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PLASMIX management: LCA of six possible scenarios

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ABSTRACT

Only a small percentage of the separately collected plastic is recycled. The mechanical selection process of source segregated plastic materials generates considerable amounts of residues that are commonly named as *Plasmix*. By means of a life cycle assessment (LCA) modelling, the environmental performances of the main Plasmix management options (thermal treatment, energy recovery, and landfilling) were compared. Six treatment scenarios, with different pre-treatment alternatives, were evaluated.

Landfilling after waste washing and Plasmix substitution of coke in a blast furnace represent the most favorable options, since the performances of thermal treatment and energy recovery are worsened by specific emissions of a variety of toxic compounds and heavy metals within plastic materials as additives.

1. Introduction

Modern sustainable waste management strategies cannot exclude source segregation and separate collection of valuable materials (D'Onza et al., 2016; Vučijak et al., 2015).

Among these, separate collection of plastic packaging waste plays an important role, since it is commonly recognized as a environmental and social problem due to the ubiquitous presence of plastic packaging for daily-use and short-life applications like transportation, preservation and distribution of goods (Bajracharya et al., 2015; Sevigné-Itoiz et al., 2015). In Europe, post-consumer plastic waste generation reached 25.8 million tons, corresponding to approximately 50 kg/p/y in 2014 (Plastics Europe, 2015). For this reason, plastic material recycling is pivotal in limiting the exploitation of non-renewable resources, such as the fossil oil needed for production of virgin plastic (Luijsterburg and Goossens, 2014). Source separation of all plastic (80% efficiency for bottles; 50% efficiency for the other plastic fractions), leading to an overall plastic collection efficiency of about 58% (Rigamonti et al., 2014). Besides the quantity of residues, plastic material waste represents a potential threat due to chemical additives, several of which are hazardous, used for producing plastic polymers which are derived from non-renewable crude oil. Monomers polymerization usually needs the addition of solvents and stabilizers (antioxidant metal compounds), flame retardants, pigments (heavy metals) and fillers (inorganic mineral powders) to assure a good quality product. All these non-polymeric components are usually characterized by low molecular weight and, therefore, may be released during the production, use and disposal of the plastic product migrating to air, water or other contact media (Lithner et al., 2011).

Separately collected plastic waste is usually mechanically treated for the recovery of the most valuable polymers but this process is associated to limited efficiencies (Kunwar et al., 2016; Subramanian, 2000). The residual part arising from mechanical treatment is a mixture of polymers which is called "Plasmix" in Italy (COREPLA, 2015; ISPRA, 2015). Plasmix consists of two different fractions coming from plastic waste mechanical treatments namely the undersieve from the size separation equipment and the final residues from the whole mechanical sorting operations also known as "End-of-line" or "End-of-belt" (Fig. 1). In the Italian context, Plasmix composition was reported by Rossi et al. (2010) as a mixture of the following percentages based on wet weight: plastic (57%), paper and cardboard (10%), wood (3%), textiles (3%), inerts and others (including metals) (27%).

At present in Italy, Plasmix is incinerated (57%), used as a substitute to coal burning in cement kilns (27%), or landfilled (16%) (COREPLA, 2015; Rigamonti et al., 2014; Rossi et al., 2010). Therefore, different alternatives for Plasmix management ranging from thermal options (direct incineration, gasification, cement kiln, thermal power plant) to landfilling may be considered. Some of these alternatives could be preceded by refuse-derived fuel (RDF) preparation.

A theoretical way of defining the best Plasmix management option in terms of environmental sustainability is offered by the Life Cycle Assessment (LCA) methodology, which was proven to be a reliable decision-making support tool for modern integrated

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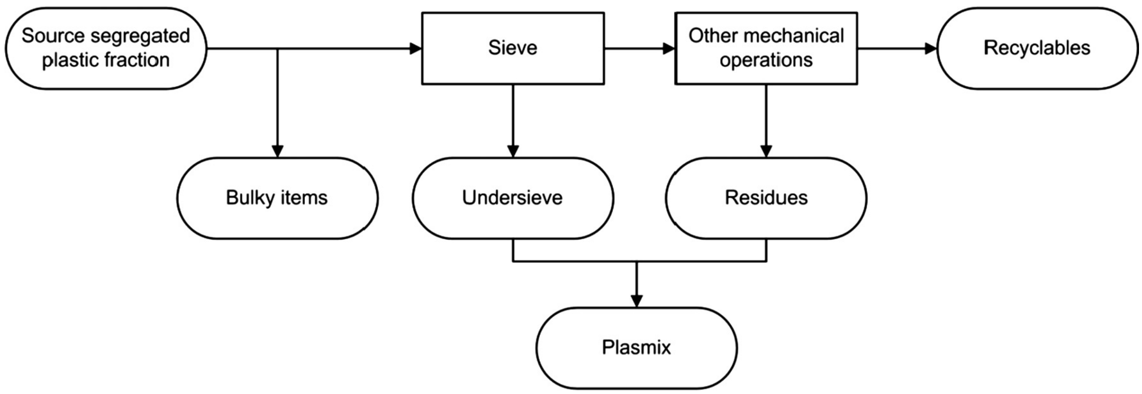

Fig. 1. General layout of a facility for the selection of material derived from plastic recycling. Modified from Rossi et al. (2010).

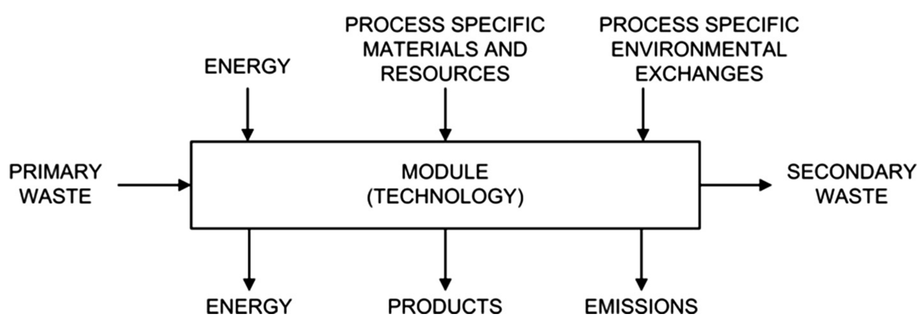

Fig. 2. Conceptual design of a process module in EASEWASTE. Modified from Riber et al. (2008).

waste management systems (Rossi et al., 2010; Blengini et al., 2012). LCA is a tool to assess the potential environmental impacts and resources used throughout a product's life-cycle, i.e., from raw material acquisition, via production and use phases, to waste management (Finnveden et al., 2009). LCA is a comprehensive assessment and considers all attributes or aspects of natural environment, human health, and resources (ISO, 2006).

The novel analysis performed in this study does not address economical aspects or the evaluation of the recycling process itself, but aims to assess the main options for Plasmix management with the LCA-model EASEWASTE to compare their potential environmental impacts (Fig. 2). EASEWASTE (Environmental Assessment of Solid Waste Systems and Technologies), is a computerized LCA-based model for integrated waste management (Christensen et al., 2007). EASEWASTE provides a versatile system modelling facility combined with a complete life-cycle impact assessment and in addition to the traditional impact categories addresses toxicity-related categories (Christensen et al., 2007). EASEWASTE provides default datasets (Kirkeby et al., 2007). Real Plasmix characterization data were used to calibrate the scenarios of the model, boundary condition considers only the treatment of the material, without taking into account its production. Results obtained from the same initial residues were compared each other by means of some environmental impact categories to evaluate the best performing scenario. A sensitivity analysis was also performed.

2. Materials and methods

2.1. Plasmix characterization

The functional unit for the LCA analysis was represented by the treatment of 1 ton of Plasmix fraction produced by a generic plastic packaging selection plant. For this purpose, chemical composition, comprehensive of ash, chlorine and heavy metals, was performed on samples taken from a plastic packaging waste selection plant located in the North of Italy (Table 1). The plant receives the source segregated plastic waste fraction of the municipal solid waste collected door to door. This specific waste stream includes plastic containers (PE, PET, PP), plastic films (PE), and non-recyclable plastic (PVC). A total of five samples (500 kg) were collected and analyzed during one year in order to consider the possible seasonal variations. Chemical analysis was performed after shredding the waste with a laboratory-scale chipper. The LCA investigation took into account only the environmental impacts produced by the transportation and treatment of Plasmix exiting the selection plant, thus neglecting the previous phases. All the considered parameters were determined according to the Italian Analytical Standards for solid samples (CNR-IRSA, 64/1986). Plasmix was characterized by a high heating value that makes this material even classifiable as RDF.

Table 1
Plasmix chemical characterization.

Name	Unit	Value	Name	Unit	Value
Heating value	(GJ/tonTS)	25.3	S	(%TS)	0.08
H_2O	(%)	23%	Al	(%TS)	0.56
TS	(%)	77%	As	(%TS)	0.001
TC	(%TS)	70.6	Cd	(%TS)	0.0006
TOC	(%TS)	55.4	Cr	(%TS)	0.01
Ca	(%TS)	1.1	Cu	(%TS)	0.001
Cl	(%TS)	0.62	Fe	(%TS)	0.08
F	(%TS)	0.01	Hg	(%TS)	0.00074
H	(%TS)	6.4	Mg	(%TS)	0.04
K	(%TS)	0.12	Mn	(%TS)	0.06
N	(%TS)	1.0	Ni	(%TS)	0.007
Na	(%TS)	0.11	Pb	(%TS)	0.05
O	(%TS)	11.1	Zn	(%TS)	0.007
P	(%TS)	0.56			

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