

MODELING OF MUNICIPAL SOLID WASTE (MSW) INCINERATION IN SPAIN AND PORTUGAL

María Margallo ^{(1)}, Rubén Aldaco ⁽¹⁾, Alba Bala ⁽²⁾, Pere Fullana ⁽²⁾, Angel Irabien ⁽¹⁾*

*⁽¹⁾Departamento de Ingeniería Química y Química Inorgánica, Universidad de Cantabria,
Avda. de Los Castros, s.n., 39005, Santander, Spain*

Tel. +34 942 200931, e-mail: margallom@unican.es; fax: +34 942 201591;

*⁽²⁾Escola Superior de Comerç Internacional (ESCI-UPF), Pg. Pujades 1., 08003 Barcelona,
Spain*

*Keywords: incineration, Municipal Solid Waste (MSW), multifunctional process, Portugal,
Spain*

ABSTRACT

LCA of waste management systems involve the treatment of a waste mixture with different characteristics. So, it was necessary to estimate the impacts associated to each waste fraction using different allocation rules. These types of systems are so called multi-functional process being incineration a clear example. In this paper the Life Cycle Inventory (LCI) and a multi functional model were developed to describe Municipal Solid Waste (MSW) incineration in Spain and Portugal. In the model, whenever possible, physical and chemical causation allocations were applied. When a causation relationship cannot be established, allocation was done based on a physical parameter (energy or mass).

1. INTRODUCTION

In the recent years several LCA studies have been focused in the waste management field. The main difficulty found in these studies was that it involves the treatment of a mixture of waste with different characteristics. So, it was necessary to estimate the impacts associated to each waste fraction using different allocation rules. These types of systems are so called multi-functional being incineration process a clear example, where several inputs and outputs coexist. In this work the Life Cycle Inventory (LCI) and a multi-input/output allocation model were developed to describe Municipal Solid Waste (MSW) incineration in Spain and Portugal. This work was developed within the framework of FENIX-Giving Packaging a New Life, a 3-year European LIFE+ funded project. The aim of this project is to develop a flexible and user-friendly software tool to be used by Spanish and Portuguese municipalities and other territorial organizations, to obtain LCA results for waste management, integrating environmental, economic and social aspects.

2. MUNICIPAL SOLID WASTE INCINERATION IN SPAIN AND PORTUGAL

According to the European Pollutant Release and Transfer Register E-PRTR and Directive 2008/1/EC, the so-called IPPC Directive (that replaced Directive 96/61/EC), there are 10

Spanish facilities and 3 Portuguese plants included in group 5.b; installations for the incineration of non-hazardous waste with a capacity of 3 tonnes per hour (European Parliament and Council, 2006) (Margallo et al., 2012).

Similar technologies are applied in all these plants; they differ on the age, number of lines and incineration capacity. Particularly, two types of thermal treatment technologies, grates and in a less extend fluidized beds are used in the Spanish and Portuguese incinerators. About flue gases treatment, there is not a significant variation in the type of technology used and the reagents consumed. In particular, for particles reduction, electrofilters and bag filter are the most common technologies, and to a less extent cyclones and multicyclones. For acid gases such as HCl, HF and SO_x it is common the use of a dry and semi-dry scrubbers with an alkaline reagent such as CaO and Ca(OH)₂. To remove NO_x two technologies are applied, the Selective Non Catalytic Reduction (SNCR) and the Selective Catalytic Reduction (SCR). In both cases NH₃ or urea is the reagent used to reduce the NO_x to N₂. Other important pollutants generated during the combustion are organic compounds like Polycyclic Aromatic Hydrocarbons (PAHs) or dioxins and furans (PCDD/F). These substances are usually treated by an injection of activated carbon.

The main product and one of the most important environmental benefits of the incineration process is the energy recovery. Energy production is similar in all the plants and in the range of other studies; however, the oldest plant the lower energy recovery. In the Iberian Peninsula 83% of this energy is sold to the grid and the rest is consumed in the incineration plant. During the combustion apart from the energy and flue gases, ashes and slag are generated. 19% wt. of the input waste are transformed in slag. The total weight of inert materials, aluminium, steel and glass, is transferred to slag, whereas burnable materials are transferred in a less extend. Subsequently, slag is subjected to a magnetic separation in order to obtain scrap that will be use in the steel production. In Spain and Portugal about a 9.8% of scrap is recovered from slag. On the other hand, about 4.3% of ashes are generated. Basically ashes are composed of non inert materials, HDPE, LDPE, Beverage carton, plastic mix, organic matter and paper and cardboard. A solidification process is required to stabilize the ashes in order to be landfilled (Margallo et al., 2013).

3. LIFE CYCLE ASSESSMENT METHODOLOGY

3.1 Goal and scope

The aim of the work is to develop the LCI of the incineration process in Spain and Portugal and to model it. As the main function of incineration is to treat waste so as to reduce the volume and hazard of waste, the functional unit has been defined as 1 ton of MSW fractions (PET, HDPE, LDPE, plastic mix, paper and cardboard, beverage carton, glass, steel, Al, rest of materials and organic matter). In this study were included all the material and energy inputs and outputs of the different incineration process stages. Out of system boundaries are the construction of major capital equipment as well as the maintenance and operation of support equipment. The system is divided 4 subsystems: thermal treatment, flue gases treatment, ash solidification with cement, ash landfill and slag landfill.

3.2 Data collection: Life Cycle Inventory

Data inventory is coming from (a) site specific operating data collected from the Spanish

Association of MSW valorisation plants (AEVERSU), the Spanish packaging waste management association (Ecoembes) some incinerators and the European Pollutant Release and Transfer Register (E-PRTR) and, (b) bibliographic data. These data consist of annual material and energy inputs and outputs for the operation of Spanish and Portuguese plants in 2009. The main inputs are the amount of waste incinerated and the consumption of water, air, combustible and reagents. The main outputs are the energy and solid residues generated and the emissions to air.

3.3 Modelling of the multi input/output allocation process

In this section the allocation rules applied are going to be discussed.

- *Combustible, reagents and auxiliary materials consumption*: as there isn't relation between these consumptions and waste composition so non causality criterions such as mass allocation must be applied.
- *Emissions to air*: emissions of CO₂, CH₄, CO, carbon compounds, heavy metals, SOX, HCl and HF depend on the input waste composition. So they are allocated according to causality criterion based on the carbon and fossil carbon, Cl, F, S and heavy metals content of the input waste fraction. On the other hand, the emission of other pollutant such as nitrogen compounds and particles depends on the applied technology rather than waste composition. These pollutants are allocated based on non causality criterions.
- *Energy recovery*: in this case, the heating value of each waste fraction must be used to carry out the energy production allocation.
- *Waste generation*: both solid residues must be allocated to the input waste fraction using mass allocations.

3.4 Life Cycle Impact Assessment

The environmental assessment of the proposed scenarios was carried out following the ISO 14040 and ISO 14044 requirements (ISO 14040, 2006 and ISO 14044, 2006) with the LCA software GaBi 4.4 (PE International, 2011) and the environmental impact method proposed by CML. The selected impact categories were: Acidification Potential (AP) [kg SO₂-Equiv.], Global Warming Potential (GWP 100 years) [kg CO₂-Equiv.] and Human Toxicity Potential (HTP inf.) [kg DCB-Equiv.]. Table 1 shows the main results of the impact assessment for a packaging waste fraction divided in the different stages of the process: thermal treatment, flue gases treatment, ash solidification and landfill.

Table 1. Environmental impacts of incineration process.

| | Thermal treatment | Flue gases treatment | Ash solidification | Ash landfill | Slag landfill |
|---|--------------------------|-----------------------------|---------------------------|---------------------|----------------------|
| AP [kg SO ₂ -Eq.] | 5.91E-01 | 1.49E-02 | 1.75E-02 | 3.74E-03 | 2.12E-02 |
| GWP 100 years [kg CO ₂ -Eq.] | 2.31E+03 | 2.31E+01 | 9.57E+00 | 5.31E-01 | 1.01E+01 |
| HTP [kg DCB-Eq.] | 6.80E+00 | 1.55E-01 | 3.35E-01 | 1.27E-02 | 3.47E-01 |

According to these results, thermal treatment represents the highest impact in all the

categories due to the combustion process, where green house gases (global Warming), acid gases (acidification), dioxins and furans and heavy metals (human toxicity) are generated. In other order of magnitude, are the impacts of ash solidification, flue gases treatment and ash and slag landfill. The impact of flue gases treatment is associated to the reagents production, mainly urea that has a high toxicity. And finally, cement production is the main contributor in the ash solidification impact.

5. CONCLUSIONS

In this work the most relevant technologies applied in MSW incineration in Spain and Portugal were determined. Regarding the thermal stage, grate incinerators, and FB are in the Iberian Peninsula. Specifically, in Spain the application of grate incinerators makes up 80% of incinerators, rising to 100% in Portugal. The majority of the energy produced is used for the self consumption at the plant (83%) and the rest is sold to the public grid. The amount of energy produced differs from one plant to another and depends on the amount of waste incinerated and the heating value.

When incineration is going to be modelled it is important to note that it is a multi-input/output allocation process. To solve this problem several allocation where applied. When a relationship could be established, physical allocation based on waste composition were applied and when this was not possible a mass or energy allocation was used.

Finally, the results of the impact assessment show that the thermal is the stage with a highest impact due to the emissions generated in the combustion.

ACKNOWLEDGEMENT

The authors gratefully acknowledge the financial support of FENIX-Giving packaging a New Life project.

REFERENCES

- European Parliament and Council (2006). Regulation (EC) No 166/2006 of the European Parliament and of the Council of 18 January 2006 concerning the establishment of a European Pollutant Release and Transfer Register and amending Council Directives 91/689/EEC and 96/61/EC.
- Fullana P. & Puig R. (1997). Análisis de Ciclo de Vida. Ed. Rubes.
- ISO 14040. (2006). Environmental management - Life cycle assessment - Principles and framework.
- ISO 14044. (2006). Environmental management - Life cycle assessment –Requirements.
- Margallo M., Aldaco R., Bala A., Fullana P., & Irabien A. (2012). Best Available Techniques in municipal solid waste incineration: state of the art. *Chemical Engineering Translations*, 29, 1345-1350.
- Margallo M., Aldaco R., Bala A., Fullana P., & Irabien A. (2013). Life Cycle Inventory of Municipal Solid Waste Incineration (MSWI) in Spain and Portugal. *Proceedings of the Vth International Conference on Life Cycle Assessment, CILCA 2013. Best Available Techniques in municipal solid waste incineration: state of the art. Chemical Engineering Translations*, 29, 1345-1350.
- PE International. (2011). GaBi 4.4 Software and Databases for Life Cycle Assessment. Leinfelden-Echterdingen, Germany.