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Biofiltration of α-pinene vapours using municipal solid waste (MSW) – Pruning residues (P) composts as packing materials

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HIGHLIGHTS

- Biofiltration of α-pinene vapours using composts as packing materials was evaluated.
- Biofilter composts were made from MSW with and without pruning waste.
- The influence on removal efficiency of the moisture of biofilters beds was monitored.
- α-pinene removal efficiencies reached values higher than 90% for all compost.
- e-nose was highly sensitive and had high discrimination power to small odour nuances.

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ABSTRACT

In this study, a biofiltration system was designed using mature composts of municipal solid waste (MSW) or MSW mixed with pruning residues (MSW-P) as packing materials to treat vapours of α-pinene (a dominant volatile organic compounds (VOC) emitted during the MSW-P co-composting). Monitoring the efficiency of the biofiltration system was carried out using a photoionization analyser, a commercial electronic nose (e-nose) and gas chromatography – mass spectrometry (GC/MS). Using an EBRT of 66 s, removal efficiencies for both kinds of biofilters were greater than 90% removal at different stages of the experiment. The acclimatisation periods were 10 and 25 days for the MSW biofilter and MSW-P biofilter, respectively. Removal efficiency of the system was strongly dependent upon the moisture content of the packing materials. As moisture content in the biofilters fell to below 66% for the MSW and 51% (dry basis) for MSW-P, the removal efficiency decreased to less than 90%. E-nose and GC/MS data indicate a complete degradation of the α-pinene. The e-nose detected a characteristical background emission (odour fingerprint) of each type of biofilter. Results suggest that e-nose's will become a more powerful tool for monitoring VOCs in biofiltration and composting processes in the future.

1. Introduction

One of the main problems associated with composting facilities is the odours generated during the process, including the odours produced during the reception and the handling of materials, aerobic treatment and stock piling. The emission of these by-products can cause community annoyance and public opposition to composting plants, not only due to the odours but also due to the potential health risks to workers and inhabitants in the local area [1]. The most important group of chemicals responsible for this odour are VOCs and some inorganic gases (ammonia and hydrogen sulfide) produced during the biodegradation of organic residues [2–5]. The family of terpenes is one of the most representative classes of VOCs emitted during the degradation process of vegetal materials (chips, grass clippings and pruning residues). Amongst them, α-pinene is frequently the predominant compound, representing between 10.2% and 72.7% of the total emissions [6]. Furthermore, α-pinene is also emitted by wood processing industries, in particular, saw mills, composite board mills, and paper industries [7,8]. Although, the optimisation of the operational parameters of composting processes is an important objective for

Abbreviation: d.b., dry basis.

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the scientific community in order to reduce the VOCs emissions [5,9]; different techniques exist when the minimisation at source is ineffective. Amongst these techniques, the most widely used are the adsorption on activated carbon, scrubbers and bioscrubbers, condensation, thermal or catalytic incineration, and biofiltration [10–12].

Biofiltration is considered to be an advantageous system for deodorisation due to low operating costs and their abilty to treat large volumes of waste gas streams containing low concentrations of odorous compounds [13,14]. Biofilters allow for the conversion of gas-phase chemical compounds to transform into common biological degradation products, such as carbon dioxide, water, and mineral salts. In the bioreactor, contaminated air is passed through a bed of porous and moist medium (packing material), and the contaminants are sorbed to the medium surface where they are degraded by microorganisms [15]. As the treatment of VOCs in this kind of technology requires the transportation of the compound from the gas phase to the biofilm that forms upon a packing material to be available for the degradation by microorganisms [16], the solubility of the compound in water is a limiting factor in the process. For this reason, the study and optimisation of hydrophobic compounds treatment, using biofiltration technology is a challenge for the scientific community [8,17,18].

α-pinene, one of the major hydrophobic compounds, was selected as the marker VOC in this study. Considering the low solubility of α-pinene in the water phase (2.5 mg l^{-1} at 23 °C) [19,20], it was interesting to evaluate the treatment of this contaminant through biofiltration technology [21]. Biofilter monitoring is usually carried out using GC/MS and olfactometric techniques when an evaluation of the odours is required [9,22–24].

The use and advantages of e-noses have already been widely reported in order to evaluate the presence of VOCs and odours [25–29]. Nevertheless, few studies have assessed the application of e-noses in the monitoring of biofiltration. Online instruments such as photoionization detector (PID) have also been proposed to obtain rapid information on the concentration of VOCs in different kinds of processes [30–33]. The main advantages of the VOCs analyser are its portability, accuracy, quick response time and reliability in the case of a specific VOC gas (less than 2 s) [28].

This study focused on the evaluation of the VOCs removal efficiency for biofilters that used compost either MSW and MSW-Pruning residues as the packing material. The biofilters treated an artificial stream of gases containing a hydrophobic VOC (α-pinene). This evaluation was supported by several analytical techniques, such as VOC analyser, e-nose and GC/MS analysis. There was a particular focus on the removal efficiencies achieved in the biofilters with different moisture contents in their packing materials.

Table 1
Relevant physic-chemical properties of the packing materials used in the biofiltration system proposed (over dry basis) (average ± standard deviation[a]).

		MSW[b]	MSW-P[b]
pH (1:5 extract)		6.55 ± 0.2	5.60 ± 0.1
Electrical Conductivity (EC) (1:5 extract)	mS m^{-1}	1245 ± 0.1	1157 ± 0.1
Organic Matter	g kg^{-1}	301 ± 82	842 ± 93
Kjeldahl-N	g-N kg^{-1}	14.1 ± 1.4	11 ± 0.4
C/N		12.6	45.0
Bulk density	g L^{-1}	705 ± 50	374 ± 54

[a] Average ± standard deviation, over four samples, (d.b.).
[b] MSW: Municipal solid waste composts; MSW-P: Municipal solid waste – Pruning residues composts.

2. Materials and methods

2.1. Biofiltration unit

The biofiltration system consisted of two laboratory scale biofilters (Fig 1), each using a different type of mature compost as its packing material. Each biofilter consisted of a PVC cylinder of 11 cm in diameter and 1 m in height filled with the packing material in the upper 95 cm (bed volume 9.0 L). One biofilter was filled with compost from MSW and the other one with a mixture of compost from MSW and Pruning residues (P) in a volumetric ratio 1:1. Some relevant physico-chemical characteristics of the packing materials are shown in Table 1, additional details can be found in Delgado-Rodriguez et al. [5]. The granulometry of both packing materials was from 7 to 20 mm, in order to improve removal efficiency and avoid operational problems (clogging and control of air flux). The packing materials had previously been used to treat a gas stream composed of a VOC mixture from the active composting of

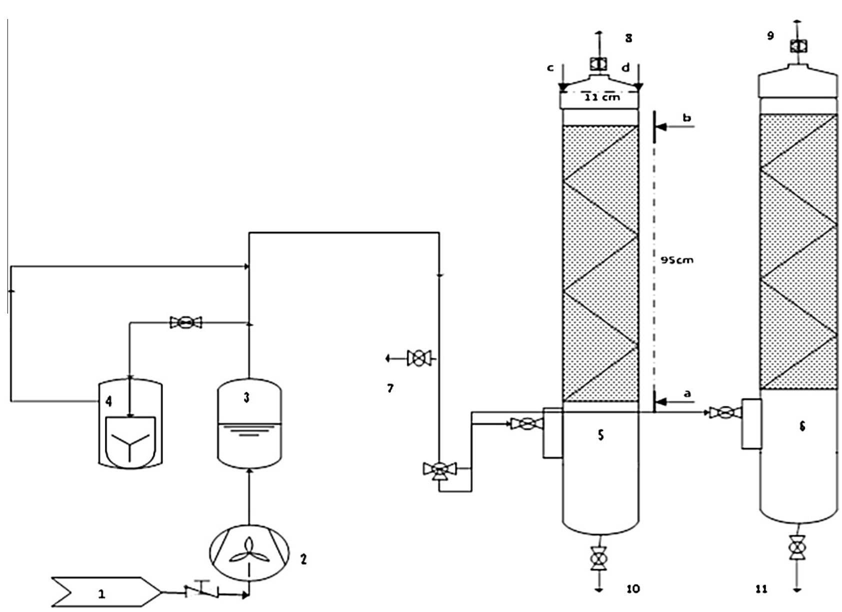

Fig. 1. Schematic diagram of the biofiltration system. (1) Ambience air; (2) Compressor; (3) Humidifier; (4) α-pinene sparger; (5) Biofilter compost MSW; (6) Biofilter compost MSW-P; (7) input sampling port; (8 and 9) outlet biofilter gas/output sampling port; (10 and 11) Water drainage.