Question to EURCAW-Pigs: Measuring air quality
9 July 2025

Question
Received: 13 December 2024

EURCAW-Pigs received the following question from a policy worker in one of the Member States:

What measuring equipment do other European countries use to assess ammonia (NH3) and carbon dioxide (CO_2) levels on pig farms, and what measuring procedures are in place and practical for inspectors to use?

Several EURCAW-Pigs experts contributed to the response below. The EURCAW-Pigs secretariat did the final editing, and may be contacted for queries: info.pigs@eurcaw.eu.

Answer
In short, the answer is:

- Ammonia (NH_3) and carbon dioxide (CO_2) in pig housing pose significant risks to animal welfare, particularly NH_3, which irritates pigs' mucous membranes and should ideally remain below 20 ppm. CO_2 levels are less critical for pigs but indicate overall air quality and ventilation effectiveness.
- Portable sensors—using electrochemical or optical (infrared) methods—are essential tools for inspectors. NH_3 sensors must detect 0–100 ppm; CO_2 sensors, 400–10.000 ppm. Measurements should be taken at pig level, especially in pens with older animals, where gas levels are typically highest. For best accuracy, sensors must be regularly calibrated and placed away from animal interference. Temperature and humidity must be considered, as they can influence gas detection accuracy.
- Most EU member states follow Directive 98/58/EC, requiring gas concentrations not to harm animals. National thresholds and equipment types vary, but common limits are 20 ppm for NH_3 and 3000 ppm for CO_2.

Background

EURCAW-Pigs performed a short literature review and a questionnaire to inspectors in the Member States. EURCAW-Pigs cannot not recommend certain brands of sensors.

Effect on Animal Welfare
Ammonia (NH_3) and carbon dioxide (CO_2) in the indoor air of pig houses are a threat to animal (and human) welfare. Literature on experiments with different concentrations of NH_3 show that pigs choose areas with low NH_3 concentrations. NH_3 in the indoor air irritates the mucous membranes of pigs and that is why the animals try to avoid it. Higher NH_3 concentrations can be harmful to the animals, both in terms of health, welfare and productivity. Based on the literature, a gradual effect of NH_3 can be expected – more NH_3 is more harmful. Ideally a dose-response relationship between NH_3 and health and welfare parameters would be best for an animal science based standard. However, the number of studies for this relationship is relatively

small. It has been suggested that keeping NH_3 below 20 ppm avoids the majority of negative welfare consequences in pigs (Vermeer and De Greef, 2024). The levels of CO_2 in commercial pig houses never exceed level that pigs would avoid. However, higher CO_2 concentrations indicate a lower replacement of indoor air and a lower air quality in general. The emphasis in this Q2E will be on NH_3.

Most national regulations are based on EU-Directive 98/58/EC, Annex: Buildings and accommodation, Article 10 that states:
"Air circulation, dust levels, temperature, relative air humidity and gas concentrations must be kept within limits which are not harmful to the animals."

Equipment
Measuring NH_3 and CO_2 concentrations in pig houses by inspectors requires portable sensors that detect and quantify these gases simultaneously in real-time. These sensors commonly use principles such as electrochemical, infrared (IR, optical), or photoacoustic detection to measure the concentration of each gas. For NH_3, electrochemical sensors are often employed due to their high sensitivity to NH_3. They detect NH_3 by reacting with a chemical electrolyte, generating a current proportional to the gas concentration. Optical methods (NDIR) with infrared light measure at very specific wavelength per gas. They are more robust than electrochemical sensors but are very sensitive to dirty environments (flies, spiders, dust) (Zhuang et al., 2020). CO_2 is typically measured using infrared sensors, where the absorption of infrared light by CO_2 molecules correlates to the gas concentration. Mobile devices can integrate multiple sensors, allowing measurements at different locations within the pig house, accounting for spatial variability in gas distribution (Korevaar and Winkel, 2022). The range of the sensors for NH_3 should be from 0 to 100 ppm and for CO_2 from 400 to 10.000 ppm.
These devices are designed to be mobile and easy to operate, providing real-time readings, often with data logging capabilities for long-term monitoring. They help farmers, inspectors and researchers to monitor air quality, optimize ventilation systems, and assess possible effects on animal welfare. Regular calibration of the sensors is necessary for accurate readings, and environmental factors such as temperature and humidity must be considered, as they can influence gas detection accuracy.

Measuring protocol
In most pig categories, the NH_3- and CO_2 concentrations increase with the age of the animals, which is closely related to the feed intake, higher N-losses and heavier animals. In all-in-all-out rooms the NH_3 concentration is low after cleaning the room and emptying the slurry pits. As a result, the highest welfare consequences will occur in the last weeks of the stay in the room.
For efficient measurement, it is recommended to focus on the oldest batches in a room of farrowing sows, weaners and finishers. In pregnant sow rooms there is often a mix of pregnancy stages, resulting in less consistent NH_3 concentrations (Ni and Heber, 2001).
Where feasible, selecting multiple rooms with the oldest batches per pig category provides the most representative and reliable data.
The measuring location within the room could be focused on the pens with the highest risks on high NH_3- and CO_2 levels.
Within a pen the NH_3- and CO_2 concentration around the preferred lying area and at a height that is just out of reach of the pigs is the best measuring point. However, an undisturbed

measurement will be very difficult. So some pig activity in the pen cannot be avoided and should be accepted.

Experience from research
Over the last few decades, several member states commissioned research on the NH_3 emission to the outdoor environment. In mechanical ventilated pig houses the sensor was often positioned at the bottom of the ventilation shaft. The concentration of NH_3 and CO_2 are marginally higher at this point compared to the concentration at pig level.
The 24h pattern of the NH_3- and CO_2 concentrations show a large variation with the highest levels during the night, when ventilation levels are the lowest. Concentrations are during early afternoon. In a Spanish study of Rodriguez et al (2020) the NH_3 concentration doubled during the night, but levels were still below 10 ppm.

Reactions from CA-inspectors in the Member States
In a short survey to the Competent Authorities of the EU member states we asked for the national regulations, the measuring technique and the measuring protocol. We received reactions of 14 inspectors from 6 countries. Five of these countries have legal limits for NH_3 between 10 and 26 ppm and for CO_2 between 700 and 3000 ppm. The most common limits are 20 ppm for NH_3 and 3000 ppm for CO_2. Most measuring techniques are portable electrochemical sensors or optical sensors, but some are using single use gas tubes. Prices vary widely, ranging from several hundred euros to as much as € 40.000 per measuring device.
Per room 1 to 6 measurements are recorded in multiple pig categories. Preferably on pig height and 50, 100 and 150 cm height were mentioned as standards.

Practical implications
To monitor the air quality in pig buildings a wide range of instruments is available. For instantaneous measurements both electrochemical and optical methods can be used. For continuous measurements the optical sensors are favourable because they will have a longer lifetime in sometimes aggressive conditions in pig buildings. Concentrations of gases should be measured in the pen on pig level, as long as there is no interaction between the pigs and the sensor. Measuring in the colder seasons and in older pigs within category will result in higher concentrations.

References
EC (1998). Council Directive 98/58/EC of 20 July 1998 concerning the protection of animals kept for farming purposes. *Official Journal of the European Communities L221/23*. https://edepot.wur.nl/146796

Korevaar, M., & Winkel, A. (2022). Quickscan meettechnieken https://edepot.wur.nl/575873

Ni, J-Q., & Heber, A.J. (2001). Sampling and Measurement of Ammonia Concentration at Animal Facilities. *Advances in Agronomy 98*:201-269. https://doi.org/10.1016/S0065-2113(08)00204-6

Rodriguez, M.R., Losada, E., Besteiro, R., Arango, T., Velo, R., Ortega, J.A., & Fernandez, M.D. (2020). Evolution of NH_3 concentrations in weaner pig buildings based on setpoint temperature. *Agronomy 10*:107. https://doi.org/10.3390/agronomy10010107

EURCAW-Pigs was designated by the European Union on 5 March 2018 through Regulation (EU) 2018/329,
in accordance with Articles 95 and 96 of Regulation (EU) 2017/625.

Vermeer, H.M., & de Greef, K. (2024). Effecten van ammoniak (NH_3) op gezondheid en welzijn van varkens, *Wageningen Livestock Research, Openbaar rapport 1506*. https://edepot.wur.nl/673557

Zhuang, S., Brusselman, E., Sonck, B., & Demeyer, P. (2020). Validation of Five Gas Analysers for Application in Ammonia Emission Measurements at Livestock Houses According to the VERA Test Protocol, *Appl. Sci. 10*:5034. https://doi.org/10.3390/app10155034