Waste Management 43 (2015) 50–60

Contents lists available at ScienceDirect

Waste Management

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

Influence assessment of a lab-scale ripening process on the quality of mechanically–biologically treated MSW for possible recovery

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ARTICLE INFO

Article history:
Received 26 February 2015
Accepted 22 May 2015

Keywords:
Biological stability
Heavy metal
Leaching behaviour
Mechanical–biological treatment
Municipal solid waste
Ripening process

ABSTRACT

In this study, the influence of an additional ripening process on the quality of mechanically–biologically treated MSW was evaluated in the prospective of recovering the end material, rather than landfilling. The biostabilised waste (BSW) coming from one of the MBT plants of Rome was therefore subjected to a ripening process in slightly aerated lab test cells. An in-depth investigation on the biological reactivity was performed by means of different types of tests (aerobic and anaerobic biological tests, as well as FT-IR spectroscopy method). A physical–chemical characterisation of waste samples progressively taken during the ripening phase was carried out, as well. In addition, the ripened BSW quality was assessed by comparing the characteristics of a compost sampled at the composting plant of Rome which treat source segregated organic wastes. Results showed that the additional ripening process allowed to obtain a better quality of the biostabilised waste, by achieving a much higher biological stability compared to BSW as-received and similar to that of the tested compost. An important finding was the lower heavy metals (Co, Cr, Cu, Ni, Pb and Zn) release in water phase at the end of the ripening compared to the as-received BSW, showing that metals were mainly bound to solid organic matter. As a result, the ripened waste, though not usable in agriculture as found for the compost sample, proved anyhow to be potentially suitable for land reclamation purposes, such as in landfills as cover material or mixed with degraded and contaminated soil for organic matter and nutrients supply and for metals recovery, respectively. In conclusion the study highlights the need to extend and optimise the biological treatment in the MBT facilities and opens the possibility to recover the output waste instead of landfilling.

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1. Introduction

In the last two decades, hundreds of mechanical–biological treatment (MBT) facilities were built in Europe to treat the residual municipal solid waste (MSW) from at-source separate collection (Lornage et al., 2007; Barrena et al., 2009; Bayard et al., 2010; Ponsá et al., 2010; Tintner et al., 2010; Di Lonardo et al., 2012). Main goal of MBT is to reduce the environmental impacts and risks to human health related to landfilling, as set by the European Landfill Directive 1999/31/EC (European Commission, 1999). One of the output of the MBT is the biostabilised waste (BSW) produced from the aerobic biological treatment of the organic fraction mechanically separated from the input MSW. In the majority of the MBT facilities, the biological process consists in an active biodegradation phase at forced aeration conditions for 20–28 days (Adani et al., 2004a; Di Lonardo et al., 2012; Puyuelo et al. 2010). Differently, in the common practice of the composting processes, the active decomposition phase at forced aeration conditions is followed by a windrow or static pile system at natural aeration conditions for the later stages of decomposition and ripening in order to raise the output compost quality (Richard, 1992). Such a difference in the biological treatment management depends upon the fact that MBT was firstly developed and seen as a MSW pre-treatment for disposal in order to reduce the biodegradable municipal waste going to landfills (Di Lonardo et al., 2012), therefore no high quality of the output was expected.

Recently the interest in the possibility to recover the biostabilised waste from MBT is increasing (MacLeod et al., 2008), especially considering the large amounts that are now being produced in efforts to divert waste from landfill (Farrell and Jones, 2010). However, MacLeod et al. (2008) argued that the MBT output must be highly stable so that the users can be confident that

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http://dx.doi.org/10.1016/j.wasman.2015.05.028
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contaminants in the material such as heavy metals have reached their maximum concentration.

Many studies showed that an efficient reduction of the biological reactivity of mechanically–biologically treated MSW is achieved by means of optimised aerobic biological process lasting at least 8 weeks, including both an active biodegradation phase and a ripening phase (Zach et al., 2000; Francou et al., 2005; Lornage et al., 2007; MacLeod et al., 2008; Barrena et al., 2009; Shao et al., 2009; Bayard et al., 2010; Tintner et al., 2010).

In the city of Rome the separate collection of biodegradable municipal waste (BMW) and the related treatment facilities are poorly developed. Data reported in "Municipal Solid Waste Report 2014" (ISPRA, 2014) show that in 2013 a low percentage of BMW, i.e. only 23.9% of the total MSW produced in Rome (corresponding to 1,754,823 Mg), was source segregated. As a result, the residual MSW fed to the MBT plants (about 60% of the total amount of MSW produced in this city) were composed of significant percentages of biodegradable waste, namely 40–50% by weight, as observed by several investigations on material composition performed in the years 2006–2013 (Franzese et al., 2013). In these MBT facilities, about 80% of the biodegradable waste amount, which the input MSW is composed of, is separated through a primary mechanical sieving and then subjected to an aerobic biological treatment at forced aeration conditions for 4 weeks (active biodegradation treatment). Afterwards, the end biostabilised waste is not subjected to a further ripening phase but it is directly landfilled.

In previous surveys performed on the biological stability degree, by measuring the dynamic respiration index (DRI) (Di Lonardo et al., 2014), several samples of biostabilised waste coming from the MBT plants of Rome were found highly reactive. Specifically, DRIs were higher than the maximum limit value of 1000 mg O_2/kg VS h below which the waste is considered biologically stable (Adani et al., 2004a) and compliant with the requirement set by the Italian landfill regulation for the waste acceptance in landfill (Italian Ministerial Decree, 2010). The high reactivity was mainly related to the relatively short processing period as well as to the significant content of biodegradable waste in residual MSW.

Therefore, in this study, the biostabilised waste coming from one of the MBT plants of Rome was subjected to an additional ripening process in slightly aerated lab test cells in order to analyse and evaluate the variation and the increase of the biological stability degree with time of ripening. A physical–chemical characterisation of waste samples progressively taken during the ripening phase was carried out. Furthermore, the ripened BSW quality was also assessed through a comparison with the characteristics of a compost sampled at the composting plant of Rome which treat source segregated organic wastes. The purpose was to evaluate the influence of the additional ripening process on the quality of BSW in the perspective of recovering the end material, rather than landfilling.

2. Materials and methods

2.1. Biological process in the MBT plants of Rome

In the city of Rome four MBT plants are currently in operation with a maximum treatment capacity of 3000 Mg MSW/d. The facilities differ in the type of mechanical pre-treatment employed but the biological process is performed in the same conditions and duration, as hereafter described. BSW used for this investigation was sampled in one of the four MBT facilities whose Fig. 1 shows the flow scheme and the outputs of the treatment. Focusing on the biological process, after metal removal by belt-type electromagnetic separators, the biodegradable fraction (i.e. the undersize flow coming from the primary screening unit at 80 mm) is sent to a biostabilisation basin where an aerobic biodegradation occurs for 4 weeks at forced aeration conditions. Three augers moved by a crane have a dual function: turning over the material in order to keep proper free air space (pores) for satisfying aeration (avoiding the formation of anaerobic conditions, especially at the bottom of the basin) and moving the material along the basin. During turning/moving, water is added to the material by nozzles mounted on the crane, in order to keep the water content favourable for microbial activity. The biostabilised output then is sieved at 20 mm by means of a trommel screen in order to separate an oversize fraction mainly composed of plastics and inert materials from the undersize fraction, namely the final biostabilised waste (BSW) which is daily landfilled.

BSW was taken at the outlet of the biodegradation process lasting 4 weeks after the sieving unit at 20 mm, following the procedure laid down in the Italian standard UNI 10802 (2013), and after mixing and quartering, an amount of roughly 30 kg was collected.

Furthermore a mature compost sample of roughly 20 kg was collected at the composting plant of Rome which treat the organic fractions of municipal solid waste coming from the at-source separate collection. In this case, beside the 4 weeks of aerobic biodegradation at forced aeration conditions, the treatment includes a ripening phase of up to 6 months, differently from the biological process carried out in the MBT plants.

The BSW sample was sent to the laboratory at the Institute of Waste Management of the University of Natural Resources and Life Sciences in Vienna (ABF-BOKU) where it was subjected to a lab scale ripening process and analysed in order to measure the biological reactivity. A further physical–chemical characterisation was instead carried out at the Environmental Laboratory of the University of Rome "Tor Vergata". Differently, all tests performed to characterise the compost sample were conducted at the latter laboratory.

2.2. Lab ripening phase

The sampled amount of BSW was subjected to a ripening phase by placing it in a vertical cells system simulating an open windrow configuration (Fig. 2).

A relatively low air flow rate was fed to the bottom of the system in order to simulate natural aeration conditions. Each single cell was half-filled with the rotting waste placed on a grid (with mesh opening of 10 mm) to let the air passing through the material homogeneously. A biofilter composed of mature compost was placed at the top of the system to reduce odour emissions. Ambient and rotting material temperature, as well as oxygen and carbon dioxide concentrations in the waste air were daily measured for each single cell in order to monitor the process. Mixing, adjusting in water content and turning of the material were carried out once per week to keep optimised conditions for the ripening process. During mixing of material, samples were taken in order to analyse the biological reactivity and evaluate the changing in reactivity with time.

From the measures of temperature, O_2 and CO_2 concentrations, as well as of the VS (as described in Section 2.4) during the ripening, the actual O_2 consumed rates (mg O_2/kg VS h) and the actual CO_2 released rates (mg CO_2/kg VS h) per unit of organic matter (VS) were calculated through the following Eqs. (1) and (2) (Komilis and Kanellos, 2012):

$$O_{2\ cons} = \frac{(O_{2in} - O_{2out}) \cdot Q \cdot MW_{O_2} \cdot 1000}{MV \cdot VS} \quad (1)$$

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