Establishing ammonia emission factors for straw-based buildings

Summary

Ammonia (NH_3) emissions levels determined for a straw flow pig building were recorded to be significantly lower than current figures being used by the Environment Agency (EA) for permitting and permissions.

The reduction in determined emission levels are anticipated due to a variety of factors, eg improved measuring capability and control in building environment, in addition to developments in diet formulation, genetics and modern production systems. It has been reported that 'Much of the work on which UK emissions estimates from buildings and stores are based has not reported data with enough explanatory variables to fully account for variation among reported NH_3 emissions' (Ricardo-AEA, 2014). 'Existing studies used in the preparation of the UK NH_3 inventory provide little supporting data, particularly with respect to factors such as the diet fed to the pigs, nitrogen (N) and total available N (TAN) excretion and the floor area allowed per animal' as reported by (Ricardo-AEA, 2014). Key factors that were not reported include growth rate and feed conversion ratio (FCR) of the pigs.

The study was conducted on a commercial farm operating to their standard practice. The study followed the Verification of Environmental Technologies for Agricultural production (VERA) Test Protocol for Livestock Housing and Management to ensure the results could be compared with other studies and were not open to the same uncertainty of past studies.

Ammonia was quantified over a year for three batches of pigs from approximately 50–100kg. This allowed us to capture emissions values during all four seasons to remove any seasonal variation. The average ammonia emission was found to be 1.22kg per animal place per year. The range recorded was 0.49 to 1.69kg. In comparison, the EA ammonia emissions factor (kg NH_3/animal place/year) is currently at 2.97 for this type of system.

Background

Ammonia is a key air pollutant that can have significant effects on both human health and ecosystems. Agriculture plays a significant role in contributing to NH_3 emissions and accounts for approximately 81 per cent of total ammonia emissions on an annual basis (Defra, 2018). As a consequence, reduction targets of 23 per cent by 2020 have now been put into place.

Emissions for inventory purposes (Environmental Permitting Regulation/Integrated Pollution Prevention and Control) and environmental impact modelling are calculated from a series of emissions factors that are linked to pig age and housing type. In October 2014, a report for AHDB Pork (formerly BPEX) by AEA Technology highlighted a shortcoming with the emission factors currently in use. In summary, it was concluded that 'from what the emission estimates from buildings and stores are based on, it has not reported data from enough explanatory variables to fully account for variation among reported NH_3 emissions'. These variables include protein levels of the feed fed (growth rate and FCR) and the floor area allowed per animal, both of which have changed dramatically over the last few years. The need for up-to-date, accurately and scientifically measured emissions factors has become all the more relevant as the European Commission published the Intensive Farming Best Available Techniques reference document (BREF), Version 2 in February 2017. This now includes emission limits associated with Best Available Techniques ammonia emission limits (BAT AELs), which must be complied with by IPPC/EPR permit holders. The aim of the study is to establish an ammonia emission factor in kilograms per animal place per year (kg/AP/yr) from a fully ventilated straw-based pig finisher building.

Materials and Methods

Buildings

A steel portal-framed building was used for the study, typical of the type currently in favour by the industry. The building is managed as a straw flow system. The dung passage is scraped through and new straw added to the bed area daily. Wet material is removed from the bed area by hand, when necessary. The internal layout of the building consists of two rows of pens, running the length of the building with a central gantry. The building is designed to house approximately 900 pigs in 40 pens with a scrape through dunging passage located adjacent to the outer wall on both sides. This arrangement provides a differentiated lying and dunging area. The layout of the building is demonstrated in Figure 1.

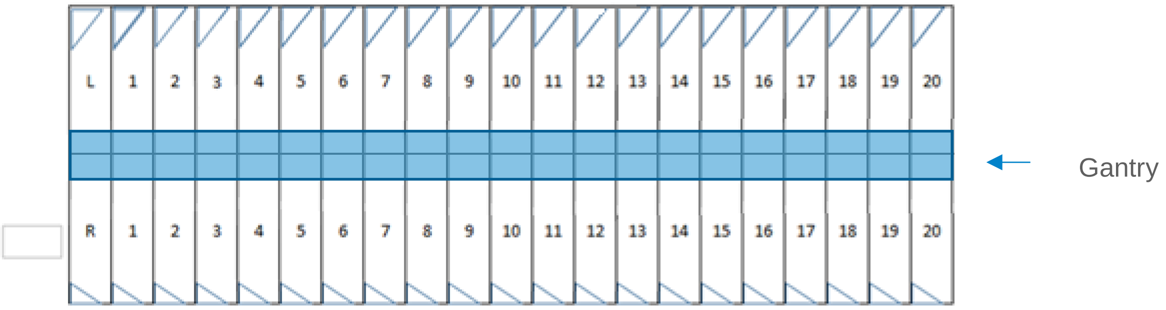

Figure 1: Layout of pens (not to scale)

The dimensions and measurements of the building are outlined in Table 1.

Table 1: Dimensions and measurements of the building

Building feature	Detail/measurement
Length of building	45 metres
Width of building	15.5 metres
Height of eaves	5.5 metres
Height of ridge	11 metres
Flooring type	Solid concrete with straw
Drinkers	2 nipple drinkers per pen
Pen size	7.62 metres x 2.32 metres
Feeder space	20 pens with 2 per pen and 20 pens with 4 per pen
Feed form	Pellet
Building set temperature	15-17°C

Pigs enter the building at approximately 50kg and leave at approximately 100kg.

The building is modified for forced fan ventilation with computer controlled side inlets, fan speed and flap control which is controlled by a Microfan Argos S3 unit. The building conforms to the requirements of the Verification of Environmental Technologies for Agricultural production (VERA) Test Protocol for Livestock Housing and Management Systems. The building has been used for more than one batch of pigs. In excess of 50 pigs are housed in the weight range of 25–110kg liveweight. Growth rate in previous batches are in excess of 760g per day.

The building was fitted with four axial fans in 450mm diameter chimneys. Control flaps are fitted and fan speed computer controlled to maintain constant airspeed, irrespective of volume. All four fans were run in parallel creating an even environment along the axis of the building.

Stocking rates in the building meet RSPCA Assured Standards, which are 0.80 m^2 per pig up to a liveweight of 110kg.

Monitoring

Ammonia concentration

Measurements of ammonia concentration were taken at the inlet and exhaust points in accordance with the Test Protocol for Livestock Housing and Management Systems, developed by Verification of Environmental Technologies for Agricultural Production (VERA). The equipment used to monitor ammonia levels was an LGD F200 sensor. This sensor was packaged into a gas analyser by Harper Adams and is based on the tuneable diode laser spectrometry principle (see appendix 1, 2, 3 for more detail). The machine was calibrated at the beginning and end of the study and was rechecked at the end of the study and found to be accurately recording ammonia within specification. For details of the calibration, see report (Appendix 4). Ventilation systems were checked prior to the study commencing to ensure they were functioning correctly.

Air samples for analysis were taken from 12 individual points, with the thirteenth acting as a purge of the optic. F2, F5, F8 and F11 as shown in figure 2 are exhaust points located in the chimney shaft. The location of inlets (to get ambient inlet air concentrations) and chimney exhaust points are shown in Figure 2.

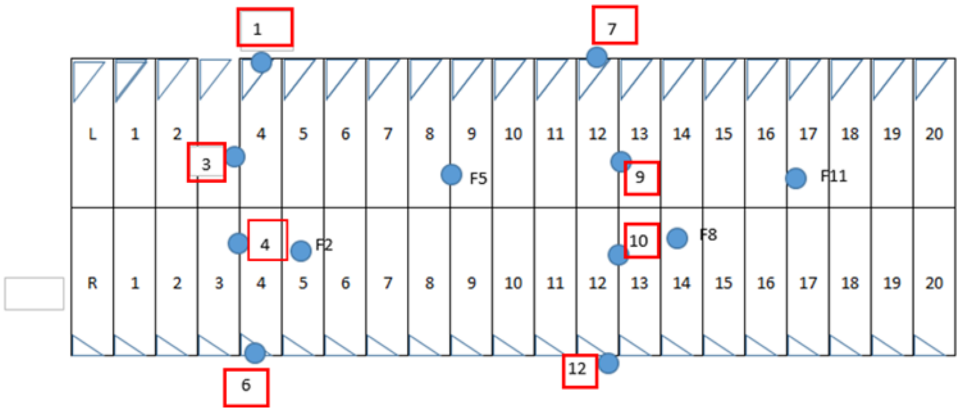

Figure 2: Pen layout and numbering for ammonia analyser sampling points (not to scale)

Samples were collected for a period of 1.5 days at a time. This was to allow for the equipment to be fully stabilised and results from a continuous 24-hour period to be collected. The maximum length of sample tube was 50m, which resulted in the maximum expected travel time for each sample to be 29 seconds. Each sample was analysed for a period of four minutes. Analyser sample time was set to ensure air from the sample point had reached the sampler optic and the optic had had time to adjust and stabilise. With this considered, the sample was then analysed and recorded.

Three production cycles (batches) were monitored in total across a 12-month period. Four measurements were taken in each batch and were evenly distributed throughout the production period.

Filters were placed at each end of the sampling tubes and were capped off before the shed was washed out.

The analyser was located on a catwalk approximately 3m above the pigs by the door, and measurements recorded onto an SD card.

Ventilation rate

Ventilation rate was measured using a measuring fan incorporated into the ventilation system. Data is then logged to the ventilation controller and to the removable SD card at 10-minute intervals. This data was downloaded at the same time as the data from the ammonia analyser.

Pig numbers

The number of pigs entering the building at 50kg and any mortality during the finisher period was recorded by the producer and reported back after each batch. Total numbers varied from 720 to 860.

Straw Usage

The date and the amount of straw used in bales was recorded throughout the study.

Analysis of data

1. Average inlet and outlet ammonia gas concentration were calculated for each sampling cycle period (approximately 17 minutes).
2. The average inlet ammonia concentration was subtracted from the average outlet value to create a 'net' concentration figure.
3. The net concentration figure provides the ammonia concentration in the air leaving the building via the fan shaft (exhaust point) in ppm (attributed to the housed pigs).
4. The net concentration figure was then converted to grams of ammonia per m3 of air (g/m^3) using the fixed conversion figure of 0.0007*.
5. This figure was then multiplied by the ventilation rate closest in time to the concentration readings (to provide a kg of ammonia leaving the building per hour, as ventilation rate is expressed as m^3/hr), multiplied by 8760 (to provide kg ammonia per year) and then divided by the number of pigs that entered the building at the beginning of each batch recorded.
6. This figure was then multiplied by a percentage occupancy figure of 95 per cent to provide a kg/ap/yr ammonia figure.
7. The calculation methodology was verified by Rothamsted Research.

*The fixed figure of 0.0007 is derived from the ideal gas law that states that any gas at 1 atm pressure and 25°C occupies 24 litres. 17 (the molar mass of ammonia) is then divided by 24 to provide a conversion from PPM to grams per m3 of 0.7. This was divided by 1000 to provide a conversion factor of 0.0007 from ppm to kg/m3 of ammonia (assuming the building is at 1 atm at 25°C).

Results

Table 2: Results from the study

Batch	Season	NH_3 Emission Factor (kg/ap/yr)	Number of pigs	CP % of finisher 1	CP % of finisher 2
1	Spring	0.49	720	19	16.25
2	Summer	1.69	800	19	16.25
3	Autumn/Winter	1.49	780	19	16.25
Average		1.22	/	/	/

Measurements were taken over a typical growing period of nine weeks, giving an average daily liveweight gain (DLWG) across the batches of 793 g/day.

Discussion

Table 2 shows that all four batches have an emission factor lower than current figures used by the EA. This creates an average of 1.22kg of ammonia per pig place per year.

A study carried out by Kavolelis (2006) reported 2.2kg per pig per year was achieved by keeping pigs on abundant straw litter that was changed every week and 2.8kg on a concrete floor system. On a fully slatted system, the emission factor was 2.5kg per pig per year. Although higher than this study's findings, all are below the official EA standard of 2.97kg for a sloid floor straw-based system for pigs over 30kg. It should be noted, however, the protein levels, growth rate and FCR for these studies were not reported.

Gilhespy et al (2008) investigated the effects of straw bedding on ammonia emissions and stated that additional straw may reduce NH_3 emissions by reducing airflow across surfaces soiled by urine, and by immobilisation of ammonium-N. This would explain the findings from Kavolelis (2006) study where the straw litter system had the lower ammonia emissions levels. However, Philippe and Nicks (not dated) acknowledged a large variation in results when comparing emission factors from bedded systems and slatted floor systems. Emissions will be influenced by litter substrate, amount, space allowance and the litter management. These parameters influence the physical structure (density, humidity) and chemical properties of the litter that interact to modulate gas emission levels (Gilhespy et al., 2008).

Table 2 also shows the protein content of the feed provided to the pigs throughout the duration of the study. Panetta et al., 2005, reported a 10 per cent reduction in ammonia-N emissions for every percentage point decrease in dietary CP. The results from other EU countries are broadly in agreement with this relationship.

Kavolelis (2006) states that ammonia emissions are dependent on several factors such as room temperature, floor construction, distribution of manure on the floor surface, manure removal frequency, feed composition and use of feed and manure additives. Kavolelis (2006) also reports that emission levels are higher in the summer than in the winter, which supports findings from this study where emissions are the highest in batch two, which was from June to October and significantly lower in batches one and three. Similarly, Philippe and Nick stated that emissions are positively correlated to ambient temperature and ventilation rate (ie as ambient temperature and ventilation rate increase, ammonia emissions increase). Their report highlighted that, when temperature increased from 17 to 28°C, ammonia emissions increased by 1.8g NH_3 per pig per day (0.66 kg/AP/year). When ventilation rate increased from 9.3 to 25.7m^3/h per pig, emission levels increased by 25 per cent. However, most ventilation is controlled by temperature.

Significance and relevance to the pig industry

IPPC/EPR is a challenge for some pig businesses when they look to expand their holding. Ammonia modelling and the prediction of ammonia emissions is a key part of the IPPC/EPR process. The models are based on emissions factors that were highlighted in a 2014 report that was commissioned by BPEX (now AHDB Pork) as not reporting 'data from enough explanatory variables to fully account for variation among reported NH_3 emissions'.

These studies have allowed for more up-to-date and accurate figures to be scientifically determined for a variety of pig housing in the UK, using current diets, ventilation and management practices. Currently, these figures are all lower than those used in the existing model by government agencies or consultants. This suggests that existing and future planned sites may be emitting less ammonia than was previously thought. This may ease the permitting process for many producers, or even alter the stocking limits on non-permitted sites.

The potential impact of this on UK pig production is enormous. These findings possibly limit the need for farmers to invest large amounts of capital in abatement technologies, which are then expensive to run on a per pig basis. As more emissions factors from other housing types are added to the study, we can more accurately compare UK-based emissions factors for these various housing types. This means that producers could potentially choose their housing type taking emissions levels into consideration. This would reduce the environmental impact of their production system and future-proof their businesses against future emissions regulations to some degree. It also allows the pig industry in the UK to actively engage with and contribute toward the industry target of a 27 per cent reduction in emissions by 2020.

In conclusion, the results from this study have been highly encouraging. A rolling programme of work is being carried out to allow for emissions factors to be accurately quantified from as many differing types of finisher and sow housing as possible, to create a database of routinely updated, scientifically established emissions factors for UK production.

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Appendices

Appendix 1. Monitoring gases from pig buildings – testing and calibration of an ammonia sensor (Phase 1)

Monitoring gases from pig buildings: testing and calibration of an ammonia sensor (Phase 1)

Harper Adams University
Project Report 100

SUMMARY

- European Union rules, protecting habitats and health, are making pig farmers adopt low emissions housing systems. Current atmospheric ammonia-measuring devices are prohibitively expensive which limits the validation of housing types. A lower cost alternative is sought.
- The aim of this first phase of a 3-phase study was to calibrate and assess the capacity of an ammonia sensor, LGD F200, (based on the tunable diode laser principle) to monitor ammonia concentrations at typical levels for pig buildings.
- Many practical tests were undertaken to assess the reliability and stability of the sensor. Overall, the sensor proved suitable for monitoring ammonia levels within the expected range. The recommended flow rate is 3 litres per minute (LPM). The temperature around the sensor should be stabilised and the start-up time before measurements are taken should be at least 1.5 hours.

AMMONIA LEVELS REGULATIONS

The level of ammonia emissions within and from pig buildings to the atmosphere is an important environmental issue. Ammonia can be produced as a gas from slurries and manures and causes soil acidity and damage to plants. Reductions in ammonia emissions from farm livestock buildings, by 2020, have been proposed by the European Union under the revised National Emission Ceilings Directive (NECD). For the UK, the proposed reductions are expected to be in the region of 10%.

However, currently there is no suitable affordable technology to measure and monitor the levels of ammonia in livestock buildings at a practical level. A standard sensing system, known as the Innova PhotoAcoustic, can be used for research purposes but would be costly for farm-scale use.

The AHDB Division-BPEX recognised the need for a cost-effective monitoring system with low maintenance for measuring and monitoring ammonia concentrations in pig buildings. This needs to be integrated into a sensing system for the building which would include other functions such as the measurement of CO_2, exhaust air, temperature and humidity.

AIM OF THIS PHASE OF THE STUDY

The aim of this first phase of a 3-phase study, at Harper Adams University and commissioned by the AHDB Division-BPEX, was to calibrate, and assess the capacity of, a particular sensor, the LGD F200, to monitor ammonia emissions at typical concentrations found in pig buildings. Other phases are described in reports noted in 'Further Information'.

PRACTICAL TESTING

Tests were undertaken to check the reliability and stability of the LGD F200 which incorporates the technology of TDLS (see box). The tests included:

- the effect of temperature and humidity;
- reading stabilisation after a cold start;
- linearity and relative accuracy;
- precision;
- response time;
- calibration and zero drift.

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Tunable Diode Laser Spectrometry (TDLS)

Tunable diode laser spectrometry works on the principle that all gases have a characteristic absorption band in the infrared wavelength region so gases can be identified and measured.

Acknowledgement

The external funding for this project from the AHDB Division-BPEX is gratefully acknowledged.

Harper Adams University

TEST RESULTS

The tests were all undertaken at Harper Adams University. Figure 1, below, shows the relative accuracy and repeatability from the testing of the sensor (twice) with different known ammonia concentrations. The agreement of the sensor with standard dilutions is very evident for most of the values tested. (The higher ammonia concentrations showed the greatest deviation from the standard dilution.)

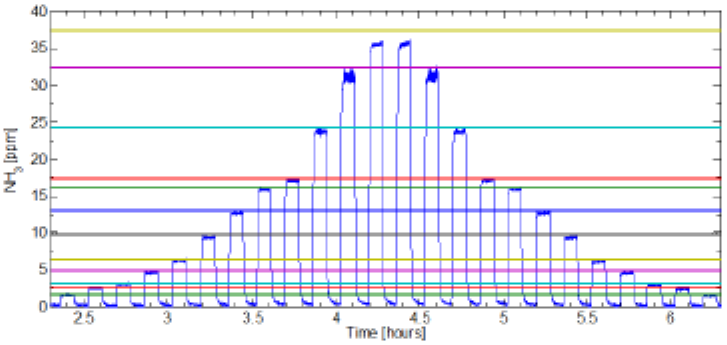


Fig 1. Accuracy of the sensor when exposed to different ammonia (NH_3) concentrations

OVERALL ADVANTAGES

The advantages of the LGD F200 sensor for ammonia measurement include the following.

- The high sensitivities are comparable to those obtained by the standard Innova PhotoAcoustic.
- There is a reduced possibility of interference from other gases.
- The cell volume is very small thus reducing the amount of sample and calibration gas needed, and the instrument is compact and lightweight (approximately 3 kg).
- No consumables are needed, keeping operational costs low.
- The functional temperature range is from -30°C to 65°C.
- This sensor is considerably cheaper than the standard Innova PhotoAcoustic.

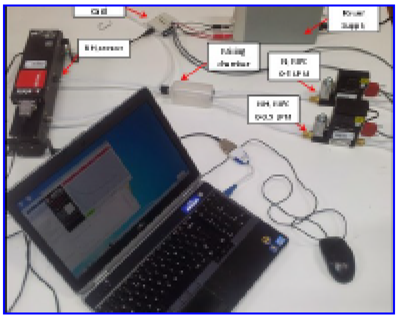
LIMITATIONS

Limitations of the LGD F200 sensor include the following.

- The system is based on a multi-pass measurement cell which may present a problem with the maintaining of optical alignment.
- Absorbance is measured indirectly.
- Only ammonia and water vapour concentration can be measured in the sample simultaneously.

CONCLUSION AND RECOMMENDATIONS

Overall the LGD F200 proved suitable for measuring ammonia levels within the range that is expected in the field. The largest deviations from the dilution standards were seen when flow rates through the sensor were less than that those used by the vendor during calibration. Therefore, the recommended flow rate is 3 litres per minute (LPM). Additionally, it is advised that the temperature around the sensor is kept stabilised and the start-up time should be at least 1.5 hours (see box).



Effects of Temperature

The results demonstrated that a temperature increase of around 1°C per second added low frequency noise to the reading which took about 40 minutes to stabilise.

When the sensor was rapidly heated from cold it also took time (1.5 hours) for the reading to stabilise.

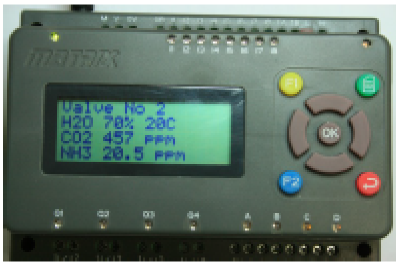
Further Information

Norton, T. and Clare, D. 2014. *Monitoring gases from pig buildings: development of a multi-channel monitor (Phase 2)*. HAU Project Report 102. Available from: http://ofi.openfields.org.uk/1.14070029

Norton, T. and Clare, D. 2014. *Monitoring gases from pig buildings: field evaluation of a multi-channel monitor (Phase 3)*. HAU Project Report 104. Available from: http://ofi.openfields.org.uk/1.14070030

HAU Project Report 100

Monitoring gases from pig buildings: development of a multi-channel monitor (Phase 2)



Harper Adams University
Project Report 102

SUMMARY

- There is a recognised need for a cost-effective monitoring system to reliably measure ammonia, CO_2 and other parameters across a range of pig buildings.
- The first phase of this 3-phase study assessed and calibrated the capacity of an ammonia sensor, LGD F200, (based on the tunable diode laser principle) to monitor ammonia concentrations at typical levels for farm buildings. The aim of this second phase of study (reported here) was to design and build a multi-channel monitor for farm-scale research to meet the specific requirements of the commissioned brief.
- The designed monitor successfully met the set brief and could record data for more than 14 days.

THE NEED FOR A MULTI-CHANNEL MONITOR

The level of ammonia emissions within and from pig buildings is an important environmental issue. The AHDB Division-BPEX recognised the need for a cost-effective and portable monitoring system that could be used for farm-scale research. Harper Adams University was commissioned to design and build a suitable system with the following requirements:

- to measure ammonia, CO_2, temperature and humidity;
- to be able to monitor up to twelve points within a building;
- to monitor for extended periods without supervision;
- to achieve low running costs;
- to be easily portable and fit in a car boot; and
- to be easy to set up by non-technical staff, with only minimal training.

THE CONCEPT

The concept that Harper Adams University devised was to use an LGD F200 Tunable Diode Laser Spectrometer to measure the ammonia level and a CO_2 (COZIR) analyser to measure CO_2, temperature and humidity. The cost of monitoring 12 points using 12 individual LGD F200 units would be prohibitive. Therefore, a system of pipes and a vacuum pump would be used to suck air from 12 points around the building, with solenoid valves to sequentially direct the air flow through the sensors.

PNEUMATIC VALVE SYSTEM

The pneumatic valve system had a total of 13 stainless steel two-way valves, switched by 12V solenoids (see figure 1). These gave rise to twelve sampling points and a clean air input. A 240V vacuum pump continuously sucked air from all 12 sample points and the clean air input. Each valve could be switched to direct air from a particular sample point to the sensors via a moisture trap.

It is possible that, over a period of time, ammonia could contaminate the sensors, therefore, between each sample, clean air was directed to the sensors, purging them to help stop long-term contamination. The material used for the system pipe work was an important aspect (see box).

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System pipework

All pipework, both internal and external, was either stainless steel or Teflon®. This ensured that ammonia did not affect any of the pipes and there was no risk of plasticiser leaching which could have affected the measurements being taken.

Acknowledgement

The external funding for this project from the AHDB Division-BPEX is gratefully acknowledged.

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CONTROL SYSTEM

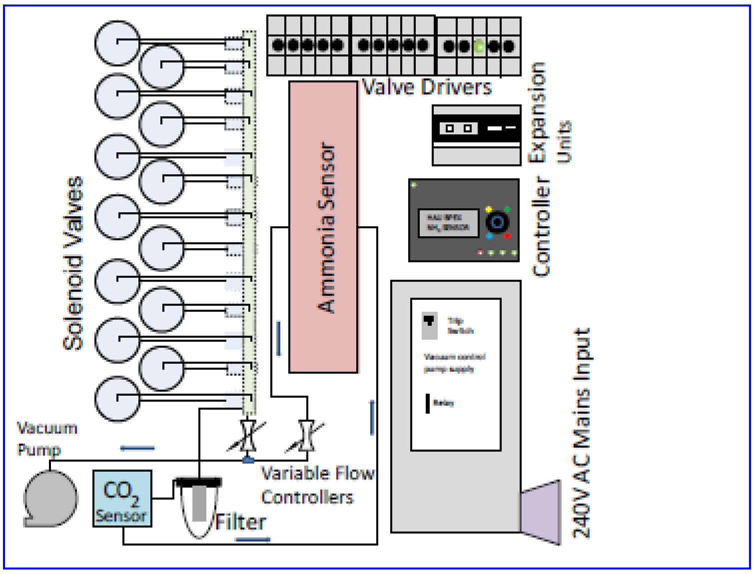

Fig 1. Diagram showing pneumatic and electrical elements of sensing system

The heart of the control system (see figure 1) was a **Matrix Industrial Automotive Controller (MIAC)** which was a **programmable logic controller (PLC)**. The basic PLC had a built-in 16 x 4 character screen which was used to display the status of the system, with buttons to control the operation of the system.

A MIAC Serial expansion module and Advanced expansion module were also used. These modules had serial input ports through which data from the sensors was transferred. They also increased the number of outputs, enabling the thirteen valves and vacuum pump to be individually controlled. The outputs from the expansion modules were low current transistor-transistor logic (TTL) outputs. These were connected to the valves via valve drivers (built in-house) to enable the system to control the higher current required by the valves.

The Advanced expansion module had a real time clock with a battery backup to allow the collected data to be time stamped. **The Serial expansion module** had a Secure Digital (SD) card slot, enabling data to be stored directly to an SD card.

The whole system was programmed using **Matrix's Flowcode 5 graphical programming language.**

SYSTEM ENCLOSURE

The control system and valves were enclosed in a steel industrial enclosure which could be locked to prevent tampering when in use. Externally there were power connections for the 240V mains supply and vacuum pump. The pipework could be easily connected and cleaned (see box).

CONCLUSION

The multi-channel monitor met the set brief and could record data for more than 14 days. It was successfully tested on the Harper Adams University pig unit and is now in use by AHDB Division-BPEX. Future units could include additional sensors for dust detection, or other gases.

Pipework Connections

The pipework could be easily connected, without the use of special tools. This was aided by the 14 quick-fit pneumatic connections for the 12 sample points, clean air input and vacuum pump. Disposable filters on the Teflon® pipes stopped dust entering the system.

Further Information

Norton, T. and Clare, D. 2014. *Monitoring gases from pig buildings: testing and calibration of an ammonia sensor (Phase 1).* HAU Project Report 100. Available from: http://ofi.openfields.org.uk/1.14040633

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HAU Project Report 102

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Appendix 3. Monitoring gases from pig buildings – field experiment final (Phase 3)

Monitoring gases from pig buildings: field evaluation of a multi-channel monitor (Phase 3)

Harper Adams University
Project Report 104

SUMMARY

- The European Union is placing greater emphasis on the reduction of gaseous pollutants, including ammonia, from livestock buildings. There is a need for one cost-effective monitor to accurately measure a range of parameters across several pig buildings.
- This third phase of a 3-phase study aimed to evaluate the multi-channel monitor, combining an ammonia sensor (LGD F200) and CO_2 (COZIR) analyser, (designed and developed during earlier phases of work) through field investigations.
- The multi-channel monitor was suitable for use in the pig buildings monitored in this study phase. Recommendations include regular calibration of CO_2 and installation of water traps outside the unit for operation in cold temperatures.

THE NEED FOR A NEW MONITORING SYSTEM

The European Union is placing greater emphasis on ammonia reduction from livestock buildings. The need for accurate monitoring of gaseous pollutant concentrations from livestock buildings is recognised by livestock farmers and government agencies.

The first phase of this study calibrated and assessed the capacity of an ammonia sensor, the LGD F200, (based on the tunable diode laser principle) to accurately monitor ammonia concentrations in pig buildings.

Currently there is no practical, cost-effective monitor available to accurately measure multiple variables (such as ammonia, CO_2, temperature and humidity) and monitor several pig buildings simultaneously. Phase 2 of this study addressed the design and development of a multi-channel ammonia sensor (LGD F200) and CO_2 (COZIR) analyser.

The third phase of the study (reported here) incorporated the field testing of the designed multi-channel monitor. All phases were undertaken by Harper Adams University, and supported by the AHDB Division-BPEX.

AIM OF THIS PHASE OF THE STUDY

The aim of this third phase of the study was to evaluate the multi-channel monitor, combining an ammonia sensor and CO_2 analyser, through field investigations. In particular, the need was to identify any obvious problems such as instability due to temperature variations and potential condensation.

FIELD TESTING METHOD

The multi-channel monitor was tested on two farms.

- Firstly, the Harper Adams University farm was used to assess any sensor or analyser faults in three types of buildings. These were: a small fan-ventilated weaner building; a new fan-ventilated cross-flow building; and a naturally-ventilated building.
- Secondly, two buildings on a commercial farm were used to test the stability of the multi-channel monitor over a longer time (14 days).

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Zeroing and Cleanliness

Before the field testing, the sensor and analyser were zeroed and the ammonia sensor was checked using a span (standard) gas.

The multi-channel monitor was thoroughly cleaned down and disinfected in between the two farm monitoring surveys.

Acknowledgement

The external funding for this project from the AHDB Division-BPEX is gratefully acknowledged.

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Harper Adams University

FIELD TEST RESULTS

It should be noted that all the results are relevant only to the specific housing systems as each building housed a different number of pigs.

The monitor successfully monitored the ammonia concentrations in all three buildings at **Harper Adams University** without any problems. The CO_2 analyser needed to be regularly zeroed to re-stabilise.

Two buildings on **the commercial pig unit** were monitored during two weeks of stable weather. The outdoor temperature and relative humidity were satisfactorily measured and traces are shown in figure 1, below.

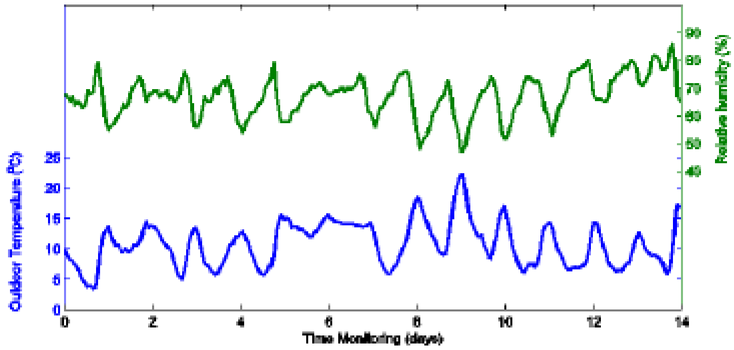


Fig 1. Traces of outdoor temperature and relative humidity over 14 days

The ammonia emission rate of building 1 was lower than that of building 2, averaging about 10 parts per million (ppm). The monitor was able to detect a significant within and between-house variation in ammonia emission rates.

Figure 2, below, shows the emission rates of ammonia from each specific building, after combining ventilation rate with detected ammonia concentrations, at the exhaust of each building (see box).

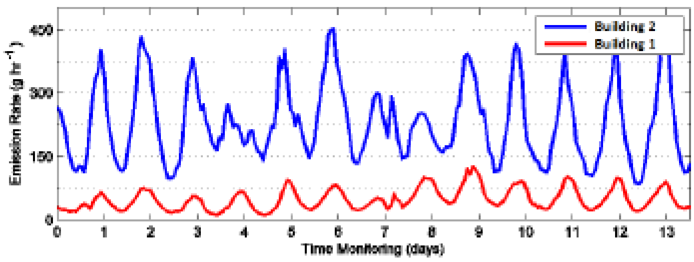
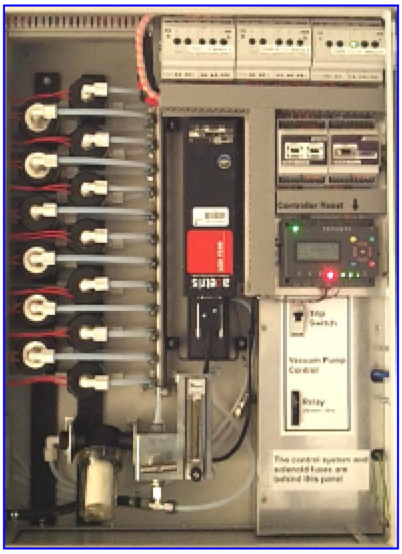


Fig 2. The emission rate of ammonia (g per hour) from both buildings over the monitoring period

CONCLUSION AND RECOMMENDATIONS

The measurement surveys on the University and commercial farming units proved that the multi-channel monitor was suitable in these contexts, without encountering any major faults. Overall, it was cost-effective when compared to the commercially-available photoacoustic system.

Recommendations include: regular CO_2 calibration; and installation of water traps outside the unit for operation in cold temperatures. Future developments could focus on the addition of a sensor for dust detection and, possibly, particle sensors for disease detection.



Ventilation Rate

Measurement of the ventilation rate is crucial to determine the emission factors. The study showed that CO_2 emitted by the animals can be used as a tracer to predict ventilation rates.

Further Information

Norton, T. and Clare, D. 2014. *Monitoring gases from pig buildings: testing and calibration of an ammonia sensor (Phase 1).* HAU Project Report 100. Available from:
http://ofi.openfields.org.uk/1.14040633

Norton, T. and Clare, D. 2014. *Monitoring gases from pig buildings: development of a multi-channel monitor (Phase 2).* HAU Project Report 102. Available from:
http://ofi.openfields.org.uk/1.14070029

HAU Project Report 104

Appendix 4. Ammonia analyser calibration information

a:etris
Company of the Leister Group

LGD F200 Calibration Certificate

Product Information

Serial No.	LGD_F200_NH3_A_1211220008
Firmware:	Ve.1.16
Configuration:	7792
Date:	15.01.2016
Operator:	TRA

Calibration Conditions

Target Gas	NH3	
Range	100	**ppm**
Gas Flow	4500	**sccm**
Cell Temperature	190	**°C**
Ambient Temperature	20	**°C**
Pressure	1000	**mbars**

Gas Matrix

Gas Name	Concentration in %
N2	100
O2	-
CO2	-
CO	-
CH4	-
H2O	0 - 30

Definitions

ppm vol	parts per million
Precision (2σ) (mean value in specified operating temperature range)	2 times the standard deviation (σ) over 2 minutes
Accuracy (at calibration conditions)	deviation between the average measured value and the real concentration

Maximum Deviation

dry ± 2 ppm NH3

Verification Measurements

	REALISED CONCENTRATION	MEASURED CONCENTRATION	SPECIFIED MAX DEVIATION	ACCURACY	PRECISION
	NH3 in ppm	NH3 in ppm	in ppm	in ppm	in ppm
linearity	99.99	100.97	2.00	0.98	0.46 @ 1s integration
	49.94	50.67	2.00	0.73	
	20.03	19.86	2.00	-0.17	
	10.02	9.64	2.00	-0.38	0.22 @ 10s integration
	5.07	4.71	2.00	-0.36	
	0.00	-0.45	3.00	-0.45