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Environmental performances of different configurations of a material recovery facility in a life cycle perspective

Filomena Ardolino, Chiara Berto, Umberto Arena *

Department of Environmental, Biological, Pharmaceutical Sciences and Technologies, University of Campania "Luigi Vanvitelli", Via Vivaldi, 43, 81100 Caserta, Italy

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ABSTRACT

The study evaluated the environmental performances of an integrated material recovery facility (MRF) able to treat 32 kt/y of unsorted mixed waste, made of residuals from household source separation and separate collection. The facility includes a mechanical sorting platform for the production of a solid recovered fuel (SRF) utilized in an external waste-to-energy plant, bio-cells for tunnel composting of organic fraction, and a sanitary landfill for the safe disposal of ultimate waste. All the MRF sub-units have been analysed in depth in order to acquire reliable data for a life cycle assessment study, focused on the environmental performances of different configurations of the facility. The study investigated a "past" configuration, including just mechanical sorting, landfilling and biogas combustion in a gas engine, and the "present" one, which includes also a composting unit. Two possible "future" configurations, having a gasifier inside the MRF battery limits, have been also analysed, assessing the performances of two fluidized bed reactors of different size, able to gasify only the residues generated by the sorting platform or the whole amount of produced SRF, respectively. The analysis evaluated the contributions of each unit in the different configurations and allowed a reliable assessment of the technological evolution of the facility. The results quantified the positive effect of the inclusion of an aerobic treatment of the waste organic fraction. The SRF gasification in situ appears to improve the MRF environmental performances in all the impact categories, with the exclusion of that of global warming.

1. Introduction

The solid waste management systems that operate successfully in different areas of the world indicate that a single option is not suitable to handle efficiently the full array of waste types composing a municipal solid waste (Mastellone et al., 2009; Brunner and Rechberger, 2015). Large part of the municipal solid waste (MSW) can be efficiently reused or recycled, after appropriate steps of household source separation, separate collection and material sorting. The remaining part of residual or post-recycled solid waste (unsorted mixed waste) has to be treated further to obtain a large and sustainable recovery of resources, together with the maximum diversion from landfill disposal (CLA-DPW, 2016). Recently, it has been recalled (Grosso et al., 2016) that a debate on the more appropriate systems for energy recovery from this residual mixed waste still exists: specific waste-to-energy (WtE) units for energy production or existing industrial plants where a solid recovered fuel (SRF) can replace fossil fuels. The debate is further complicated by different environmental and economic assessments about the actual need of an intermediate step of mechanical and biological treatment in a material recovery facility (MRF), particularly when the produced SRF is finally burned in a dedicated WtE unit. In any case, the number and capacity of these MRFs significantly grew in the last two decades, thanks to their increasing efficiency to separate and stabilize the wet biodegradable fraction, to reduce the amount of biodegradable waste in landfills, and to recover recyclable materials and SRF from mixed waste streams (Nasrullah et al., 2014; Montejo et al., 2016). This capability appears

List of Acronyms: BA, Bottom Ash; CE, Combustion Engine; CGE, Cold Gas Efficiency; EWC, European Waste Catalogue; FBG, Fluidized Bed Gasifier; GHG, Greenhouse Gas; GWP, Global Warming Potential; ISO, International Organisation for Standardization; LCA, Life Cycle Assessment; LCI, Life Cycle Inventory; LCIA, Life Cycle Impact Assessment; LHV, Low Heating Value; LOP, Land Occupation Potential; MFA, Material Flow Analysis; MRF, Material Recovery Facility; MSW, Municipal Solid Waste; NCP, Non Carcinogens Potential; NMOCs, Non Methane Organic Compounds; NREP, Non-Renewable Energy Potential; PE, Polyethylene; PET, Polyethylene terephthalate; RINP, Respiratory INorganics Potential; SFA, Substance Flow analysis; SR, Sensitivity Ratio; SRF, Solid Recovered Fuel; TOC, Total Organic Carbon; URW, Unsorted Residual Waste; VFA, Volatile Fatty Acids; VOC, Volatile Organic Compounds; WTP, Wastewater Treatment Plant; WtE, Waste-to-Energy; WEEE, Waste of Electrical and Electronic Equipment.

* Corresponding author.
E-mail address: umberto.arena@unicampania.it (U. Arena).

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particularly appreciated in the areas where it is difficult to organise an efficient network of source separation and separate collection. This is the situation of the case study investigated in this work.

The MRF facilities can have different configurations, specifically designed as a function of the composition of the mixed waste and the expected target of material recovery. Some recent studies (Barlaz et al., 2015; Beylot et al., 2015; Damgaard, 2015) investigated in depth how the analysis of these facilities should be carried out, in order to obtain a reliable assessment of the environmental performances, independently of the specific configuration. In particular, they highlight the necessity to take into account, with high quality data, some specific aspects such as mixed waste composition, impurities, sorting technology, purity targets, equipment performance, properties of final recovered material, residual contaminants, direct emissions, fuel and energy consumptions. A mechanistic approach in a life cycle perspective, which quantifies material and energy flows throughout each sub-units of the MRF by assessing emissions and consumptions, has to be preferred.

Following these guidelines, the paper aims to evaluate the environmental performances of an integrated MRF, which has a crucial role in the MSW management planning of Molise, a region in the middle of Italy, characterised by a low level (about 22%) of household source separation and separate collection. The study quantified and compared the potential environmental impacts of the MRF, by following the standard procedure of a life cycle assessment, as established by ISO 14040/44 (ISO, 2006a, 2006b), and with the support of material (MFA) and substance (SFA) flow analyses (Brunner, 2004; Brunner and Ma, 2008). This allowed assessing the performances of the configurations that characterise the technological evolution of the facility along the time, and those of two possible future scenarios, which both include a gasification conversion technology for SRF exploitation inside the MRF battery limits. Some recent studies adopted a similar procedure to analyse and assess the environmental performances of this kind of facilities (CLA-DPW, 2016; Grosso et al., 2016; Montejo et al., 2016). They have been taken into account, even though the results cannot be directly compared since they can be strongly affected by the specific assumptions, system boundaries, quality of data, allocation procedure, etc. For instance, in the study by Montejo et al. (2016), the avoided burdens have been estimated by assuming the substitution of coal or natural gas (and not of an energy mix), and this implies better environmental performances of the analysed MRF. The comparison with the results obtained by Grosso et al. (2016) is even more difficult since the authors assumed the utilisation of the produced SRF in a cement factory, where it substituted a coke: this again could lead to improved environmental impacts. Similar considerations about the effect of a different set of avoided burdens can be made for the study carried out by the County of Los Angeles-Department of Public Works (CLA-DPW, 2016), where the analysed system is more similar to that presented here. Finally, it is noteworthy that the structure of this paper differs from that of a conventional scientific paper in order to provide a better description of the case study. The next paragraph reports data and information about the technological evolution of the analysed MRF. Then, a standard attributional LCA identifies and quantifies the environmental burdens and potential impacts of each of the analysed configurations of the facility.

2. The technological evolution of the material recovery facility

Different plant configurations define the technological evolution of the MRF under analysis. The "past" configuration, active until few years ago, includes a mechanical sorting platform, a landfill and a gas engine for biogas combustion. The "present" configuration, active since 2015, includes also a composting unit. Finally, two possible "future" configurations include also a gasification-based waste-to-energy unit of different size, inside the MRF battery limits.

The facility is able to treat 100 t/d (about 32 kt/y) of mixed waste, which is made, for about 80% of the total input, of unsorted residual waste (URW) from the operations of household source separation, and, for the remaining part, of a residue from sorting process of separately collected, dry material. The composition of the URW (having the European Waste Catalogue code, EWC 20.03.01) has been obtained by the Waste Management Planning of the area under analysis (Regione Molise, 2016), by taking into account the sorting efficiencies of the different waste fractions, as already reported elsewhere (Arena and Di Gregorio, 2014). The technical management of the external sorting units (Rateni, 2016) has instead provided the composition of the second stream (EWC 19.12.12). The average composition of the waste fed to the MRF is reported in Fig. 1. The output streams of the mechanical sorting platform are ferrous metals and mixed plastics, which are sent to the specific recycling processes, a solid recovered fuel (SRF), which is utilized in an external waste-to-energy plant, and a low-quality organic fraction, which in the past was sent to landfill and now is treated in an on-site composting unit. The solid residues generated by these processes are disposed in the annexed landfill. The landfill produces a leachate, which is treated in an external wastewater treatment plant (WTP), and a biogas, which is collected and burned in a gas engine. Each of the mentioned configurations is analysed in depth in the next paragraphs.

2.1. The past configuration

The flow sheet of Fig. 2 refers to the situation active until few years ago. It identifies and quantifies the flows of materials exchanged between the main units present inside the MRF battery limits, i.e. the sorting platform and the sanitary engineered landfill, and the external waste-to-energy unit (WtE), which burns the produced SRF.

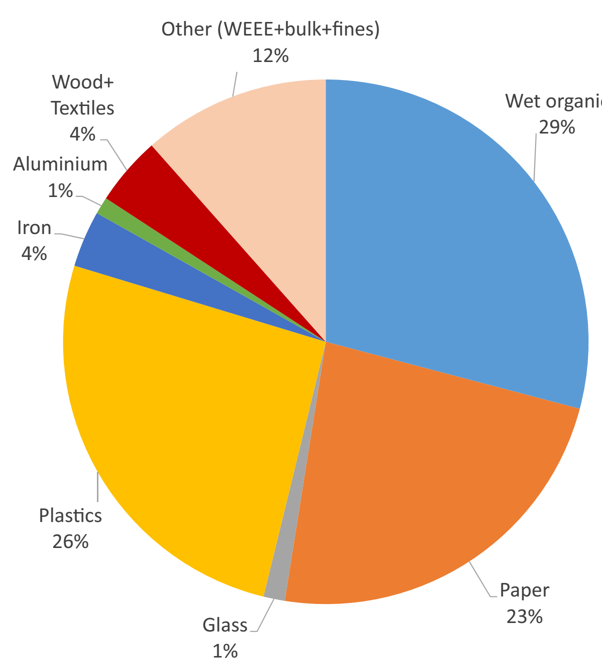

Fig. 1. The composition on mass basis of the mixed waste entering the MRF facility.

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