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Research Paper

Evaluation of manure drying tunnels to serve as dust filters in the exhaust of laying hen houses: Emissions of particulate matter, ammonia, and odour☆

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Poultry houses are important emission sources of ammonia, odour, and particulate matter (PM). Manure drying tunnels (MDTs) might act as 'end of pipe' PM filters, but might also emit additional ammonia and odour. This study aimed to gain insight into this matter (parts A and B) and into the perspective of two strategies to reduce additional emissions: (1) by pre-drying the manure on the belts inside the house (part C), and (2) by reducing manure accumulation time (MAT) in the house to 24-h followed by rapid drying inside the MDT (part D). This study was set up as an emission survey at 16 laying hen farms with a MDT. Results from parts A through C showed that PM_{10} removal efficiency of the MDTs increases linearly with manure layer thickness: from about 35% at 4 cm to 84% at 17 cm. Ammonia and odour concentrations in the drying air increased substantially upon passing the manure layers, from on average 5.5 to 13.9 ppm ammonia and from 822 to 1178 $OU_E\ m^{-3}$. In part C, ammonia emission decreased with increasing DM content of the manure, but even at DM content levels beyond 50%, substantial ammonia emission remained. In part D, the emission rates of houses and MDTs together were 44% lower for PM_{10}, 20% higher for ammonia, and 40% higher for odour compared with the theoretical situation of the houses without MDT. Further shortening MAT to 18, 12, or 6 h might be needed to reduce emissions from MDTs.

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Nomenclature

CO_2	carbon dioxide
COPD	chronic obstructive pulmonary disease
DSA	drying surface area of the manure drying tunnel (cm^2 $bird^{-1}$)
DT	drying time inside the manure drying tunnel (days or hours)
E	emission rate of pollutant (mg h^{-1} $bird^{-1}$ or OU_E s^{-1} $bird^{-1}$)
EF	emission factor for ammonia in Dutch regulation (g $year^{-1}$ bird $place^{-1}$)
Fco_2	factor for conversion of total heat to the volumetric carbon dioxide production by the animal and its manure (m^3 h^{-1} kW^{-1})
MAT	manure accumulation time: time between a full running cycle of the belts inside the housing system. Note that at a MAT of 24 h, the manure has a manure residence time (MRT) of 12 h
MBA	manure belt aeration; inside the housing system
MDT	manure drying tunnel
MLT	manure layer thickness inside the manure drying tunnel (cm)
MRT	manure residence time: the time a dropping resides on average on the manure belt inside the housing system
NH_3	ammonia
OU_E	European odour unit (EN 17025)
P	level of significance
PM	particulate matter
PM_{10}	particulate matter which passes through a size-selective inlet with a 50% efficiency cut-off at 10 μm aerodynamic diameter (EN 12341)
$PM_{2.5}$	particulate matter which passes through a size-selective inlet with a 50% efficiency cut-off at 2.5 μm aerodynamic diameter (EN 14907)
SD	standard deviation
SE	standard error
Q_{drying}	ventilation rate through the MDT (m^3 h^{-1} $bird^{-1}$)
Q_{bypass}	ventilation rate from the poultry house not directed through the MDT (m^3 h^{-1} $bird^{-1}$): $Q_{bypass\_during\_drying} + Q_{bypass\_during\_loading}$
$Q_{bypass\_during\_drying}$	ventilation rate from the poultry house during drying of the MDT (m^3 h^{-1} $bird^{-1}$)
$Q_{bypass\_during\_loading}$	ventilation rate from the poultry house during loading of the MDT (m^3 h^{-1} $bird^{-1}$)
$Q_{total\_during\_drying}$	total ventilation rate of MDT and house during drying (m^3 h^{-1} $bird^{-1}$): $Q_{drying} + Q_{bypass\_during\_drying}$
Q_{total}	total ventilation rate (m^3 h^{-1} $bird^{-1}$): $Q_{drying} + Q_{bypass}$
Φ_{total}	total heat production by the animal (kW)

1. Introduction

In areas with high densities of livestock houses, emissions from poultry houses represent an important source of airborne pollutants, such as malodourous compounds (Mielcarek & Rzeźnik, 2015; Ogink & Groot Koerkamp, 2001), gaseous ammonia (Groot Koerkamp et al., 1998; Wood, Cowherd, & Van Heyst, 2015), and particulate matter (PM) (Takai et al., 1998; Winkel, Mosquera, Groot Koerkamp, Ogink, & Aarnink, 2015). These pollutants are associated with adverse effects on the environment and on the health and wellbeing of residents in these areas. The chronic exposure of residents to odours from nearby livestock houses may cause an array of physical and emotional complaints, either directly by exposure to irritant odorants, or indirectly, through mechanisms related to annoyance, sensitisation, stress, and conditioning (Hooiveld et al., 2015; Nimmermark, 2004). Gaseous ammonia causes acidification and eutrophication of soils and surface waters (ApSimon, Kruse, & Bell, 1987). Furthermore, ammonia is a precursor of secondary PM (i.e., inorganic, fine, and solid ammonium nitrate and ammonium sulphate) formed through chemical reactions in the atmosphere (Erisman & Schaap, 2004) and linked to adverse health outcomes (Brunekreef et al., 2015; Schlesinger, 2007). In contrast to secondary PM, primary PM is emitted as particles from livestock houses which mainly fall in the size range larger than 2.5 μm (Lai et al., 2014). It originates from organic sources inside the house, such as manure, feathers, and skin debris (Cambra-López, Hermosilla, Lai, Aarnink, & Ogink, 2011), and contains micro-organisms and pro-inflammatory endotoxins (Seedorf et al., 1998; Zhao, Aarnink, De Jong, & Groot Koerkamp, 2014). Recent work on effects of livestock emissions on public health suggests both protective and adverse effects, such as a higher prevalence of pneumonia and more exacerbations in patients suffering from Chronic Obstructive Pulmonary Disease (COPD) (Borlée, Yzermans, Van Dijk, Heederik, & Smit, 2015; Hooiveld et al., 2016; O'Connor et al., 2010; Schinasi et al., 2011; Smit et al., 2014).

Although ambient PM concentrations in the Netherlands as a whole have decreased in recent years, exceedances of the European limit values for PM with aerodynamic diameters smaller than 10 μm (PM_{10}), laid down in EU Directive 2008/50/EC (EU, 2008), are persistent in some typical farming areas. In addition, PM_{10} levels in many other farming areas are only just below the limit values, making those areas vulnerable for future exceedances (Van Zanten et al., 2014).

To facilitate the mitigation of primary PM emissions from poultry farms, an action plan was set up for the Netherlands (Ogink & Aarnink, 2011). Within the framework of this plan, effective, economically feasible, and market-ready systems for the poultry industry were developed in cooperation with air cleaning companies. One of these systems was the manure drying tunnel (MDT), which could be applied for both manure drying and filtration of primary PM from the exhaust air. In Dutch regulation on ammonia emissions from livestock houses, MDTs are allowed only for use in hen-rearing and hen-laying houses under the requirements that the manure

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