Measuring ammonia concentrations in the barn using the Draeger™ and pHydrion™ tests

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Summary

Purpose: To determine the precision and cost-effectiveness of the pHydrion™ ammonia test relative to the Draeger™ volumetric pump/ammonia detector tube method in measuring ammonia concentrations in swine barns.

Methods: Ammonia concentrations in farrowing, nursery, finisher, and gestating barns were monitored for 8 weeks using both the pHydrion™ test strips and the Draeger™ unit. The ammonia measurements were compared using bivariate correlation analysis. Average ammonia concentrations in each barn type were compared using an ANOVA. The precision and cost-effectiveness of each assay were demonstrated by plotting the width of the confidence interval by the number of dollars available for ammonia detection, as well as by the number of tests performed.

Results: The mean ammonia concentrations differed by room type ($P < .05$) and increased in the following order: nursery, farrowing, gestating, and finishing rooms. Ammonia concentrations in all barn types frequently (52%) exceeded 7.5 ppm; ammonia concentrations greater than 7.5 ppm are associated with respiratory problems in humans. The concentrations reached or exceeded 25 ppm 7.6% of the time. Although the Draeger™ unit provided more precise measurements when a small number of tests were performed, the cost of each test was quite high. It was found that the pHydrion™ ammonia test provided more precise measurements when available funding was taken into consideration. Correlation analysis found that the ammonia measurements taken with the Draeger™ unit and pHydrion™ test strips were highly correlated (r=.80).

Implications: The variability between barn types and measurement days underlies the importance of regular ammonia monitoring. The pHydrion™ ammonia test provides a precise and cost-efficient means of monitoring ammonia concentrations in swine confinement buildings.

Keywords: swine, ammonia, air quality

Received: June 3, 1998
Accepted: February 18, 2000

The air quality of swine units may have significant effects on human health. Although respirable dust and endotoxins are of primary concern, ammonia is also related to impaired respiratory function. Ammonia is released as a by-product of anaerobic manure decomposition and may reach unacceptable concentrations in swine confinement buildings.[1–4] In fact, epidemiological studies suggest that ammonia concentrations approach or exceed the threshold limit value of 25 ppm in a large majority of swine units.[2–4]

The adverse health effects of ammonia inhalation are well documented. Donham[5] found that swine workers experienced respiratory symptoms when working in buildings with ammonia concentrations as low as 7 ppm. Increased incidence of chronic cough, wheezing, shortness of breath, chest tightness, organic dust toxic syndrome, hyperreactive airways disease, chronic fatigue, asthma, bronchitis, airway obstruction, and irritation of the eyes, nose, pharynx, and sinuses have all been associated with the combined effects of inhaled dusts and gases in confinement buildings.[6–10] Ammonia has been linked to reduced lung function tests in persons working in swine barns.[10] Ammonia is hygroscopic and therefore is expected to stay in the upper respiratory tract.[6,7] However, ammonia can adhere to respirable dust particles and then will be carried to the smaller airways. Thus, ammonia and dust concentrations have an additive negative effect on the respiratory system.[6,7,11,12] A maximum concentration of 7.5 ppm of ammonia is recommended as a target for the occupational health of people working with pigs.[8]

The results of reports on the effect of various concentrations of ammonia on the health of pigs have been inconsistent.[11,13,14] It is difficult to replicate a natural barn environment in a laboratory setting. Ammonia at 50 ppm was consistently associated with health problems in pigs. Urbain, et al., found a reactive nasal cellular response in pigs after 5 days of exposure to 25 ppm ammonia.[14] This local irritation can promote the local proliferation of bacteria.[15] The exposed pigs were also depressed, which was related to a reduction in growth rate. From these studies, Urbain, et al., recommended a maximum concentration of 15 ppm for optimum pig health.[14] Drummond, et al., also found a 12% reduction in body weight gain in young pigs exposed to these ammonia concentrations.[1] We lack substantial data on pigs exposed to < 25 ppm ammonia because this is typically the lowest concentration used in laboratory studies.[11,14] Ammonia accumulation may be particularly problematic in farrowing and nursing barns, as young pigs produce a relatively larger quantity of urine and feces per pound of body weight and are more sensitive to the toxic effects of this gas.[3]

The adverse effects of ammonia on humans and pigs underscore the importance of regularly monitoring ammonia concentrations in swine confinement buildings. The human health issue is even more important now that swine units are becoming larger and people are spending a full workday in

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This article is available online at http://www.aasp.org/shap.html.

Dewey CE, Cox B, Leyenaar J. Measuring ammonia concentrations in the barn using the Draeger™ and pHydrion™ tests. *Swine Health Prod.* 2000;8(3):127–131.

confinement units.

Although a number of methods are available to evaluate ammonia concentration, the equipment is often considered prohibitively expensive for routine use. The most widely recommended apparatus for ammonia detection consists of a $306.00 volumetric pump (Draeger™ Accuro Pump, Draeger Safety Inc.; Pittsburgh, Pennsylvania) and disposable amine detector tubes that cost $4.12 each (Short-term Draeger-Tube CH20501, Draeger Safety, Inc.). While this method is advocated as highly precise and accurate, its high cost may limit the number of measurements that are performed in practice.

An alternate ammonia measurement tool is the pHydrion™ (pHydrion™ ammonia test, Micro Essential Laboratory; Brooklyn, New York) ammonia test strip, which costs only $0.06 per test. This test involves placing a drop of distilled water on a paper test strip, waving the strip in the air for one minute, and estimating the ammonia concentrations by matching the color change with a calibrated color chart. Due to its low cost, this test may be performed repeatedly at a number of locations around swine units. Given that ammonia concentrations vary considerably with animal densities, time after fill, manure management, and stage of production,[2,16] it is beneficial to make multiple and frequent measurements. These allow the farm personnel to locate the problem areas and determine the actions required to reduce ammonia accumulation.

The objective of our study was to determine the precision and cost effectiveness of the pHydrion™ ammonia test relative to the Draeger™ volumetric pump and ammonia detector tube method in the measurement of ammonia concentrations in swine barns. The distribution of ammonia concentrations between barn type and days is also described.

Materials and methods

This study was conducted in a 700-sow farrow-to-finish unit in Nebraska from February 18, 1994–April 15, 1994. The farrowing and nursery rooms had fully slatted floors over a manure pit. These rooms were managed all-in–all-out and were cleaned and disinfected between batches. The breeding and gestating barns were run in a continuous-flow manner and had solid concrete floors. The breeding barn used stalls, whereas the gestating barn housed animals in pens of 15 sows. The finisher barn had partially slatted concrete floors and was run as a continuous-flow facility. The gestating and finishing barns were naturally ventilated. The other barns were mechanically ventilated with fans.

Ammonia concentrations were measured in three farrowing rooms, four nursery rooms, three finisher rooms, one gestation room, and one breeding barn. Once a week, a university technician measured the ammonia concentrations in each room using both the Draeger™ unit and pHydrion™ test strips. During the first herd visit, the technician trained one staff member in each of the farrowing, nursery, finisher, and breeding areas to use the pHydrion™ test strips. These barn staff then took daily ammonia measurements using pHydrion™ test strips, and these measurements were compared to those taken by the technician in each location. Measurements were taken each morning, at the level of the person's head. Accounting for days off, approximately five measurements were taken each week.

Statistical analysis

The data recorded by barn personnel was entered into PC/SAS (SAS. Version 6 ed. SAS Institute Inc.; Cary, North Carolina) for analysis. The simultaneous ammonia measurements taken by the Draeger™ unit and the pHydrion™ test strips were compared using bivariate correlation analysis. The average daily ammonia concentrations among barn types, as measured by the pHydrion™ test, were pooled by barn type and then compared using an ANOVA. Differences were considered significant at $P \leq .05$.

Precision is the ability of a test to provide the same results over time. The width of the confidence interval, equivalent to two times the standard error, was calculated to indicate the relative precision of the two ammonia detection techniques.[17,18] The width of the confidence interval decreases proportionally as the precision of a measurement technique increases.

To illustrate the precision and cost effectiveness of the pHydrion™ test strip method compared to the Draeger™ unit, the width of the confidence bound was plotted by the number of dollars available for ammonia detection, as well as by the number of measurements taken. We determined that the pHydrion™ test cost $0.06 per test while the Draeger™ unit costs $4.93 per test. The latter was determined by the $4.12 per disposable detector tube plus $0.61 per use of the volumetric pump, based on 500 ammonia tests. Assuming the test takes 10 minutes and the hourly wage is $10.00, $1.67 was added to the cost of each measurement.

Results

A total of 380 samples were taken with the pHydrion™ test (Table 1). The technician took 110 Draeger™ samples with simultaneous pHydrion™ samples.

In the nursery and finisher rooms, a trend towards decreasing ammonia concentrations from February to April was observed (Figure 1). In contrast, the ammonia concentrations in the gestation and farrowing rooms did not show consistent decreases.

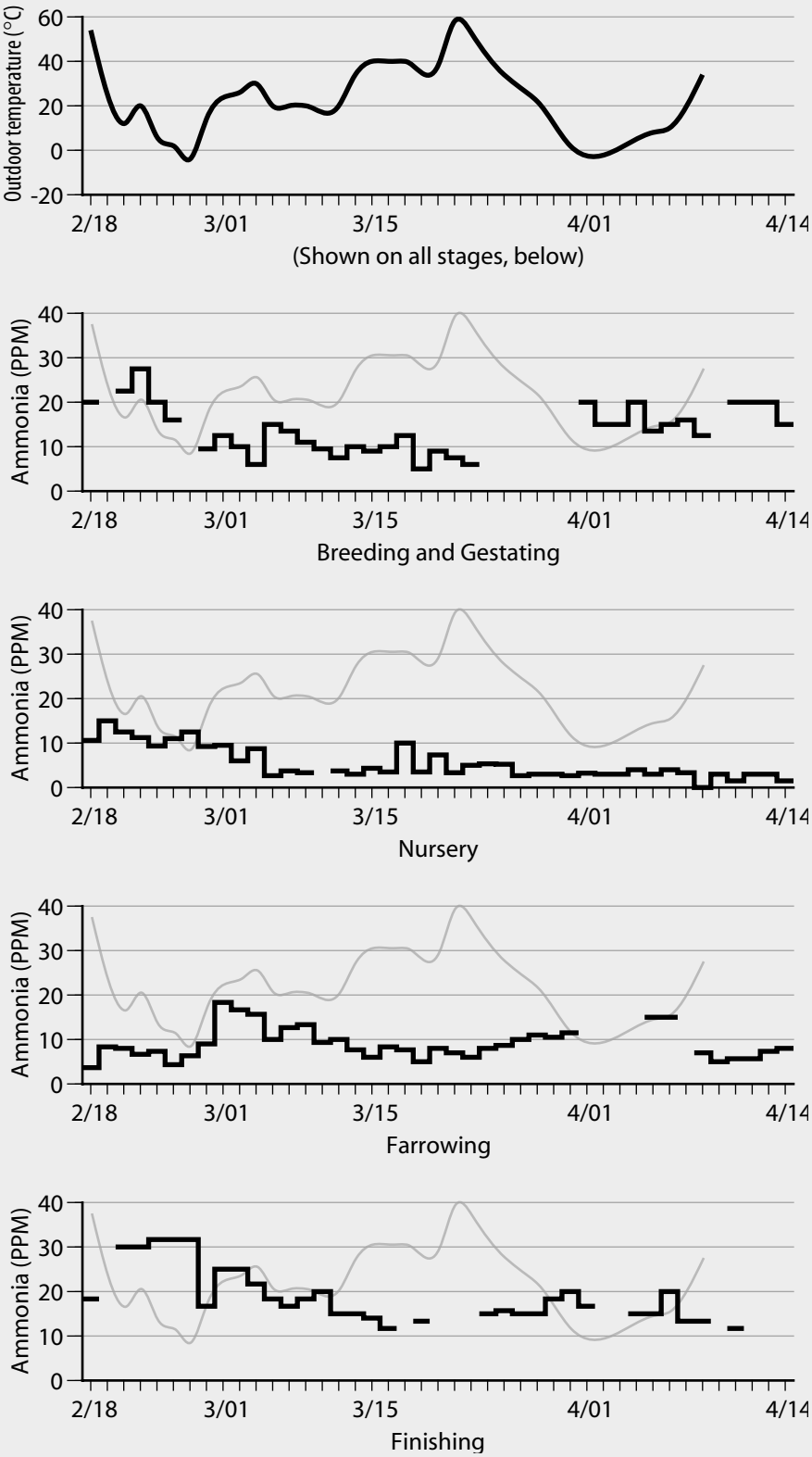
The mean ammonia concentrations among the room types all differed significantly at $P \leq .05$ and increased in the following order: nursery rooms, farrowing rooms, gestation rooms, and finishing rooms (Table 1). The ammonia levels frequently exceeded 7.5 ppm and occasionally equalled or exceeded 25 ppm.

In the 110 samples measured with both the Draeger™ unit and the pHydrion™ strip, the results were well correlated (r=.80; P=.003). On average, the pHydrion™ result was 3 ppm higher than the Draeger™ result; however, this bias was not consistent.

Table 1: Ammonia concentrations as measured by the barn personnel using pHydrion™ test strips

	n	Mean ± SE	95%CI	Samples > 7.5 ppm	Samples 25 ppm
Breeding	33	17.2 ± 1.04	15.1–19.3	31 (94%)	5 (46%)
Gestation	26	8.7 ± 1.1	6.5–10.9	8 (31%)	1 (4%)
Farrowing	98	9.03 ± 0.5	7.9–10.1	45 (46%)	1 (1%)
Nurseries	130	6.2 ± 0.58	5.0–7.3	30 (23%)	5 (4%)
Finishing	93	19.1 ± 0.79	17.5–20.7	89 (96%)	19 (20%)

Figure 1: Outdoor temperature and average daily ammonia concentrations in each of the barn types as measured by farm personnel using pHydrion™ test steps



The pHydrion™ method provided a more precise measurement than the Draeger™ unit when the cost of testing was taken into consideration (Figure 2).

Discussion

Monitoring of ammonia concentrations inside swine confinement buildings is important for maintaining both swine and human health. Barn personnel need precise and cost-efficient ammonia detection methods. However, the true ammonia concentration in a barn can never be known exactly. Instead, ammonia detection equipment can be used to estimate that concentration, with the precision of the estimate depending on a number of factors.

In this study we always measured the ammonia in the same location in each barn. This was at the person's head level in the center of the room. It is important to note that ammonia concentrations in the breathing zone of pigs are sometimes 60% higher than in the human breathing zone.[2] Thus, it is expected that the pigs were exposed to ammonia concentrations higher than those recorded in this study.

Precision may be defined as the repeatability or reproducibility of the test results.[15] It may be maximized by using the best available technology, shown to yield consistent and accurate results. Alternately, precision may be increased by increasing the number of measurements performed. Increasing the number of tests decreases the probability that the sample mean will deviate by large distances from the true mean.[17] In other words, performing a large number of tests makes it more likely that the average measured value is close to the true ammonia concentration.

Although the Draeger™ unit provides more precise data when a small number of tests are performed (Figure 3), the cumulative cost of these tests is significantly greater than the cost of the pHydrion™ method. For example, to get an ammonia measurement that is within 2 ppm of the true value 95% of the time, we would have to do 20 tests with the Draeger™ unit and spend $95. For the same precision, we could spend only $5.40 and do 90 tests with the pHydrion™ paper strips.

We calculated the cost of labor to measure ammonia to be $1.67 per test, assuming the farm worker is paid $10.00 per hour and it takes a maximum of 10 minutes per test. Given that the pHydrion™ test cost $1.73 per test ($0.06 materials + $1.67 for labor) while the Draeger™ unit cost $6.40 per test ($4.12 for the disposable detector tube plus $0.61 per use of the volumetric pump, based on 500 ammonia tests), the pHydrion™ method provided more precise measurements when $10–$200 is available. If $100 was spent on ammonia

Figure 2: Relative precision of the ammonia detection techniques according to the number of dollars available for ammonia monitoring

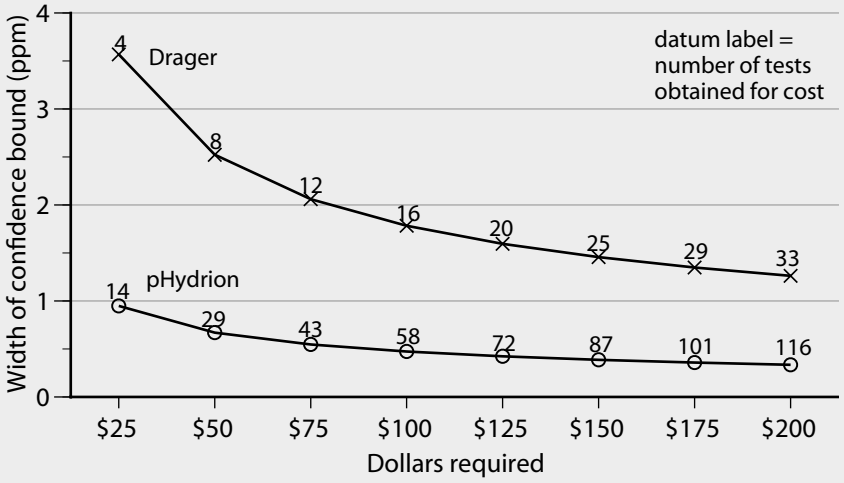
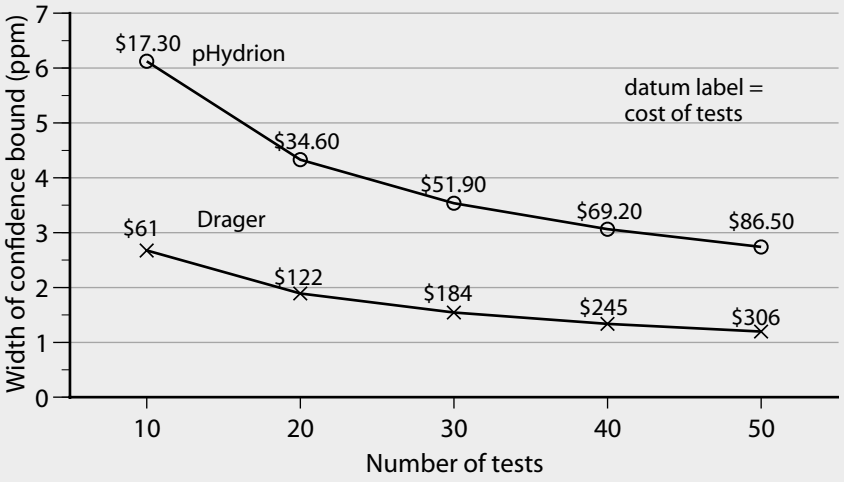


Figure 3: Relative precision of the ammonia detection techniques according to the number of tests performed



testing, the pHydrion™ test would provide measurements that were within 0.5 ppm of the true value 95% of the time. In contrast, measurements taken with the Draeger™ unit would only be within 1.75 ppm 95% of the time. As the width of the confidence interval increases, the precision of the technique decreases. Therefore, within the funding range shown on Figure 2, the pHydrion™ test was a more precise ammonia detection tool.

Comparing the Draeger™ and pHydrion™ on the basis of funds available for ammonia detection revealed that more than $2000 must be spent before the precision of the Draeger™ method exceeded that of the pHydrion™ ammonia test (Figure 2). Because the majority of herd owners would be unlikely to spend more than $200 per building per year on air quality monitoring, the precision of the pHydrion™ ammonia test would exceed that of the Draeger™ method.

Our observation that air quality differed among the various rooms in this swine production unit is consistent with the observations of other researchers.[12] The fact that ammonia concentrations change by facility type and change over time indicates that one measurement per swine unit is not sufficient to precisely measure the ammonia exposure of swine barn workers. By identifying the source of ammonia air contamination, farm personnel can make the necessary changes to ensure both swine and human health.

Implications

- Regular monitoring of ammonia concentrations in swine confinement buildings is important to ensure both swine and human health.
- Ammonia concentrations frequently exceed 7.5 ppm, a concentration that has been associated with respiratory symptoms in humans.
- Ammonia concentrations occasionally exceed 25 ppm, which may exacerbate respiratory problems in pigs.
- Ammonia concentrations may vary considerably among rooms and barns.
- The pHydrion™ ammonia test provides a precise and cost-effective means of detecting ammonia concentrations in swine confinement buildings. It is considerably less expensive than the Draeger™ volumetric pump and amine detector tubes, and may provide more precise estimates of ammonia concentrations when limited funding is available.

Acknowledgements

We would like to thank the personnel at the Lorenzen hog farm for the effort involved with taking the daily measurements.

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