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Chemical Engineering Journal 113 (2005) 105–110

Chemical Engineering Journal

www.elsevier.com/locate/cej

Biofiltration for ammonia removal from composting exhaust gases

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Received 11 November 2004; received in revised form 27 January 2005; accepted 1 March 2005

Abstract

A study was conducted to investigate the utilization of mature compost as a biofilter media for the removal of ammonia from the exhaust gases of the composting process. Source-selected organic fraction of municipal solid wastes, digested wastewater sludge and animal by-products were composted in a pilot-scale reactor and the exhaust gas was treated in a biofilter. Due to the high ammonia adsorption and absorption capacity of the compost media, no delay or start-up phase was observed and high removal efficiencies were achieved from the beginning of the experiments. A global ammonia removal efficiency of 95.9% was obtained in the biofilter for a loading rate range of 846–67,100 mg NH_3 m^{-3} biofilter h^{-1}. However, an important reduction of ammonia removal was observed when the waste gas contained high NH_3 concentration (more than 2000 mg NH_3 m^{-3}), which corresponded with the case of animal by-products composting.

Keywords: Ammonia removal; Biofiltration; Compost media; Composting; Organic solid wastes

1. Introduction

At present, solid waste management is becoming a global problem in developed countries. Composting is an environmentally friendly technology to treat and recycle organic wastes. Composting is not only used for the organic fraction of municipal solid wastes, but is also applied to residuals coming from industrial activities. Municipal or industrial wastewater sludge [1] and animal by-products [2] are examples of organic solid wastes susceptible to composting.

At present, odor emissions and atmospheric pollution are the most common problems associated with composting of organic wastes in large-scale facilities. Composting installations present numerous odor sources, including the reception and handling of materials, active composting, stock piling, etc. Exhaust gases from composting are usually characterized by high flow rates and low pollutant concentrations. Ammonia has received much attention as it can be easily identified from other composting odors, often represents the main nitrogen gas emitted during composting and it can be released in large amounts. Degradation of protein, urea or uric acid produces ammonium [3]. In this process, pH, temperature and moisture content determine the NH_3/NH_4^+ balance and hence the ammonia emission. Nitrogen losses from composting material normally imply a poor agronomical quality of the final compost and environmental pollution problems, such as odor nuisance and acid rain [4]. Ammonia emissions in a composting process of organic fraction of municipal solid wastes varies between 18 and 150 g NH_3 Mg^{-1} waste [5], while ammonia concentrations up to 700 mg NH_3 m^{-3} have been reported in exhaust gases from sludge composting [6].

Among the available technologies for gas treatment, biofiltration is an odor reduction technique that can be adapted to reduce emissions from composting processes [7]. It is considered a suitable technology in terms of waste recycling, emissions reduction, and low construction and operating costs [8]. In a biofilter, a contaminated/odorous gas stream passes through a biologically enriched layer of a filter material such as soil, wood chips, compost or mixed materials, followed by

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1385-8947/$ – see front matter
doi:10.1016/j.cej.2005.03.004

biodegradation of the absorbed/adsorbed pollutant. The by-products of microbial oxidation are primarily water, carbon dioxide, mineral salts, some volatile organic compounds and microbial biomass [9].

Several important variables affect the performance of a biofilter. Microbial activity is affected by moisture content, pH, nutrient limitation, temperature and microbiology of the biofilter medium. Compost-based media have been used extensively in recent years because they have complex microbial communities capable of degrading several pollutants, and they have good water retention properties and a suitable organic matter content. Mature compost media are inexpensive and readily available; therefore their use in biofilters is a good option in composting facilities. Additional nutrients are not usually required for biofilters based on compost because it has significant amounts of organic nitrogen and other micronutrients. At the same time, the high ammonia content in most composting gases supplies enough nitrogen for biofilters used on composting plants [6]. Compost can be mixed with bulking agents to avoid high pressure drop, clogging and flow channeling and to increase its durability [9,10].

Biofilters permit a high removal of ammonia, usually around 95–98% on a wide variety of support materials, either organic or inorganic [11]. Liang et al. investigated the long-term ammonia removal using a compost biofilter and achieving removal efficiencies above 95% with loads ranging from 0.33 to 16.25 mg NH_3 kg media^{-1} h^{-1} and empty bed retention time (EBRT) ranging from 31.8 to 78 s [10]. Other studies on biofiltration of exhaust gases in composting facilities indicate reductions of 98% for an average loading rate of 10,180 mg NH_3 m^{-3} biofilter h^{-1} and an EBRT of 16 s [12,13]. There is, however, a lack of knowledge about the operational limits of biofiltration when treating odorous waste gases containing high ammonia concentrations [14], such as some of the composted materials in Spain.

This work studies the efficiency of a compost biofilter for the removal of ammonia from the exhaust gases of the composting process of source-selected organic fraction of municipal solid wastes (OFMSW), digested wastewater sludge (DS) and animal by-products (AP).

2. Materials and methods

2.1. Organic wastes composted

OFMSW was obtained from the municipal composting plant of Jorba (Barcelona, Spain), DS was obtained from the urban wastewater treatment plant of La Llagosta (Barcelona, Spain), and AP, consisting of rejected parts of chicken and rabbit (viscera, carcasses, feathers, etc.), were obtained from the municipal composting plant of Jorba (Barcelona, Spain). All wastes were manually mixed with bulking agents (chopped pruning waste) to ensure an optimal porosity and moisture content. In the case of OFMSW two volumetric ratios of bulking agent:waste (5:1, 1:1) were tested.

2.2. Experimental set-up

OFMSW, DS and AP were composted in a thermally insulated 30 dm^3 laboratory reactor. Air was supplied to the reactor intermittently by a suction-type blower (Sensotran, Spain, model GCYA/BA) to control the content of oxygen (Sensotran, Spain, model Sensox 6C) in the composting material to ensure aerobic conditions (oxygen concentration above 10%). The blower extracted the air (5 dm^3 min^{-1}) through the compost mass and discharged the exhaust gas to a pilot-scale biofilter filled with mature compost as a biofilter medium. Down-flow direction was selected to improve moisture control. Since temperature of off-gases from the composting reactor was below 35 °C, it was not necessary to cool down the gas entering the biofilter and it operated within a mesophilic temperature range throughout the whole experimental period. A scheme of the composting and biofiltration system is shown in Fig. 1.

The biofilter was constructed with circular methacrylate pipe, and its dimensions were: height 1.2 m and diameter 0.2 m. The media depth was 0.23 m, resulting in a total bed volume of 7.2 dm^3, a volumetric loading rate of 0.69 dm^3 dm^{-3} media min^{-1} and a gas retention time of 86 s. Initial properties of the mature compost used as the biofilter media are shown in Table 1.

Two runs were conducted for each waste composted, and each run lasted about 1 week. Experiments were carried out

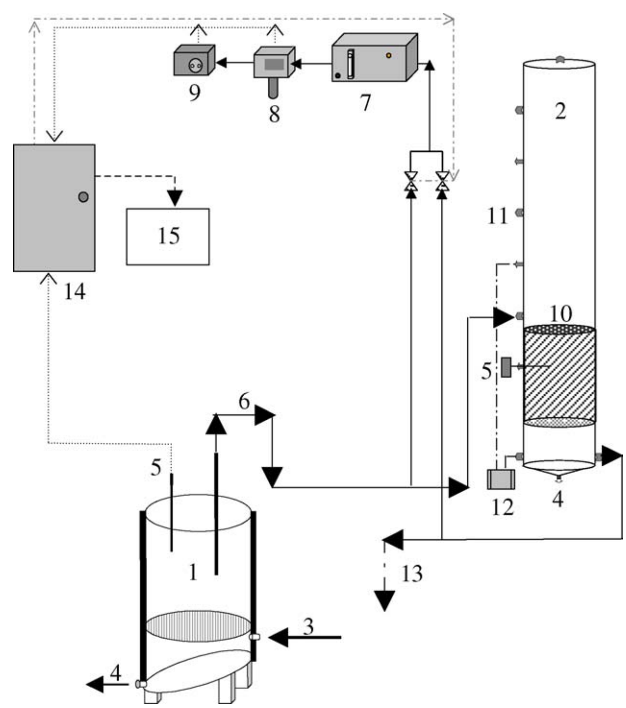

Fig. 1. Scheme of the pilot-scale composting and biofiltration system. (1) Composter; (2) biofilter; (3) air inlet; (4) leachates outlet; (5) temperature probe; (6) exhaust gas from composter and inlet biofilter gas; (7) suction-type blower; (8) ammonia sensor; (9) oxygen sensor; (10) compost media; (11) sampling ports; (12) manometer; (13) outlet biofilter gas; (14) data logger and control system; (15) personal computer.