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Research Paper

Measurement and analysis of ammonia, hydrogen sulphide and odour emissions from the cattle farming in Estonia

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Emissions from cattle farms in Estonia may vary from emissions in other regions of Europe due climatic differences and the housing systems used. Emission factors (EF) for the tie and loose housing systems for dairy farming were measured. Ammonia, odour and H_2S emission measurements were made in tie and loose housing cattle farms with solid and liquid manure systems. Measurement were carried out in 2007 (10 different days from February to October) and in 2013 (in 30 different days in July–August). The gaseous EFs calculated for the tie housing cow building were 5.34 ± 0.47 kg [NH_3] y^{-1} AU^{-1}, 19.36 ± 4.39 g [H_2S] y^{-1} AU^{-1} and for odour was 1.77 ± 3.06 OU y^{-1} AU^{-1}. The EFs for the loose housing cow barn were 6.50 ± 4.01 kg [NH_3] y^{-1} AU^{-1}, 51.34 ± 30.34 g [H_2S] y^{-1} AU^{-1} and for odour were 15.63 ± 20.96 OU y^{-1} AU^{-1}. The NH_3 and H_2S EFs were validated through dispersion modelling against ambient levels measured in vicinity of the farms using passive samplers. An Eulerian advection-diffusion model with meteorological data was used to validate NH_3 and H_2S emission data. There was in general good correlation between measured and modelled levels for NH_3 in both farms and for H_2S in farm B. In general the EF were reliable and can be used in local and regional emission inventories and in dispersion calculations, but variation of emissions with temperature needs be taken into account. Further research is required to investigate emissions from more dairy farms over longer periods.

1. Introduction

Two of the most important noxious gases found in livestock buildings are ammonia (NH_3) and hydrogen sulphide (H_2S) (Algers et al., 2009) and livestock production is a major contributor of NH_3 emissions (Groot Koerkamp et al., 1998; Steinfeld et al., 2006). Emissions of potentially harmful gases such as NH_3 and H_2S from confined animal feeding operations have become a major concern in recent years (Aneja et al., 2001). Public concerns about potential environmental and health effects of air emissions from animal farming have

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Nomenclature

Abbreviations

BAT	Best available technique
LV	Limit values
EF	Emission factors
OU	Odour unit
LRTAP	The 1979 Convention on Long-range Transboundary Air Pollution
EAIA	Estonian Agricultural and Information Agency
WS-CRDS	Wavelength-scanning cavity ring-down spectroscopy
SD	Standard deviation
ppm	Part per million
TAN	Total Ammonia Nitrogen
AAP	Average annual population
TMR	Totally mixed ration

increased along with growth and consolidation of the industry (Blunden, Aneja, & Westerman, 2008). Gases are generated from livestock manure decomposition (i) shortly after it is produced, (ii) during storage and treatment, and (iii) during land application (Jacobson et al., 2003).

Ammonia is released from animal sources due to the inefficient conversion of feed nitrogen to animal product. Livestock and poultry are often fed surplus nitrogen with high-protein feeds to ensure that nutritional requirements are met (Jacobson et al., 2003). In cases of intensive management which aim at achieving high production (profit), nutrients originating from manure frequently become a source of environmental pollution. The main risk to the environment is through emissions into the atmosphere in the form of NH_3 (Kaasik et al., 2007). Gaseous NH_3 emissions from livestock production are deemed responsible for the acidification of several ecosystems and also for the formation of secondary particulate matter (Bluteau, Massé, & Leduc, 2009).

At concentrations around 30 ppb the H_2S odour can be detected by over 80% of the population (Schiffman, Auvermann, & Bottcher, 2002). H_2S is produced as manure decomposes anaerobically, resulting from the mineralisation of organic sulphur compounds as well as the reduction of oxidised inorganic sulphur compounds such as sulphate by sulphur-reducing bacteria (USEPA, 2001). The magnitude of H_2S emission is a function of liquid phase concentration, temperature and pH. (USEPA, 2001). Sulphate is responsible for H_2S emission apart from the presence of sulphur-containing amino acids (cysteine and methionine) and elements (sulphur) in the diet that directly affect the concentration of H_2S (Zahn et al., 2001). Higher manure sulphate contents produce higher H_2S emissions (Arogo, Zhang, Riskowski, & Day, 2000). Reduced sulphur compounds and volatile fatty acids also contribute to odour emissions which can create negative physical and psychological responses in the human populations residing downwind from sulphur emitting regions. Sulphur compounds released into the atmosphere eventually form sulphate aerosols and acidic compounds (i.e., sulphuric acid or methanesulphonic acid) which occur primarily as aerosol particles of sub-micrometre size. Sulphate acid deposition can also be detrimental to ecosystems, harming aquatic animals and plants, and damaging a wide range of terrestrial plant life. (Aneja et al., 2008).

In the last few years significant efforts have been made to reduce agricultural emissions and to fulfil the relevant European Union (EU) directives and international agreements (Melse, Ogink, & Rulkens, 2009; UNECE, 1999). Nevertheless, more than 90% of European NH_3 emission originates from agriculture (8–9 Tg yr^{-1}) and about 97% of the emissions from agriculture originate from livestock and related activities (Buijsman, Maas, & Asman, 1987; Melse et al., 2009). Domestic animals are the largest source of atmospheric NH_3 (32 Tg NH_3–N yr^{-1}), comprising approximately 40% of global emissions (Aneja et al., 2008). In Estonia, the emission of NH_3 has decreased from 29 Gg in 1990 to 9.6 Gg in 2000 (Maasikmets & Kaasik, 2006) but more than 90% of this comes from agriculture.

H_2S is also emitted from manure management but global estimates are not available largely due to a lack of accurate data (Aneja et al., 2008). H_2S emission factors for livestock are not available in literature except for pig (USEPA, 2001). The factors for an anaerobic lagoon were calculated by using H_2S factors for pig assuming that the pH of manure from all animal species is the same. This approach has been considered not scientific (Atia, Haugen-Kozyra, & Amrani, 2004). At present, there are no data available for total Estonian H_2S emissions. According to the Estonian air pollution permits database, H_2S emissions amount to 36 Gg yr^{-1}. However, this statistic accounts for industrial sources only and it may be inadequate.

The European Industrial Emission directive (IED, 2010) specifies requirements for significant pollution sources and also stipulates that the best available technique (BAT) shall be used. This applies to the intensive pig and poultry farms in agricultural sector. Estonia has implemented the above-mentioned directive and has additionally set BAT requirements for intensive cattle farms with more than: 400 dairy cows, more than 533 sucklers or more than 800 cattle younger than 24 months (Valitsus, 2013). To assess the BAT for these animal houses the Cattle BAT description was prepared by the Estonian Life Science University (Kaasik et al., 2007).

In addition to the EU air quality limit values, Estonia has set 1- and 24-h limit values (LV) for NH_3 and H_2S for the protection of human health (Table 1). Odour occurrence is limited by the 15% odour hours per year (Ministerial Regulation no 50, 2007). These limit values should be followed by the agricultural facilities as well.

The objective of this paper is to obtain emission factors (EF) for the tie and loose housing dairy farming systems which are

Table 1 – Ambient air quality limit values in Estonia (Ministerial Regulation no 43, 2011).

Substance	1-h Limit value ($\mu g\ m^{-3}$)	24-h Limit value ($\mu g\ m^{-3}$)
NH_3	200	40
H_2S	8	8