Municipal Solid Waste bio-drying eco-balance and Kyoto protocol

Ragazzi Marco, Rada Elena Cristina

Department of Civil and Environmental Engineering, University of Trento, Italy

Abstract

Bio-drying is a process aimed to Refuse Derived Fuel generation through water evaporation and post-treatment of selection. This option allows avoiding direct combustion of waste and opens to alternative strategies as co-combustion in thermal power plants where the efficiency of electricity generation could be higher than the one of conventional incinerators. The present paper analyses in details a few aspects related to CO_2 balances for bio-drying in order to give a contribution to a correct understanding of the process.

Keywords

Bio-drying, CO2, emissions, Kyoto Protocol, MSW, RDF

1 Introduction

The European Union (EU) policy recommends to reduce the contribution of municipal solid waste (MSW) management to the environmental impacts and to improve the material recycling and the energy recovery. One of the topic on the carpet today regards the green house emissions from the waste treatment and disposal plants and the Kyoto protocol targets.

One of the waste treatment options that takes into account the aspects requested from the EU policy is the bio-drying process. Bio-drying is an aerobic process that makes part of the Mechanical Biological Treatments (MBT).

For the management of this process an aeration into the waste is adopted. The aim of this process is to exploit the exothermic reactions for evaporating the highest part of the wetness of the waste with the lowest conversion of organic Carbon. This approach is adopted for obtaining a bio-dried material that can be transformed into Refuse Derived Fuel (RDF) after some post-treatments: a post separation of metals, glass and inert allows generating an amount of recyclable materials. Additional post treatments could be adopted in order to obtain a lower amount of RDF with a higher Lower Heating Value (LHV), but this strategy would cause a generation of residues to be landfilled. The impact of landfilling those residues is not zero as fine materials with a residual biological activity could support an uncontrolled anaerobic digestion process in the landfill. The consequent biogas generation, that could not be totally collected, should be responsible for a greenhouse gas impact depending of the amount of methane in the fugitive emissions.

The scheme of this strategy is shown in Figure 1, where an alternative BMT option is also reported: bio-drying is related to the concept of one-stream treatment, as no initial screening is adopted; in the BMT sector the two-stream option is widely adopted but has the disadvantage of generating a stabilized organic fraction that showed big troubles in being used on land alternatively to being landfilled. For this reason the present paper analyses only the one-stream strategy.

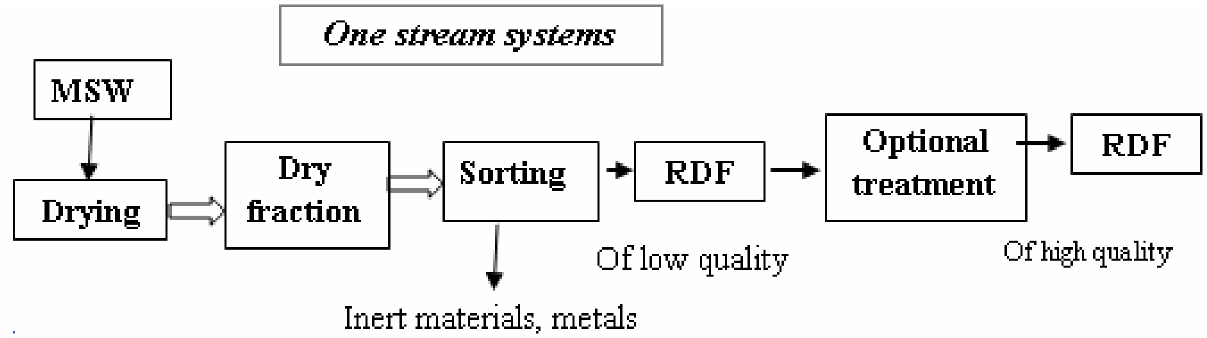

Figure 1 One-stream option based to MSW bio-drying

When bio-drying is proposed, it must be taken into account the organic percentage in the MSW to be processed. That depends on the waste management politics (selective collection efficiency) and economic situation of each country.

The main contents of this paper concern the MSW bio-drying strategy eco-balance and its link to the Kyoto Protocol. The generation of carbon dioxide is related to the biological step where the organic fraction is bio-chemically oxidated. Thus this CO_2 has not to be taken into account referring to the Kyoto Protocol. Anyway the BMT option plays a role in the greenhouse gas balances by the need of electricity (with indirect CO_2 emissions for its generation), by the emission of N_2O and by the CO_2 balance related to the exploitation of RDF through combustion. Concerning the emissions to air, the presence of N_2O gives a contribution that could be not negligible, taking into account that the organic Nitrogen during the bio-drying process is converted into NH_3 and N_2O. The landfilling of the residues generated from the RDF production are not considered in this paper as its generation is taken into account only referring to post-treatment of separation of recyclable materials. To this concern it must be pointed out that the LHV obtainable for RDF without residues generation to be landfilled strongly depends on the LHV of the initial MSW, on its organic fraction content and on its content of glass, metals and inert.

2 Methods

In order to have adequate information on the greenhouse gas emissions from the bio-drying process, a bio-chemical model was used [Rada et al., 2007]. Starting from the ultimate analysis of MSW and using the mass, air flow and temperature dynamics of pilot experimental runs, the model gives as one of the results the dynamics of NH_3 during the bio-drying process. The adoption of an experimental factor in order to assess the N_2O emissions starting from the NH_3 concentrations allows having data useful for a CO_2 balance (N_2O is 310 times more impacting than CO_2). Thanks to this model and assessing the RDF composition from the separation of glass, inert and metals from the bio-dried waste, some scenarios related to the RDF can be created.

From the process point of view, the model gives the parameters reported in Table 1, to be used for overall balances, integrated with real scale data [Rada et al., 2005a and 2006a].

Table 1 Bio-drying parameters

Parameter	Units	Value	Notes
Lasting	D	7-14	Depending on the presence of a recirculation system of process air
Air flow-rate	m^3/kg_{MSW}	3-10	Depending on the presence of a recirculation system of process air and on the amount of organic fraction in the MSW
Mass loss	%	OF%*0.65	OF% = percentage of organic fraction in MSW
Energy loss	%	2%	Referred to the initial LHV of MSW
Volatile solid loss	%	12%	Referred to the overall mass loss
C/VS_{OF}	%	55.7%	Carbon in OF

An important aspect to be taken into account concerns the electrical consumption of the one-stream strategy. In Table 2 some data related to electricity needs are reported. The efficiency of post-separation can be assumed as 100% as a first approximation (high values depends on the fact that the separation process is applied to dried materials) [Rada et al., 2006b].

Table 2 Electrical consumptions

Stage	Units	Value	Notes
Shredding	kWh/kg_{MSW}	0.011	Adopted to open bags
Aeration	kWh/kg_{MSW}	0.035	Without air recirculation
Moving	kWh/kg_{MSW}	0.015	Before and after bio-drying
Post-separation	kWh/kg_{MSW}	0.008	Inert, metals and glass separation

At the base of the calculations it is important to state the emission factors related to bio-drying and process air treatment. In Table 3 some data are reported. Two scenarios are taken into account: a simple bio-filter or a bio-filter with a regenerative thermal oxidation system (RTO). In the second case a consumption of natural gas characterises the approach with a consequent generation of CO_2. Data refers to real scale plants [Rada et al., 2005b and 2006c]. An intermediate case could be set with process air treatment based only on RTO. The limit of this intermediate approach is related to the emissions of NH_3, as the efficiency of bio-filter should be missed. As NH_3 plays an important role in the generation of secondary particulate (reacting with NO_x [Rada et al., 2006d]) in the present paper it has been chosen to study the effect of coupling bio-filter and RTO. Additionally the absence of a bio-filter could worsen the emission factor of N_2O.

Table 3 Emission factors related to CO_2

Pollutants	Units	Emission factors for the case with bio-filter	Emission factors for the case with bio-filter+RTO
CO_2 (fossil)	kg/t	0	19.6
N_2O-N	g/t	5.5	5.5
CH_4	g/t	0	0
CO_2 (non fossil)	kg/t	47.6	47.6

The calculations refer to the MSW characterized in Table 4. In particular, apart from the general data on MSW, it was important to assess some details on organic fraction content, on Carbon presence in and out of biodegradable fractions, on Nitrogen presence in the volatile solids.

Table 4 MSW characterisation for the case-study

Parameter	Units	Value	Notes
Wetness	%	33.57	-
VS/TS	%	72.87	TS = total solids
C_{MSW}	%	29.18	Overall MSW
H_{MSW}	%	4.02	Overall MSW
O_{MSW}	%	14.91	Overall MSW
N_{MSW}	%	0.30	Overall MSW
OF%	%	30	Organic fraction %
C_{fossil}	%	12.13	Referred to MSW
$C_{non.fossil}$	%	17.05	Referred to MSW

Concerning the use of RDF many options are potentially available: co-combustion in cement works, co-combustion in thermal power plants (both as partial substitute of conventional fuels as coal), combustion in dedicated plants. In the present paper the selected case-study concerns the use in existing thermal power plants as the aim is the comparison between a conventional option (direct combustion) and an alternative option with the maximisation of electricity generation by RDF exploitation (high capacity thermal power plants show high efficiency to this concern).

Concerning direct combustion, data from Table 4 allow the assessment of a greenhouse gas balance apart from three aspects. The first one is related to the CO_2 emissions from plant construction. This aspect will not be taken into account for all the considerations (thus also for the construction of a bio-drier). The second one concerns the emission factor of N_2O. In this case, the literature gives data in the case of direct combustion: a value of 6 g N_2O /t_{MSW} will be assumed [Rada et al., 2006c] supposing the adoption of a catalytic treatment of the off gas. In the case of a thermal power plant the emission factor of direct combustion without a catalytic stage [Rada et al., 2006c] has been adopted as the process is anyway a combustion: 30 g N_2O /t_{MSW}. The third one concerns the efficiency of electricity generation through direct combustion of MSW. In this case, supposing the construction of a large MSW incinerator, the net efficiency of electricity conversion can be assumed as 28%.

Co-combustion as substitution of coal means partial substitution of fossil CO_2. For making this calculation the emission factor from coal is necessary. In the case study data for the thermal power plant that receive the RDF for co-combustion are reported in Table 5.

Table 5 Thermal power plant data

Parameter	Units	Value	Notes
LHV	MJ/kg_{coal}	30	Coke
C	%	90	-
Electrical efficiency	%	40	Referred to a large scale

3 Results and discussion

In Table 6 some results related to the presented case-study (bio-drying of MSW with 30% organic fraction content) are reported. In particular, data refer to the characterisation of the RDF that can be generated. Additional data refer to the substitution of coal through RDF. From Table 6 it is clear that the effect of bio-drying and post-treatment is a concentration of energy in a lower mass. The resulting LHV of RDF can be considered good as higher than 15 MJ/kg value considered a target for RDF generation.

Table 6 RDF characterisation and balances for the case-study

Parameter	Units	Value	Notes
Initial LHV	kJ/kg_{MSW}	11818	-
Initial mass loss	%	19.5	Only by bio-drying
$LHV_{biodried\ mat.}$	$kJ/kg_{biod.mat.}$	14387	-
Post-selection loss	$kg_{reciclable}/kg_{MSW}$	0.108	Glass, metals, inert
Net RDF mass	Kg_{RDF}/kg_{MSW}	0.697	-
$C_{fossil.RDF}$	kgC_{fossil}/kg_{RDF}	0.174	Useful for CO_2 assessment
LHV_{RDF}	kJ/kg_{RDF}	16129	-

In Tables 7 and 8 the balances of CO_2 are reported. The calculations take into account direct and indirect CO_2 emissions. N_2O has been converted into equivalent CO_2 through an equivalent factor. In this case the bio-filter option has been considered.

Table 7 CO2 balances for direct combustion

Parameters	**Units**	**Direct combustion**	**Notes**
Fossil C	kg_{CO2}/kg_{MSW}	0.444	-
N_2O role	kg_{CO2}/kg_{MSW}	0.002	-
Electricity generation	kg_{CO2}/kg_{MSW}	-0.900	Saving coal
Overall balance	kg_{CO2}/kg_{MSW}	-0.454	-

Table 8 CO_2 balances for indirect combustion (co-combustion)

Parameters	**Units**	**Indirect combustion**	**Notes**
RDF generation	kg_{CO2}/kg_{MSW}	0.068	Electricity from coal
Biological N_2O role	kg_{CO2}/kg_{MSW}	0.002	-
C_{RDF} combustion	kg_{CO2}/kg_{MSW}	0.444	Fossil C in RDF
Thermal N_2O role	kg_{CO2}/kg_{MSW}	0.010	-
Electricity generation	kg_{CO2}/kg_{MSW}	-1.135	Saving coal by RDF
Overall balance	kg_{CO2}/kg_{MSW}	-0.611	-

It must be pointed out that according to the hypotheses, no difference between options is taken into account as depending on transportation emissions. That means the plants are assumed to be all close one to the other.

Data in Tables 7 and 8 demonstrate that in spite pre-treatment of MSW for RDF generation costs energy (electricity and a minor amount of the initial LHV), the availability of a large scale thermal power plant where RDF could substitute coal could be an interesting opportunity. Even if we consider an RTO the advantages of RDF in a large thermal power plant are confirmed.

This advantage would be more clear if the conventional strategy of direct combustion were based on a small area of MSW generation. In this case a low capacity incinerator would be associated to a low electrical generation efficiency: the scale effect is one of the problems of MSW combustion.

4 Conclusions

In this paper a strategy based on MSW bio-drying for RDF generation has been analysed. By this option direct combustion is avoided. Among the alternative strategies based on RDF, co-combustion in thermal power plants has been selected as a case study as the efficiency of electricity generation can be higher than the one of conventional incinerators. The present paper has analysed in details a few aspects related to CO_2 balances for bio-drying in order to give a contribution to a correct understanding of the process. Results show that the role of N_2O is not dominant in the case of the bio-drying option. Also in direct combustion this pollutant plays a secondary role. RTO has some disadvantages related to the use of natural gas but in terms of CO_2 the results are acceptable.

5 Literature

Rada E.C., Franzinelli A., Taiss M., Ragazzi M., Panaitescu V., Apostol T.	2007	Lower Heating Value dynamics during municipal solid waste bio-drying, Environmental Technology, vol. 28, pp.463-469.
Rada E. C., Taiss M., Ragazzi M., Panaitescu V., Apostol T	2005.a	Un metodo sperimentale per il dimensionamento della bioessiccazione dei rifiuti urbani, Rifiuti Solidi, Anno XIX, N.6, pp. 346-353, ISSN: 0394-5391.
Rada E. C., Ragazzi M., Panaitescu V., Apostol T	2006.a	Experimental characterization of Municipal Solid waste bio-drying, Waste Management and Environment III, Vol. 92, pp. 295 – 302, ISBN I-84564-173-6.
Rada E. C., Ragazzi M., Fabbri L., Panaitescu V., Apostol T	2006b	Life Cycle Analisis applicata alla bioessiccazione: aspetti energetici, Rifiuti Solidi, Vol. XX, N.2, pp. 89-97, ISSN: 0394-5391.
Rada E. C., Ragazzi M., Panaitescu V., Apostol T	2005b	Energy from waste: the role of bio-drying, Stintific Buletin (Ro), seria C: Electrical Engineering, vol 67, nr. 2, pp. 69-76, ISSN 1454-234x.
Rada E. C., Fabbri L., Ragazzi M., Panaitescu V., Apostol T	2006c	Life Cycle Analisis applicata alla bioessiccazione: aspetti ambientali, Rifiuti Solidi, Vol. XX, N.3, pp. 183-190, ISSN: 0394-5391
Rada E. C., Cocarta D., Ragazzi M., Panaitescu V., Badea A.	2006d	Trattamenti meccanico-biologici di RU e particolato secondario, XII Convegno di Igiene Industriale – Corvara (BZ), versione CD, Italy.