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Short mechanical biological treatment of municipal solid waste allows landfill impact reduction saving waste energy content

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HIGHLIGHTS

- We described MBT in reducing impact preserving energy content before landfilling.
- Anaerobic Biogasification Potential (ABP) reduction was used to asses process performance.
- ABP was mathematically modeled to describe the effect of MBT vs. time.
- Short MBT allows preserving energy and reducing process inhibition in landfill.
- Short MBT allows reducing treatment cost with respect to long-term MBT.

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ABSTRACT

The aim of this work was to evaluate the effects of full scale MBT process (28 d) in removing inhibition condition for successive biogas (ABP) production in landfill and in reducing total waste impact. For this purpose the organic fraction of MSW was treated in a full-scale MBT plant and successively incubated vs. untreated waste, in simulated landfills for one year.

Results showed that untreated landfilled-waste gave a total ABP reduction that was null. On the contrary MBT process reduced ABP of 44%, but successive incubation for one year in landfill gave a total ABP reduction of 86%. This ABP reduction corresponded to a MBT process of 22 weeks length, according to the predictive regression developed for ABP reduction vs. MBT-time.

Therefore short MBT allowed reducing landfill impact, preserving energy content (ABP) to be produced successively by bioreactor technology since pre-treatment avoided process inhibition because of partial waste biostabilization.

1. Introduction

Municipal solid wastes (MSW) are mainly disposed into a landfill (Table 1) because it is the simplest, cheapest and low cost-effective method of waste disposal (Allen, 2001). Between different fractions the organic ones constituted the major component of MSW, that because of its biodegradation in landfill under anaerobic condition represents, also, the major fraction affecting waste pollution in landfill. Therefore to reduce or prevent environmental pollution the European Commission emanated the Landfill Directive (European Parliament and Council Directive, 1999) to drive the member states to draw up strategies for progressively reducing the amount of the biodegradable MSW in landfill. The reduction of organic fraction of MSW to be landfilled can be obtained by three different approaches: (i) source separated collection of organic fraction of MSW to produce compost; (ii) MSW burning to produce energy and, (iii) mechanical–biological treatment (MBT) of MSW to produce a stabilized or a composting-like material prior landfilling (Scaglia and Adani, 2008).

The MBT consists of mechanical pre-treatment of MSW, followed by an aerobic (composting-like) process (Velis et al., 2009, 2010). In particular, MBT involves primary mechanical screening (grid holes of 40–90 mm) to obtain two fractions. The upper-grid fraction (35–50% of wet weight, w.w.), which consists mainly of plastic and paper, is used as a refuse-derived fuel or is landfilled without further treatment. The lower-grid fraction (50–65% w.w.) is biologically treated to reduce its biological reactivity prior landfill disposal (Norbu et al., 2005). The aim of MBT is therefore to reduce waste impacts, i.e. leachate, biogas and odour (Bayard et al., 2010). Moreover oxidative process determine the biodegradation

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Table 1
Characterisation of USMSWs before and after MBT process.

Parameters	Measure unit	I-USMSW	S-USMSW
DRI	(mgO_2 kg VS^{-1} h^{-1})	3910 ± 358b[a]	978 ± 153a
Moisture	(g kg^{-1} w.w.)	492 ± 19b	240 ± 22a
VS	(g kg^{-1} dm)	556 ± 19b	525 ± 15a
C		298 ± 15b	267 ± 8a
N		11.7 ± 0.8a	11.3 ± 0.8a
H		4.1 ± 1.3b	3.4 ± 0.2b
S		7.1 ± 0.1a	7.7 ± 0. 9a
O		196 ± 22a	205 ± 9a
pH		5.6 ± 0.2a	6.8 ± 0.2b
VFA	(mg CH_3COOH l^{-1})	4123 ± 21b	816 ± 197a
BOD_5	(mgO_2 l^{-1})	4618 ± 421b	2148 ± 206a
COD	(mgO_2 l^{-1})	7239 ± 1005b	4913 ± 1143a
ABP	(Nl kg^{-1} dm)	250 ± 87b	140 ± 3a

[a] Means followed in the same line by the same lower-case letter in the same line are not statistically different ($P < 0.05$) according to Tukey test.

of the labile organic fractions and the preservation/modification of the more recalcitrance molecules, giving a biologically stable product. The length of the biological treatment can vary so that biostabilized product shows different degree of biological stability. In Austria, Germany and more recently England, for example, the biostabilization process takes place for 2–6 months in order to get high biological stability of waste before its disposal in landfill. On the other hand in other countries (e.g. Italy), the biostabilization process takes place, generally, only for 2–4 weeks to obtain a product with medium biological stability level. This choice comes from the fact that degradation processes of organic matter (OM) is well described by a first order kinetic (Scaglia et al., 2010) and processes longer than 4 weeks do not lead to increase significantly the degree of biological stability (Scaglia et al., 2010).

Among different landfill impacts, biogas/methane emission has the highest environmental impact in landfill (De Gioannis et al., 2009) because of its greenhouses properties that lead to ozone depletion between 40 and 60 km. On the other hand it seems that methane increases ozone content in low atmospheric strata (Montzka et al., 2003). Approximately one-third of anthropogenic emissions of methane in European Union depends on MSW landfills (De Gioannis et al., 2009).

Biological pre-treatment of waste allows a strong reduction of the potential biogas production depending by process length. Biogas reduction after biological treatment is due to the reduction of both anaerobic biogasification potential (ABP) by waste unit, because of changing of OM quality (Pognani et al., 2009), and total dry matter content of MSW because of OM degradation.

New issue regarding renewable energy production has to be taken into consideration when a correct waste management must be selected. Anaerobic vs. aerobic process are now preferred to treat organic waste as both energetic and environmental aspects are favorable to the former (Fricke et al., 2005). Therefore if MBT allows landfill impact reduction it requires both high energetic input and high plant cost (Consonni et al., 2005), above all if long term treatment are considered. On the other hand stabilization of waste directly in landfill with appropriate technology, i.e. bioreactor, cannot be achieved since of inhibition condition occurred because of the presence of fresh organic matter (Salati et al., 2013).

A good agreement between aerobic treatment length, able reducing biological inhibition in landfill, and preservation of biogas producible in landfill can be a good solution to treat waste. This goal can be achieved by using short MBT process (Tambone et al., 2011) that because of the partial degradation of organic matter contained in waste allows reducing biogas inhibition occurring with the presence of fresh organic waste.

The aim of this work was to evaluate the effect of short full scale MBT process performed for 4 weeks in reducing inhibition conditions for residual biogas production of waste in simulated landfill for one year in comparison with untreated waste. In addition the total waste impacts reduction after short MBT plus simulated landfill, was measured in order to understand the effect of a such process in minimizing impacts.

2. Methods

2.1. Biostabilization process

Biostabilization process was performed at the MBT full-scale plant of Sorain Cecchini Tecno that is located in Rome, Italy, and treats 1200 Mg d^{-1} of unsorted MSW. Biological process was performed to treat the undersize fraction of MSW (USMSW) coming from MSW sieving (sieve-hole diameter of 90 mm); biological process was conducted for 28 days under forced aeration and mass turning (more details on http://www.soraincecchini.it/, on April 4, 2013).

2.2. MSW samples

The USMSW was sampled at the start of the biological process (I-USMSW, i.e., undersize fraction of MSW sieved at 90 mm) and after 28 days of the biological process (S-USMSW). Samples were took by using standard sampling procedures (European Committee for Standardization, 2006); doing so about 40–50 kg of wet weight (w.w.) of untreated and biostabilized MSWs were brought to the laboratory. Samples were stored at 4 °C and processed within 3–5 days from receipt. A homogeneous sub-sample of 3 kg was taken from each USMSW sample to determine dry matter (DM) content after sample drying at 105 °C.

2.3. Landfill lab-scale reactors and MSW incubation

No-biostabilized and biostabilized USMSW samples were incubated in laboratory-scale landfill reactors for 12 months. Landfill reactors consisted in prototype Plexiglas reactors (high of 150 cm and Ø of 25 cm) (Salati et al., 2013). Reactors were designed to allow performing simulated rains from the top of the reactor and to collect leachate from the bottom. Lab-scale reactors were loaded with 8.8 kg w.w. of I-USMSW and S-USMSW at a WHC of 75% (UNI, 2006), resulting a final bulk density of the mass of 0.8 Mg m^{-3}. Reactors were hermetically sealed and flushed with N_2 for 2 h before their closure. Anaerobic conditions were periodically verified using anaerobic kit test (microbiology anaerotest, Merck, NJ 08889-0100 USA). The trials started on April 2010 and finished on March 2011 (12 months length). Three replicates were performed for each USMSW (three reactors), for a total of six reactors.

2.4. Rain events

Artificial rain (amount and event periods) was reproduced taking into consideration rain events for Rome Ciampino location (1970–2007 series) such as reported by the European Climate Assessment & Dataset (http://eca.knmi.nl/dailydata/) (Salati et al., 2013), being this location very close to the Rome landfill (Italy) in which biostabilized material under study will be allocated in the next future.

2.5. Waste characterization

2.5.1. Biological characterization

USMSWs were sampled before and after MBT, at the beginning of incubation period and every four months, and characterized from both the biological and chemical points of view.