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The effect of different pen cleaning techniques and housing systems on indoor concentrations of particulate matter, ammonia and greenhouse gases (CO_2, CH_4, N_2O)

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ABSTRACT

The objective of this study was to investigate the effect of two pen cleaning techniques for pig fattening houses on the indoor concentrations of particulate matter (PM_1, $PM_{2.5}$ and PM_{10}), ammonia (NH_3) and greenhouse gases (CO_2, CH_4, N_2O), using a multi-pollutant approach. Both cleaning techniques were tested in a conventional housing system and in a low-ammonia-emission housing system. In total, four compartments from the conventional housing system and four from the low-ammonia-emission housing system were sampled during two consecutive fattening periods between August 2011 and June 2012. Two compartments from each housing system were only cleaned dry, while the other two received a more intensive cleaning. Indoor concentrations of NH_3, CO_2, CH_4, N_2O and PM were measured continuously.

Overall, the low-ammonia-emission housing system showed no reduction in indoor pollutant concentrations compared to the conventional system, except for CH_4. The additional wet cleaning and disinfection step in the more intensive cleaning protocol did not result in consistently lower indoor concentrations for the studied pollutants.

1. Introduction

The environmental impact of pig husbandry is largely related to aerial emissions from housing systems. These emissions can contain pollutants such as ammonia (NH_3), greenhouse gases (methane (CH_4), nitrous oxide (N_2O) and carbon dioxide (CO_2)) and particulate matter (PM). NH_3 emissions can lead to eutrophication and acidification of waterways and soils (Koerkamp et al., 1998). The emissions of greenhouse gases contribute to global warming, which is considered to be a major threat for the global environment (Flessa et al., 2002). PM is strongly associated with human health problems (Bates, 2000). Furthermore, PM can be a carrier of endotoxins and microorganisms, facilitating the transmission of pathogenic microorganism and the transportation of odourous compounds which can cause a nuisance for nearby inhabitants (Hooda et al., 2000; Oehrl et al., 2001; Seedorf et al., 1998; Yuan et al., 2010; Zhao, 2011).

Over past few decades pig production in Flanders has intensified (European Commission, 2003; van Gijseghem et al., 2002). To minimise the environmental impact of this production intensification, new legislation has been implemented, especially with regard to NH_3 emissions. All European pig fattening facilities with more than 2000 fatteners, are subjected to the European Integrated Pollution Prevention and Control (IPPC) convention. The Intensive

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Rearing of Poultry and Pigs BREF (Best Available Techniques (BAT) reference document) gives an overview of the BAT, with good agricultural practice as an essential part of it, to reduce NH_3 emissions. Regarding housing systems, the main principles to reduce ammonia emissions are: reduction or cooling of the emitting manure surfaces, quick removal of manure out of the stable or the use of surfaces (e.g. slats and manure channels) which are smooth and easy to clean. Other possibilities are end-of-pipe techniques (e.g. chemical wet air scrubber or bioscrubber) (European Commission, 2003).

Legislation passed in 2004 requires pig and poultry producers in Flanders to use officially approved low-ammonia-emission housing systems when renovating, expanding or building new animal housing. These housing systems are usually more expensive than conventional housing systems. Furthermore, some of these techniques are pure end-of-pipe techniques. Such end-of-pipe techniques are not expected to reduce indoor concentrations of ammonia.

The indoor air quality of pig housing is gaining increasing attention in relation to human and animal health (Banhazi et al., 2008a; Wathes et al., 1998). Exposure to high indoor concentrations of NH_3, CO_2 or PM can negatively affect the health of workers in pig houses (Asmar et al., 2001; Laitinen et al., 2001; Von Essen and Donham, 1999; von Essen and Banks, 2009) and of the pigs themselves (Busse, 1993; Donham, 1991, 2000; Lee et al., 2005; Urbain et al., 1999). The suggested maximum allowed CO_2 concentration for workers (5000 ppm) is rarely exceeded inside pig houses (Choudat et al., 1994; CIGR, 1992).

According to the study of Banhazi et al. (2008a, 2008b), a decrease in pen cleanliness results in higher indoor concentrations of ammonia, airborne bacteria and respirable particles. These researchers stated that improved pen cleanliness can be considered the most practical recommendation for decreasing concentrations of ammonia, respirable particles and bacteria (Banhazi et al., 2008a, 2008b). Recently Chen et al. (2011) developed an emission model for commercial swine finishing barns based upon a two-year emission dataset from a commercial swine finishing farm. The vacancy period of the barn and the emissions after high pressure washing were included. In this dataset, they observed a reduction in the emissions of NH_3 and PM_{10} after wet cleaning of the barns. However, due to the limited amount of data for the empty-barn and power washing conditions, it was difficult to make accurate estimations of the influence of cleaning on the emissions (Chen et al., 2011).

Information on this topic is scarce. Most studies evaluate only one single or a few important pollutants simultaneously. Furthermore, the cleaning techniques used usually differ greatly and are not always applicable in practice. Therefore we used a multi-pollutant approach to explore the effect of two practically applicable pen cleaning techniques on the indoor concentrations of NH_3, greenhouse gases (CO_2, CH_4 and N_2O) and PM in two types of housing systems for fattening pigs. In this study, the chosen pen cleaning techniques were (1) dry cleaning versus (2) dry and wet cleaning with an additional disinfection step.

2. Materials and methods

2.1. Location of the measurements

The study was conducted in a commercial fattening pig barn (Diksmuide, Belgium) with all-in/all-out management. Two types of housing systems were studied: (1) four conventional compartments with fully slatted floors (Fig. 1, compartments A, B, G and H) and (2) four low-ammonia-emission compartments with reduced emission surfaces (i.e. partly-slatted floors with a central convex solid floor, a manure channel with sloped pit walls and a water channel (Fig. 2)) (Fig. 1, compartments C, D, E and F). All compartments had a central exhaust fan and automated temperature-regulated ventilation. Fresh air entered the compartments through an opening in the lower part of the door (door ventilation). Phase feeding was applied in all compartments, with pelleted feed and water available ad libitum. The feed was delivered automatically by a feeding chain in the open troughs. An overview of the main characteristics of the different compartments is shown in Table 1.

2.2. Experimental design

All measurements were performed between August 2011 and June 2012. Two fattening periods were monitored per compartment and the eight compartments were divided into two groups with a difference of four weeks

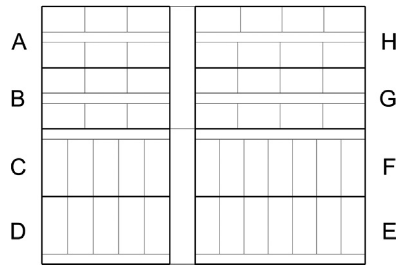

Fig. 1. Two-dimensional floor plan of the barn with indication of the different compartments.

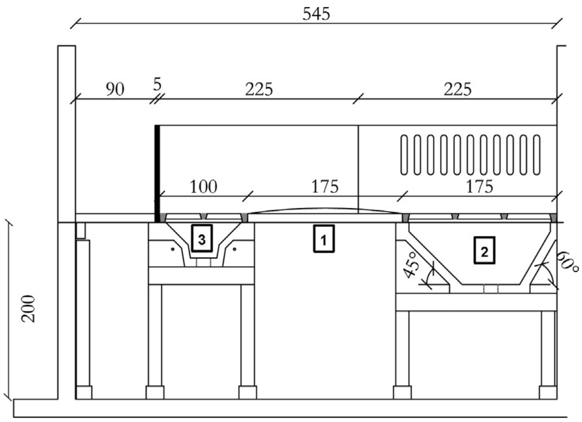

Fig. 2. Schematic overview of the manure pit in the low-ammonia-emission compartments with partly-slatted floors and a central convex solid floor [1], a manure channel with sloped pit walls [2] and a water channel [3] (adapted from N.V. Betonbedrijf R. Dobbelaere –Bonte).