



## Inventory and treatment of compost maturation emissions in a municipal solid waste treatment facility



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### ABSTRACT

Emissions of volatile organic compounds (VOCs) from the compost maturation building in a municipal solid waste treatment facility were inventoried by solid phase microextraction and gas chromatography–mass spectrometry. A large diversity of chemical classes and compounds were found. The highest concentrations were found for n-butanol, methyl ethyl ketone and limonene (ppm<sub>v</sub> level). Also, a range of compounds exceeded their odor threshold evidencing that treatment was needed. Performance of a chemical scrubber followed by two parallel biofilters packed with an advanced packing material and treating an average airflow of 99,300 m<sup>3</sup> h<sup>-1</sup> was assessed in the treatment of the VOCs inventoried. Performance of the odor abatement system was evaluated in terms of removal efficiency by comparing inlet and outlet abundances. Outlet concentrations of selected VOCs permitted to identify critical odorants emitted to the atmosphere. In particular, limonene was found as the most critical VOC in the present study. Only six compounds from the odorant group were removed with efficiencies higher than 90%. Low removal efficiencies were found for most of the compounds present in the emission showing a significant relation with their chemical properties (functionality and solubility) and operational parameters (temperature, pH and inlet concentration). Interestingly, benzaldehyde and benzyl alcohol were found to be produced in the treatment system.

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### 1. Introduction

The rapid increase in volume and types of solid and hazardous wastes as a result of continuous economic growth, urbanization and industrialization, is becoming a burgeoning problem for national and local governments to ensure effective and sustainable management of wastes (United Nations Environment Programme, 2009). It was estimated that in 2006 the total amount of municipal solid waste (MSW) generated globally reached 2.02 billion tones, a 7% annual increase since 2003. It was further estimated that between 2007 and 2011, the global generation of municipal wastes would rise by 37.3%, equivalent to roughly 8% increase per year. The EU estimates that its 25 member states produce 700 million tons of agricultural wastes annually (Global Waste Management Market Assessment, 2007). In this scenario, municipal solid waste

treatment facilities (MSWTF), whose main goal is to reduce the biodegradable organic matter content and stabilize wastes by means of chemical and biological processes (solid waste stream can contain a range of 35–50% of organic materials), have received special attention from European authorities (Ponsa et al., 2008).

During processing of solid wastes, generation of gases with complex mixtures of compounds creates odor problems in a huge number of sources. The importance of managing odorous emissions at these facilities has become more significant in recent years, mainly due to the increasing number of complaints and reported failures in the performance of odor abatement systems (Gostelow et al., 2001; Lebrero et al., 2011). Gaseous emissions in MSWTF are typically generated by decomposition of nitrogen-based compounds, sulfur-based compounds and a wide range of compounds dominated by volatile organic compounds (VOCs) (Eitzer, 1995). However, most references in literature target the analysis of the composting process and its emissions characterization, while VOC emissions inventories are lacking from compost maturation areas, and particularly from MSWTF. The majority of the studies devoted to composting facilities include the emissions of the process as a whole, mainly if the process takes place in enclosed facilities where gaseous emissions treatment is not often performed separately.

*Abbreviations:* SPME/GC–MS, solid phase microextraction/gas chromatography–mass spectrometry; MSW, municipal solid waste; MSWTF, municipal solid waste treatment facility; VOC, volatile organic compound.

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Adsorption and chemical scrubbing have been traditionally used as cost-effective, simple and safe methods for controlling odors either as primary treatment and/or as polishing stage in odor abatement. However, other techniques such as biofilters, biotrickling filters or bioscrubbers have spread as efficient treatment processes for odor removal, and more recently employed specifically in MSWTFs (last 10–20 years). In general, low removal efficiencies are commonly reported for VOCs, which is related to the complexity of the VOCs mixture emitted and the variability throughout the composting process (Pagans et al., 2007). Moreover, in the case of emissions from MSWTF, high gas flows must be treated which entail bioreactors with large bed volumes. To avoid extreme designs, biofilters are often designed and operated at short gas contact times, which affects mainly VOCs abatement due to the low solubility of these compounds and the corresponding mass transfer limitation.

The complex nature of MSWTF odors provides many challenges with regards to monitoring and control of these emissions, particularly in the design and operation of odor abatement processes. To this aim as well as to manage emissions to an acceptable level to limit receptor impact, deeper knowledge on real emissions composition and removal efficiencies of odor abatement processes are required because, even at trace level concentrations, most VOCs are malodorous and have very low odor thresholds (Leonardos et al., 1969). The objectivity, repeatability and accuracy of the identification and quantification of chemical compounds presented in the emission are warranted to properly manage the facility as well as to design and operate treatment systems. A large number of instrumental techniques are used with this purpose, including gas chromatography; colorimetric reaction-based assays; catalytic, infrared and electrochemical sensors; differential optical absorption spectroscopy; and fluorescence spectrometry (Dewulf and Van Langenhove, 1999; Muñoz et al., 2010).

However, a limited number of full-scale studies have assessed the removal performance of complex mixtures of VOCs. Often, the monitoring approach to evaluate the performance is based on total carbon removal using total-VOC analyzers equipped with photoionization detectors (Lafita et al., 2011; Martínez-Soria et al., 2009), which is an alternative unable to assess the fate of individual compounds present in the gases to be treated. Among the instrumental techniques presented above, gas chromatography is viewed as the most precise and powerful analytical tool for the quantification and identification of VOCs and volatile sulfur compounds (Dewulf and Van Langenhove, 2002). To increase the accurate quantification of compounds, solid phase microextraction (SPME) is used as a pre-concentration technique based on the adsorption of volatile compounds using microfibers coated with polymeric organosilicon compounds (Ábalos et al., 2002; Larroque et al., 2006).

The aim of this study was to provide a VOCs emissions inventory and to analyze the performance of two full-scale biofilters packed with an advanced packing material and a chemical scrubber for the treatment of gaseous emissions from a compost maturation building at a MSWTF in the Barcelona Metropolitan area. Removal efficiencies and odorant concentrations were determined by SPME/GC–MS for a range of VOCs present in the inlet and outlet of the abatement system to identify critical compounds emitted to the atmosphere.

## 2. Materials and methods

### 2.1. Full-scale biofilters and chemical scrubber characteristics

The MSWTF under study is located in the metropolitan area of Barcelona (Spain). The yearly nominal treatment capacity of the

facility is around 240,000 tons of solid residues while approximately 38,000 tons of compost are produced per year. Compost is produced in two different, completely independent lines. Line 1 process organic MSW separate collected while line 2 processes unsorted MSW. In both lines mechanical pretreatments are performed to separate non-proper materials such as metals, glasses or plastics. After pretreatment, a combined process consisting in anaerobic digestion followed by digestate composting is performed in line 1. Line 1 compost is not matured and produced as high-quality compost useful for gardening and agricultural uses. In line 2, pretreatment is followed by direct composting of waste in composting tunnels. Later, a maturation stage allows further compost refining to produce compost categorized as stabilized organic waste not adequate for gardening and agricultural uses. In terms of gas treatment, the composting stage of both line 1 and 2 takes place in the same building in independent tunnels. Then, composting emissions of line 1 and 2 are mixed and treated in a set of 4 scrubbers followed by four biofilters. Instead, maturation off-gases are independently treated in the treatment units under study. Waste gases collected from the maturation area are blown through an acid chemical scrubber and two identical biofilters running in parallel (Fig. 1).

The acid chemical treatment consists of a 12.6 m<sup>3</sup> acid chemical scrubber that treats a measured average airflow of 99,300 m<sup>3</sup> h<sup>-1</sup> corresponding to an average gas contact time of around 0.5 s. At such low gas contact time, only ammonia removal takes place in this reactor due to the low solubility of VOCs (Baquerizo et al., 2009). Airflow was measured by means of an S-type Pitot tube (Kymo Instruments, France). The biofiltration system is composed by two identical, covered biofilters with 30 m in length and 17 m in width. The inlet gas flow is equally divided in two streams in an air plenum and directed to both biofilters. Biofilters are packed with a layer of 20 cm of Leca® (bloated particles of burnt clay) for proper air distribution plus 1 m of a hybrid packing material which consisted of spherical clay pallets covered by a thin layer of compost. Such packing material has been designed elsewhere as an advanced packing material (Almarcha et al., 2013) compared to classical packing materials often consisting in organic materials such as wood chips. Further details about packing materials characteristics can be found elsewhere (Andreasen and Poulsen, 2013; Dorado et al., 2010; Hernández et al., 2010). Thus, a treatment volume of 610 m<sup>3</sup> and a gas contact time of 44 s per biofilter were warranted. A set of sprinklers are used in each biofilter to humidify the packing material. Water is sprinkled for 10 min over the top of the packing material twice per day. The average humidity in the surface of the packing material was 52% and 55% in each biofilter. Excess water is collected at the bottom. The average pH of the biofilters leachate along the study was 5 and 5.8. A desktop pH-meter was used for leachate pH analysis (Crison Instruments, Spain).

### 2.2. Sample collection and measurement

Gas samples from sampling points (Fig. 1) were collected in 3 L Tedlar bags (SKC Inc., USA) and analyzed by SPME/GC–MS the same day they were collected. A portable SKC 224-PMCTX8 Air Sampler Pump was used to collect samples from both sampling points due to negative or low positive pressure in the pipes. Samples were transferred into 0.125 L Supelco gas sampling bulbs with Teflon and stopcock valves. According to Davoli et al. (2003), deuterated p-xylene was used as internal standard (IS) by injecting in each bulb a total of 5 µL of a dilution of 2 µL of pure deuterated p-xylene (99.9% atom deuterated p-xylene, Sigma Aldrich) in 100 mL of pure methanol. The final concentration of the IS in each sample injected was 145.9 ppb.

Samples were analyzed by SPME/GC–MS according to Scaglia et al. (2011) using granulated activated carbon fibers supported

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