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Stephen J. Reynolds PhD, CIH , Kelley J. Donham MS, DVM , Jason Stookesberry BS , Peter S. Thorne PhD , Periasamy Subramanian PhD , Kendall Thu PhD & Paul Whitten MS

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# Air Quality Assessments in the Vicinity of Swine Production Facilities

Stephen J. Reynolds, PhD, CIH  
Kelley J. Donham, MS, DVM  
Jason Stookesberry, BS  
Peter S. Thorne, PhD  
Periasamy Subramanian, PhD  
Kendall Thu, PhD  
Paul Whitten, MS

**SUMMARY.** With the transition to increasingly larger swine production facilities, nearby residents have voiced concerns about environmental contamination, odor, and adverse health effects. The goal of this study was to evaluate outdoor airborne concentrations of am-

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Stephen J. Reynolds is Associate Professor, Department of Preventive Medicine and Environmental Health and Deputy Director, Great Plains Center for Agricultural Health; Kelley J. Donham is Professor, Department of Preventive Medicine and Environmental Health and is Director, Iowa's Center for Agricultural Safety and Health; Jason Stookesberry, Peter S. Thorne, Periasamy Subramanian, Kendall Thu, and Paul Whitten are affiliated with the Department of Preventive Medicine and Environmental Health; The University of Iowa, 100 Oakdale Campus, 124 AMRF, Iowa City, IA 52242-5000.

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monia, dust, and endotoxin in the environment near four types of swine production facilities and one control farm with no livestock. Dust and endotoxin were detected at a distance of 60 meters outside of facilities but generally, concentrations were below limits of accurate detection. The mean (and standard deviation) for outdoor ammonia concentrations were: 0.251 (0.064) ppm-large confinement; 0.086 (0.091) ppm-medium confinement; 0.214 (0.160) ppm-small confinement; 0.139 (0.188) ppm-small conventional; less than 0.004 ppm-control farm. While the airborne concentrations of ammonia measured outside the production facilities were below current occupational health standards, it is possible that ammonia could be a physical irritant in combination with other exposures, or it could serve as a cue capable of initiating a physical response. Furthermore, ammonia may serve as a surrogate measure for other gases (sulfides) emitted by these facilities. [Article copies available for a fee from The Haworth Document Delivery Service: 1-800-342-9678. E-mail address: [getinfo@haworth.com](mailto:getinfo@haworth.com)]

**KEYWORDS.** Ammonia, swine production facilities, odor, air sampling

### *INTRODUCTION*

Iowa is the leading pork producing state in the USA, with over 23 million head grown per year.<sup>1</sup> Economic forces, technologic advances, and agricultural policy are combining to accelerate an industry transition to fewer, larger, more intense swine production operations. With this transition, residents living in the neighborhood of these facilities have voiced increasing concern for environmental contamination, odors, and adverse health effects. Health complaints have ranged from symptoms of asthma and other upper respiratory conditions, to gastrointestinal disturbances, and neurological symptoms.

While detrimental health effects among workers exposed to airborne agents inside swine production facilities have been well documented,<sup>2-25</sup> there have been no published reports evaluating exposures or physical health effects among populations living near swine production facilities. However, there was one report of adverse mood shifts in residents living downwind of large facilities.<sup>26</sup> Approximately 60% of swine production workers complain of at least one respiratory symptom, most of which are acute symptoms.<sup>2,12</sup> Among this group of workers with respiratory symptoms, approximately 30% also experience chronic bronchitis, 30% have reactive airway disease, and 30% experience episodes of organic dust

toxic syndrome.<sup>14,15</sup> These conditions can be directly attributable to exposure to aerosolized dust and its biologically active constituents (endotoxin, allergens) in addition to gases such as ammonia and hydrogen sulfide. Dose-response studies among Iowa swine farmers indicate that changes in pulmonary function are associated with dust levels as low as 2.4 mg/m<sup>3</sup> and ammonia concentrations at 7 ppm.<sup>24,25</sup>

The goals of this study were: (1) to conduct detailed health interviews of residents living in the vicinity of large scale swine production facilities; and (2) to evaluate potential exposure to airborne ammonia, dust, and endotoxin in the immediate neighborhood of different types of swine production facilities. This paper presents the results of the environmental study.

## **METHODS**

### ***Site Descriptions***

Recruitment letters were sent to 26 swine producers (stratified by size and type of operation, i.e., small, medium, large confinement, and conventional facility) who had previously participated in research on agricultural health concerns. A total of eight agreed to participate in this study. The "Large Confinement" facility had eight buildings with 980 sows, 2,700 feeder pigs, and 250 breeding stock. One building had a deep manure pit, and the others had pull-plug systems. There were also three manure lagoons onsite. The indoor reference sample was collected inside the nursery. The "Medium Confinement" facility had six buildings with a total of 430 sows, 1,950 nursery/grower pigs, and 1,650 finishing hogs. Manure was stored in a 250,000 gallon slurrystore located outside of the buildings, in addition to deep manure pits under the finishing buildings. The reference indoor sample was collected inside the central feeder building. The "Small Confinement" facility had four buildings with 240 sows, 100 nursery/grower pigs, and 1,800 finishing hogs. Manure was stored in a 200,000 gallon lagoon, and two buildings had deep pits. The indoor reference sample was collected inside the farrowing/nursery building. The "Small Conventional" facility had 52 sows, farrow to finish, but no lagoon. A farm without livestock production, and with no neighboring farms with livestock within 1 mile was selected as a control facility, with an indoor sample collected inside a storage building.

### ***Air Samples***

Air sampling was conducted on one day at each site over a time period of 6 hours. One sample was collected inside a livestock building (the

source), and five samples were collected outside of each facility. The outside samples were arrayed surrounding the source at a distance of 60 meters and a height of 2 meters. Data from air samples included: ammonia; hydrogen sulfide; total dust; endotoxin; temperature; and relative humidity. Wind speed and direction were also recorded.

Ammonia was collected in two midjet impingers (SKC Inc.) connected in series containing 10 ml of 0.01 N sulfuric acid, at a flow of 0.8 Lpm using personal sampling pumps (SKC Inc. and MSA Inc.). Following sampling the final volumes were measured and the solutions were stored at 4°C until analyzed using a fluorometric enzyme method.<sup>27</sup> Ammonia in the solutions reacted with  $\alpha$ -ketoglutarate and NADH in the presence of l-glutamate dehydrogenase, in a pH 8.2 buffered solution (Sigma Chemical) with reduction in fluorescence detected at 460 nm using a Hitachi F-1050 spectrofluorimeter. The limit of detection for ammonia was 0.004 ppm.

Hydrogen sulfide was sampled using colorimetric direct reading dosimeters (Gastech).

Air samples for total dust and endotoxin were collected on 37 mm Glass Fiber filters (Gelman Sciences, Ann Arbor, MI) in three piece closed face cassettes (Nuclepore, Pleasanton, CA), at a flow rate of 2 Lpm using personal sampling pumps (SKC Inc., Eighty Four, PA and MSA Co., Pittsburg, PA). Total dust was determined gravimetrically according to NIOSH Method 0500. Filters were desiccated and weighed before and after sampling using a Mettler MT-5 Ultrabalance (Mettler Instrument Corp., Highstown, NJ). Following weighing, filters were extracted with 30 ml of pyrogen-free, sterile water with continuous mixing for 120 minutes at 22°C. The extracts were then analyzed for endotoxin using the chromogenic endpoint QCL1000 Limulus Ameobocyte Lysate assay as previously described (BioWhittaker, Walkersville, MD).<sup>28</sup> The limits of detection for dust and endotoxin were respectively 0.2 mg/m<sup>3</sup> and 4 EU/m<sup>3</sup>.

Temperature and relative humidity were measured using a sling psychrometer at one hour intervals throughout the sample period. Wind speed was measured using a direct reading wind speed indicator.

### *Data Analysis*

Data were analyzed using SAS software. The means and standard deviations of airborne concentrations at each facility were calculated. Wilcoxon rank sum tests were used to evaluate differences in airborne concentrations between different types of facilities, and to test for differences between indoor and outdoor concentrations. Wilcoxon rank sum scores were also used to test for the effects of wind direction (upwind vs. down-

wind), farm type, temperature, and relative humidity on outdoor airborne concentrations of dust, endotoxin, and ammonia. Spearman correlations were also calculated to evaluate relationships between airborne concentrations and environmental conditions.

## RESULTS

Outdoors, levels of total dust and endotoxins were below detectable limits ( $0.2 \text{ mg/m}^3$  and  $4 \text{ EU/m}^3$ , respectively) in most cases. Indoor total dust concentrations ranged from  $0.75 \text{ mg/m}^3$  in the Medium Confinement farm to  $2.59 \text{ mg/m}^3$  in the Large Confinement farm. Indoor endotoxin concentrations ranged from  $58 \text{ EU/m}^3$  at the Small Confinement farm to  $526 \text{ EU/m}^3$  at the Large Confinement farm. Hydrogen sulfide was not detected at any sample location. Mean temperatures ranged from  $72$  to  $89^\circ\text{F}$ , with relative humidity ranging from  $44$  to  $85\%$  (samples were collected during summer and fall). Windspeed ranged from  $0$  to  $20$  miles per hour, and wind direction was extremely variable.

Outdoor ammonia concentrations at the four test farms are presented in Figures 1-4. The mean ( $n = 5$  in all cases) and standard deviations of outdoor ammonia concentrations were as follows:  $0.251 (0.064)$  ppm-Large Confinement;  $0.086 (0.091)$  ppm-Medium Confinement;  $0.214 (0.160)$  ppm-Small Confinement;  $0.139 (0.188)$  ppm-Small Conventional. Ammonia was not detected (less than  $0.004$  ppm) at the Control farm. Outdoors, ammonia concentrations ranged from  $0.01$  to  $0.46$  ppm. Indoor ammonia concentrations ranged from  $1.27$  ppm in the Medium Confinement farm to  $2.59$  ppm in the Large Confinement farm. Concentrations of ammonia were always greater downwind of sources than upwind ( $p = 0.002$ ). The differences between indoor and outdoor concentrations of ammonia were also significant ( $p < 0.05$ ) for all four production facilities ( $p < 0.01$ ). The outdoor airborne concentrations of ammonia at all four swine production facilities were significantly higher than the concentration of ammonia at the control farm. Temperature and relative humidity were not correlated with ammonia, dust, or endotoxin.

## DISCUSSION

Airborne concentrations of ammonia were detectable at low concentrations downwind of swine production facilities. This is the first study that has shown the evidence of contaminants from swine facilities present in the outdoor air. The airborne concentrations of ammonia, dust, and endo-

FIGURE 1. Ammonia Concentrations in Large Confinement Facility

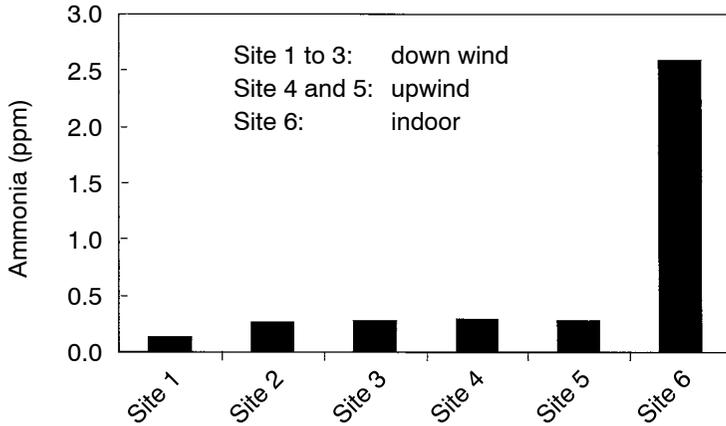
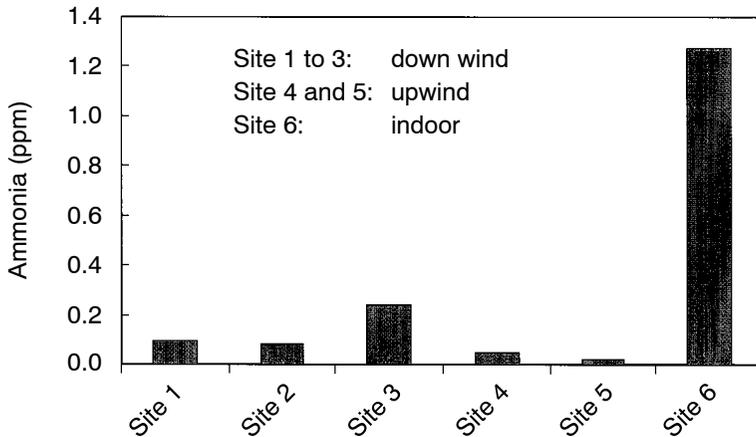


FIGURE 2. Ammonia Concentrations in Medium Confinement Facility



toxin detected outdoors were lower than current occupational health guidelines for acute physical toxicity, including the 7 ppm level recommended for inside swine production facilities.<sup>24,25</sup> However, this does not limit the possibility that these concentrations cause psychological stress that secondarily manifests in physical symptoms. Work by Schiffman in North Carolina suggests the possibility that this may happen in some instances.<sup>26</sup> The concentrations of ammonia measured in this study were also below the

FIGURE 3. Ammonia Concentrations in Small Confinement Facility

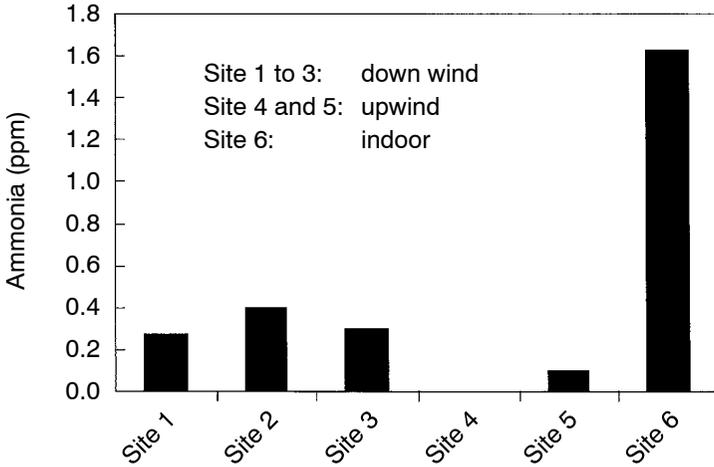
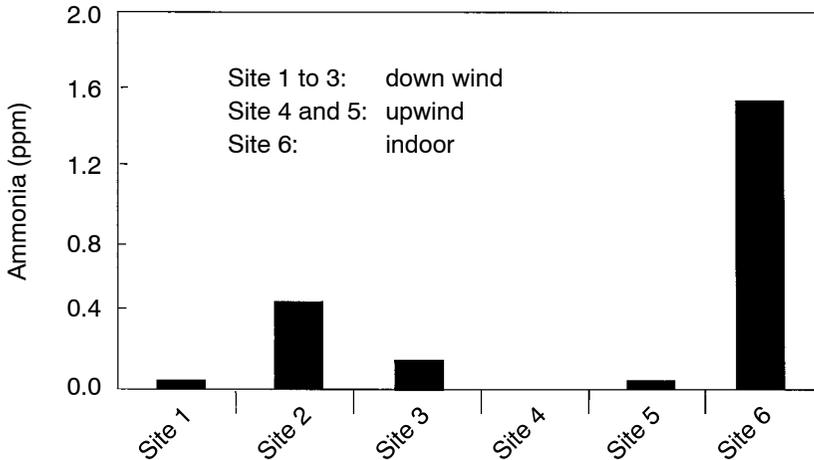


FIGURE 4. Ammonia Concentrations in Small Conventional Facility



NIOSH-reported odor threshold of about 1 ppm.<sup>29</sup> Higher concentrations of contaminants were generally associated with larger swine facilities, and with confinement type of production versus conventional systems. It is possible that ammonia may serve as a surrogate measure for other gases, especially sulfides, released from manure that may account for odor and

other complaints from individuals residing near these facilities. Further investigation focusing on more sophisticated and sensitive methods for evaluating airborne concentrations of sulfides, mercaptans, and other manure-generated gases in the vicinity of swine production facilities is warranted.

## REFERENCES

1. Facts on Iowa Agriculture, Communication Division, Iowa Farm Bureau Federation, Des Moines, Iowa, 1992.
2. Donham KJ, Rubino MJ, Thedell TD, et al. Potential health hazards of workers in swine confinement buildings. *J Occup Med* 1977;19:383-387.
3. Rylander R, Essle N, Donham KJ. Bronchial hyperreactivity among pig and dairy farmers. *Am J Ind Med* 1990; 17(2):66-69.
4. Donham KJ, Popendorf WJ, et al. Characterization of dusts collected from swine confinement buildings. *Am J Ind Med* 1986; 10:294-297.
5. Donham KJ, Popendorf WJ. Ambient levels of selected gases inside swine confinement buildings. *Am Ind Hyg Assoc J* 1985; 46: 658-661.
6. Donham KJ, Yeggy J, Dague R. Chronic and physical parameters of liquid manure from swine confinement facilities: Health implications for workers, swine, and environment. *Agricultural Wastes* 1985; 14:97-113.
7. Donham KJ, Knapp LW, Monson R, et al. Acute toxic exposure to gases from liquid manure. *J Occup Med* 1982; 24:142-145.
8. Donham KJ, Gustafson KE. Human occupational hazards from swine confinement. *Annals Am Conf Governmental Ind Hyg* 1982; 2:137-142.
9. Donham KJ. Hazardous agents in agricultural dusts and methods of evaluation. *Am J of Industr Med* 1986; 10:205-220.
10. Donham KJ, Yeggy J, Dague R. Chemical and physical parameters of liquid manure from swine confinement facilities: Health implications for workers, swine, and the environment. *Ag Wastes* 1985; 14:97-113.
11. Donham KJ, Zavala DC, Merchant JA. Respiratory symptoms and lung function among workers in swine confinement buildings: A cross-sectional epidemiological study. *Arch Env Hlth* 1984; 39:96-100.
12. Adapted from Donham KJ, Gustafson KE. Human occupational hazards from swine confinement. In: Kelley WD, ed. *Agricultural Respiratory Hazards. Annals of the American Conference of Governmental Industrial Hygienists* 1982; 2:139. Reproduced with permission from W.D. Kelley.
13. Donham KJ, Yeggy J, Dague R. Production rates of toxic gases from liquid manure: Health implications for workers and animals in swine buildings. *Biological Wastes* 1988; 161-173.
14. Donham KJ, Haglind P, Rylander R, et al. Environmental and health studies of workers in Swedish swine buildings. *Br J Ind Med* 1989; 46:31-37.
15. Donham KJ. Health effects from work in swine confinement buildings. *Am J of Industr Med* 1990; 17:17-25.

16. Donham KJ, Zavala DC, Merchant JA. Acute effects of the work environment on pulmonary functions of swine confinement workers. *Am J Ind Med* 1984; 5:367-376.

17. Donham KJ, Merchant JA, Lassise D, Popenorf W, Burmeister L. Preventing respiratory disease in swine confinement workers: intervention through applied epidemiology, education, and consultation. *Am J of Industr Med* 1990; 18:241-262.

18. Donham KJ, Leininger JR. The use of laboratory animals to study potential chronic lung disease in swine confinement workers. *Am J Vet Res* 1984; 45:926-931.

19. Donham KJ. Relationships of air quality and productivity in intensive swine housing. *Agri-Practice* 1989; 10:15-26.

20. Dosman JA, Graham GL, Hall D, Pahwa P, McDuffie H, Lucewits M, To T. Respiratory symptoms and alterations in pulmonary function tests in swine producers in Saskatchewan: Results of a survey of farmers. *J Occup Med* 1988; 30:715-720.

21. Holness DL, O'Blenis EL, Sass-Kortsak A, Deliger C, Nethercott JR. Respiratory effects and dust exposures in hog confinement farming. *Am J Ind Med* 1987; 11:571-580.

22. Pederson B, Iversen M, Dahl R. Bronchoalveolar lavage of pig farmers. *Am J Ind Med* 1990; 17:118- 119.

23. Donham, KJ. Respiratory disease hazards to workers in livestock and poultry confinement structures. *Seminars in Respiratory Medicine* 1993; 14:49-59.

24. Donham KJ, Reynolds SJ, Whitten P, Merchant JA, Burmeister L, Popenorf WJ. Respiratory dysfunction associated with enclosed swine facilities: Dose-response of pulmonary function to environmental exposures. *Am J Ind Med* 1995; 27:405-418.

25. Reynolds SJ, Donham KJ, Whitten P, Merchant JA, Burmeister LF, Popenorf WJ. Longitudinal evaluation of dose-response relationships for environmental exposures and pulmonary function in swine production workers. *Am J Ind Med* 1996; 29:33-40.

26. Schiffman S, Miller EAS, Suggs MS, Graham BG. The effect of environmental odors emanating from commercial swine operations on the mood of nearby residents. *Brain Res Bulletin* 1995; 37(4):369-375.

27. Subramanian P, Reynolds SJ, Thorne PS, Donham KJ, Stookesberry J, Thu K. Analysis of airborne ammonia in swine farming environment by the fluorimetric enzyme method. *Intl J Environ Anal Chem*. In press.

28. Reynolds SJ, Milton DK. Comparison of methods for analysis of airborne endotoxin. *Appl Occup Environ Hyg* 1993; 8 (9):761-7.

29. NIOSH/OSHA: Occupational Health Guidelines for Chemical Hazards. U.S. Dept. of Health and Human Services, U.S. Dept. of Labor, DHHS (NIOSH) Publication No. 812-123. Ammonia:1-5 (1981).