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# Evaluation of performance indicators applied to a material recovery facility fed by mixed packaging waste

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ABSTRACT

Most of the integrated systems for municipal solid waste management aim to increase the recycling of secondary materials by means of physical processes including sorting, shredding and reprocessing. Several restrictions prevent from reaching a very high material recycling efficiency: the variability of the composition of new-marketed materials used for packaging production and its shape and complexity are critical issues. The packaging goods are in fact made of different materials (aluminium, polymers, paper, etc.), possibly assembled, having different shape (flat, cylindrical, one-dimensional, etc.), density, colours, optical properties and so on. These aspects limit the effectiveness and efficiency of the sorting and reprocessing plants. The scope of this study was to evaluate the performance of a large scale Material Recovery Facility (MRF) by utilizing data collected during a long period of monitoring. The database resulted from the measured data has been organized in four sections: (1) data related to the amount and type of inlet waste; (2) amount and composition of output products and waste; (3) operating data (such as worked hours for shift, planned and unscheduled maintenance time, setting parameters of the equipment, and energy consumption for shift); (4) economic data (value of each product, disposal price for the produced waste, penalty for non-compliance of products and waste, etc.). A part of this database has been utilized to build an executive dashboard composed by a set of performance indicators suitable to measure the effectiveness and the efficiency of the MRF operations. The dashboard revealed itself as a powerful tool to support managers and engineers in their decisions in respect to the market demand or compliance regulation variation as well as in the designing of the lay-out improvements.

The results indicated that the 40% of the input waste was recovered as valuable products and that a large part of these (88%) complied with the standards of the recycling companies. The evaluation of the indicators led to the decision to modify the layout to improve the interception of some polymers for which the performance indicators were poor. In particular, two additional optical sorters have to be inserted to increase the yield indicator and to the overall performance of the facility. Definitely, the results of the work allowed to: increase the yield and purity of products' flows; ensure the compliance of waste flows; increase the workability.

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## 1. Introduction

Waste management is become a crucial point of the political agenda of industrialized Countries since late 1960s, when the effect of indiscriminate use of landfilling and incineration without effluent treatment and energy recovery created environmental concerns and societal impacts. Today, the new paradigm of circular economy considers the waste management as an inseparable part of the manufacturing of goods production, farming as well as energy production (Mastellone, 2015). The reprocessing of recyclable materials extracted by waste flows has been approached in two significantly different ways: (1) source separation at

*Abbreviations:* MRF, material recovery facility; LCA, life cycle assessment; LDPE, low density polyethylene; HDPE, high density polyethylene; PP, polypropylene; PET, polyethylene terephthalate; Plasmix, residual composed by plastic mixture from MRF sorting operations; 2D, referred to two dimensional shape materials; 3D, referred to three dimensional materials; $LWW_a$, light weight waste coming from household collection; $LWW_b$, plastic liquid containers as obtained by pre-processing and bailing; LC, packaging liquid containers larger than 350 ml.

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individual households and subsequent separate collection systems; and (2) mechanical processing and sorting of mixed residual waste at central facilities. Currently, the waste flows separated at household level need to be mechanically sorted and cleaned to carry out the reprocessing to obtain secondary materials. The material recovery facilities (MRFs) play a pivotal role in today integrated solid waste management systems (Cimpan et al., 2015) to favour the increasing of material recovery, to pre-treat the waste destined to a cleaner energy recovery and to promote the reducing of the economic costs of the total waste management chain. The MRF plant design and process configurations change owing to regional differences such as inflowing waste compositions, plant size, availability of manual labour and regulatory frameworks (Cimpan et al., 2015). Some Authors studied the effect of MRF in the waste management system with a specific reference to the costs (Cimpan et al., 2016b), environmental impacts by Life cycle assessment (LCA) (Bueno et al., 2015; Cherubini et al., 2009) and technical features (Feil et al., 2016; The Dougherty Group, 2006). Nonetheless, in general, industry surveys and benchmarks for MRFs are rare and the data on process efficiency are largely missing (Cimpan et al., 2016a; The Dougherty Group, 2006).

The main waste component, for which the efforts to increase its recovery is continuously growing, is the packaging fraction constituted by plastics, ferrous, aluminium and cellulose-based materials, also known as lightweight waste (LWW). The plastic packaging represents in fact the 39.5% of the whole plastic market and its utilization is continuously growing in China and Asian Countries (PlasticsEurope, 2015). The recycling of polymers has to be preceded by an accurate sorting; a number of techniques have been developed in order to separate and sort plastic waste in such a way to increase the effective recovery and recycling (Al-Salem et al., 2009; Cimpan et al., 2015; Muise et al., 2016; Schlosser et al., 2015; Subramanian, 2000). In the recycling industry, beside the different Countries regulations affect the market of secondary materials in a dominant way (Stromberg, 2004), the sorting and identification must be attempted within a short time and on large throughout in order to have a good economic revenue (da Cruz et al., 2014).

In the case of lightweight waste sorting, automated techniques are based on difference in shape, size, colour and optical properties. The MRF utilizes automatic sorting to reach high yields and treatment capacities but also needs of the manual sorting in order to maximize the purity of each single output material flow. The MRF to which this study refers, is a part of a waste management system characterized by a waste separation made at a household level and by a kerbside collection system. Kerbside collection is generally realized by using trucks dedicated to collect a given waste stream that citizens prepared by separating the recyclables upstream the collection. The general request to increase quality of recyclables induces to modify the collection method in order to increase the centralized sorting efficacy in the MRF. Generally, two prevailing collection systems are utilized: (a) single-stream commingled, whereby all recyclables, i.e. paper (old newspapers, advertisement and magazines, office paper), cardboard, plastic bottles and containers, aluminium and steel cans, glass and liquid carton containers, are collected in a single mixed form (not all materials enumerated are always included), allowing pickup using standard semi-automated or automated refuse collection vehicles; (b) dual-stream commingled, whereby recyclable materials are kept separate in two categories: paper and cardboard, so called "fibres" and plastic, metal and glass, so called "containers". In the reference region to which the study refers, located in the South of Italy, the kerbside collection has been further disaggregated into three streams whereby glass is kept out of the bag containing plastics and metals (Mastellone and Romeo, 2012; Zaccariello et al., 2015) in order to increase its recovery rate. The waste is then constituted only by lightweight materials with a limited fraction of paper and cardboard.

The scope of this paper is providing a reliable set of data about the MRF sorting effectiveness that operates in the framework of a national network of waste recycling companies using the lightweight waste collected from a wide territory and pre-processed waste coming from the whole Country. To do this, the mass flows obtained by operating the MRF have been completely characterized by determining mass rates and compositions in order to perform a complete material balance. This allowed as a consequence, the evaluation of performance indicators of the MRF and the identification of room for improvement. The performance indicators can be used for any other MRFs because they have been designed to be generally applicable.

## 2. Apparatus, materials and methods

### 2.1. The qualitative description of the MRF

The input flow to the MRF is the lightweight waste coming from a kerbside collection not including glass materials and cellulosic materials; it is mainly constituted by plastic, ferrous and aluminium packaging waste. Glass bottles and cellulosic materials are collected as source separated streams so that their presence in the lightweight waste is accidental. The output flows are products (Low Density Polyethylene - LDPE; light Polyethylene Terephthalate - light PET; light-blue Polyethylene Terephthalate - light-blue PET; opaque Polyethylene Terephthalate - opaque PET; coloured Polyethylene Terephthalate - coloured PET; High Density Polyethylene - HDPE; Polypropylene - PP, ferrous, aluminium) and waste (named "plasmix" because it is mainly composed by plastics). The facility can be represented by a number of unit processes connected each to other by flows and characterized by own set of operating and performance parameters. The MRF is sketched by means of a block diagram as reported in Fig. 1.

The input waste enters the facility by means of a constant volumetric feeder able to guarantee mass feed rate in the range 0–20 t/day providing also the bag opening with an effectiveness of 95%. The waste is then addressed to a rotating drum having two different series of holes with different size - 5 cm and 35 cm - and generating three flows:

- Fines, having size <5 cm. This flow of waste is mainly constituted by biowaste, glass, ceramics, etc., and it is addressed to landfill. These waste are undesired and accidental due to a household separation not completely efficient. It is generally comprised in the 5–10% weight fraction range of total input.
- Bulky, having size >35 cm. This flow is generally composed by large plastic films, toys, vegetable black boxes, etc., separated by the rotating drum and manually sorted; its amount is generally in the range 8–11%.
- Medium, having 5 cm < size < 35 cm. This is the main flow and it is mainly composed by recyclable packaging goods. It represents about 79% of the initial waste.

The medium flow is addressed to the ballistic separator to be divided into three flows: flat materials (two dimensional materials - 2D), rolling materials (three dimensional materials - 3D) and fines. The role of ballistic separator is to take advantage of the different shape of the waste component (bottles, sheets, etc.) to separate them into two main flows by means of an inclined and vibrating board. The separation of rolling materials (that fall down along the ballistic board and leave it from the lower extremity) by the flat ones (that remains on the board until leaving it from the upper extremity) makes a first repartition of the waste flow. In fact, rolling materials is mainly made by plastic bottles while flat

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