INSTRUMENTATION KIT FOR MEASURING AIRBORNE POLLUTANTS IN LIVESTOCK BUILDINGS

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Introduction

Different airborne pollutants, sometimes in high concentrations can be found in the airspace of intensive piggery buildings (Cargill *et al.* 2002). High airborne pollutant concentrations could potentially affect the environment, production efficiency of animals and the health/welfare of both humans and livestock. A coordinated national project was undertaken in Australia to identify key factors affecting the concentrations of airborne pollutants in piggery buildings in order to predict and control the concentrations and emissions of these pollutants. Other researchers who conducted similar surveys usually used sophisticated and relatively complicated instrumentation (Phillips *et al.* 1998). However, this survey purposely used a more simplified instrumentation kit in order to ensure that the results of the survey and more importantly the equipment used during the survey can be applied routinely on farms, after the study concluded. The selection of the components of the measurement kit used during the study was based on reliability, accuracy, practicality and cost effectiveness of the individual items. Fulfilling all of these, sometimes opposing requirements for the many components used was difficult. Therefore the selection of the components was based on a healthy balance between different requirements and involved compromises. This paper describes the methodology and the instrumentation kit used during the field survey of the project and reports on operational experiences.

Farm selection and monitoring procedures

A total of 160 piggery buildings were surveyed between the autumn of 1997 and the autumn of 1999. The standardised instrumentation kit, data collection forms and associated graphing and reporting softwares were developed in South Australia (SARDI) and distributed to participating research organisations in other states. Training programs were implemented for the collaborators to standardise data collection procedures. The study sheds included a wide range of design and management options to provide a representative sample of industry practice in Australia. Five working days were allocated to individual buildings to complete all tasks associated with the measurements. Equipment was set up usually on either Monday or Tuesday and collected on Thursday or Friday from the buildings. The remaining day of the week was used to implement a very thorough cleaning and disinfection procedure to avoid any cross contamination between farms and/or buildings. On each farm, dry sow, weaner, grower/finisher buildings, farrowing rooms and on some farms, deep bedded shelters (DBS), were surveyed during the study. Continuous data was collected over a 3.5 day period, but the data was truncated to 60 hours to provide a balanced data set. The level of hygiene was assessed visually by estimating the percentage of manure-covered solid area in the pen and classifying into three distinct classes (poor=more than 50% manure cover on pen floors, fair=between 10 and 50% manure cover on pen floors, good=less than 10% manure cover on pen floors) at the time of data recording (Banhazi *et al.* 2002). Seasons were arbitrarily defined as summer from November to April and winter from May to October. A pro-forma was developed to collect data relating to the management and engineering characteristics of the buildings (Table 1). In Figure 1 the usual layout of the monitoring instrumentation used in the study buildings is shown.

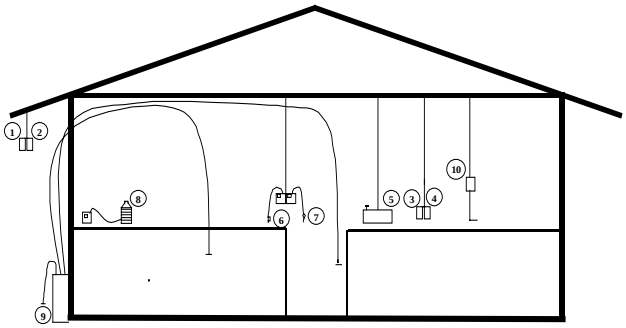

Figure 1: Instrumentation kit used for the survey (1-external temperature, 2-external humidity, 3-internal temperature, 4-internal humidity, 5-continuous dust monitoring, 6-inhalable dust, 7-respirable dust, 8-Andersen samplers, 9-MGM machine, 10-internal wind-speed measurements).

Table 1. Information collected about the study buildings.

Questions	Comments
Farm identification	Unique ID
Shed identification	Unique ID
Management system	CF vs AIAO
Class of pigs	Weaner, grower/finisher, dry sow, farrowing, deep-bedded
Age of pigs	Weeks
Age of buildings	Years
Farm size	Number of sows
Pen size	Length, width and area
No of pens/building	#
No of pigs/building	#
Volume of building	Length, width, height and volume
Average no. of pigs/pen	#
Drain/pit area	Percentage of pen area
Slat material	Concrete, steel, plastic etc
Flushing frequency	Eg. Twice a week
Cleaning method used	Pressure cleaning, hosing etc
Level of hygiene	Good, fair, poor
Solid or open pen walls	Concrete vs tubes
Feeder type	Wet/dry; single/multi-space etc
Feed presentation	Mash vs pelleted
Feeding regime	Ad-lb vs restricted
Ventilation type	Natural vs mechanical
Ventilation control	Manual vs automatic
Air inlets	Height of shutters/blinds
Ridge vent size	Width, height
Forced ventilation	Negative vs positive pressure
Climate control	Heaters or cooling devices
Roof/wall insulation	Eg. Sandwich panels, asbestos etc
Insulation thickness	Centimetres

Particle measurements
The concentration of airborne particles was determined gravimetrically using cyclone and "seven-hole" samplers for respirable (< 5 µm) and inhalable particles, respectively (SKC Inc., Pennsylvania). The sampling rate was controlled at 1.90 L/min for respirable and at 2.00 L/min for inhalable particles. The samplers were connected to GilAir (Gilian® Instrument Corp., USA) air pumps and were placed in a standardised position, usually above the walkways. An eight-hour sampling time was standardised throughout the project, starting at 09.00 h. The equipment was placed in the buildings the day before the actual measurement to allow animals to settle. A built-in timer automatically started the sampling routine. The sampling time was selected in the light of previous publications and aimed at sampling during times when the particle concentrations were likely to peak (Pedersen and Takai 1999).

Endotoxin measurements
For the estimation of endotoxins in airborne dusts, the exposed dust filters were extracted with sterile and pyrogen-free water at room temperature. The commercially available test kit used was based on the Limulus Amoebocyte Lysate (LAL) test. This test utilises the initial part of the LAL endotoxin reaction to activate an enzyme that in turn releases p-nitroaniline from a synthetic substrate, producing a yellow colour. The measurement of endotoxin concentration was performed using a microplate method, which involved reading the absorbency of each microplate well at 405nm, with distilled water used to adjust the photometer to zero. All disposable products used were pyrogen-free (SARSTEDT, Germany). Each filter was diluted with pyrogen-free water (Delta West Pty Ltd, Australia) at 25mL per filter. The optimum pH was 7 and was adjusted by the addition of NaOH or HCl. The water/dust suspension was vortexed for 20 seconds, shaken for 2 h at room temperature and centrifuged at 2000rpm for 10 minutes. A 50 µL aliquot was taken for subsequent analysis. For calibration, six standard solutions were made with the endotoxin of *E. coli* (BioWhittaker Inc., USA) with a control standard endotoxin (CSE) potency equivalent to 10 EU/ng. A multipoint calibration with 50 µL solutions with concentrations of 20, 5, 1, 0.5, 0.25 and 0.10 EU/mL was used and the magnitude of colour intensity measured by photometry. All data were analysed by linear regression and compared with a standard curve from the reference endotoxin and a coefficient of correlation of 0.97 or higher was accepted. Solutions of endotoxin-free water and lysate served as controls. The measurements were made using a QCL-1000® Chromogenic LAL test kit (BioWhittaker Inc., USA) with a Kinetic-QCL™ Reader (BioWhittaker Inc., USA).

Bacteria measurement
Sampling of airborne microorganisms was carried out using a standard Anderson sampler or six-stage bacterial impactor (Jones *et al.* 1985). Horse-blood-Agar (HBA) was used (Medvet Science, Australia) for the determination of the total amount of microorganisms. Samples were taken around mid-day between 11.00 h and at 15.00 h, usually in the centre of the animal house and above the pens. The flow rate during sampling was 1.9 L/min and the sampling time was 5 minutes. The exposed HBA plates were incubated at 37 ^{o}C under aerobic conditions and bacteria colonies were counted after 24h.

Temperature and humidity measurements
Self-contained and battery operated data loggers with built-in sensors (Tinytalk®-2, Hasting Dataloggers, Australia) were used to measure temperature and relative humidity in all buildings at each visit and outside temperature and humidity data were logged simultaneously. Sensors were placed as close to pig level as practically possible, without allowing the pigs to interfere with the instruments. Most loggers were attached to the ceiling or a beam, using wire cable and were lowered to pig level above a selected pen, representing the average condition of the shed.

Measurement of gas concentrations
Carbon dioxide and ammonia concentrations were measured continuously inside and outside the buildings using a Multi Gas Monitoring (MGM) machine (Banhazi and Cargill 2000) with built-in sensors. An electrochemical monitoring head (Bionics TX-FM/FN, Bionics Instruments Co., Japan) was used to detect the internal concentrations of ammonia and an infrared monitoring head was used to detect carbon dioxide (CO_2) (GMM12, Vaisala Oy, Finland). The MGM machine incorporated an air sampling system, which delivered air samples from the sampling points within and outside of the buildings to the actual enclosure containing the gas monitoring heads. Air was drawn at a nominal rate of 0.5-0.8 l/min from the sampling points and between the sampling points the system was purged using fresh air drawn from outside of the buildings. After each sampling point was monitored for 15 minutes, the system was purged for 15 minutes to flush out the sampling lines and zero the ammonia monitoring head. An electronic (voltage) tag was logged corresponding to the internal and external sampling sites, which enabled the automatic separation of the data. A computer program was built in MS Excel® to facilitate the automatic separation and graphing of the data. The program also contained the algorithms to calculate the amount of time spent above and below the relevant recommended levels. At the end of each data collection period the raw data was assessed by the data collectors. If drift had occurred in the raw data set (i.e. the data did not return to zero in the case of ammonia or to expected ambient levels in the case of carbon dioxide during the purge periods), the data was discarded. The MGM machine was frequently calibrated using a custom-made 2,500 ppm carbon dioxide mixture and a standard 50 ppm ammonia calibration gas mixture. All intake tubes had a filter attached to the end of the line to prevent deposition of particles in the sampling line.

Data storage and statistical analysis
Survey data collected in all states were transferred to a central location in South Australia for storage and analysis. A detailed model was developed to test various interactions based on fixed effects and covariates. This

was done using a general linear model procedure (PROC GLM) (SAS 1989). The effects treated as fixed effects were building type, assessment of hygiene level, management type and season. The effects treated as covariates were weight of pigs per building (kg), building size (m^3), ventilation air flow (m^3 air/hour), internal temperature (^oC), humidity (%), and farm size (number of sows). Due to model size restrictions only first order interactions could be tested. The models were developed from the maximum model tested by sequentially removing non-significant interactions and effects ($P<0.05$, based on type III estimable functions) until only significant effects and interactions remained. The results from this analysis presented in subsequent papers are based on LS means of predicted building values and the best-fit slopes, where this is relevant.

Assessment of methodology and instrumentation

The instrumentation kit used during the survey proved to be relatively easy to install/remove under field conditions. The large number of buildings included in the study and the varied nature of the buildings selected ensured that the study population of the buildings was representative. Particle measurements were done using a simplified instrumentation, compared to previous studies (Phillips *et al.* 1998). The commercial kit used for endotoxin measurements required considerable additional work and fine-tuning. However, as one operator conducted all analysis, the comparative concentrations of samples were consistent ensuring reliable interpretation of the statistical analysis. The self-contained temperature and humidity loggers proved to be useful and reliable instruments. The measurement accuracy of humidity sensors was occasionally questionable. However as large amount of data was collected and averaged over a period of time the overall results were considered to be reliable. The MGM machine performed well, but the ammonia sensors required frequent calibration. The transportation of the enclosure was sometimes problematic, due to the size and weight of the equipment. The statistical analysis applied proved to be sophisticated, sufficiently complex to ensure interpretable results.

The instrumentation kit is currently under development to further simplify the operation of the various components and therefore make it routinely available for the farming community for building assessment purposes (Banhazi 2003).

Conclusion

1. A large number of buildings were included in the survey to ensure a good representation of industry practices.
2. Particle, temperature, bacteria and carbon dioxide measurements proved to be relatively simple and reliable. Ammonia sensors needed frequent calibration and endotoxin measurements required extra care and fine-tuning.
3. The statistical modelling was sophisticated but necessary to enable main effects and interactions to be tested simultaneously. Simultaneous comparisons are important when many factors affect the variable being studied.
4. The kit is currently undergoing further development to be used routinely in livestock buildings by the farming community.

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