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

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CONTENT

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 CO_2 production from the animals (and manure)
- Steady state conditions
- Ideal mixing (turbulence)

Q = Air flow ($m^{-3}\ h^{-1}$)

C = Concentration ($m^3\ m^{-3}$)

E = Emission ($m^{-3}\ h^{-1}$)

$$Q \cdot C_{CO2,\ out} = Q \cdot C_{CO2,\ in} + E_{CO2}$$

$$Q = \frac{E_{CO2}}{C_{CO2\ out} - C_{CO2\ in}}$$

$$Q \cdot C_{NH3,\ out} = Q \cdot C_{NH3,\ in} + E_{NH3}$$

$$E_{NH3} = Q\ (C_{NH3,\ out} - C_{NH3,\ in})$$

HEAT AND CO_2 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:
  - CIGR (2002) 4th Report of Working Group on Climatization of Animal Houses. Heat and moisture productionat animal and house levels
- 0.185 m^3 CO_2 HPU^{-1}

For cows:

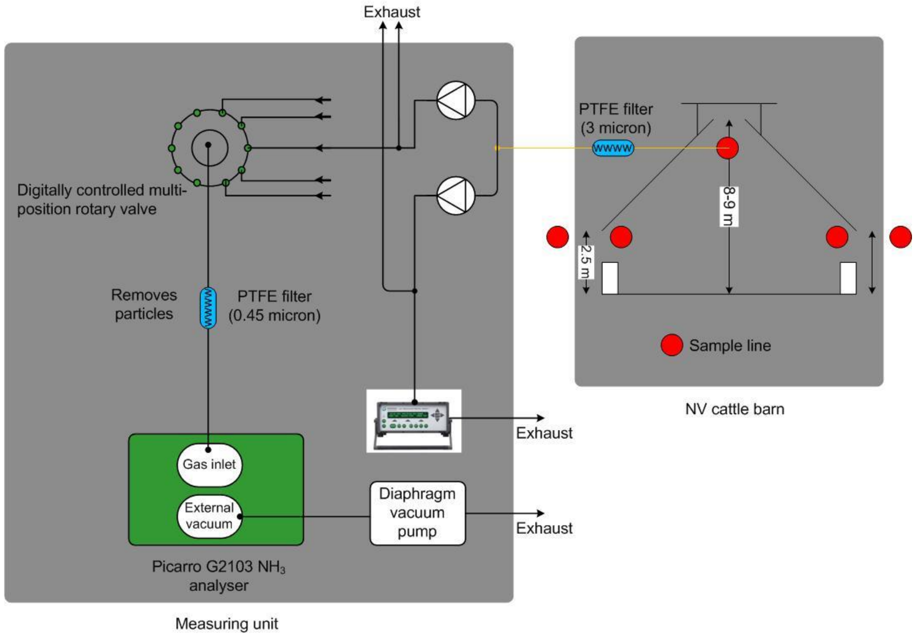
- H_{tot} (w) = 5.6 $m^{0.75}$ + 22 Y + 1.6 510^{-5} p^3
- m = mass, kg
- Y = milk production, kg/day
- p = days of pregnancy

For finishing pigs:

- H_{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

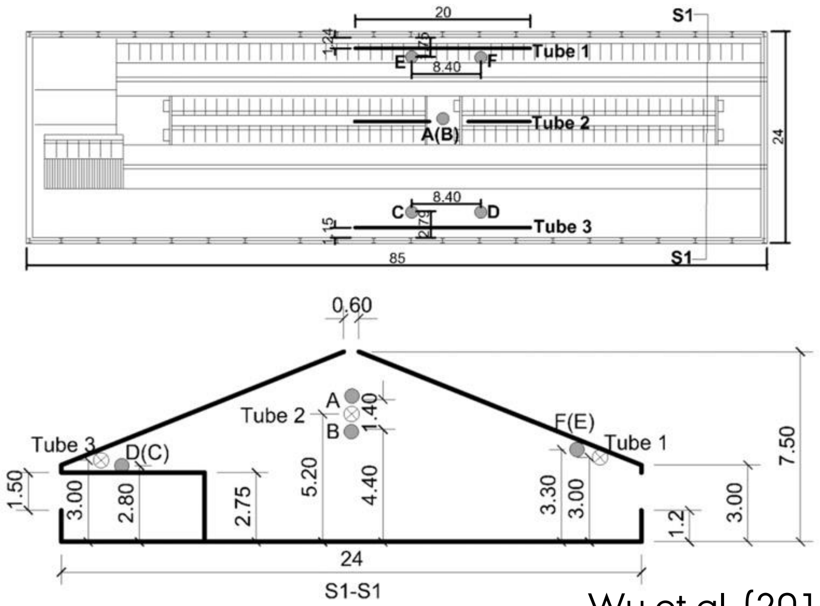
- Constant flow in sampling lines
- Heated sampling lines and instruments
- Use of proper materials (PTFE, Peek etc.)



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

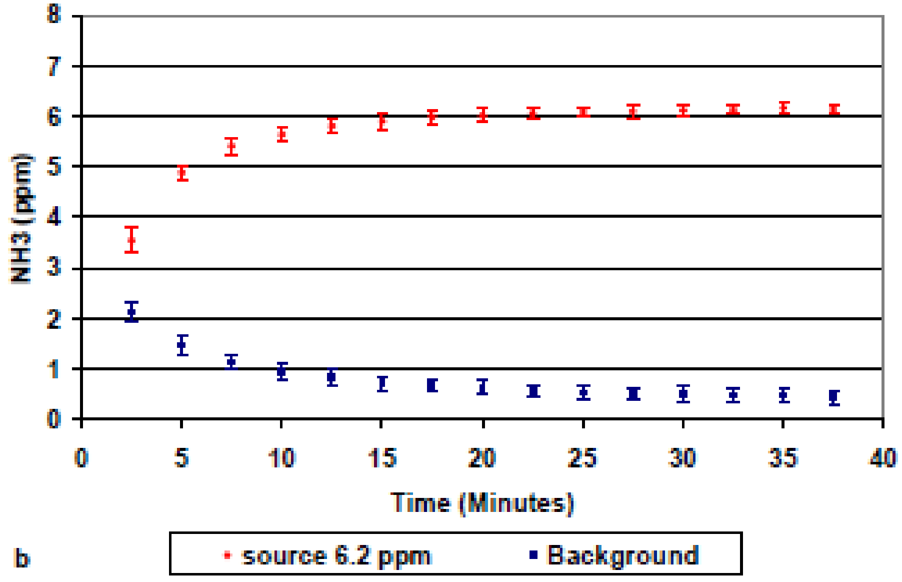
Hitherto the most used analyser has been photo-acoustic infrared spectrometry (PAS):

- 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

PAS – SETTLING TIME FOR AMMONIA

Ammonia is sticky:

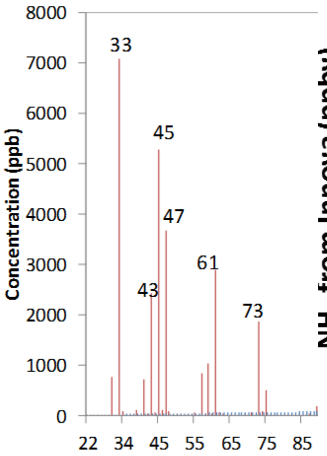
- all inside walls should be of PTFE
- all inside walls should be heated
- high settling time in Innova:
  - underestimation of high concentrations
  - overestimation of low conc. (outdoor values)

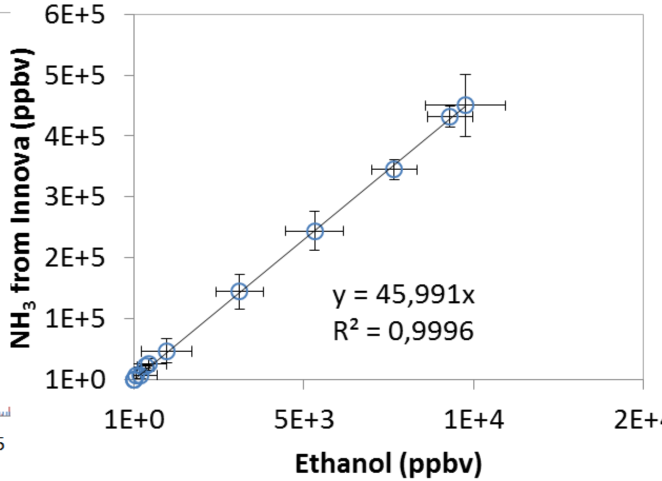


Rom & Zhang (2010)

INTERFERENCE PHOTO-ACOUSTIC INFRA RED SPECTROMETRY

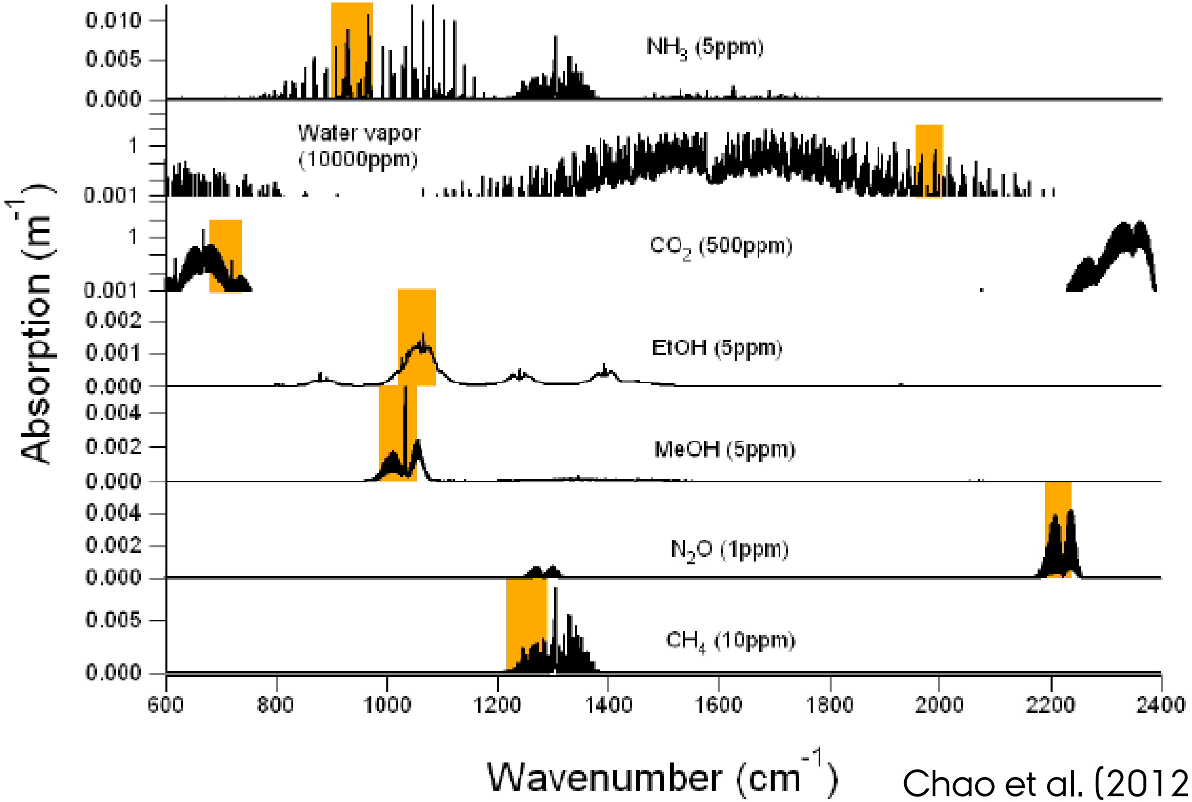
- Risk of significant interference with photo acoustic spectrometry, e.g. Innova
  - from manure
  - from feed
    - e.g. silage - see PTR-MS scan of box with silage (x-axis m/z +1)
- Important to evaluate analytic methods carefully before use in new applications





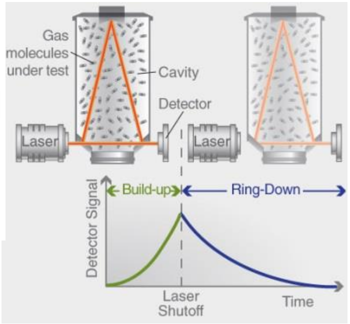
INTERFERENCE PHOTO-ACOUSTIC IR SPECTROMETRY

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



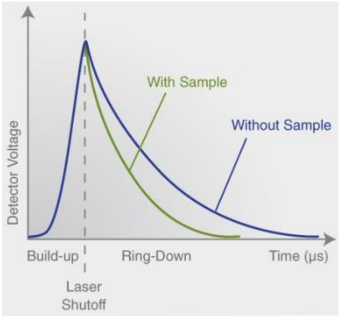
Chao et al. (2012)

CAVITY RING-DOWN SPECTROMETER



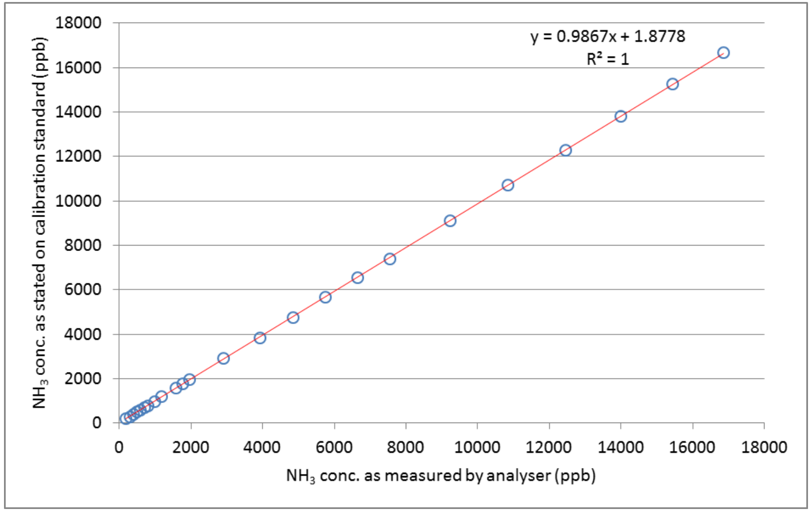
Picarro Model G2103 analyser for NH_3/H_2O

- 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_2O, CO_2, CH_4 and N_2O



CAVITY RING-DOWN SPECTROMETER

Excellent linearity from few ppbv and up >10 ppmv



No cross-interference (< 5 ppbv) with:

- H_2O
- CO_2
- CH_4
- N_2O

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

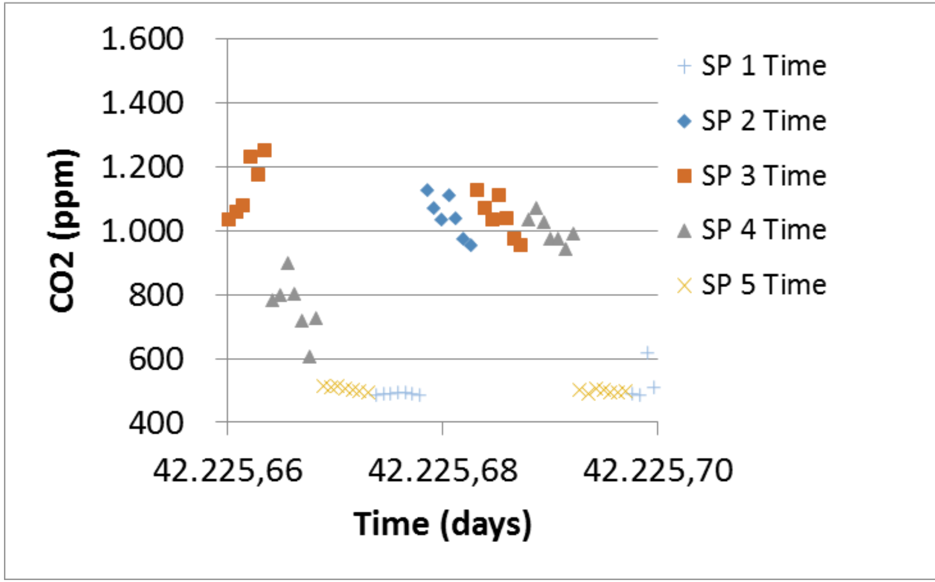
How to do it:

- 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

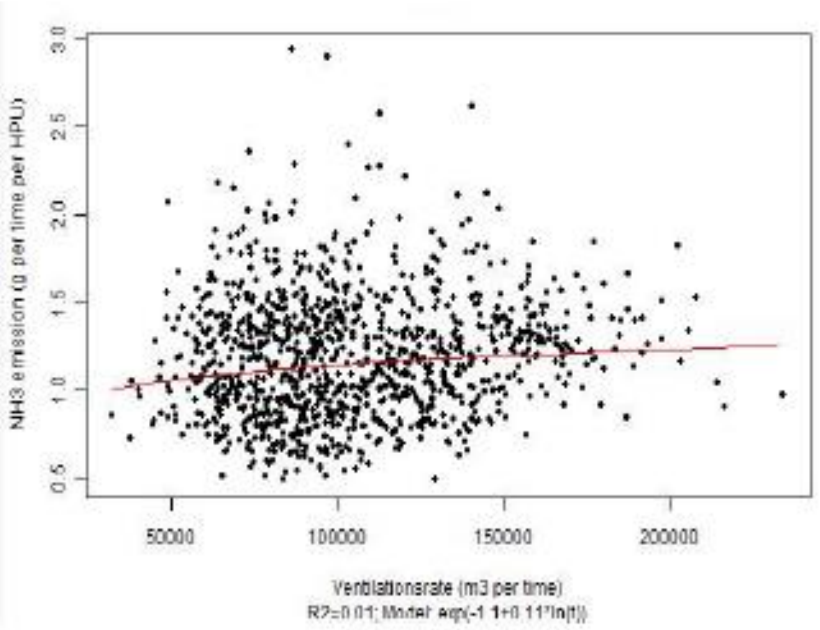
Most instruments collect samples sequentially (i.e. outdoor samples and indoor samples)

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



DATA TREATMENT

- Δ CO_2 > 200 ppmv (or 100 ppmv)
- Require enough CO_2 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 CO_2 > 200 ppmv (or 100 ppmv))
  - use the values with lowest acceptable Δ CO_2 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 CO_2 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

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