



Sampling locations and measurement techniques of ammonia in naturally ventilated livestock buildings

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The tracer gas ratio method has been widely applied in ammonia emission studies in naturally ventilated livestock buildings, and it is also adopted as an official reference method by the European Union and several member countries. Because the method assumes a perfect gas mixture inside a building, which is untrue for most practical cases, selection of sampling locations becomes the most substantial problem due to unknown distribution of gases and flow characteristics. The complexity of air composition and operation condition (e.g. dust and humidity) in livestock facilities poses additional challenges as most of the commercialized gas sensing instruments are not designed for agricultural applications. Both inappropriate sampling locations and sensors could lead to a significant estimation bias. This research aims to investigate the variability of measured NH_3 concentrations at variant sampling locations and compare the performance of multiple commercialized gas analysers under practical conditions. Tests were conducted in a $114.6 \text{ m} \times 36.6 \text{ m} \times 12 \text{ m}$ (ridge) naturally ventilated dairy barn, with around 120 free-stall housed cows. Windbreak nettings and barn entrances were opened or closed according to the actual requirement of the farming practice. NH_3 concentrations were measured by three closed-path analysers that were respectively based on cavity ring-down spectroscopy (CRDs), quantum-cascade laser spectroscopy (QCLs) and tunable diode laser absorption spectroscopy (CP-TDLAs), and one open-path tunable diode laser spectroscopy analyser (OP-TDLs). Multiple trials were conducted to identify the horizontal and vertical spatial variations of gas distribution by placing sampling lines at different locations in the barn. In each trial four multi-inlet sampling lines were installed at predefined locations to transport air samples to the closed-path analysers from distributed locations. The sampling lines and the OP-TDLs beam were set parallel to the side openings (the long side) of the barn in all cases. Uniformity of the four sampling lines were verified before starting the tests to avoid biases due to subtle structural differences. A custom assembled gas sampling multiplexer was used to switch between sampling lines. Wetted parts of the multiplexer manifold were coated with Polytetrafluoroethylene (PTFE) to reduce adsorption and desorption of ammonia. Due to practical constraints the OP-TDLs was only used to take measurement at a fixed location and thus was not available for all trials. Current results showed a significant spatial variation of NH_3 concentration. The measured value were also compared between analysers. Several issues associated with the practical implementation of the measuring techniques were discussed.