Waste Management 44 (2015) 206–215

Contents lists available at ScienceDirect

Waste Management

journal homepage: www.elsevier.com/locate/wasman

Improvement of the management of residual waste in areas without thermal treatment facilities: A life cycle analysis of an Italian management district

Francesco Di Maria [a,*], Caterina Micale [a], Emanuela Morettini [a], Luciano Sisani [b], Roberto Damiano [c]

[a] LAR Laboratory, Dipartimento di Ingegneria, Via G. Duranti 93, Perugia, Italy
[b] TSA spa, Via Case Sparse 107, Magione, Italy
[c] GESENU spa, Via della Molinella 7, Perugia, Italy

ARTICLE INFO

Article history:
Received 2 February 2015
Revised 6 July 2015
Accepted 7 July 2015
Available online 14 July 2015

Keywords:
Life cycle assessment
Residual municipal solid waste
Mechanical biological treatment
Mechanical physical treatment
Bioreactor landfill

ABSTRACT

Starting from an existing waste management district without thermal treatment facilities, two different management scenarios for residual waste were compared by life cycle assessment (LCA). The adoption of a bioreactor landfill for managing the mechanically sorted organic fraction instead of bio-stabilization led to reduction of global warming and fresh water eutrophication by 50% and 10%, respectively. Extraction of recyclables from residual waste led to avoided emissions for particulate matter, acidification and resource depletion impact categories. Marginal energy and the amount of energy recovered from landfill gas marginally affected the LCA results. On the contrary the quality of the recyclables extracted can significantly modify the eco profile of the management schemes.

1. Introduction

In compliance with the latest Waste Framework Directive of the European Community (WFD 2008/98EC), the amount of materials recycled from waste in Europe has increased significantly in the last years. Even if there are some differences among the EU States, the average amount of recycled waste in the EU-15 is about 42% (including the organic fraction) of the whole amount generated (ISPRA, 2014). About 24% is incinerated and about 34% landfilled. In Italy these figures are: recycled and recovered about 40% (including the organic fraction); incinerated about 20%; landfilled about 40%.

Both incineration and landfill are mainly used for disposal of the residual municipal solid waste (RMSW) left after the recycling and recovery operations and from source segregated (SS) collection. Furthermore, according to the EU Landfill Directive (1999) 99/31/EC, which imposes limits on the amount of biodegradable waste directly landfilled, the mass and biological reactivity (Di Maria and Micale, 2014a) of RMSW has to be reduced before final disposal. In the absence of incinerators this can be achieved by pre-treating RMSW in mechanical biological treatment facilities (MBT) (Di Maria, 2012; Frike et al., 2005; Nguyen et al., 2007).

The environmental impacts of management options for RMSW have been analyzed by several authors using life cycle assessment (LCA). In comparing incineration to landfilling for the disposal of RMSW, Moberg et al. (2005) found that the global warming potential (GWP) associated with incineration was significantly lower. Similar results were also obtained by Di Maria et al. (2003) and Di Maria and Micale (2014b,c,d). Assamoi and Lawryshyn (2012) confirmed the lower GWP in managing RMSW by incineration rather than by landfilling, even though the cost of incineration is significantly higher.

Together with social acceptance, the high sensitivity of incineration costs to scale factor is one of the main obstacles to its diffusion in many small size (*i.e.* <500,000 inhabitants) Italian and European areas where MBT facilities continue to be widely used. In compliance with the recycling goals for 2020 imposed by the WFD 2008/98/EC for plastics, paper, metals and glass (*i.e.* >50%), a noticeable reduction in RMSW is foreseen in the near future. As a consequence, for small size areas, the feasibility of the construction of new incinerators will be further reduced. On the other hand, due to emissions and energy consumption, MBT benefits in processing RMSW before landfilling have been demonstrated to be minimal and in some cases less than direct landfilling (Di Maria

* Corresponding author.
E-mail address: francesco.dimaria@unipg.it (F. Di Maria).

http://dx.doi.org/10.1016/j.wasman.2015.07.012
0956-053X/

et al., 2013a; Di Maria and Micale, 2014b,c; Valerio, 2010). For these reasons, improvement in the sustainability of RMSW management for these areas is of prominent importance in the near future. Possible strategies for achieving this goal can be by increasing the amount of recyclables extractable from the residual waste (*i.e.* reduction of landfill needs) together with reducing the impacts generated by MBT. These objectives can be pursued by processing the RMSW after mechanical sorting in mechanical physical separation facilities (MPS) (Di Maria et al., 2013b) and by managing the mechanically sorted organic fraction (MSOF) directly in a bioreactor landfill. Previous studies demonstrate that there is a lack of information about the effects that these alternative solutions can have on the environment. The demonstration of this management scheme was financed by a LIFE12 ENV/IT/000411 grant from the EC and tested in an existing Italian district in which an MBT, a MPS and a bioreactor landfill operate. In this study the results were analyzed in a life cycle perspective to give useful information for supporting technical decisions for future waste management strategies in the area considered and in areas with similar features.

2. Materials and methods

2.1. Base scenario

The district consists of about 410,000 inhabitants and generates about 200,000 tonnes/year of municipal waste. After collection, the RMSW was transported to an existing MBT facility (Fig. 1) (Di Maria, 2012; Di Maria et al., 2013a). This facility consists of two main sections:

(1) a mechanical sorting (MS) section; and
(2) an aerobic biological treatment section.

After initially removing the bulky materials, the RMSW stream enters the bag opener of the MS section and is then conveyed to the first metal separation section before being screened with drum sieves. The waste stream passing through the sieve holes (100 mm diameter) is the MSOF, whereas the oversize stream is the Dry fraction that is directly landfilled. The MSOF undergoes further metal extraction and is then moved to the aerobic biological treatment section. This section consists of a continuous flow aerobic basin, with an aerated floor, on which moves a crane bridge with screws used to stir and move the MSOF from the inlet to the outlet section. The residence time of the MSOF inside the basin is about 2 weeks, after which the material is placed in static windrows on concrete platforms for further aerobic treatment for reducing the residual biological reactivity to the values imposed by Italian regulations before landfilling. The platforms for further aerobic treatment are also equipped with ducts and electric fans to supply air to the waste during this phase.

2.2. Improved scenario

In the improved scenario (Fig. 2) the Dry fraction of RMSW sorted in the MS section is further processed in an existing MPS facility (Fig. 3) before disposal. The MPS is equipped with an air classifier, disk and trommel screens, a near infra-red (NIR) selector for PET and HDPE selection and a ferrous and non-ferrous metal separator. After slight shredding, the Dry fraction is conveyed to the air classifier for removal of the lighter materials before the ferrous metals separation. The lighter fraction is screened by a trommel with 200 mm diameter holes and the undersize is conveyed to the inlet of the disk sieve. The undersize of the disk sieve is the glass, whereas the oversize is conveyed to the NIR classifier. After removing the plastics, the waste stream is moved to the eddy current section for extraction of aluminum. The remaining waste stream is then mixed with the oversize of the 200 mm diameter hole trommel (*i.e.* other) and is disposed of in a traditional landfill.

The MSOF is directly disposed of in an existing bioreactor landfill, which has been operating since July 2012. In the bioreactor landfill, the MSOF is stored in cells of about 5000–7000 m^3 equipped with a leachate recirculation system and wells for LFG extraction. On the basis of the current MSOF rates, it takes about 3–4 months to construct each cell. Once the cell is completed it is covered with plastic tarpaulins and leachate recirculation is started. The LFG quality at each wellhead, in terms of methane and oxygen concentration is monitored. When $CH_4 \geqslant 40\%$v/v and $O_2 \leqslant 2\%$v/v, the wells are connected to the LFG collection network and used for fuelling the co-generators for electrical energy generation. The incidence of transport in this scenario was practically similar to the one in the base scenario. For this reason in the LCA, the transport activities were disregarded.

2.3. Methodology

2.3.1. Goal, scope and context

The environmental impact of the base and improves scenario for managing the RMSW generated in an existing Italian district consisting of about 410,000 inhabitants and generating about 230 tonnes/day of RMSW were compared.

In accordance with the current waste management scheme adopted in the district, the option of producing solid recovered fuel from residual waste was not considered. Due to the impossibility of obtaining a complete and specific set of data for all the processes and activities included in the study, the inventories were built by retrieving data available from Ecoinvent v2.2 (Hischier et al., 2010) and ELCD 2.0 (European Commission, 2008). These data were adjusted on the basis of information obtained from direct observations and the experimental tests performed during the study. Both in field and experimental tests were necessary for assessing the effective performances of the facilities already operating in the management district. In particular, due to the lack of more specific data, the amount of LFG generable by the MSOF

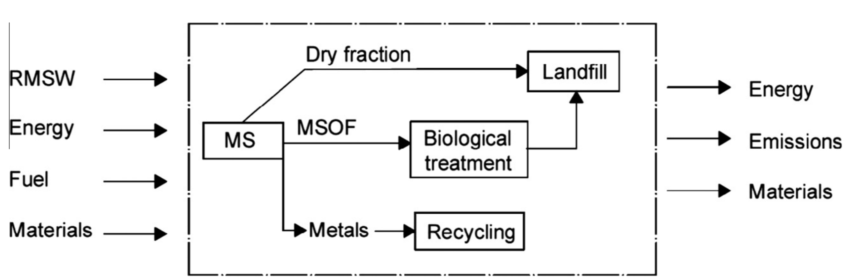

Fig. 1. System boundary of the base scenario.