MEASURING AMMONIA LOSSES FROM OPEN ANIMAL HOUSES – HOW TO HANDLE LARGE AND VARIABLE SYSTEMS

Anders Peter S. Adamsen
Albarune Chowdhury
Dezhao Liu
Anders Feilberg
Air Quality Engineering
1. Background
2. Constant tracer gas methods
3. Heat and CO2 production
4. Positions of sampling points
5. Gas analyses
6. In-situ calibration
7. Data treatment
8. Conclusion
AMMONIA EMISSION FROM OPEN BUILDINGS

Estimation of ammonia emission:

- **Mass balance of nitrogen (N)**
  - difficult as gaseous N loss is small
  - difficult with outdoor areas

- **Direct estimation of ammonia emission**
  - difficult (huge variation in wind speed and directions)
  - requires information of ventilation rate (air exchange rate)
  - concentration of ammonia (incoming and outgoing air)
CONSTANT TRACER GAS METHOD

Assumptions:

- Constant gas production – here CO₂ production from the animals (and manure)
- Steady state conditions
- Ideal mixing (turbulence)

Q = Air flow (m⁻³ h⁻¹)
C = Concentration (m³ m⁻³)
E = Emission (m⁻³ h⁻¹)

\[ Q \cdot C_{\text{CO}_2, \text{out}} = Q \cdot C_{\text{CO}_2, \text{in}} + E_{\text{CO}_2} \]

\[ Q = \frac{E_{\text{CO}_2}}{C_{\text{CO}_2, \text{out}} - C_{\text{CO}_2, \text{in}}} \]

\[ Q \cdot C_{\text{NH}_3, \text{out}} = Q \cdot C_{\text{NH}_3, \text{in}} + E_{\text{NH}_3} \]

\[ E_{\text{NH}_3} = Q \left( C_{\text{NH}_3, \text{out}} - C_{\text{NH}_3, \text{in}} \right) \]
HEAT AND CO₂ PRODUCTION

- 1 HPU corresponds to 1000 W at 20 °C (both latent and sensible heat dissipation)
- Equations for calculation of HPU is described in details in:
- 0.185 m³ CO₂ HPU⁻¹

For cows:
- \( H_{\text{tot}} (w) = 5.6 m^{0.75} + 22 Y + 1.6 \times 10^{-5} p^3 \)
  - \( m = \) mass, kg
  - \( Y = \) milk production, kg/day
  - \( p = \) days of pregnancy

For finishing pigs:
- \( H_{\text{tot}} (w) = 5.09 m^{0.75} + (1-K_Y) (F_d - F_m) \)
  - \( K_Y = \) coefficient of efficiency at weight gain
  - \( F_d = \) daily feed energy intake
  - \( F_m = \) heat dissipation due to maintenance
NH3 SAMPLING & MEASUREMENT SYSTEM

- Constant flow in sampling lines
- Heated sampling lines and instruments
- Use of proper materials (PTFE, Peek etc.)
POSITIONS OF SAMPLING POINTS

Where to measure?

- outgoing air at all important openings
  - how much is flowing out of side wall vs ridge?
- ingoing air
- If good mixing:
  - sampling points positioned to give a good average value

Wu et al. (2012)
GAS ANALYSES

Hitherto the most used analyser has been photo-acoustic infrared spectrometry (PAS):

- reliable instrument
- possible to measure up to 5 gases
- multiplexer (up to 12 channels)
- possible for calibration for selected gases and concentration at supplier
- correction for water interference
Ammonia is sticky:

- all inside walls should be of PTFE
- all inside walls should be heated
- high settling time in Innova:
  - underestimation of high concentrations
  - overestimation of low conc. (outdoor values)

Rom & Zhang (2010)
INTERFERENCE PHOTO-ACOUSTIC INFRA RED SPECTROMETRY

- Risk of significant interference with photo acoustic spectrometry, e.g. Innova
  - from manure
  - from feed
    - e.g. silage - see PTR-MS scan of box with silage (x-axis m/z +1)
- Important to evaluate analytic methods carefully before use in new applications
INTERFERENCE PHOTO-ACOUSTIC IR SPECTROMETRY

- Evaluation can be done by compared absorption spectra for expected gases
- Innova can correct for cross-interference from:
  - water
  - 4 other gases

Chao et al. (2012)
CAVITY RING-DOWN SPECTROMETER

Picarro Model G2103 analyser for NH$_3$/H$_2$O

- CRDS is a direct absorption technique
- Very narrow laser – a band width within few nm
- CRDS is based on the principle of measuring the rate of decay of light intensity inside an optical cavity
- This ring-down time can be used to calculate the concentration of the absorbing substance in the gas mixture in the cavity
- Negligible cross-interference with H$_2$O, CO$_2$, CH$_4$ and N$_2$O
CAVITY RING-DOWN SPECTROMETER

Excellent linearity from few ppbv and up >10 ppmv

No cross-interference (< 5 ppbv) with:

- H₂O
- CO₂
- CH₄
- N₂O
IN SITU CALIBRATION

If possible in situ calibration should be done:

- takes into account all interfering gases
- realistic humilities
- use gases with concentration of e.g. 80% of maximal concentration

How to do it:

- make a split using calibration gas, mass flow controllers (or flow meters) so the ratios of calibration gas and ambient air can be 1:2, 1:1 and 2:1
DATA TREATMENT - FILTERING

Most instruments collect samples sequentially (i.e. outdoor samples and indoor samples)

- settling time
- compare with in-situ calibration
- statistical evaluation (e.g. use of last 4 data per round)
DATA TREATMENT

- Δ CO₂ > 200 ppmv (or 100 ppmv)
- Require enough CO₂ production in the area with the sampling points:
  - width of the building
  - flow reduction (reduction of openings, e.g. use of curtains)
- Correction of missing data (where Δ CO₂ > 200 ppmv (or 100 ppmv))
  - use the values with lowest acceptable Δ CO₂ to give a weighted average of the air exchange

Hansen et al. (2012)
CONCLUSION

- Needs for describing sampling positions in the buildings
- Important with good analytical methods
  - that have been calibrated for the system of interest
  - include cross interferences
- Important with transparent and systematic data treatment
  - handling of discharged date due to high air exchange rate (low CO2 difference between indoor and outdoor concentrations)
- Calculation of ammonia emission
  - average of inside sampling positions, or
  - flow and concentration of major openings?
- Necessary with a protocol for open buildings
THE FUTURE

- Work in the international VERA expert group on development of protocol for measurement of emissions in open livestock building:
  - Meeting next Friday at Kiel University