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Research Paper

Impact of global warming on the odour and ammonia emissions of livestock buildings used for fattening pigs☆

Günther Schauberger [a,*], *Martin Piringer* [b], *Christian Mikovits* [a], *Werner Zollitsch* [c], *Stefan J. Hörtenhuber* [c], *Johannes Baumgartner* [d], *Knut Niebuhr* [d], *Ivonne Anders* [e], *Konrad Andre* [e], *Isabel Hennig-Pauka* [f], *Martin Schönhart* [g]

[a] *WG Environmental Health, Unit for Physiology and Biophysics, University of Veterinary Medicine, Vienna, Austria*
[b] *Department of Environmental Meteorology, Central Institute of Meteorology and Geodynamics, Vienna, Austria*
[c] *Division of Livestock Sciences, Department of Sustainable Agricultural Systems, University of Natural Resources and Life Sciences, Vienna, Austria*
[d] *Institute of Animal Husbandry and Animal Welfare, University of Veterinary Medicine, Vienna, Austria*
[e] *Department for Climate Research, Central Institute of Meteorology and Geodynamics, Vienna, Austria*
[f] *University Clinics for Swine, Department for Farm Animals and Veterinary Public Health, University of Veterinary Medicine, Vienna, Austria*
[g] *Institute for Sustainable Economic Development, Department of Economics and Social Sciences, University of Natural Resources and Life Sciences, Vienna, Austria*

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Ammonia and odour are the most relevant pollutants emitted from livestock buildings used for monogastric animal production. Whereas odour can cause annoyance in the close vicinity of the source, emission of ammonia is a precursor for the formation of particulate matter and acidification on a regional scale. Because of clean air regulation in Europe, total ammonia emissions reduced by 23% between 1990 and 2015 whilst, over the same period, anthropogenic warming became more and more evident. By a simulation of the indoor climate of a confined livestock building with a mechanical ventilation for 1800 fattening pigs, the modification of the odour and ammonia emission was calculated for the period between 1981 and 2017. For ammonia emission, a relative increase of 0.16% per year was determined. But following the clean air endeavour between 1990 and 2015 emissions over that period were reduced by 23%. The global warming signal counteracting this reduction in the range of 4% during over this period, which means that the overall reduction for the ammonia emission was only 19%. For Austria with a global warming increase of 1% from 1990 to 2015, this gives an increase in emissions of 5% instead. Odour emissions also increased by about 0.16% per year. The relative increase of the separation distances for the four cardinal directions was about 0.06% per year, the related increase for the separation

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* *Corresponding author*. University of Veterinary Medicine, Department of Biomedical Sciences, WG Environmental Health, Veterinärplatz 1, A 1210 Vienna, Austria.
E-mail address: gunther.schauberger@vetmeduni.ac.at (G. Schauberger).

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area was 0.13% per year. This case study on the fattening pigs shows that the global warming signal has a negligible impact on separation distances.

Nomenclature

m_{start} (kg) body mass values at the beginning of the fattening period
m_{end} (kg) body mass values at the end of the fattening period
t_A (d) duration of the fattening period
t_S (d) duration of the service period
t_{FP} (d) overall duration of a fattening period
n_{FP} number of fattening periods per year
$e_{OD,0}$ (ou $s^{-1}LU^{-1}$) reference body mass specific emission factor for odour
$e_{NH3,0}$ (kg $a^{-1}AP^{-1}$) reference body mass specific emission factor for ammonia
R (–) release modification factor
T_i (°C) temperature
V (m^3/h) ventilation rate
A (–) physical activity of animals
t (h) daytime
F_T (–) modification factor for the indoor temperature
F_V (–) modification factor for the ventilation rate
F_A (–) modification factor for the relative animal activity
T_R (°C) reference temperature
V_n (–) normalised ventilation rate
V_d (m^3/h) reference ventilation rate
a (–) amplitude
τ (h) period
φ (h) time lag
A_0 (–) daily mean of the relative animal activity
r (–) relative release modification factor
R_{1981} (–) mean modification factor for 1981
E_{OD} (ou s^{-1}) odour emission rate of the entire livestock building
E_{NH3} (kg a^{-1}) ammonia emission rate of the entire livestock building
N (–) number of animals
m_M (kg) mean body mass
D_{Sep} (m) separation distance
F (%) relative frequency
W (m s^{-1}) mean wind velocity for each 10° sector of the wind direction
P (%) exceedance probability for odour perception
A_{Sep} (m^2) separation area
RG release factor of Gyldenkærne et al. (2005)
v_i (m/s) air velocity at animal level
a and b exponents for the RG for pigs
NH_3 ammonia
PM particulate matter
AP (–) animal place
LU (–) livestock unit LU, 1 LU = 500 kg

1. Introduction

The most important pollutants that impact on the environment that are emitted from livestock buildings used for the production of monogastric animals are odours and ammonia (NH_3) (Blanes-Vidal, Nadimi, Ellermann, Andersen, & Løfstrøm, 2012). Whereas odorous substances are more relevant on a local scale causing annoyance to nearby residents, NH_3 is predominantly relevant as a pollutant on a regional scale.

NH_3 is an important precursor of fine particulate formation in the atmosphere (Backes et al., 2016a, 2016b; Xu & Penner, 2012). It plays a crucial role in the acidification and eutrophication of ecosystems, and contributes to indirect emissions of nitrous oxide. The relation between emission and concentration of NH_3 shows a complex pattern. After the emission, NH_3 is transported in the atmosphere. It is chemically transformed into secondary non-gaseous inorganic aerosols such as ammonium nitrate and ammonium sulphate and it is removed from the atmosphere by dry and wet deposition (van Zanten, Wichink Kruit, Hoogerbrugge, Van der Swaluw, & van Pul, 2017).

Agriculture has been identified as the major source of atmospheric NH_3, contributing 55–56% of the global emissions (Sutton et al., 2013). For Europe, about 94% of NH_3 emissions are related to agriculture (EEA, 2017), although natural odour sources are not included into this inventory (Sutton et al., 2013). The major part is caused by livestock housing, stored manure, and animal exercise areas. About 10% of the agricultural emissions are related to synthetic fertilisers. In the near range of agricultural sources, NH_3 emission causes considerable ambient concentrations (Fowler et al., 1998; Geels et al., 2012; Hallsworth et al., 2010; Kryza, Dore, Błaś, & Sobik, 2011).

For clean air initiatives and climate related investigations, emission inventories have been conducted on various spatial scales (Backes et al., 2016a; Bouwman et al., 1997; Kang et al., 2016; Pinder, Adams, Pandis, & Gilliland, 2006; Sutton et al., 2013). Depending on the availability of data, the complexity of these inventories varies extensively. Especially on a global scale, inventories are based on the use of an emission factor (e.g. an animal place related emission factor) for a certain type of NH_3 emission and the related activity value (e.g. number of animals inside a grid cell) and this is used for scaling the emission values (Faulkner & Shaw, 2008; Mikkelsen, Albrektsen, & Gyldenkærne, 2014; Misselbrook et al., 2000; US EPA, 2004; Webb & Misselbrook, 2004). These emission factors are not temperature sensitive and are assumed constant over the years. More sophisticated emission models include the indoor temperature modifying the NH_3 release and include the spatial distribution of local agricultural practice