DUST FILTERING PROPERTIES AND AMMONIA EMISSION OF ON-FARM DRYING SYSTEMS FOR POULTRY MANURE

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ABSTRACT: In the Netherlands, measures for mitigation of Particulate Matter (PM) emissions are needed for poultry houses to lower their contribution to elevated ambient PM concentrations. In this study, we 1) investigated whether on-farm drying systems (DS) for poultry manure can remove PM from the exhaust air flow, and 2) evaluated the contribution of DS to ammonia emissions. At two layer facilities, a total of twelve 24-hour measurements were carried out of temperature, relative humidity, ventilation rate, PM and ammonia between December 2009 and February 2010. A substantial removal of inhalable dust (69% for house 1), PM_{10} (83% for house 1; 33% for house 2) and $PM_{2.5}$ (57% for house 1; 32% for house 2) was found. Concentrations of ammonia however, increased by a factor 5.0 (house 1) and 3.6 (house 2) over the manure layer. This study shows that DS for poultry manure show good ability to remove PM, but further research is necessary to avoid problem swapping by elevating emissions of other pollutants.

Keywords: poultry, manure drying systems, particulate matter, ammonia, abatement

INTRODUCTION: Elevated concentrations of particulate matter (PM) in the ambient air are considered a public health risk (Heederik et al., 2011). PM emissions from animal houses contribute significantly to ambient PM concentrations in the Netherlands (CBS et al., 2009). Measures are needed to mitigate animal house PM emissions to comply with PM limits in ambient air set in EU Directive 2008/50/EC (Annex XI). A practical measure to reduce PM emissions from poultry houses may be the dual use of poultry manure drying systems (DS) for both manure drying and dust filtration. In the Netherlands, DS are mainly applied at hen-rearing and laying facilities for drying fresh or pre-dried droppings to >80% of dry matter (DM) within 48-96 h. After drying, manure is transported to arable farms, biomass power plants or fertilizer producers. Inside these poultry facilities, hens deposit their manure on belts (underneath cages, raised slatted floors or wired floors in aviary systems), and manure is frequently transported to the DS, usually located in a separate space next to the house. Depending on the type and sizing, the DS is usually composed of 2-12 vertical tiered perforated polypropylene or metal belts. The manure is spread in a layer of 3-15 cm onto the uppermost belt. Drying is done by forcing warm exhaust air through the manure layers by means of pressure fans that maintain overpressure in a pressure corridor between the house and the DS. Usually, the minimum required house ventilation (1-2 m^3 h^{-1} $bird^{-1}$) is used for drying, and any extra ventilation is released through bypass fans, directly to the outside air. When manure reaches the end of a belt, it falls down onto the next belt below, until it finally reaches the end of the lowermost belt, after which the dry manure is further transported to storage. In earlier research on similar DS, some extra ammonia emission was found, but PM concentrations were not determined (Groot Koerkamp and Montsma, 1995, Huis in 't Veld et al., 1999). In this study, we 1) investigated whether on-farm DS for poultry manure can remove PM from the exhaust air flow, and 2) evaluated the contribution of DS to ammonia emissions.

1. MATERIAL AND METHODS:

1.1. General design of the study: The study was done at two commercial laying facilities in the Netherlands. A description is given in Table 1. At these locations, we carried out in simplo measurements of temperature and relative humidity, and duplicate measurements of CO_2 (calculation of ventilation rate), PM (inhalable dust, PM_{10}, and $PM_{2.5}$), and ammonia, both upstream (pressure corridor) and downstream of the DS. Six 24-hour measurements were done per house between December 2009 and February 2010.

Table 1. Characteristics of the layer houses and drying systems.

	House 1	House 2
Type of housing	2-story house; aviaries	2 houses; cages
Manure belt aeration	Not present	1 house; 0.7 m^3 h^{-1} $bird^{-1}$
Ventilation type	Side wall inlets; end wall fans	Belt aeration + side wall inlets; side wall fans
Number of hens	65,000	76,800 + 49,600
Type of drying system	Metal belts	Polypropylene belts
Drying levels (belts)	1 System of 4 levels	2 Systems of 10 levels
Belt dimensions (m)	18.5 x 2	40 x 1.5
Layer thickness (cm)	15–20	9
Max. drying vent. (m^3 h^{-1} $bird^{-1}$)	2.1	2.4
Max. bypass vent. (m^3 h^{-1} $bird^{-1}$)	3.9	3.6
Manure loading	Every 12 hours	Every 24 hours
Manure drying time	4 days	5 days

1.2. Temperature, relative humidity and ventilation rate: Temperature and relative humidity were measured continuously with combined sensors (Rotronic; ROTRONIC Instrument Corp., Huntington, NY, USA) and data were stored in a data logging system. A 24-hour average air sample was taken using the lung principle (40 L Nalophan air sampling bags, sampling at 0.02 L min-1) and analysed for CO_2 concentration by gas chromatography (Interscience/Carbo Erba Instruments, GC 8000 Top) to determine ventilation rate using the CO_2 mass-balance method (Pedersen et al., 2008, CIGR, 2002).

1.3. Particulate Matter: Inhalable dust was sampled using IOM samplers (at 2 L min-1; SKC Inc., Eighty Four, PA, USA), following EN 481. PM_{10} and $PM_{2.5}$ were sampled using cyclone pre-separators (URG corp., Chapel Hill, NC, USA), glass fibre filters (type MN GF-3, Ø 47 mm, Macherey-Nagel GmbH & Co., Düren, Germany) and sampling pumps (at 1 m^3 h^{-1}; Ravebo Supply BV, Brielle, the Netherlands), following CEN-EN 12341 for PM_{10} and CEN-EN 14907 for $PM_{2.5}$. For more details on the sampling procedure, see Zhao et al. (2009).

1.4. Ammonia: Ammonia was collected using acid traps (critical capillary of 1 L min^{-1}; impingers with 100 ml of nitric-acid solution at 0.05 M), and ammonia content was determined by spectrophotometry.

2. RESULTS AND DISCUSSION: Main results of measurements are summarised in Table 2. In both DS, the air humidity increased to levels above 90% accompanied by a drop in air temperature of 3-5 °C, in agreement with earlier studies on similar systems (Groot Koerkamp and Montsma, 1995, Huis in 't Veld et al., 1999). This represents the evaporation of water from the manure into the gas phase, which requires the input of thermal energy. Because of the low outside temperatures in winter, DS ventilation was sufficient to maintain the target house temperature during 11 of 12 measurements, when no extra bypass ventilation occurred.

Table 2. Mean values (± SD) of upstream and downstream measurements.

	House 1 (*n*=6)		House 2 (*n*=6)	
	Upstream	Downstream	Upstream	Downstream
Air temperature (°C)	17.1 ± 0.6	12.8 ± 1.0	20.4 ± 1.4	17.6 ± 0.8
Relative humidity (%)	65.1 ± 3.4	97.7 ± 4.4	70.8 ± 7.2	90.6 ± 6.2
Vent. rate (m^3 h^{-1} $bird^{-1}$)	1.7 ± 0.6		1.4 ± 0.6	
Inhalable dust (mg m^{-3})	5.00 ± 0.66	1.66 ± 1.63	not determined	
PM_{10} (mg m^{-3})	2.58 ± 0.37	0.42 ± 0.07	0.42 ± 0.04	0.28 ± 0.02
$PM_{2.5}$ (mg m^{-3})	0.17 ± 0.05	0.07 ± 0.02	0.03 ± 0.01	0.02 ± 0.01
NH_3 (ppm)	4.3 ± 0.9	23.8 ± 15.7	14.6 ± 3.5	48.7 ± 5.4

Concentrations of the three PM fractions were all reduced over the manure layer. For inhalable dust (only house 1), mean reduction (± SD) was 69 ± 27%. Mean PM_{10} reductions (± SD) were 83 ± 5% for house 1 and 33 ± 3% for house 2. Mean $PM_{2.5}$ reductions (± SD) were 57 ± 18% for house 1 and 32 ± 12% for house 2. Both PM_{10} and $PM_{2.5}$ reductions were generally higher for the DS of house 1, which may be due to the larger layer thickness, resulting in a longer air residence time, and greater chance for particles to be captured in the pores between the sticky droppings.

For ammonia, substantial extra emission occurred from the manure layer. On average, the ammonia concentration increased by a factor 5.0 for house 1 and 3.6 for house 2. A previous study of a similar drying system attached to an aviary house, however, reported a mean extra ammonia emission of only 2 g $year^{-1}$ animal $place^{-1}$ on top of a house emission of 96 g $year^{-1}$ animal $place^{-1}$ (Huis in 't Veld et al., 1999). But also in this study, ammonia concentrations increased when passing the manure layer. Mean ammonia concentrations were 3 ppm upstream and 6 ppm downstream of the DS (increase by a factor of 2) in winter, whereas in summer, mean concentrations were 16 ppm upstream and 18 ppm downstream (increase by a factor of 1.3). Due to the low drying ventilation rate (0.14 m^3 h^{-1} $bird^{-1}$ versus 9.3 m^3 h^{-1} $bird^{-1}$ of bypass ventilation capacity), small extra emissions were reported. In the current DS designs however, much higher drying ventilation rates are applied, probably causing active stripping of ammonia from the manure (Groot Koerkamp, 1994). Further research is necessary to identify effective measures to avoid this. Reducing the time between deposition of fresh manure and transport to the DS, followed by more rapid drying (e.g. >60% of DM within 24 h), may be one such measure (Groot Koerkamp and Montsma, 1995).

CONCLUSION: This study shows that DS for poultry manure show good abilities to remove PM, but further research is necessary to avoid problem swapping by elevating emissions of other pollutants.

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