Controlled release of methane and ammonia to validate flux estimates obtained by inverse dispersion modelling

Yolanda M Lemes*, Jesper N. Kamp, Sven G Sommer, Tavs Nyord, Anders Feilberg

Department of Engineering, Aarhus University, Finlandsgade 10, DK 8200 Aarhus, Denmark.

Corresponding author: email: ymlp@eng.au.dk; Telephone: +45 93522067

Declaration of interest: none

Extend Abstract

Agriculture contributes with 21% of the total global greenhouses gas (GHG) emissions which make this sector the world's second largest source of GHGs (FAO, 2016). In addition, agriculture is globally the largest source of ammonia (NH_3) in the atmosphere (Behera et al., 2013). Agriculture must contribute to climate change mitigation, and valid estimates of GHG emissions are important for national inventories regulation strategies and for selecting efficient mitigation techniques. Solid animal manure heaps are large sources of the GHG methane (CH_4) and nitrous oxide (N_2O) and of NH_3, and the emissions of these gases are much affected by the composition of the manure, geometry and covering of the heap (Bernal et al., 2017). Due to difficulties in carrying out accurate measurements of gas emissions from full scale heaps, emission data is mostly from laboratory or pilot scale studies based on dynamic chambers or wind tunnels (Hu et al., 2014). Optimized manure management and identification of the best techniques to reduce gas emissions are made difficult by the limited numbers of field measurements of gas emissions from full scale heaps. Therefore, there is a need for estimates of the emission from full scale heaps and documentation of emission abatement by reliable measuring techniques.

Micrometeorological methods using inverse dispersive modelling (IDM) have been used to measure emissions of gases, including CH_4 and NH_3, from open sources (Flesch et al., 2007; Häni et al., 2018). Selecting the right location of the measuring devices (up and down wind the source) is critical for this approach. It is a requirement that the source does note influence on wind conditions around the source

(Flesch et al., 2005). In full scale studies, these conditions are difficult to reach, but research has shown that the IDM method can be used in these studies with acceptable accuracy (Flesch et al., 2014)

This work presents data from a test of the IDM method for measuring fluxes of CH_4 and NH_3. This is accomplished by controlled release of both gases in combination with up- and downwind measurements using cavity ring-down spectroscopy and a sonic anemometer. The aim of this study is to validate this setup for the measurements of gas emission from manure heaps, and the use of these two gases will give us an opportunity to assess potential loss of NH_3 downwind from the source by deposition or gas-to-particle conversion, processes that will not occur for CH_4. The implementation of this method will enable measurements of fluxes of multiple gases from stored solid manure and evaluate the effects of mitigation strategies on the emissions (i.e. the effect of covering the manure).

Keywords: Emissions, Ammonia, Methane, Inverse-Dispersion method, manure heaps

250 words Abstract

Agriculture contributes with 21% of the total global greenhouses gas (GHG) emissions, which make this sector the world's second largest source. In addition, agriculture is globally the largest source of NH_3 in the atmosphere. Optimized manure management and identification of the best techniques to reduce gas emissions are made difficult by the limited numbers of field measurements of emissions from full scale heaps. Therefore, there is a need for estimates of the emission from full scale heaps and documentation of emission abatement by reliable measuring techniques.

Micrometeorological methods using inverse dispersive modelling (IDM) have been used to measure emissions of gases, including CH_4 and NH_3, from open sources. Selecting the right location of the measuring devices is critical for this approach.

This work presents data from a test of the IDM method for measuring fluxes of CH_4 and NH_3. This is accomplished by controlled release of both gases in combination with up- and downwind measurements using cavity ring-down spectroscopy and a sonic anemometer. The aim of this study is to validate this setup for the measurements of gas emission from manure heaps, and the use of these two gases will give us an opportunity to assess potential loss of NH_3 downwind from the source by deposition or gas-to-particle conversion, processes that will not occur for CH_4. The implementation of this method will enable measurements of fluxes of multiple gases from stored solid manure and evaluate the effects of mitigation strategies on the emissions (i.e. the effect of covering the manure).

References

Behera, S.N., Sharma, M., Aneja, V.P., Balasubramanian, R., 2013. Ammonia in the atmosphere: a review on emission sources, atmospheric chemistry and deposition on terrestrial bodies. Environmental Science and Pollution Research 20, 8092–8131. https://doi.org/10.1007/s11356-013-2051-9

Bernal, M.P., Sommer, S.G., Chadwick, D., Qing, C., Guoxue, L., Michel, F.C., 2017. Current Approaches and Future Trends in Compost Quality Criteria for Agronomic, Environmental, and Human Health Benefits, in: Advances in Agronomy. Elsevier, pp. 143–233. https://doi.org/10.1016/bs.agron.2017.03.002

FAO (Ed.), 2016. Climate change, agriculture and food security, The state of food and agriculture. FAO, Rome.

Flesch, T.K., McGinn, S.M., Chen, D., Wilson, J.D., Desjardins, R.L., 2014. Data filtering for inverse dispersion emission calculations. Agricultural and Forest Meteorology 198–199, 1–6. https://doi.org/10.1016/j.agrformet.2014.07.010

Flesch, T.K., Wilson, J.D., Harper, L.A., 2005. Deducing Ground-to-Air Emissions from Observed Trace Gas Concentrations: A Field Trial with Wind Disturbance. Journal of Applied Meteorology 44, 475–484. https://doi.org/10.1175/JAM2214.1

Flesch, T.K., Wilson, J.D., Harper, L.A., Todd, R.W., Cole, N.A., 2007. Determining ammonia emissions from a cattle feedlot with an inverse dispersion technique. Agricultural and Forest Meteorology 144, 139–155. https://doi.org/10.1016/j.agrformet.2007.02.006

Häni, C., Flechard, C., Neftel, A., Sintermann, J., Kupper, T., 2018. Accounting for Field-Scale Dry Deposition in Backward Lagrangian Stochastic Dispersion Modelling of NH_3 Emissions. https://doi.org/10.20944/preprints201803.0026.v1

86 Hu, E., Babcock, E.L., Bialkowski, S.E., Jones, S.B., Tuller, M., 2014. Methods and Techniques for
87 Measuring Gas Emissions from Agricultural and Animal Feeding Operations. Critical Reviews in
88 Analytical Chemistry 44, 200–219. https://doi.org/10.1080/10408347.2013.843055

89 McGinn, S.M., Janzen, H.H., 1998. Ammonia sources in agriculture and their measurement. Canadian
90 Journal of Soil Science 78, 139–148. https://doi.org/10.4141/S96-059

91