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Greenhouse gas emissions from home composting of organic household waste

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ABSTRACT

The emission of greenhouse gases (GHGs) is a potential environmental disadvantage of home composting. Because of a lack of reliable GHG emission data, a comprehensive experimental home composting system was set up. The system consisted of six composting units, and a static flux chamber method was used to measure and quantify the GHG emissions for one year composting of organic household waste (OHW). The average OHW input in the six composting units was 2.6–3.5 kg week^{-1} and the temperature inside the composting units was in all cases only a few degrees (2–10 °C) higher than the ambient temperature. The emissions of methane (CH_4) and nitrous oxide (N_2O) were quantified as 0.4–4.2 kg CH_4 Mg^{-1} input wet waste (ww) and 0.30–0.55 kg N_2O Mg^{-1} ww, depending on the mixing frequency. This corresponds to emission factors (EFs) (including only CH_4 and N_2O emissions) of 100–239 kg CO_2-eq. Mg^{-1} ww. Composting units exposed to weekly mixing had the highest EFs, whereas the units with no mixing during the entire year had the lowest emissions. In addition to the higher emission from the frequently mixed units, there was also an instant release of CH_4 during mixing which was estimated to 8–12% of the total CH_4 emissions. Experiments with higher loads of OHW (up to 20 kg every fortnight) entailed a higher emission and significantly increased overall EFs (in kg substance per Mg^{-1} ww). However, the temperature development did not change significantly. The GHG emissions (in kg CO_2-eq. Mg^{-1} ww) from home composting of OHW were found to be in the same order of magnitude as for centralised composting plants.

1. Introduction

Home composting is an interesting alternative to centralised composting. Since the landfill directive came into force in 1999 (CEC, 1999), the organic fraction of waste going to landfills in the European Union has been diverted to other treatment facilities such as composting plants. This has generated a greater need for well-managed composting plants or the possibility of avoiding organic waste in municipal waste streams by composting at home. The actual amount of organic household waste (OHW) that is composted at home and thereby diverted away from landfills is poorly researched. However, it has been estimated that approximately 20% of OHW could be diverted to home composting in a study area of west London, UK (Smith and Jasim, 2009). This number, however, depends on the motivation of the people in the survey area compared with the motivation of people in the average home composting community.

Like centralised composting, home composting has some advantages such as the production of a nutrient-rich humus-like material for use on soil as a substitute for fertiliser and/or for peat in growth media. When composting organic waste in private gardens, less waste has to be directed to centralised composting (or other treatment facilities) thereby saving emissions related to collection and transportation. The use of electricity, diesel, lubricating oils, and motor oil during the operation of centralised composting plants is also avoided when organic waste is home composted (Andersen et al., in press). Home composting is a unique waste management option because the waste producer is also the processor and end-user of the product. This, however, results in a large variety of operation schemes, which means that there is no standardised procedure for home composting. This is one of the reasons for the lack of scientific knowledge in this field.

Like centralised composting, there are environmental impacts associated with home composting, in which the potential emission of greenhouse gases (GHGs) is one of the most important (Colón et al., 2010). The GHGs of interest are mainly methane (CH_4) and nitrous oxide (N_2O) because they have high global warming potentials (GWPs) and thereby contribute to climate change. The GWP of CH_4 and N_2O is 25 and 298 over a 100-year time frame, respectively (Solomon et al., 2007), indicating that they are 25 and 298 times more potent GHGs than (fossil) carbon dioxide (CO_2). The CO_2 emitted during composting originates from the degradation

Abbreviations: EF, emission factor; GHG, greenhouse gas; GWP, global warming potential; OHW, organic household waste.

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of plant material and is usually accounted as neutral with respect to global warming (i.e. the GWP is zero) (Christensen et al., 2009).

GHG emissions have previously been addressed in composting studies in bench scale (Beck-Friis et al., 2001), pilot scale (Beck-Friis et al., 2000), and full scale (Amlinger et al., 2008; Andersen et al., 2010) studies, with a variety of waste types such as garden and food waste. In addition, Boldrin et al. (2009) reported on a wide range of estimated and measured GHG emission data in a literature review covering open and closed technologies as well as home composting. Collectively, it was found that CH_4 is produced and emitted when composting organic waste even under well-aerated conditions. Nitrous oxide is also produced under all these different operation schemes. GHG emissions have previously been addressed in home composting but with very different approaches and conclusions. Some studies have found GHG emissions to be negligible because the measuring systems were set with too high detection limits. In home composting studies by Wheeler and Parfitt (2002), McKinley and Williams (2007), and Smith and Jasim (2009), CH_4 emissions were quantified with measuring equipment with detection limits of 0.1%, 0.1% and 1% (by volume). The detection limit has to be significantly lower (in the $\mu L\, L^{-1}$ level) to measure CH_4 emissions from home composting units. Other authors argue that home composting piles are rarely large enough to permit anaerobic conditions and, therefore, their studies neglect CH_4 emissions (USEPA, 1998; Smith et al., 2001). By contrast, Amlinger et al. (2008) reported in a comprehensive experimental setup (high-load home composting) that GHG emissions from home composting are at the same level as from centralised composting. Weidema et al. (2006) modelled (in a lifecycle-based cost-benefit assessment) that home composting is an intermediate between aerobic and anaerobic digestion. This resulted in home composting being the least preferable waste management option in respect to global warming, even worse than central composting and uncontrolled landfills. In a life cycle assessment by Lundie and Peters (2005) different food waste management options were assessed in relation to global warming contributions. The most favourable option was found to be home composting assuming aerobic conditions (no methane) while the least favourable option was home composting assuming anaerobic conditions. These studies show the need for reliable GHG emission factors (EFs) from home composting systems. In this context, EFs are expressed as the mass of the respective gas per mass of input OHW (in $kg\, Mg^{-1}$ input wet waste (ww)). Emission factors can be used in green accounts and for environmental assessments, but it is important to gather quantitative data to improve the comparability, consistency, and accuracy of databases and models.

The main objectives of this paper were to establish a representative single-family home composting system and measure the GHG emissions to obtain reliable EFs from home composting of OHW. It was important that the experimental setup represented a common single-family home composting practice based on conditions in Denmark, which is in a temperate climate zone with average winter temperatures of 0.5 °C and average summer temperatures of 15 °C. All EFs given in this paper are representing the contributions from the actual degradation of OHW. All other contributions from for example making the composting unit, collection, transport and mechanical turning have not been included.

2. Materials and methods

2.1. Composting units

The six home composting units (Humus/Genplast, 8230 Åbyhøj, Denmark) used in the study are the most commonly used units in Denmark. They are cone-shaped, made of recycled PE and PP and weigh 22 kg. The total volume is 0.32 m^3 and the dimensions are 95 cm in height and 48 cm and 105 cm in diameter (top and bottom, respectively). The composting units are equipped with a lid, a fine-masked steel net at the bottom, which prevents mice and rats from entering, a hatch where the mature compost can be withdrawn, and a net to prevent flies from entering. The bottom has plenty of holes from where the surrounding air can enter the composting unit. A plastic rim, which acted as a base for the flux chamber (used to measure the emissions; see Section 2.5), was inserted below the lid of each unit. The plastic rim was inserted below the anti fly net so it functioned as the only outlet during the emission measurements. A schematic drawing of one of the composting units is shown in Fig. 1 (left) and a picture is shown in Fig. 1 (right). The only differences in the management of the six units were the type and amount of input waste and frequency of mixing. Mixing consisted of manually aerating the material using a mixing stick made of recycled PE and PP (delivered together with the composting unit). Units 1 and 2 represented eager management (mixing every week), which is not considered a likely management approach. Units 3 and 4 were considered the most likely setup for home composting (mixing every sixth week), whereas Units 5 and 6 represented the lazy home composters that spend little time on the process (no mixing). The management of the composting

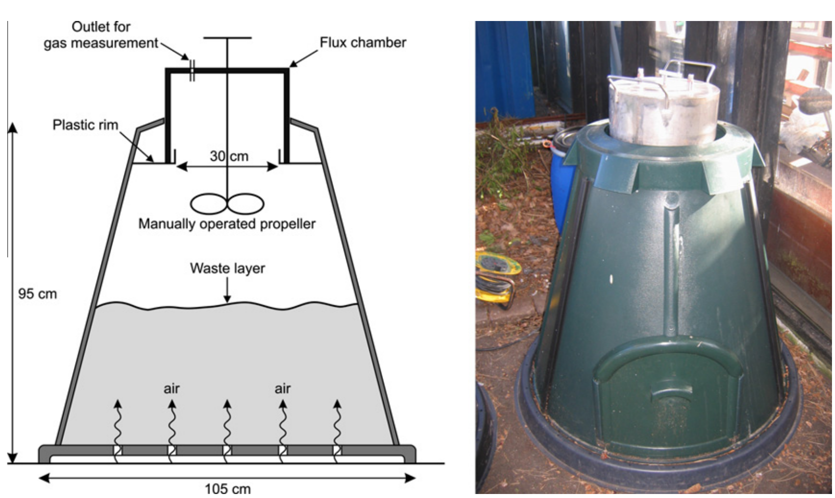

Fig. 1. Left: Schematic drawing of one of the composting units including the position of the flux chamber system during measurement campaigns. The possible flow of air through the bottom of the composting unit is shown with arrows on the drawing. Right: Picture of one of the composting units.