based on the experimental results of a two years research developed by the University of Trento in collaboration with the Politehnica University of Bucharest and recently achieved (RADA, 2005B). The biological stability modelling, implemented for the characterisation of the materials to be landfilled, is based on the experimental results of another two years research recently developed in the University of Trento (LAZAR ET AL., 2005; VENTURI, 2005-2006). The aim was to develop a tool useful to understand the potential problems related to the generation of refuses to be landfilled as a result of the refinement necessary to obtain a high quality RDF.

Presently the modern concept of acceptability of waste for landfilling is based on limits both in terms of biological stability and in terms of maximum allowable Lower Heating Value. That means that when RDF is generated, the materials unsuitable for its generation must have a low putrescibility and must not have a high energy content.

2 Materials and methods

In Table 1 the ultimate analysis of MSW not selectively collected and used for the experiments (RADA, 2005B; VENTURI 2005-2006), is presented. The used processes (one stream = bio-drying, and two stream = screening and bio-stabilization) are schematically represented in Figure 1. The RDF I and RDF II refer to two different qualities of the final product. The main difference concerns in the lower heating value and in the amount of materials discarded.

Table 1 Ultimate analysis of MSW

MSW fractions	kg/kg_{MSW}	kg_{H2O} /kg	kg_C/kg_{ST}	kg_H/kg_{ST}	kg_O/kg_{ST}	kg_N/kg_{ST}
Cellulosic material	7,75%	8,00%	45,00%	6,00%	44,00%	0,16%
Plastic material	4,88%	2,00%	60,00%	14,00%	20,00%	0,08%
Glass	7,52%	2,00%	0,50%	0,10%	0,40%	0,03%
Inert	5,00%	2,00%	0,50%	0,10%	0,40%	0,00%
Organic material	61,59%	67,50%	51,00%	13,00%	28,50%	0,45%
Textiles / leather	0,68%	10,00%	46,00%	7,00%	42,00%	4,65%
Mixed material	9,87%	5,00%	13,00%	5,00%	12,00%	0,08%
Wood	0,00%	0,00%	0,00%	0,00%	0,00%	0,09%
Aluminium	0,00%	0,00%	0,00%	0,00%	0,00%	0,05%
Metals	2,71%	2,00%	4,00%	1,00%	3,00%	0,05%

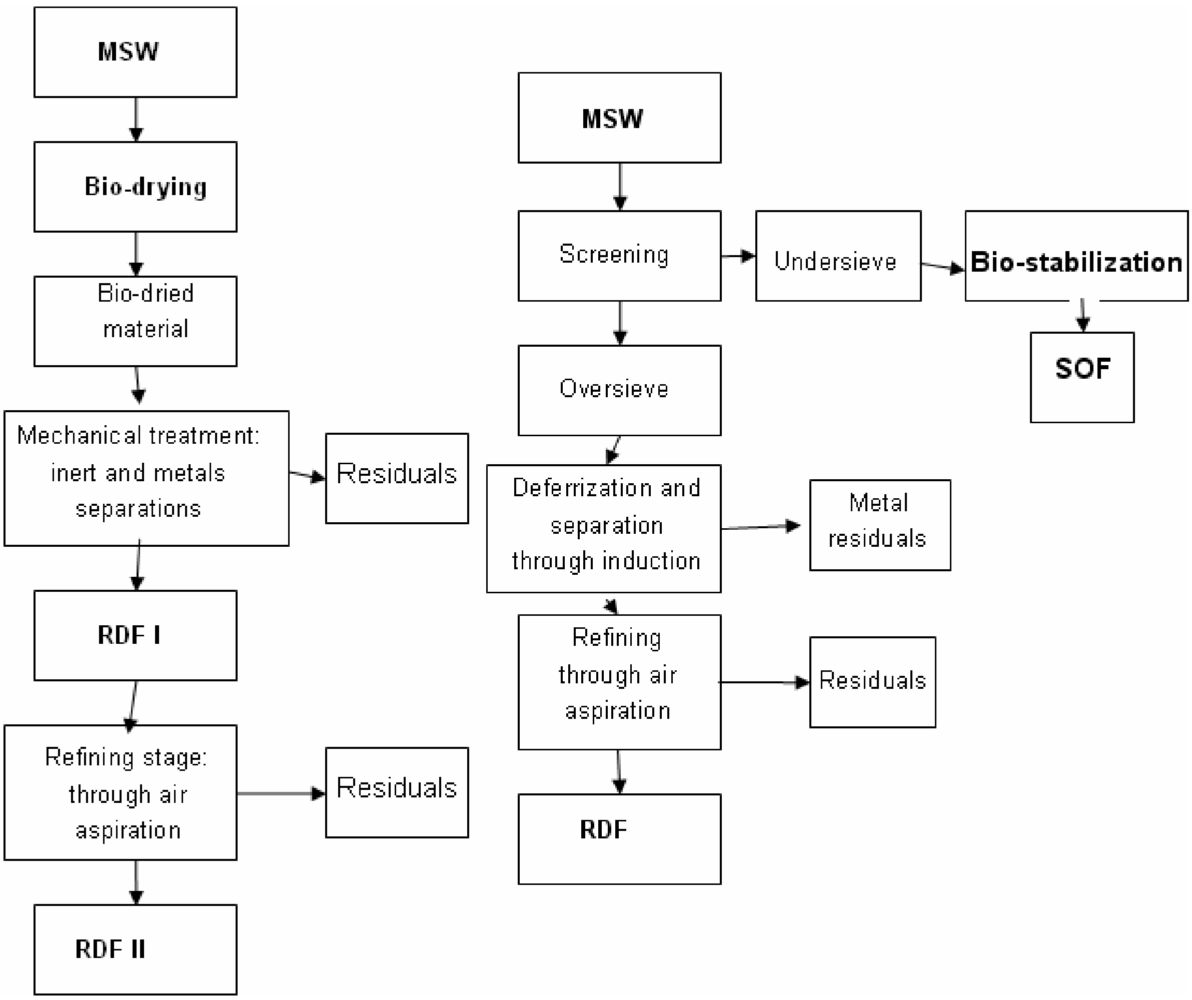

Figure 1 One stream and two streams option

2.1 One stream process

The one stream process lasted 14 days (conventional bio-drying process). At the end of the process it was evidenced a volatile solids (VS) consumption of 15 g and a water loss of 160g (RADA, 2005B).

The next steps after the bio-drying stage are the glass, inert and metals separation for obtaining a RDF and the refinement through an air classifier for arriving to a high quality refuse derived fuel (RDF II).

2.2 Two stream process

For the two stream process the beginning stage is the initial waste sieving (using different sieve mesh). The wet fractions (undersieve material) are sent to a bio-stabilization plant. This material is used for environmental recovery processes or sent to landfilling. The dry fractions (oversieve material), after a deferrization and refining through air aspiration stage, are transformed in RDF.

3 Modelling

For the modelling it was used the same waste compositions for both processes, bio-drying and bio-stabilization. Also for the material obtained after those two processes (bio-dried material from bio-drying and SOF from bio-stabilization) it was assessed the respirometric index (RI) taking into account the VS consumption (Adani el al., 1998). The biodegradability of the waste was assumed depending only on the organic fractions. Using the experimental data (ANDREOTTOLA ET AL., 2001 AND 2005; SILVESTRI ET AL., 2003 AND 2005), it was possible to find a high correlation between consumed VS and the consumed oxygen during the Respirometric tests. As a consequence an RI modelling was implemented (VENTURI, 2005-2006).

3.1 One stream process

Modelling of bio-drying (RADA, 2005B) is based on the following concepts. The input data of the model are the composition of waste sent to bio-drying process. The experimental research previously developed allows to forecast :

- the dynamics of the quantity of air necessary for the process;
- the dynamics of the process air temperature (for energy balances);
- the weight loss dynamics during the bio-drying process.

Using this information the model determines the LHV in three different cases:

- for MSW before sending it into the biological reactor (LHV of MSW as is);
- for MSW after the bio-drying treatment (LHV of the bio-dried material);
- for the material obtained from bio-dried waste after post-refinement (LHV).

The RDF is obtained after a sequence of refinement treatments that is separation of glass, inert and metals from the bio-dried waste. Making other refinements an RDF with more elevated quality can be produced and this is modelled apart. This last refinement generates refuses to be landfilled complying with the EU regulations. To this concern, the developed model takes into account two aspects:

- the refinement is aimed to the extraction of high LHV fractions and then an efficiency is attributed for each fraction of the treated waste based on literature data; the LHV of the discarded materials can then be assessed;
- the putrescibility of the discarded materials depends on the previous history (initial characteristics of waste and lasting of bio-drying); the model converts the composition of the discarded materials in terms of RI, useful for direct considerations on suitability for landfilling.

3.2 Two stream process

Modelling of bio-stabilization (VENTURI, 2005-2006) with a parallel generation of RDF is based on the following concepts. The input data of the model are:

- the material and ultimate composition of waste entering into the plant;
- the efficiency of screening for each fraction (if no data are available, literature data are used; interactions between the fractions are taken into account).

The experimental research previously developed allows to forecast :

- the dynamics of the VS consumption during bio-stabilization of the undersieve;
- the mass balance during the process of bio-stabilization.

The model determines:

- the LHV of waste before and after screening (oversieve and undersieve);
- the LHV for the material obtained from the oversieve after removal of glass, metals and inert (LHV of RDF) with the respective separation efficiencies.

Making other refinements an RDF with more elevated quality can be produced and this is modelled apart. Similarly to bio-drying, this last refinement generates refuses to be landfilled complying with the EU regulations, but their composition is different and the developed model points it out.

4 Results and discussion

The main results for the two strategies are presented as follows. These results are only a part of those generable through the presented modelling.

4.1 Respirometric Index

In Table 2 the results of one stream modelling are presented referring to the respirometric aspects. RI_{24} was calculated as the integral average of data from a 24 hours interval of oxygen consumption under controlled conditions.

Table 2 Results of the modelling of the residues from the second refinement in the one-stream option

	VS (g kg^{-1})	(%)	RI_{24} (mg_{O2} kg^{-1}_{sv} h)
Residues from 2nd refinement	187.06	39.12%	3347.69

Concerning RI of the discarded materials, it has been confirmed that bio-drying gives only a slight conversion of the of the volatile solid content of the MSW. As a consequence, the RI values obtained from modelling pointed out that their values are not significantly different before and after bio-drying. The water content decrease causes an inhibition of the biodegradation reactions, but this inhibition is only temporary: a water addition can reactivate the bio-chemical reactions. The stabilization is only partial (a change in the process lasting cannot be considered as bio-drying slows down for water limitation).

Concerning the two-stream option, an important aspect refers to the RI of the material sent to landfilling. Data concerning this output are reported in Table 3. The values generated from modelling seem to be quite high. However it must be taken into account that the initial MSW has been considered with a high percentage of organic fraction. The mesh with 80 mm presents the best performances, confirming the typical design choices that characterise the sector: the percentage of discarded material is the lowest and the RI is the lowest too. Concerning RI, lower values could be obtained changing the lasting of the process.

Table 3 Modelling characterisation of the material to be landfilled after 2nd post-refinement.

	VS (g kg^{-1})	(%)	RI_{24} (mg_{O2} kg^{-1}_{sv} h)
150 mm	120.76	34.65	3101
100 mm	87.42	24.03	2515
80 mm	84.20	22.70	2442
70 mm	89.82	24.70	2552
60 mm	110.65	32.06	2958

4.2 Lower heating value dynamics

In case of one-stream, bio-drying increases the LHV of a 20%. The following refinement increases the value of an additional 11%. Finally, the second refinement stage gives an additional increase of 15%. Referring to the initial LHV, the specific calorific value of the final material (RDF) shows an increase of 54%. This is a result of energy concentration in a smaller amount of mass. It must not be confused with energy generation.

Concerning the material discarded, the LHV is high, but below the regulation limit. Referring to this parameter, the material can be landfilled but in the reality a light variation of the characteristics of the waste could cause problems for complying the regulations.

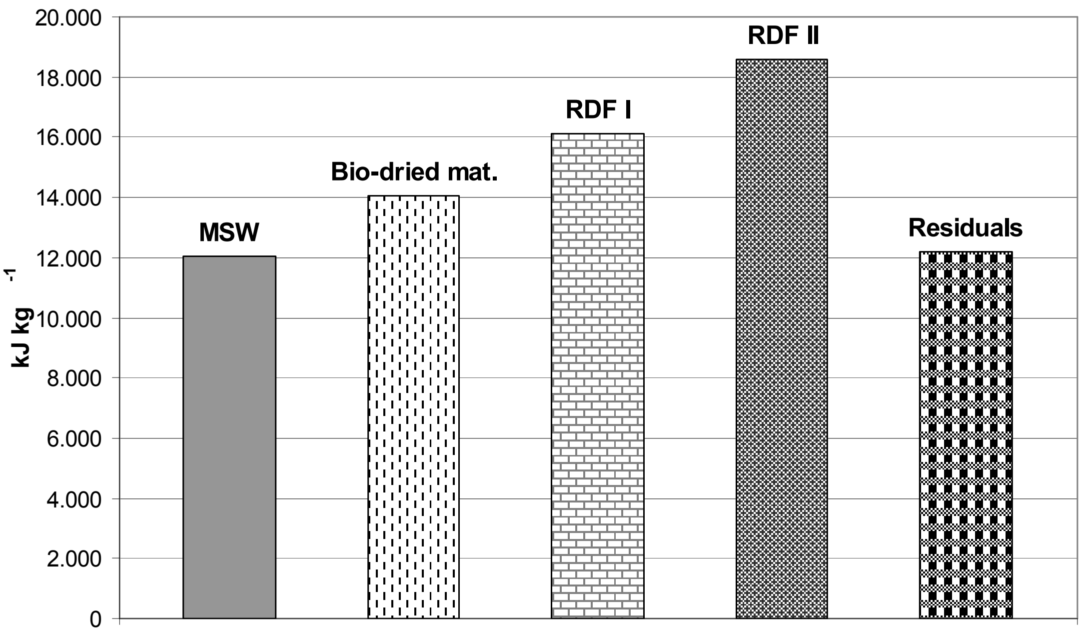

Figure 2 Comparison of LHVs in case of one-stream option

For the case of two streams, the Figure 3 show the balances of the LHVs in a few cases. The mesh 80 mm gives the best results in term of RDF LHV. Landfilling of residuals is not problematic in any case if the LHV were the only parameter to be taken into account.

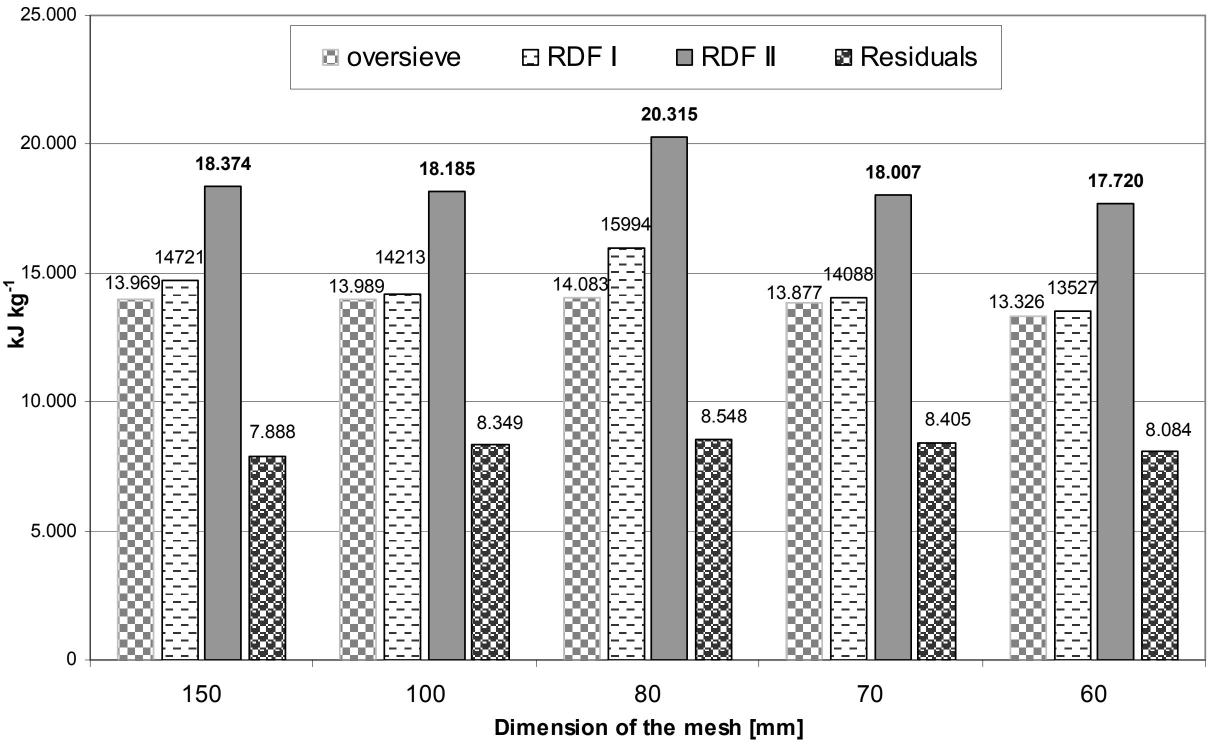

Figure 3 LHVs in the two-stream option

5 Summary

The present paper showed some results of a modelling of two bio-mechanical processes applied to MSW: one stream treatment (bio-drying aimed to RDF generation through post refinement) and two stream treatment (screening for RDF and SOF generation). Experimental data were adopted for completing the scenarios.

In case of one stream treatment, the residuals to be landfilled have a medium-high LHV and a high RI. The value of LHV is suitable for landfilling but troubles related to fluctuations of the MSW characteristics can be expected. RI is too high for landfilling apart form cases where a high RI is accepted anyway (but this strategy does not comply in full with the principles of the EU directives). In Germany, for instance, the required RI is more stringent than the one required in Italy.

Referring to the two stream option, an interesting LHV value for the RDF from oversieve post-refinement has been assessed. The RI of the bio-stabilised undersieve is more compatible for landfilling compared with the case above.

In case a medium quality RDF must be generated, with a zero-ing of landfilling, the one stream option seems to be preferable. In case of high quality RDF must be generated, guaranteeing the landfilling of stabilised material, the two streams seem to be preferable.

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