The Scientific Research Basis for "Unintended Consequences": Loss of the Hygiene Hypothesis

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Within the large framework of argumentation, assertion, and proof, scientific research studies serve as a major bulwark of credibility. This gold standard for credibility occurs for several reasons:

- researchers are highly trained in the research standards and critical procedures of their field.
- researchers possess an extensive knowledge base developed through years of study which is evidenced by advanced degrees in their field.
- the research conducted must meet:
  - the research standards of their field as evidenced by publication in a peer-reviewed journal.
  - the critical review standards of additional researchers once the research is published.

This presentation will focus upon three critical research studies which undergirded the "Unintended Consequences" discussion of CAFO's negative impact upon children's health at North Winneshiek.

The discussion of the three University of Iowa research studies will illustrate several characteristics of scientific research studies. These characteristics include:

- how assertions are buttressed by previous studies.
- how a research-based argument is constructed.
- how research studies build on previous research findings, questions, and suggestions for additional research.

Even more specifically, the discussion of the three University of Iowa research studies will present:

- the previous research focused on the intersection of agriculture and health.
- the existing body of scientific research focused on childhood asthma.
- the larger body of scientific research exploring the impact of CAFOs upon health & the environment.

THE THREE STUDIES

The Rural Childhood Asthma Study

Chrischilles E, Ahrens R, Kuhl A, Kelly K, Thorne P, Burmeister L, & Merchant (2004 January). Asthma prevalence and morbidity among rural Iowa schoolchildren. *The Journal of Allergy and Immunology, 113*(1): 66-71.

The Merchant Study

Merchant JA, Naleway AL, Svendsen ER, Kelly KM, Burmeister LF, Stromquist AM, Taylor CD, Thorne PS, Reynolds SJ, Sanderson WT, & Chrischilles EA (2005 March). Asthma and farm exposures in a cohort of rural Iowa children. *Environmental Health Perspectives, 113*(3): 350-356.

The Kline Study

Sigurdarson ST & Kline JN (2006 June). School proximity to concentrated animal feeding operations and prevalence of asthma in students. *Chest, 129*(6): 1486-1491

The Rural Childhood Study, headed by Dr. Chrischilles, will be presented within the discussion centered on the Merchant Study. The Merchant Study will be analyzed first followed by a review of the Kline Study.

The Merchant Study

Most of the initial work on childhood asthma focused on "inner-city" and "urban" populations. Later research then began to focus on rural childhood asthma.

The majority of rural childhood asthma studies prior to the Twenty-first (21st) Century found a health benefit for farm children.

The technical term for this health benefit is the "Hygiene Hypothesis." The vast majority of rural childhood asthma studies confirmed various portions of the "Hygiene Hypothesis," which, when applied to rural families, stated that children raised on farms:

- **"are less often atopic,"** [having an allergic hypersensitivity that typically triggers an overproduction of usually type IgE antibody]

Braun-Fahrlander C, et al. (1999). Prevalence of hay fever and allergic sensitization in farmer's children and their peers living in the same rural community. SCARPOL team. **Swiss** Study on Childhood Allergy and Respiratory Symptoms with Respect to Air Pollution. *Clinical and Experimental Allergy, 29*(1): 28-34.

Downs SH, et al. (2001). Having lived on a farm and protection against allergic diseases in **Australia**. *Clinical and Experimental Allergy, 31*(4): 570-575.

Riedler J, et al. (2000). **Austrian** children living on a farm have less hay fever, asthma and allergic sensitization. *Clinical and Experimental Allergy, 30*(2): 194-200.

Riedler J, et al. (2001). Exposure to farming in early life and development of asthma and allergy: A cross-sectional survey. *Lancet, 358*(9288): 1129-1133.

- **"have lower rates of allergic diseases,"**

Braun-Fahrlander C, et al. (1999). Prevalence of hay fever and allergic sensitization in farmer's children and their peers living in the same rural community. SCARPOL team. **Swiss** Study on Childhood Allergy and Respiratory Symptoms with Respect to Air Pollution. *Clinical and Experimental Allergy, 29*(1): 28-34.

Kilpelainen M, et al. (2000). Farm environment in childhood prevents the development of allergies. *Clinical and Experimental Allergy, 30*(2): 201-208.

Riedler J, et al. (2000). **Austrian** children living on a farm have less hay fever, asthma and allergic sensitization. *Clinical and Experimental Allergy, 30*(2): 194-200.

Riedler J, et al. (2001). Exposure to farming in early life and development of asthma and allergy: A cross-sectional survey. *Lancet, 358*(9288): 1129-1133.

Von Ehrenstein OS, et al. (2000). Reduced risk of hay fever and asthma among children of farmers. *Clinical and Experimental Allergy, 30*(2): 187-193.

Wickens K, et al. (2002). Farm residence and exposures and the risk of allergic diseases in New Zealand children. *Allergy, 57*(12): 1171-1179.

- **"and, in several reports, also have lower rates of asthma."**

Ernest P & Cormier Y (2000). Relative scarcity of asthma and atopy among rural adolescents raised on a farm. *American Journal of Respiratory and Critical Care Medicine, 161*(5): 1563-1566.

Kilpelainen M, et al. (2000). Farm environment in childhood prevents the development of allergies. *Clinical and Experimental Allergy, 30*(2): 201-208.

Riedler J, et al. (2000). **Austrian** children living on a farm have less hay fever, asthma and allergic sensitization. *Clinical and Experimental Allergy, 30*(2): 194-200.

Riedler J, et al. (2001). Exposure to farming in early life and development of asthma and allergy: A cross-sectional survey. *Lancet, 358*(9288): 1129-1133.

Von Ehrenstein OS, et al. (2000). Reduced risk of hay fever and asthma among children of farmers. *Clinical and Experimental Allergy, 30*(2): 187-193.

"However," the Merchant Study continued, "several studies have not found positive associations between asthma and asthma symptoms among children and farm exposures" which raised "questions regarding the influence of unmeasured risks and/or selection in these cross-sectional studies."

Chrischilles E, et al. (2004). Asthma prevalence and morbidity among rural Iowa schoolchildren. *The Journal of Allergy and Clinical Immunology, 113*(1): 66-71.

Downs SH, et al. (2001). Having lived on a farm and protection against allergic diseases in Australia. *Clinical and Experimental Allergy, 31*(4): 570-575.

Salam MT, et al.: Children's Health Study (2004). Early-life environmental risk factors for asthma: Findings from the Children's Health Study. *Environmental Health Perspectives, 112*(6): 760-765.

Wickens K, et al. (2002). Farm residence and exposures and the risk of allergic diseases in New Zealand children. *Allergy, 57*(12): 1171-1179.

The Merchant Study, continued

In other words,

- unidentified risk factors that weren't measured could refer to toxic emissions from CAFOs, while
- selection of subjects could refer to the absence in the study of children who were exposed to the model of Industrial Agriculture practiced so prevalently in Iowa.

What does research have to say about these two possibilities?

The Merchant Study, continued

You'll recall that the vast majority of childhood asthma studies completed in the 20th century were divided into two main groupings based on a bi-polar, urban/rural classification scheme.

- Urban, inner-city childhood asthma studies, and
- Rural childhood asthma studies.

You'll also recall that almost all of the rural childhood asthma studies found a health benefit to rural living. The exceptions, noted by the Merchant Study, were rural childhood studies conducted in the early 21st century. The four scientific research studies cited by the Merchant Study **did not find a health benefit to rural life**.

The **Rural Childhood Asthma Study** (Chrischilles et al., 2004), cited by the Merchant Study as one of the exceptions to the Health Benefits Hypothesis of Rural Living, provides more insight into the issue.

Chrischilles E, Ahrens R, Kuehl A, Kelly K, Thorne P, Burmeister L, & Merchant J (2004 January). Asthma prevalence and morbidity among rural Iowa schoolchildren. *The Journal of Allergy and Clinical Immunology, 113*(1): 66-71.

That study, based on a rural cohort in Keokuk County (Iowa), began by noting:

> "There are conflicting findings about the prevalence of asthma among farm and nonfarm children."

The Merchant Study, continued

Because of the conflicted findings, the Chrischilles Study

> "sought to estimate asthma prevalence and morbidity and determine differences between farm and nonfarm children."

The Rural Childhood Asthma Study, aka the Chrischilles Study, found that

> "in this large, rural, population-based study, asthma prevalence rivaled that in several large Midwestern cities."

The researchers surmised that "unmeasured risk factors" might be at work in Keokuk County. The Chrischilles Study concluded:

> "These findings cast doubt on a protective effect of rural life for the development of childhood asthma."

Back to the Merchant Study:

The researchers posed a solution to the problem whereby one set of studies of rural childhood asthma found a positive health benefit for farm life while a different set of studies questioned the positive health benefit of rural lifestyles.

First, they noted the changes in the agricultural model from a more traditional scheme of many smaller family farms with diverse crop and livestock operations to the current scheme prevailing in Iowa today:

> "Over the last three decades, the development of a vertically integrated livestock industry has significantly reduced the number of U.S. family farms raising hogs, poultry, and cattle but has rapidly increased the number of large animal-feeding operations (AFOs)."

The Merchant Study, continued

Next, the researchers noted the vast body of research studies documenting the health problems suffered by CAFO workers. They did this by referencing a single study whereby the scientists conducted a review of the scientific literature - a review that consisted of **972** research studies:

Schenker MD, Christiani D, Cormier Y, Dimich-Ward H, Doekes G, Dosman J, et al. (1998 November). Respiratory health hazards in agriculture. *American Journal of Respiratory and Critical Care Medicine, 158*(5 pt 2): S1-S76.

The Merchant Study researchers then itemized the negative effects of CAFOs on worker health centering on "inflammatory airway diseases." This list included:

- "asthma,"
- "chronic bronchitis,"
- "organic dust toxic syndrome;" and
- "progressive airway obstruction."

The Merchant Study, continued

The medical and scientific research team also noted that, at the time of the Merchant Study, only a handful of research studies had been conducted which examined the impact of CAFOs upon the health of children and adults living in the neighborhood of such operations. These studies included:

Reynolds SJ, Donham KJ, Stookesberry J, Thorne PS, Subramanian P, Thu K, & Whitten P (1997). Air quality assessments in the vicinity of swine production facilities. *Journal of Agromedicine, 4*(1-2): 37-45.

Salam MT, et al.; Children's Health Study (2004). Early-life environmental risk factors for asthma: Findings from the Children's Health Study. *Environmental Health Perspectives, 112*(6): 760-765.

Thu K, Donham K, Ziegenhorn R, Reynolds S, Thorne PS, Subramanian P, Whitten P, & Stookesberry J (1997). A control study of the physical and mental health of residents living near a large-scale swine operation. *Journal of Agricultural Safety and Health, 3*(1): 13-26.

Wing S & Wolf S (2000 March). Intensive livestock operations, health, and quality of life among eastern North Carolina residents. *Environmental Health Perspectives, 108*(3): 233-238.

The researchers conducting the Merchant Study then contrasted the model of Industrial Agriculture with a more traditional model of agriculture:

> "Farms in Northern Europe tend to be smaller than Iowa farms and to have livestock that are often housed in immediate proximity to living quarters, and these farm families have been described as more traditional in their way of life. Farms in Canada, Australia, and New Zealand are described as larger but typically not as livestock intensive as Iowa farms (Downs et al. 2001; Ernst and Cormier 2000; Wickens et al. 2002)."

The Merchant Study, continued

By solving the riddle posed by contradictory results from studies of rural childhood asthma, the Merchant Study broke new ground. As a result, studies of childhood asthma no longer consisted of urban and rural studies.

Studies of childhood asthma now were subdivided into three groups based not only on residential locale, but also upon the type of agricultural activities to which subjects were exposed:

- Urban, inner-city childhood asthma studies;
- Traditional agriculture childhood asthma studies, and
- Industrial Agricultural childhood asthma studies.

Having reviewed the literature, having solved the dilemma posed by contradictory results of rural childhood asthma studies, and having posed a new tri-partite division of childhood asthma research studies, the Merchant Study researchers identified the purpose of their study.

"We studied a cohort of rural Iowa children to determine the associations between farm and other environmental risk factors with four asthma outcomes:

- doctor-diagnosed asthma,
- doctor-diagnosed asthma/medication for wheeze,
- current wheeze, and
- cough with exercise."

The Merchant Study, continued

Continuing to clarify the purpose of their study, the researchers involved in the Merchant Study stated:

> "The aim of the present study was to estimate asthma prevalence and assess whether farm exposures result in:
>
> - less atopy,
> - less allergic disease, and
> - less asthma
>
> … among this cohort of farm children."

In other words, what they were really doing was checking to see whether or not the hypothesis of the Health Benefit for agriculture **held true for** children exposed to the effects of **Industrial Agriculture**.

WHO WAS STUDIED?

Children from "birth through 17 years of age collected in round 1 of the KCRHS [**Keokuk County Rural Health Study**], which began in 1994 and ended in 1998," were selected to participate in the study.

Keokuk County had been chosen "because it is intensely agricultural and entirely rural."

In other words, Keokuk County provided a typical representative setting that featured the major components of Industrial Agriculture - CAFOs and row-crop agriculture focused on corn and beans.

WHO WAS STUDIED?

Out of the original KCRHS, 1,004 households agreed to participate in the Merchant Study. They formed three basic groups:

- farm - 224 families,
- rural nonfarm - 155 families, and
- town households - 462 families.

The farms in the cohort primarily produced "corn, soybeans, and hogs" with "very few other livestock."

WHO WERE THE RESEARCHERS?

James A. Merchant, M.D., Dr.P.H.,Department of Occupational and Environmental Health, **University of Iowa College of Public Health**, Iowa City, IA.

Allison L. Naleway, Ph.D., Center for Health Research, **Kaiser Permanente Northwest**, Portland, OR.

Erik R. Svendsen, Ph.D., National Health and Environmental Effects Research Laboratory, Human Studies Division, Epidemiology and Biomarkers Branch, **U.S. Environmental Protection Agency**, Research Triangle Park, NC.

Leon F. Burmeister, Ph.D., Department of Biostatistics, **University of Iowa College of Public Health**, Iowa City, IA.

Ann M. Stromquist, Ph.D., Department of Occupational and Environmental Health, **University of Iowa College of Public Health**, Iowa City, IA.

WHO WERE THE RESEARCHERS?

Craig D. Taylor, Ph.D., Department of Occupational and Environmental Health, **University of Iowa College of Public Health**, Iowa City, IA.

Peter S. Thorne, Ph.D., Department of Occupational and Environmental Health, **University of Iowa College of Public Health**, Iowa City, IA.

Stephen J. Reynolds, Ph.D., Department of Environmental and Radiological Health Sciences, **Colorado State University College of Veterinary Medicine and Biomedical Sciences**, Fort Collins, CO.

Wayne T. Sanderson, Ph.D., Department of Occupational and Environmental Health, **University of Iowa College of Public Health**, Iowa City, IA.

Elizabeth A. Chrischilles, Ph.D., Department of Epidemiology, **University of Iowa College of Public Health**, Iowa City, IA.

Studies Investigating the Impact on Health by CAFOs BEFORE the Merchant & Kline Studies:

Brunekreff B, Janssen NA, de Hartog JJ, Oldenwening M, Meliefste K, Hoek G, Lanki T, Timonen KL, Vallius M, Pekkanen J, & Van Grieken R (2005 January). Personal, indoor, and outdoor exposures to PM2.5 and its components for groups of cardiovascular patients in Amsterdam and Helsinki. *Research Report of the Health Effects Institute, 127*: 1-70; discussion 71-79.

Donham KJ (1990). Health effects from work in swine confinement buildings. *American Journal of Industrial Medicine, 17*(1): 17-25.

Donham, KJ (2000 November). The concentration of swine production. Effects on swine health, productivity, human health, and the environment. *The Veterinary Clinics of North America. Food Animal Practice, 16*(3): 559-597.

Donham KJ, Knapp LW, Monson R, & Gustafson K (1982 February). Acute toxic exposure to gases from liquid manure. *Journal of Occupational Medicine, 24*(2): 142-145.

Donham KJ, Yeggy J, & Dague RR (1985). Chemical and physical-parameters of liquid manure from swine confinement facilities: Health implications for workers, swine and the environment. *Agricultural Wastes, 14*(2): 97-113.

Donham KJ & Popendorf WJ (1985 November). Ambient levels of selected gases inside swine confinement buildings. *American Industrial Hygiene Association Journal, 46*(11): 658-661.

Studies Investigating the Impact on Health by CAFOs BEFORE the Merchant & Kline Studies:

Donham K, Haglind P, Peterson Y, Rylander R, & Belin L (1989). Environmental and health studies of farm workers in Swedish swine confinement buildings. *British Journal of Industrial Medicine, 46*: 31-37.

Donham KJ, Reynolds SJ, Whitten P, **Merchant JA**, Burmeister L, & Popendorf WJ (1995 March). Respiratory dysfunction in swine production facility workers: Dose-response relationships of environmental exposure and pulmonary function. *American Journal of Industrial Medicine, 27*(3): 405-418.

Dosman JA, Lawson JA, Kirychuk SP, Cormier Y, Biem J, & Koehncke N (2004 October). Occupational asthma in newly employed workers in intensive swine confinement facilities. *European Respiratory Journal, 24*(4): 698-702.

Eduard W, Douwes J, Omenaas E, & Heederik D (2004). Do farming exposures cause or prevent asthma? Results from a study of adult Norwegian farmers. *Thorax, 59*: 381-386.

Iversen M, Kirychuk S, Drost H, & Jacobson L (2000 November). Human health effects of dust exposure in animal confinement buildings. *Journal of Agricultural Safety and Health, 6*(4): 283-288.

Kilburn KH & Warshaw RH (1995 March-April). Hydrogen sulfide and reduced-sulfur gases adversely affect neurophysiological functions. *Toxicology and Industrial Health, 11*(2): 185-197.

Kirkhorn SR (2002 October). Community and environmental health effects of concentrated animal feeding operations. *Minnesota Medicine, 85*(10): 38-43.

Studies Investigating the Impact on Health by CAFOs BEFORE the Merchant & Kline Studies:

Larsson KA, Eklund AG, Hansson LO, Isaksson BM, & Malmberg PO (1994 October). Swine dust causes intense airways inflammation in healthy subjects. *American Journal of Respiratory and Critical Care Medicine, 150*(4): 973-977.

Legator MS, Singleton CR, Morris DL, & Philips DL (2001 March-April). Health effects from chronic low-level exposure to hydrogen sulfide. *Archives of Environmental Health, 56*(2): 123-131.

National Research Council (2002). *Air emissions from animal feeding operations: Current knowledge, future trends.* Washington, DC: National Academies Press.

National Research Council (2003). *Air emissions from animal feeding operations: Current knowledge and future needs*. Washington, DC: National Academies Press.

Osbern LN & Crapo RO (1981 September). Dung Lung: A report of toxic exposure to liquid manure. *Annals of Internal Medicine, 95*(3): 312-314.

Pope CA 3rd, Thun MJ, Namboodiri MM, Dockery DW, Evans JS, Speizer FE, & Heath CW Jr. (1995 March). Particulate air pollution as a predictor of mortality in a prospective study of U.S. adults. *American Journal of Respiratory and Critical Care Medicine, 151*(3 Pt 1): 669-674.

Pope CA 3rd (2000 Winter). What do epidemiologic findings tell us about health effects of environmental aerosols? *Journal of Aerosol Medicine, 13*(4): 335-354.

Studies Investigating the Impact on Health by CAFOs BEFORE the Merchant & Kline Studies:

Pope CA 3rd (2000 August). Epidemiology of fine particulate air pollution and human health: Biologic mechanisms and who's at risk? *Environmental Health Perspectives, 108*(Suppl 4): 713-723.

Radon K, Schulze A, Ehrenstein V, van Strien RT, Prami G, & Nowak D (2007 May). Environmental exposure to confined animal feeding operations and respiratory health of neighboring residents. *Epidemiology, 18*(3): 300-308.

Reynolds SJ, Donham KJ, Whitten P, **Merchant JA**, Burmeister L, & Popendorf WJ (1996 January). Longitudinal evaluation of dose-response relationships for environmental exposures and pulmonary function in swine production workers. *American Journal of Industrial Medicine, 29*(1): 33-40.

Rylander R, Donham KJ, Hjort C, Brouwer R, & Heederik D (1989 October). Effects of exposure to dust in swine confinement buildings – a working group report. *Scandinavian Journal of Work, Environment, & Health, 15*(5): 309-312.

Schiffman SS, Auvermann, BW, and Bottcher, RW (2001 December 11). Health effects of aerial emissions from animal production and waste management systems. In *White Paper Summaries*, National Center for Manure and Animal Waste Management, 10-12. Raleigh, NC: North Carolina State University.

Schiffman SS, Studwell CE, Landerman LR, Berman K, & Sundy JS (2005 May). Symptomatic effects of exposure to diluted air sampled from a swine confinement atmosphere on healthy human subjects. *Environmental Health Perspectives, 113*(5): 567-576.

Studies Investigating the Impact on Health by CAFOs BEFORE the Merchant & Kline Studies:

Schiffman SS, Studwell CE, Landerman LR, Berman K, & Sundy JS (2005 May). Symptomatic effects of exposure to diluted air sampled from a swine confinement atmosphere on healthy human subjects. *Environmental Health Perspectives, 113*(5): 567-576.

Smith CJ, Scott SM, & Ryan BA (1999 November). Cardiovascular effects of odors. *Toxicology and Industrial Health, 15*(7): 595-601.

Thu KM (2002 May). Public health concerns for neighbors of large-scale swine production facilities. *Journal of Agricultural Safety and Health, 8*(2): 175-184.

Vogelzang PF, van der Gulden JW, Folgering H, Kolk JJ, Heederik D, Preller L, Tielen MJ, & van Schayck CP (1998 January). *American Journal of Respiratory and Critical Care Medicine, 157*(1): 15-18.

Von Essen S, Romberger D (2003 August). The respiratory inflammatory response to swine confinement building environment: The adaptation to respiratory exposures in the chronically exposed worker. *Journal of Agricultural Safety and Health, 9*(3): 185-196.

Von Essen SG and Auvermann BW (2005). Health effects from breathing air near CAFOs for feeder cattle or hogs. *Journal of Agromedicine, 19*(4): 55-64.

Wing, S and Wolf, S (2000 March). Intensive livestock operations, health, and quality of life among eastern North Carolina residents. *Environmental Health Perspectives, 108*(3): 233-238.

Zejda JE, Barber E, Dosman JA, Olenchock SA, McDuffie HH, Rhodes C, & Hurst T (1994 January). Respiratory health status in swine producers relates to endotoxin exposure in the presence of low dust levels. *Journal of Occupational Medicine, 36*(1): 49-56.

Studies Investigating the Impact on Health by CAFOs AFTER the Merchant & Kline Studies:

Aneja VP, Schlesinger WH, Niyogi D, Jennings G, Gilliam RE, Knighton CS, Duke JB, & Krishnan S (2006 January 17). Emerging national research needs for agricultural air quality. *Eos, Transactions, American Geophysical Union, 87*(3): 25, 29.

Aneja VP, Wang B, Tong DQ, Kimball H, & Steger J (2006 August). Characterization of major chemical components of fine particulate matter in North Carolina. *Journal of the Air & Waste Management Association, 56*: 1099-1107.

Aneja VP, Ary SP, Kim DS, Rumsey IC, Arkinson HL, Semunegus H, Bajwa K, Dickey DA, Stefanski LA, Todd L, Mottus K, Robarge WP, & Williams CM (2008 September). Characterizing ammonia emissions from swine farms in eastern North Carolina: Part 1 – Conventional lagoon and spray technology for waste treatment. *Journal of the Air & Waste Management Association, 58*(9): 1130-1144.

Aneja VP, Ary SP, Rumsey IC, Kim DS, Bajwa K, Arkinson HL, Semunegus H, Dickey DA, Stefanski LA, Todd, L, Mottus K, Robarge WP, & Williams CM (2008 September). Characterizing ammonia emissions from swine farms in eastern North Carolina: Part 2 – Potential environmentally superior technologies for waste treatment. *Journal of the Air and Waste Management Association, 58*(9): 1145-1157.

Aneja VP, Arya SP, Rumsey IC, Kim DS, Bajwa K, & Williams CM (2008). Characterizing ammonia emissions from swine farms in eastern North Carolina: Reduction of emissions from water-holding structures at two candidate superior technologies for waste treatment. *Atmospheric Environment, 42*(14): 3291-3300.

Studies Investigating the Impact on Health by CAFOs AFTER the Merchant & Kline Studies:

Donham K (2008 July). Asthma in livestock producers. *Iowa Pork Producer*: 31-33.

Donham, KJ (2010 April). Community and occupational health concerns in pork production: A review. *Journal of Animal Science, 88*(13 Suppl): E102-111. Epub 2010 February 12.

Donham KJ, Lee JA, Thu K, & Reynolds SJ (2006). Assessment of air quality at neighbor residences in the vicinity of swine production facilities. *Journal of Agromedicine, 11*(3), 15-24).

Donham KJ, Wing S, Osterberg D, Flora JL, Hidne C, Thu KM and Thorne PS (2007 February). Community health and socioeconomic issues surrounding concentrated animal feeding operations. *Environmental Health Perspectives, 115*(2): 317-320.

Heerderick D, Sigsgaard T, Thorne PS, **Kline JN**, Avery R, Bønløkke JH, et al (2007 February). Health effects of airborne exposures from concentrated animal feeding operations. *Environmental Health Perspective, 115*(2): 298-302.

Horton RA, Wing S, Marshall SW, and Brownley KA (2009 Supplement 3). Malodor as a trigger of stress and negative mood in neighbors of industrial hog operations. *American Journal of Public Health, 99*(S3): S610-S615.

Kilburn KH, Thrasher JD, & Gray MR (2010 August). Low-level hydrogen sulfide and central nervous system dysfunction. *Toxicology and Industrial Health, 26*(7): 387-405. EPub 2010 May 26.

Studies Investigating the Impact on Health by CAFOs AFTER the Merchant & Kline Studies:

Kilburn KH (2012). Human impairment from living near Confined Animal (Hog) Feeding Operations. *Journal of Environmental and Public Health, 2012*: 1-11. EPub 2012 February 9.

McDonnell PE, Coggins MA, Hogan VJ, & Fleming GT (2008 December). Exposure assessment of airborne contaminants in the indoor environment of Irish swine farms. *Annals of Agricultural and environmental medicine, 15*(2): 323-326.

McElroy KG (2010 October-December). Environmental health effects of concentrated animal feeding operations: Implications for nurses. *Nursing Administration Quarterly, 34*(4): 311-319.

Merchant JA (2009 April). *Public Health Impacts of Industrial Farm Animal Production: Occupational and Community Public Health Impacts technical report: The University of Iowa College of Public Health*. Retrieved 5-22-2012 from: http://www.sph.unc.edu/images/stories/centers_institutes/accelerate/documents/Merchant-Public_Health_Impacts_4-22-09.pdf.

Mirabelli MC, Wing S, Marshall SW, & Wilcosky TC (2006 April). Race, poverty, and potential exposure of middle-school students to air emissions from confined swine feeding operations. *Environmental Health Perspectives, 114*(4): 591-596.

Mirabelli MC, Wing S, Marshall SW, & Wilcosky TC (2006 July). Asthma symptoms among adolescents who attend public schools that are located near confined swine feeding operations. *Pediatrics, 118*(1): e66-75.

Studies Investigating the Impact on Health by CAFOs AFTER the Merchant & Kline Studies:

Mitloehner FM & Schenker MB (2007 May). Environmental exposure and health effects from concentrated animal feeding operations. *Epidemiology, 18*(3): 309-311.

Pope CA 3rd, Ezzati M, & Dockery DW (2009 January 22). Fine-particulate air pollution and life expectancy in the United States. *The New England Journal of Medicine, 360*(4): 376-386.

Rogers S and Haines J (2005 September). *Detecting and mitigating the environmental impact of fecal pathogens originating from confined animal feeding operations: Review*. Cincinnati, OH: National Risk Management Research Laboratory, US Environmental Protection Agency.

Tajik M, Muhammad N, Lowman A, Thu K, Wing S, & Grant G (2008). Impact of odor from industrial hog operations on daily living activities. *New Solutions, 18*(2): 193-205.

Thorne PS (2007 February). Environmental health impacts of concentrated animal feeding operations: Anticipating hazards – searching for solutions. *Environmental Health Perspective, 115*(2): 296-297. Epub 2006 November 14.

Thorne PS, Ansley AC, & Perry SS (2009 April). Concentrations of bioaerosols, odors, and hydrogen sulfide inside and downwind from two types of swine livestock operations. *Journal of Occupational and Environmental Hygiene, 6*(4): 211-220.

Studies Investigating the Impact on Health by CAFOs AFTER the Merchant & Kline Studies:

Wing S, Horton RA, Muhammad N, Grant GR, Tajik M, & Thu K (2008 August). Integrating epidemiology, education, and organizing for environmental justice: Community health effects of industrial hog operations. *American Journal of Public Health, 98*(8): 1390-1397. Epub 2008 June 12.

Wing S, Horton RA, Marshall SW, Thu K, Mansoureh T, Schinasi L, and Schiffman SS (2008 October). Air pollution and odor in communities near industrial swine operations. *Environmental Health Perspectives, 116*(10): 1362-1368.