

## Appendix D. Literature Review

The sources provided below are organized by subject matter per the Table of Contents of the Technical Support Document. An asterisk indicates that the work cited is not specific to dairies (i.e. research may include data on non-dairy cows, other types of animal feeding operations and/or animal species). A Literature Review was conducted on three levels:

- abstracts from peer-reviewed research are included where possible;
- research articles which have been examined for pertinence, and the content has been summarized; and
- additional sources of information identified by Task Force members and agency staff as being relevant to the charge of the Task Force, but not necessarily referenced in the document and/or summarized.

Hyperlinks are provided for materials available online.

### **I.H. Types of Air Emissions from Dairies**

#### ***\*National Research Council, Air Emissions from Animal Feeding Operations: Current Knowledge and Future Needs (2003).***

*Summary:* EPA and USDA, responding to legislation and public concern, asked the National Academy of Sciences to investigate air quality issues associated with agricultural practices. A Committee was formed by the National Research Council and tasked to examine the scientific basis for estimating emissions from confined livestock and poultry operations, review the animal agricultural industry, especially confined animal feeding production systems, and identify critical research needs. It found a general lack of coordination between EPA and USDA and a need for better understanding of air emissions and their impact at several spatial scales. It recommended monitoring, both on- and off-site, and measurement of the effectiveness of management practices using standardized methodologies. The Committee recommended a process-based model for calculating air emissions in order to provide the strongest foundation possible for these estimates. It also recommended that the two agencies embark on a long-term research program focused on the overall food production system with the goal of eliminating the release of “undesirable air and other emissions to the environment.”

#### ***\*Iowa Concentrated Animal Feeding Operations Air Quality Study, Final Report; Iowa State University and the University of Iowa Study Group, February 2002.***

*Summary:* This report examines the Iowa Animal Feeding Operations (AFO) industry in a comprehensive manner. Topics covered include industry trend and

structure, air quality issues, environmental fate and transport of air pollutants from AFOs, adverse toxicological, animal health and human health effects, social and community impacts, regulatory considerations, and emission control systems. The study concludes that (1) there is experimental and epidemiological evidence that very low levels of exposure to ammonia, hydrogen sulfide, known to be ambient air toxic gases from CAFOs may result in adverse health effects among healthy volunteers and community residents, and (2) that these findings support a conclusion that CAFO air emissions constitute a public health hazard, deserving of public health precautions as well as larger, well controlled, populations based studies to more fully ascertain adverse health outcomes and their impact on community health services.

## **I.J. Environment**

***Causes of Haze in the Columbia River Gorge.* Mark Green and Jin Xu, Desert Research Institute, Las Vegas, NV, SSN:1047-3289 *J. Air & Waste Manage. Assoc.* 57:947–958, DOI:10.3155/1047-3289.57.8.947**

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*Summary:* The study showed that source types and source areas affecting visibility in the Columbia River Gorge National Scenic area vary substantially by season. Sources to the west of the gorge, notably the Portland metropolitan area shipping, Kraft pulp, and paper mills contribute substantially to summertime haze in the gorge. Sources east of the gorge, likely a coal-fired power plant, nearby dairy farm, and upriver cities, appear to be major contributors to wintertime haze in the gorge. Local sources within the gorge contribute during autumn and spring transition periods when flows within the gorge often change directions diurnally. Modeling is being done to attribute haze to sources existing during the study period and for the expected emissions in 2018. Results from the study presented here and the modeling analysis may be used to develop emissions reduction strategies for sources in the region.

**\*Strategy for Addressing Environmental and Public Health Impacts from Animal Feeding Operations, EPA. Online.**

<http://www.epa.gov/npdes/pubs/astrat.pdf>

**\*Environmental considerations of livestock producers, D. Morse, Dept. of Animal Science, UC Davis. Online.**

<http://jas.fass.org/cgi/content/abstract/73/9/2733>

**\*Deposition of Nitrogen and Sulfur in the Columbia River Gorge National Scenic Area, Oregon DEQ. Online.**

<http://www.deq.state.or.us/aq/gorgeair/docs/depositionNitrogenSulfur.pdf>

**\*Gorge Science Summary Report, Oregon DEQ. Online.**

<http://www.deq.state.or.us/aq/gorgeair/docs/gorgeExecSummary.pdf>

## **I.L. Cultural resources**

***Gorge Science Summary Report*, Mark Pitchford, et. al. Southwest Clean Air Agency. Online.**

<http://www.swcleanair.org/gorgedata/ScienceSummaryReportSep24.pdf>

*Summary:* Since 2000, the Oregon DEQ and the Southwest Washington Clean Air Agency (SWCAA) have been conducting a study of visibility in the Columbia River Gorge National Scenic Area (Gorge). This study is part of an effort to develop an air quality improvement plan for the Gorge that will help protect valued scenic and other resources in the area. This plan is not required under the Clean Air Act, but has been undertaken by the Oregon and Washington air agencies at the request of the Columbia River Gorge Commission.

As part of this study, the agencies have been identifying potential sources of visibility impairment and providing a future look at visibility conditions in the Gorge. The study suggests that visibility impairment is greatest in the winter and influenced greatly by sources east of the Gorge. Air stagnation and fog are more common in the wintertime and are responsible for the rapid conversion of precursor gases (sulfur dioxide, nitrogen oxide, and ammonia) to haze in the Gorge. It is premature to say exactly what role dairy emissions contribute to haze events in the Gorge, but emissions from sources such as electric utilities, motor vehicles and other transportation sources, dairies, and other manmade sources are likely tied to visibility impairment in the Gorge. DEQ is interested in identifying opportunities for emission reductions across all sectors to benefit the Gorge over time.

## **I.M Clean Air Act Regulation**

***\*Air Quality Issues and Animal Agriculture: A Primer***

**C. Copeland, CRS Report for Congress. Order Code RL32948 Updated August 31, 2007.**

*Summary:* This paper provides a review of the federal regulatory background for animal feeding operations (AFOs), recent national research efforts on estimating emissions from such operations, examines the contribution of AFOs to air pollution and the correlating ecological and public health effects of emissions. The report provides background on the questions surrounding such contributions, reviews the types of air emissions from livestock and poultry operations and their human health and environmental impacts. The paper also discusses the

provisions of federal laws as they pertain to AFOs, and explores the questions surrounding the applicability of such laws to livestock and poultry operations.

***\*Effects of Insufficient Air Quality Data on Regulatory Policy in Animal Agriculture.*** F. M. Mitloehner, Department of Animal Science, University of California, Davis, 2005, *J. Appl. Poult. Res.* 14:373–377

*Summary:* Public concerns related to air quality effects of intensive dairy and poultry operations have grown considerably in recent years. Pollutants of concern include particulate matter (PM), volatile organic compounds (VOC), ammonia, methane, hydrogen sulfide, and odors. Although public pressure translates into legislative and regulatory action, there are insufficient data on character, amount, dispersion, and mitigation of air pollutants to establish appropriate and effective regulations. By using California case studies, the present paper shows livestock and poultry producers as well as regulatory agencies how the lack of science in air emission estimates and mitigation can lead to dramatic effects on animal agriculture without improving air quality.

#### **I.O. How are these emissions currently regulated in other states?**

***Ammonia-Based Air Quality Permits for Idaho Dairies.*** R. Sheffield. University of Idaho Extension, Twin Falls, B. Louks. Idaho Department of Environmental Quality, Boise, Idaho. Compiled in: *Western Dairy Air Quality Symposium, Sponsored by Western States Dairy Producers Trade Association. Palms Casino Resort. Las Vegas, Nevada. April 26-27, 2007.*

***Midwest Environmental Advocate's Comprehensive Model Livestock Ordinance.*** Midwest Environmental Advocates. Online.

<http://www.midwestadvocates.org/advocacy/factories/services/zoning.html>

*Summary:* To assist local governments in developing livestock zoning controls, MEA has prepared a Model Livestock Zoning Ordinance. The Model is intended to provide sample provisions for:

- a) an animal waste storage ordinance;
- b) financial responsibility to cover manure pit abandonment;
- c) land use planning for siting animal feeding operations, including the issuance of conditional use permits;
- d) a permitting scheme for regulating animal feeding operations; and simple but effective performance standards that animal feeding operations must meet in order to operate in your community.

**San Joaquin Valley Air Pollution Control District Status Report on Dairy Research Related to SB 700 Implementation, California Air Resources Board. Online.**

(<http://www.arb.ca.gov/ag/caf/dairyresearchsummaryjune2006final.pdf> )

**\*California New Source Review Call for Revision to California State Law Agricultural Exemption, Clean Air Act, EPA. Online.**

<http://www.epa.gov/region09/air/ca/nsr/>

**\*The Study and Regulation of Agricultural Air Quality in the U.S.** Heber and Bogan. Compiled in: Proceedings from the Workshop on Agricultural Air Quality: State of the Science June 6-8, 2006.

**\*Clean Water Act (CWA): Agriculture-Related Enforcement Cases, EPA. Online.** <http://www.epa.gov/agriculture/lcwaenf.html>

## **II.A./B. Emissions Estimates**

***Monitoring Dairy Emissions using and Open-Path Ultraviolet Spectroscopy.*** R. Sheffield. Department of Biological and Agricultural Engineering, University of Idaho. M. de Haro Marti. University of Idaho Extension. Compiled in: **Western Dairy Air Quality Symposium, Sponsored by Western States Dairy Producers Trade Association. The Orleans Hotel & Casino. Palms Casino Resort. Las Vegas, Nevada. April 26-27, 2007.**

*Summary:* This paper reports on utilizing micrometeorological techniques to estimate air emissions from dairy housing and manure storage systems. This methodology has been proven to be effective in measuring the emission rate from areas sources where confined chamber sampling techniques may adversely affect the surface conditions over time and do not allow for the evaluation of various control practices while they are being conducted.

***VOC and GHG from Dairy Sources.*** F. M. Mitloehner. Department of Animal Science, University of California, Davis. Compiled in: **Western Dairy Air Quality Symposium, Sponsored by Western States Dairy Producers Trade Association. Palms Casino Resort. Las Vegas, Nevada. April 26-27, 2007.**

*Summary:* This paper reports on experiments conducted in an environmental chamber that simulates commercial free-stall cow housing. In summary, the paper concludes that dairy cows and fresh waste have the potential to emit considerable amounts of alcohols and methane and research is needed to determine effective mitigation.

***Dairy VOCs and Regional Ozone Formation.*** P. G. Green. University of California, Davis. Compiled in: **Western Dairy Air Quality Symposium, Sponsored by Western States Dairy Producers Trade Association. Palms Casino Resort. Las Vegas, Nevada. April 26-27, 2007.**

*Summary:* Results from the development of a mobile chamber for measuring volatile organic compounds from dairies were presented. A mobile chamber was developed to sample whole air VOC mixtures at their source, and to immediately assay ozone formation. The study also conducted laboratory experiments with ethanol and other dairy gases, in addition to performing computer model

calculations of the reactions known to represent the photochemical reactions, which lead to ozone.

***Effects of dietary crude protein on ammonia emissions from dairy heifers.*** F. Mitloehner. University of California Davis. Compiled in: **Western Dairy Air Quality Symposium, Sponsored by Western States Dairy Producers Trade Association. The Orleans Hotel & Casino. Las Vegas, Nevada. March 21-22, 2006.**

*Summary:* Results of the study suggest that feeding diets containing nitrogen levels in excess of the animal's requirement can have a physiological and environmental impact.

***Volatile organic compound emissions from dairy cows and fresh waste.*** F. Mitloehner. University of California Davis, A. Goldstein, University of California Berkley. Compiled in: **Western Dairy Air Quality Symposium, Sponsored by Western States Dairy Producers Trade Association. The Orleans Hotel & Casino. Las Vegas, Nevada. March 21-22, 2006.**

*Summary:* Research results are reported for experiments conducted in chambers designed to simulate free-stall cow housing conditions. Measured VOC concentrations are less than that currently estimated by the California Air Resources Board

***Monitoring real time emissions of ammonia and methane at dairies.*** D. Goorahoo, C. Krauter. California State University-Fresno, J. Beyer. USDA-NRCS. Compiled in: **Western Dairy Air Quality Symposium, Sponsored by Western States Dairy Producers Trade Association. The Orleans Hotel & Casino. Las Vegas, Nevada. March 21-22, 2006**

*Summary:* Researchers in the San Joaquin Valley measured dairy lagoon emissions to derive information useful in making decisions related to management of the dairy effluent stream in flush systems utilizing land application.

***Monitoring dairy emissions using open-path FTIR.*** P. R. Griffiths. University of Idaho. Compiled in: **Western Dairy Air Quality Symposium, Sponsored by Western States Dairy Producers Trade Association. The Orleans Hotel & Casino. Las Vegas, Nevada. March 21-22, 2006.**

*Summary:* This paper reports monitoring results of field studies conducted to observe and measure the effects of air pollutant emissions from land application of dairy waste.

***\*Ammonia and hydrogen sulfide emissions from beef feedlot retention structures.*** K. Casey, D. Parker. Texas A&M University. Compiled in: **Western Dairy Air Quality Symposium, Sponsored by Western States Dairy Producers Trade Association. The Orleans Hotel & Casino. Las Vegas, Nevada. March 21-22, 2006.**

*Summary:* This paper presents results of a study on ammonia and hydrogen

sulfide emissions generated from beef feedlot retention structures. Through this project, estimates of ammonia and hydrogen sulfide will be obtained for each season of the year.

***\*An integrated approach to measuring emissions from confined animal feeding operations at the whole facility scale.*** G. Bingham, Utah State University, Space Dynamics Laboratory. Compiled in: **Western Dairy Air Quality Symposium, Sponsored by Western States Dairy Producers Trade Association. The Orleans Hotel & Casino. Las Vegas, Nevada. March 21-22, 2006.**

*Summary:* This paper describes standoff methods that were used to determine the sources, movement, and concentrations of emissions on a whole facility basis, opening new capabilities for model development and verification.

***Photochemical ozone formation potential of agricultural VOC sources.*** P.G. Green. University of California, Davis. Compiled in: **Western Dairy Air Quality Symposium, Sponsored by Western States Dairy Producers Trade Association. The Orleans Hotel & Casino. Las Vegas, Nevada. March 21-22, 2006.**

*Summary:* Describes the volatile organic compound emissions from dairy cows and fresh waste. The project sought to improve current understanding of the photochemical ozone formation potential in the unidentified fraction of VOC from agricultural sources.

***Monitoring and modeling of ROG at California dairies.*** C. Krauter. California State University Fresno, D. Blake. University of California Irvine. Compiled in: **Western Dairy Air Quality Symposium, Sponsored by Western States Dairy Producers Trade Association. The Orleans Hotel & Casino. Las Vegas, Nevada. March 21-22, 2006.**

*Summary:* Explains the methods used and results obtained in quantifying reactive organic gas (ROG) emissions rates from dairies.

***\*Ammonia Emissions from Agriculture and Other Sources.*** R. Strader, C. Davidson. **Agricultural Emissions, Workshop on Agricultural Air Quality, Washington D.C. June 2006**

*Summary:* Another study presented at the Workshop on Agricultural Air Quality examines existing ammonia emission inventories in the United States and proposes to compile a national inventory with a dynamic framework to allow for easy updating of inventory information. The proposed framework would allow for adjustments and modifications to be made to the inventory to use in different applications.

***Odor concentrations downwind of Idaho dairies and heifer facilities. R. Sheffield, University of Idaho. Compiled in: Western Dairy Air Quality Symposium, Sponsored by Western States Dairy Producers Trade Association. The Orleans Hotel & Casino. Las Vegas, Nevada. March 21-22, 2006.***

*Summary:* a study that sampled odor and gas concentrations on 38 dairies and 15 heifer facilities. The study concluded that the type of manure handling system and management were found to have the greatest effect on odor concentration versus facility size, the study also reports that generally, odor concentrations increase as the size of the facility increases.

***Atmospheric Flux of Ammonia from Sprinkler Application of Dairy Waste. Atmospheric Environment, 40 (2006) 7246–7258. Authors: Brian Rumburg, George H. Mounta, David Yonge, Brian Lamb, Hal Westberg, Jenny Filipy, Jay Baysb, Ron Kincaid, Kristen Johnson, Department of Civil & Environmental Engineering, Laboratory for Atmospheric Research, Center for Multiphase Environmental Research, Washington State University, Pullman, WA 99164-2910, USA Department of Civil & Environmental Engineering, Center for Multiphase Environmental Research, Washington State University, Pullman, WA 99164-2910, USA Department of Animal Sciences, Washington State University, Pullman, WA 99164-6351, USA Received 28 October 2005; accepted 6 April 2006***

*Abstract:* Atmospheric ammonia (NH<sub>3</sub>) emissions are a growing environmental and human health concern in the U.S. This paper describes an experiment to measure NH<sub>3</sub> emissions from the sprinkler application of dairy slurry to a grass field. The slurry was from milking cows that are housed in a freestall barn that is scraped daily and the waste is stored in a series of anaerobic lagoons that are emptied annually. Atmospheric measurements of NH<sub>3</sub> were made using differential optical absorption spectroscopy (DOAS) and tracer ratio flux experiments were used to determine field fluxes after application. An area source tracer ratio method was used to determine NH<sub>3</sub> field fluxes, it involved releasing SF<sub>6</sub> as the tracer gas from the upwind edge of the applied slurry and measuring the tracer concentration downwind along with the DOAS NH<sub>3</sub> measurements. The flux is calculated from the ratio of the NH<sub>3</sub> and SF<sub>6</sub> concentrations and the SF<sub>6</sub> release rate and taking into account the differences in area and dispersion. An emissions model was also developed for NH<sub>3</sub> volatilization after application based upon tracer flux data and modeling of the concentration data. Of the total ammoniacal nitrogen entering from the sprinkler pump, 18% volatilized before reaching the ground. The initial flux during the tracer experiment was 47 mgm<sup>-2</sup> s<sup>-1</sup> and this decreased to 17 mgm<sup>-2</sup> s<sup>-1</sup> during the experiment. Ambient measurements showed an exponential decay with time. An empirical exponential equation was fit to the measurement data and it had a mean bias of  $\pm 0.10$  ppbv and a normalized mean bias of  $\pm 0.050\%$ . A

theoretical model had a mean bias of  $\pm 11$  ppbv and a normalized mean bias of  $\pm 5.5\%$ . Overall sprinkler waste application emissions for the 175 milking cows was 5900 kg NH<sub>3</sub> yr<sup>-1</sup> or 34 kg NH<sub>3</sub> cow<sup>-1</sup> yr<sup>-1</sup>.

***Identification and Quantification of Volatile Organic Compounds from a Dairy.* Atmospheric Environment, 40 (2006) 1480–1494. Authors: Jenny Filipy, Brian Rumburg, George Mount, Hal Westberg, Brian Lamb Laboratory for Atmospheric Research, Department of Civil and Environmental Engineering, Washington State University, Pullman, WA 99164-2910, USA**

**Received 13 February 2005; received in revised form 21 October 2005; accepted 21 October 2005.**

*Abstract:* Volatile organic compounds (VOCs) that contribute to odor and air quality problems have been identified from the Washington State University Knott Dairy Farm using gas chromatography–mass spectroscopy (GC–MS). Eighty-two VOCs were identified at a lactating cow open stall and 73 were detected from a slurry wastewater lagoon. These compounds included alcohols, aldehydes, ketones, esters, ethers, aromatic hydrocarbons, halogenated hydrocarbons, terpenes, other hydrocarbons, amines, other nitrogen containing compounds, and sulfur-containing compounds. The concentration of VOCs directly associated with cattle waste increased with ambient air temperature, with the highest concentrations present during the summer months. Concentrations of most detected compounds were below published odor detection thresholds. Emission rates of ethanol (10267513 mg cow<sup>-1</sup> s<sup>-1</sup>) and dimethyl sulfide (DMS) (13.8710.3 mg cow<sup>-1</sup> s<sup>-1</sup>) were measured from the lactating stall area using an atmospheric tracer method and concentrations were plotted using data over a 2-year period. Emission rates of acetone (3.0370.85 ng cow<sup>-1</sup> s<sup>-1</sup>), 2-butanone (145735 ng cow<sup>-1</sup> s<sup>-1</sup>), methyl isobutyl ketone (3.4671.11 ng cow<sup>-1</sup> s<sup>-1</sup>), 2-methyl-3-pentanone (25.178.0 ng cow<sup>-1</sup> s<sup>-1</sup>), DMS (2.1970.92 ng cow<sup>-1</sup> s<sup>-1</sup>), and dimethyl disulfide (DMDS) (16.173.9 ng cow<sup>-1</sup> s<sup>-1</sup>) were measured from the slurry waste lagoon using a laboratory emission chamber.

***San Joaquin Valley Air Pollution Control District: Air Pollution Control Officer's Determination of VOC Emission Factors for Dairies.* D. L. Crow. San Joaquin Valley Air Pollution Control District. August 2005.**

*Summary:* This report presents and provides the basis for the Air Pollution Control Officer's determination of Volatile Organic Compound emission factors to be used for permitting San Joaquin Valley dairies. In addition, the District is also providing responses to address some of the general issues raised regarding the proposed emission factor determination. These responses may also eliminate some misconceptions that have arisen during the process of developing the proposed emission factors.

**\*The U.S. Agriculture and Forestry Greenhouse Gas Inventory: 1990-2001, Global Change Program Office, Office of the Chief Economist, U.S. Department of Agriculture, Technical Bulletin No. 1907, 164 pp. March 2004**

*Abstract:* A comprehensive assessment of greenhouse gas emissions and sinks in U.S. agriculture and forests. The USDA GHG Inventory provides extensive, in-depth emissions and sinks estimates for livestock, cropland, and forests, as well as energy consumption in livestock and cropland agriculture. Estimates are provided at State, regional, and national scales, categorized by land ownership and management practices where possible. Information in the report can be used to identify opportunities to reduce emissions and enhance sinks through agriculture and forest management. The report was prepared collaboratively with contributions from the United States Department of Agriculture (Forest Service, Natural Resources Conservation Service, Agricultural Research Service, Office of Energy Policy and New Uses, and the Global Change Program Office), the Environmental Protection Agency (EPA), and researchers at Colorado State University. The estimates in the USDA GHG Inventory are consistent with those published by the EPA in the official Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2001 and submitted to the United Nations Framework Convention on Climate Change in April 2003.

***Ammonia emission from dairy cow buildings: a review of measurement techniques, influencing factors and possibilities for reduction. G.J. Monteny and J.W. Erisman, Netherlands Journal of Agricultural science 46 (1998)***

*Summary:* The purpose of this study is to make an analytical inventory of ammonia emission data of dairy housing systems and to assess possibilities for its reduction, based upon the analysis of processes and factors involved in the production and volatilization of ammonia.

**\*Measuring and Modeling Gaseous NH<sub>3</sub> and Aerosol NH<sub>4</sub> at the Regional Scale: How does Ambient Concentration Respond to Emission Controls?** Compiled in Proceedings from the Workshop on Agricultural Air Quality: State of the science June 6-8, 2006.

**Dairy Air Emissions Analysis: Focus: Ammonia emissions for Typical Dairy Management Systems in Idaho; Summary of Methodology and Findings: Technical Reference Document, Final Draft**

<http://www.4cleanair.org/Documents/ThresholdReport.pdf>

**California Air Resources Board, Dairy Emissions; Summary of Dairy Emission Estimation Procedures Report, CA Air Resources Board. Online.**  
<http://www.arb.ca.gov/ag/caf/SchmidtDairyEmissions2005.pdf>

**\*National Emission Inventory –Ammonia Emissions from Animal Husbandry, EPA. Online.**

[http://www.epa.gov/ttn/chief/ap42/ch09/related/nh3inventoryfactsheet\\_jan2004.pdf](http://www.epa.gov/ttn/chief/ap42/ch09/related/nh3inventoryfactsheet_jan2004.pdf)

## **II.C.1 Existing data on occupational health impacts**

***Hazardous substances emergency events in the agricultural industry and related services in four mid-western states.*** Berkowitz Z, Orr MF, Kaye WE, Haugh GS (2002) *J Occup Environ Med* 44:714-723.

***Respiratory symptoms and bronchial reactivity among pig and dairy farmers.*** Choudat D, Goehen M, Korobaeff M, Boulet A, Dewitte JD, Martin MH (1994). *Scand J Work Environ* 20:48-54.

***Concentrated swine feeding operations and public health: a review of occupational and community health effects.*** Cole D, Todd L, Wing S (2000) *Environ Health Perspect* 108:685-699.

***Prevalence of asthma and respiratory symptoms in dairy farmers in the French province of the Doubs.*** Dalphin J, Dubiez A, Monnet E, Gora D, Westeel V, Pernet D, Polio J, Gibey R, Laplante J, Depierre A (1998) *Am J Respir Crit Care Med* 158:1493-1498.

***Twelve-year longitudinal study of respiratory status in dairy farmers.*** Gagnet M, Thaon I, Westeel V, Chaudemanche H, Venier AG, Dubiez A, Laplante JJ, Dalphin JC (2007) *Eur Respir J* 30:97-103.

***Acute hydrogen sulfide poisoning in a dairy farmer.*** Donham, KJ, S Wing, D Osterberg, JL Flora, C Hodne, K Thu, and PS Thorne. Gerasimon G, Bennett S, Musser J, Rinard J.. *Clin Toxicol (Phila)*. 2007 May 45(4):420-3.

*Abstract.* INTRODUCTION. Hydrogen sulfide is a lipid-soluble gas produced in occupational settings and from decaying organic matter. We present a 36-year-old man who developed acute respiratory arrest from hydrogen sulfide poisoning while performing work as a dairy farmer. CASE REPORT: The subject entered a poorly ventilated tank containing degrading eggs and, within seconds, collapsed. Coworkers were able to extract him within minutes but he was apneic. He was intubated by emergency medical services and subsequently managed with supportive care in the intensive care unit. Upon admission, a

powerful rotten egg scent was noted and a hydrogen sulfide poisoning was suspected. Serum analysis for the presence of thiosulfate confirmed the diagnosis. Nitrite therapy was not administered as the subject arrived outside of the therapeutic window of effectiveness and showed evidence of excellent oxygenation. His examinations following arrival were consistent with an anoxic brain injury, which slowly improved several months after the incident with intensive neuro-rehabilitation. DISCUSSION: Hydrogen sulfide is a mitochondrial toxin and inhibits cytochrome-aa (3) and prevents cellular aerobic metabolism. Therapies for toxic exposures include removal from the contaminated environment, ventilation with 100% oxygen, and nitrite therapy if administered immediately after exposure. Hyperbaric oxygen (HBO) therapy has anecdotal support and remains controversial. CONCLUSION: Hydrogen sulfide is a significant occupational health hazard. Education, personal protective equipment, and early treatment are important in improving outcomes.

***Animal production and wheeze in the Agricultural Health Study: interactions with atopy, asthma, and smoking.*** Hoppin JA, Umbach DM, London SJ, Alavanja MCR, Sandler DP (2003) *Occup Environ Med* 60:3e1-7.

***Iowa (2002) Iowa Concentrated Animal Feeding Operations Air Quality Study.*** Iowa State University and The University of Iowa Study Group, 221 p. Available online at <http://www.public-health.uiowa.edu/ehtsrc/CAFOstudy.htm>.

***A temporally and spatially resolved ammonia emission inventory for dairy cows in the United States.*** Pinder RW, Strader R, Davidson CI, Adams PJ (2004) *Atmo Environ* 38:3747-3756.

***Volatile organic compound emissions from dairy cows and their waste as measured by proton-transfer-reaction mass spectrometry.*** Shaw SL, Mitloehner FM, Jackson W, Depeters EJ, Fadel JG, Robinson PH, Holzinger R, Goldstein AH (2007) *Environ Sci Technol* 41:1310-1316.

***Odor concentrations downwind of Idaho dairies and heifer facilities.*** Sheffield RE, Chahine M, Dye B, Thompson MB (2007) *Trans ASABE* 50:255-263.

***Lung Cancer Risk: Effect of Dairy Farming and the Consequence of***

***Removing that Occupational Exposure.* Giuseppe Mastrangelo, John M. Grange, Emanuela Fadda, Ugo Fedeli, Alessandra Buja, and John H. Lange, American Journal of Epidemiology, Vol. 161, No. 11, 2005**

*Abstract:* The aim of this study was to confirm the exposure-dependent reduction in lung cancer risk reported for dairy farmers exposed to endotoxin and to evaluate the consequence of leaving dairy farming and taking employment in industry or services, where exposure to microbial agents is lower. Standardized mortality ratios, with 95% confidence intervals, for 2,561 self-employed dairy farmers were estimated, considering the general population of Veneto, Italy, from 1970 to 1998 as the reference. Sixty-two lung cancer cases, whose information was checked against clinical records, were compared with 333 controls in a cohort-nested case-control study. Odds ratios with 95% confidence intervals were estimated by logistic regression analysis. A downward trend of standardized mortality ratios for lung cancer across tertiles of number of dairy cattle on the farm was significant ( $p < 0.05$ ) from 1970 to 1984 but not from 1985 to 1998, when most subjects were no longer dairy farmers. Age- and smoking-adjusted odds ratios for lung cancer significantly decreased with increasing number of dairy cattle ( $p$  for trend  $\frac{1}{4}$  0.001) for workers for whom 15 but not  $>15$  years had elapsed from the end of work to the end of follow-up. In conclusion, increased levels of endotoxin (or other associated environmental factors) might be protective against lung cancer; protection diminishes over time after that exposure is removed.

***\*Review: Hydrogen sulfide (H<sub>2</sub>S) and sour gas effects on the eye.* Lambert, T. W.; V. M. Goodwin, D. Stefani, L. Strosher. 2006, Science of the Total Environment., 367(1), 1-22.**

*Summary:* An historical perspective examining observations of the toxicity of hydrogen sulfide and sour gas on the eye. This review, using more recent toxicology literature, draws conclusions that contrast with those drawn and published in a (2002) review published by the Alberta Health and Wellness. This study was not related directly to agricultural operations.

***\*Co-worker fatalities from hydrogen sulfide.* Hendrickson RG, Chang A, Hamilton RJ. Am J Ind Med. 2004 Apr 45(4):346-50.**

*Abstract:* BACKGROUND: Hydrogen sulfide is a colorless, odorless gas that may cause rapid loss of consciousness and respiratory depression without warning. It has produced toxicity in workers in numerous industries and occupations. METHODS: A review of the United States Bureau of Labor Statistics (USBLS) Census of Fatal Occupational Injuries (CFOI) for occupational deaths related to hydrogen sulfide from 1993 to 1999 was performed. RESULTS: Fifty-two workers died of hydrogen sulfide toxicity in this 7-year period. Deaths were most commonly reported in workers who were white (85%), male (98%), and in their first year of employment with the

company (48%). Common industries included waste management, petroleum, and natural gas. In 21% of cases, a co-worker died simultaneously or in the attempt to save the workers. CONCLUSIONS: Hydrogen sulfide toxicity is uncommon, but potentially deadly. Toxicity is predominantly in new workers and co-worker fatalities occur in a significant minority of cases. Proper training and education on the warning signs of hydrogen sulfide toxicity may help reduce worker fatalities. Copyright 2004 Wiley-Liss, Inc.

***\*Pulmonary function of workers exposed to ammonia: a study in the Eastern Province of Saudi Arabia. Ali BA, Ahmed HO, Ballal SG, Albar AA. Int J Occup Environ Health. 2001 Jan-Mar 7(1):19-22.***

*Abstract.* To determine the effect of chronic exposure to ammonia on pulmonary function among ammonia workers, 77 workers were randomly selected from an ammonia factory in the Eastern Province of Saudi Arabia and 355 were selected as controls from the administrative staffs of four industrial groups in Eastern Province. Spirometry was carried out and FEV<sub>1</sub>, FVC, and FEV<sub>1</sub>/FVC% were calculated. The ammonia level in the working environment was determined spectrophotometrically. 30% of the air samples had ammonia concentrations that exceeded the threshold limit value. Significant reductions in FEV<sub>1</sub> % predicted and FVC % predicted were observed in ammonia workers exposed to higher cumulative ammonia levels (above 50 mg/m<sup>3</sup>-years). FEV<sub>1</sub>% predicted and FEV<sub>1</sub>/FVC% were significantly lower in symptomatic than in asymptomatic workers in the exposed group. These findings may raise the possibility that exposure to a high cumulative ammonia level produces a combined restrictive/obstructive ventilatory defect.

***\*Health effects from chronic low-level exposure to hydrogen sulfide. Legator MS, Singleton CR, Morris DL, Philips DL. Arch Environ Health. 2001 Mar-Apr 56(2):123-31.***

*Abstract.* The acute toxic effects of hydrogen sulfide have been known for decades. However, studies investigating the adverse health effects from chronic, low-level exposure to this chemical are limited. In this study, the authors compared symptoms of adverse health effects, reported by residents of two communities exposed mainly to chronic, low-levels of industrial sources of hydrogen sulfide, to health effects reported by residents in three reference communities in which there were no known industrial sources of hydrogen sulfide. Trained interviewers used a specially created, menu-driven computer questionnaire to conduct a multi-symptom health survey. The data-collection process and questions were essentially the same in the reference and exposed communities. The two exposed communities responded very similarly to questions about the major categories. When the authors compared responses of the exposed communities

with those of the reference communities, 9 of the 12 symptom categories had iterated odds ratios greater than 3.0. The symptoms related to the central nervous system had the highest iterated odds ratio (i.e., 12.7; 95% confidence interval = 7.59, 22.09), followed by the respiratory category (odds ratio = 11.92; 95% confidence interval = 6.03, 25.72), and the blood category (odds ratio = 8.07; 95% confidence interval = 3.64, 21.18). Within the broader health categories, individual symptoms were also elevated significantly. This study, like all community-based studies, had several inherent limitations. Limitations, and the procedures the authors used to minimize their effects on the study outcomes, are discussed. The results of this study emphasize the need for further studies on the adverse health effects related to long-term, chronic exposure to hydrogen sulfide.

***Organic dust-related respiratory and eye irritation in Norwegian farmers. Melbostad E, Eduard W. Am J Ind Med. 2001 Feb 39(2):209-17.***

*Abstract.* BACKGROUND: Information on exposure to organic dust and work-related symptoms in farmers is sparse. METHODS: An exposure study was nested in a survey of 8,482 farmers and spouses. Task-related respiratory and eye symptoms were recorded by questionnaire. Personal exposure to total dust, fungal spores, bacteria, endotoxins, and ammonia during 12 different tasks was measured in a random sample of 127 farms (288 measurements). RESULTS: The prevalence of work-related symptoms occurring "often" was 31% and "seldom" 35%. Specific tasks provoking symptoms were reported by 5-55% of the farmers. Task mean exposures ranged from 0.04 to 2 mg dust/m<sup>3</sup>, 0.02 x 10<sup>6</sup> to 2 x 10<sup>6</sup> fungal spores/m<sup>3</sup>, 0.2 x 10<sup>6</sup> to 48 x 10<sup>6</sup> bacteria/m<sup>3</sup>, 0.5 x 10<sup>3</sup> to 28 x 10<sup>3</sup> endotoxin units/m<sup>3</sup>, and 0 to 8 ppm ammonia. Task mean exposure levels were positively correlated with task-specific symptom prevalences for total dust, fungal spores, and endotoxins but not for bacteria and ammonia. CONCLUSION: Work-related symptoms are common in farmers and are associated with exposure to total dust, fungal spores, and endotoxins. Copyright 2001 Wiley-Liss, Inc.

***\*Dose-response relationships between occupational aerosol exposures and cross-shift declines of lung function in poultry workers: recommendations for exposure limits. Donham KJ, Cumro D, Reynolds SJ, Merchant JA. J Occup Environ Med. 2000 Mar 42(3):260-9.***

*Abstract.* Numerous articles have been published regarding the adverse respiratory health consequences of working in intensive livestock and poultry housing. Threshold limit exposure guidelines are not currently applied to this environment, but they are essential to implement and monitor effective environmental controls. Previous dose-response research work with swine workers has resulted in

exposure limit recommendations of 2.5 mg/m<sup>3</sup> total dust, 0.23 mg/m<sup>3</sup> respirable dust, 100 EU/m<sup>3</sup> endotoxin, and 7 ppm ammonia. No similar recommendations have been reported previously for poultry workers. Therefore, an industry-wide study was conducted to examine dose-response relationships of bioaerosol exposures and worker respiratory health. A total of 257 poultry workers were studied for respiratory symptoms, pulmonary function, and exposure to dust (total and respirable), endotoxin (respirable and total), and ammonia. Details of the sampling plan and environmental assessment are described elsewhere. Relationships between exposures and response were studied by correlation and multiple regressions. Significant dose-response relationships were observed between exposures and pulmonary function decrements over a work shift. Exposure concentrations associated with significant pulmonary function decrements were as follows: 2.4 mg/m<sup>3</sup> total dust, 0.16 mg/m<sup>3</sup> respirable dust, 614 EU/m<sup>3</sup> endotoxin, and 12 ppm ammonia.

**\*Bronchial asthma in two chemical fertilizer producing factories in eastern Saudi Arabia.** Ballal SG, Ali BA, Albar AA, Ahmed HO, al-Hasan AY. *Int J Tuberc Lung Dis.* 1998 Apr 2(4):330-5.

*Abstract.* SETTING: Two urea fertilizer producing factories in Saudi Arabia. OBJECTIVE: To determine the prevalence of respiratory symptoms and diseases in employees exposed to ammonia gas. DESIGN: A cross-sectional study involving 161 exposed subjects and 355 controls. All completed a respiratory symptoms questionnaire, with additional questions on present and past occupations. Ammonia concentrations were measured in the different sections of the factories. RESULTS: The ammonia levels in factory B were well below the threshold limit value (TLV) (range 0.02-7.0 mg/m<sup>3</sup> of air). In factory A, the range was 2.0-130.4 mg/m<sup>3</sup>. The control and exposed groups were comparable with respect to their smoking habits. The exposed subjects in factory A had significantly higher relative risks (RR) for all respiratory symptoms; the same was true for haemoptysis (RR: 4.1, 95% confidence interval: 1.63-10.28). Bronchial asthma, chronic bronchitis, and a combined diagnosis were significantly higher among those exposed to high cumulative ammonia levels. However, in the logistic regression analysis ammonia concentration was significantly related to cough, phlegm, shortness of breath with wheezing and bronchial asthma. CONCLUSION: Exposure to ammonia gas in the workplace is significantly associated with increase in respiratory symptoms and bronchial asthma. Re-engineering measures to lower the levels of ammonia in factory A are strongly recommended. The affected employees should be removed from further exposure and followed up.

**\*Ammonia exposure: a common cause for sinusitis. A case report and review of the literature. Brautbar, N. (1998). Toxicology & Industrial Health, 14(6), 891-895.**

*Abstract:* Sinuses are a part of the upper respiratory system and sinusitis has been well-defined as an inflammation of the mucous membrane. Sinusitis occurs commonly as a result of allergies, polyps, common cold and environmental pollution. Reports of sinusitis secondary to ammonia exposure, while common clinically from a reporting point of view, have not been described extensively in the literature. We describe here a patient who was exposed to ammonia gas and developed chronic relapsing sinusitis. The mechanism of injury and review of the world literature indicate that although common clinically, chronic sinusitis as a result of ammonia exposure has not been described extensively.

**\*Serum nitrates and creatinine in workers exposed to atmospheric nitrogen oxides and ammonia. Giroux M, Ferrieres J., Sci Total Environ. 1998 Jul 3;217(3):265-9.**

*Abstract:* An epidemiological survey was carried out on 332 workers in a nitrogen fertilizer factory exposed to various levels of NO, NO<sub>2</sub>, NO<sub>3</sub>- and NH<sub>3</sub>. The population was divided into six groups as a function of the atmospheres in the different workshops and compared with a control group recruited outside the factory. We investigated the relations between the exposures of the different groups and serum levels of three nitrogen-containing derivatives involved in arginine metabolism: nitrates, creatinine and urea. The workers most exposed to the hydrogenated and oxygenated compounds of nitrogen were found to have the highest serum nitrates. Further analysis of the results showed that inhaled nitrogen oxides and ammonia were only partly responsible for the circulating nitrates. The excess nitrates were thought to have an endogenous origin due to inflammatory reactions induced by the pollutants, especially ammonia. In addition, we showed that the workers from the two groups exposed to both NO and NH<sub>3</sub> had significantly elevated levels of serum creatinine (P < 0.001). The excess creatinine was thought to have derived from the interaction of the exogenous NO with arginine metabolites.

**\*Effect of occupational exposure to ammonia on enzymatic activities of catalase and mono amine oxidase. Hamid HA, El-Gazzar RM., J Egypt Public Health Assoc. 1996;71(5-6):465-75.**

*Abstract:* The study was carried out to investigate the effect of ammonia inhalation on a total number of 60 male subjects from an urea production plant located in Alexandria. Laboratory investigations were carried out for 30 exposed and 30 controlled subjects. The results showed statistically significant inhibition (p<0.01) in the activity of catalase enzyme among the exposed than the control subjects. The

inhibition could lead to deleterious effects on electrical stability, permeability and fluidity of membranes, which could affect the liver and brain to be more susceptible to hepatotoxic and neurotoxic alterations. The present work showed a significant inhibition ( $p < 0.01$ ) of monoamine oxidase (MAO) activities and significant increase ( $p < 0.05$ , 0.01) in liver function activities among exposed subjects than the control subjects.

**\*A Review of Farm Accident Data Sources and Research. National Ag Safety Database, USDA. Online.**

<http://www.cdc.gov/nasd/docs/d001001-d001100/d001045/d001045.html>

**\*Health Effects of Airborne Exposures from Concentrated Animal Feeding Operations, Goliath. Online.**

[http://goliath.ecnext.com/coms2/gi\\_0199-6331377/Health-effects-of-airborne-exposures.html](http://goliath.ecnext.com/coms2/gi_0199-6331377/Health-effects-of-airborne-exposures.html)

**\*Concentrated Animal Feeding Operations: Health Risks to Farmers and Workers, Institute for Agriculture and Trade Policy. Online.**

<http://www.healthobservatory.org/library.cfm?refID=37389>

**\*Human Health Effects of Agriculture: Physical Disease and Illnesses, National Ag Safety Database, USDA. Online.**

<http://www.cdc.gov/nasd/docs/d001701-d001800/d001772/d001772.html>

**Hazards in California Dairy Waste Structures, Occupational Health and Safety. Online.** <http://www.ohsonline.com/articles/44823/>

**\*The Purdue Agricultural Air Quality Laboratory, PAAQL. Online.**

<http://cobweb.ecn.purdue.edu/~odor/NAEMS/>

**\*National Air Emissions Monitoring Study, EPA. Online.**

<http://www.epa.gov/agriculture/airmonitoringstudy.html>

## **II.C.2 Existing data on community health impacts**

***\*Examination of atmospheric ammonia levels near hog CAFOs, homes, and schools in Eastern North Carolina.*** Sacoby M. Wilson, Department of Epidemiology, University of Michigan, Ann Arbor and Marc L. Serreb, Department of Environmental Sciences and Engineering, University of Carolina at Chapel Hill, *Atmospheric Environment* 41 (2007) 4977–4987

*Abstract:* Hog concentrated animal feeding operations (CAFOs) release ammonia ( $\text{NH}_3$ ) in Eastern North Carolina (NC) to the atmosphere, which is potentially hazardous for nearby human populations at community locations particularly homes and schools.

We present NH<sub>3</sub> weekly average concentrations that were collected using passive diffusion tubes from October 2003 to May 2004 (20 sites) and from July 2004 to October 2004 (23 sites) near community locations

in close proximity to hog CAFOs. The data for each phase of sampling was stratified by distance from the nearest hog CAFO. The mean Phase I levels were 16, 8, 7 and 5 ppb for distances  $\leq 0.5$ , 0.5–1, 1–2, and 2 km or more, respectively. The mean levels for Phase II were 29, 16, and 11 ppb for distances  $\leq 0.5$ , 0.5–1, and 1 km or more, respectively. The results of the distance stratification are the best results of this study and provide the strongest evidence that distance to one or more CAFOs is the key variable in controlling weekly NH<sub>3</sub> atmospheric concentration at the community level in Eastern NC. Statistical analyses confirmed that source terms such as distance to a hog CAFO and live weight per operation, as well as temperature, wind speed and wind direction were important predictors of atmospheric NH<sub>3</sub> at community locations. The results indicate potential zones of exposure for human populations who live or go to school near hog CAFOs.

***\*Environmental Exposure and Health Effects From Concentrated Animal Feeding Operations. Frank M. Mitloehner, Department of Animal Science and Agricultural Air Quality Center, University of California, Davis. and Marc B. Schenker†, Department of Public Health Sciences and Western Center for Agricultural Health and Safety, University of California, Davis, Epidemiology 2007;18: 309–311***

*Abstract:* Modern concentrated animal feeding operations generate sizeable amounts of manure and related emissions into water and air. These present potential harm to human health. Adverse respiratory effects have been documented among workers in these feeding operations, but there has been little research on wider environmental effects. Few conclusions are possible at this time but recent studies (including a report in this issue of EPIDEMIOLOGY by Radon and colleagues) suggest possible adverse effects. Respiratory outcomes of greatest concern include nasal allergies, airflow obstruction and asthma. Another concern among residents near concentrated animal feeding operations is adverse effects from malodors. The potential impact of these operations on quality of life and health needs to be documented.

***\*School proximity to concentrated animal feeding operations and prevalence of asthma in students. Sigurdarson, S. T., & Kline, J. N. (2006). Chest, 129(6), 1486-1491.***

*Abstract:* STUDY OBJECTIVES: Asthma prevalence and severity are rising in industrialized nations. Studies supporting the hygiene hypothesis suggest that being raised on a farm protects against atopy

and, often, asthma. In rural United States, however, an increased rate of asthma has been found among schoolchildren. We hypothesized that the rural US environment may not be protective against airway inflammation, perhaps due to environmental effluents from a relatively high number of concentrated animal feeding operations (CAFOs). We compared the prevalence of asthma in two Iowa elementary schools, one adjacent to a CAFO, and the other distant from any large-scale farming operations. DESIGN: Cross-sectional questionnaire-based study. SETTING: Two rural Iowa elementary schools: the study school is located one-half mile from a CAFO, and the control school is distant from any large-scale agricultural operation. PARTICIPANTS: Children, kindergarten through grade 5, who attended either the study school or the control school. RESULTS: Children in the study school had a significantly increased prevalence of physician-diagnosed asthma (adjusted odds ratio, 5.71;  $p = 0.004$ ). Although this group was more likely to live on a farm and have parents who smoke, these potentially confounding variables did not account for increased prevalence in a multivariate model. No difference in measures of asthma severity was found between the two populations. Because different sets of physicians are responsible for the medical care of the groups of children, it is possible that physician bias is responsible for the different prevalence of asthma diagnoses. This was not explored in the study. CONCLUSIONS: This study supports a role for exposure to rural environmental toxicants in the etiology of asthma, and suggests a need for further study of this relationship.

***\*Race, poverty, and potential exposure of middle-school students to air emissions from confined swine feeding operations. Mirabelli, M. C., Wing, S., Marshall, S. W., & Wilcosky, T. C. Environmental Health Perspectives, 114(4), 591-596 (2006)***

*Abstract:* Previous studies suggest that airborne effluent from swine confined animal feeding operations (CAFOs) may affect the health and quality of life of adults and the prevalence of asthma symptoms among children. To investigate the extent to which public school students may be exposed to airborne effluent from swine CAFOs and to evaluate the association between schools' demographic characteristics and swine CAFO exposures, we assessed the proximity of 226 schools to the nearest swine CAFO and conducted a survey of school employees to identify schools with noticeable livestock odor. We used publicly available information describing the enrollment of each school to assess the association between race and socioeconomic status (SES) and swine CAFO exposure. Odor from livestock was noticeable outside ( $n = 47$ , 21%) and inside ( $n = 19$ , 8%) school buildings. Schools with  $< 63\%$  enrollment of white students and  $> \text{or} = 47\%$  of students receiving subsidized lunches at school were located closer to swine CAFOs (mean = 4.9 miles) than were the remaining schools

(mean = 10.8 miles) and were more likely to be located within 3 miles of an operation than were schools with high-white/high-SES enrollment (prevalence ratio = 2.63; 95% confidence interval, 1.59-4.33). The prevalence of reported livestock odor varied with SES (low SES, 25%; high SES, 17%). These analyses indicate that the potential for in-school exposure to pollution arising from swine CAFOs in North Carolina and the environmental health risks associated with such exposures vary according to the racial and economic characteristics of enrolled students.

***\*Measuring and Modeling Gaseous NH<sub>3</sub> and Aerosol NH<sub>4</sub> at the Regional Scale: How Does Ambient Concentration Respond to Emission Controls?*** D. Fowler, J. Muller, Y. S. Tang, T. Dore, M. Vienno, R. I. Smith, E. Nemitz, M. Sutton, and J. W. Erisman. **Agricultural Emissions, Workshop on Agricultural Air Quality, Washington D.C. June 2006.**

*Summary:* This white paper examines changes in the chemistry of the atmosphere over the United Kingdom and other countries in Europe during a period in which emissions of SO<sub>2</sub>, NO<sub>x</sub>, and NH<sub>3</sub> have changed appreciably with respect to the response of both ambient concentrations and the gas to aerosol partitioning to changes in emissions. Observations are made through the exploration of monitoring data and using long range transport models.

***\*Detection and Enumeration of Airborne Microbial Pathogens Associated with Swine Farms in Eastern North Carolina.*** Simmons, O.D., C.A. Likirdopulos, G.Ko, S. Qurehi, L. Worley-Davis, C.M. Williams, and M. D. Sobsey. **Workshop on Agricultural Air Quality, Wash D.C. June 5-8, 2006.**

*Summary:* Their results suggest that there are airborne microbial impacts associated with swine farms in North Carolina and that these impacts may extend off the property boundaries. Indicate that it is unclear the extent to which airborne microbial contamination extends off the farm sites and how this contamination might effect human health.

***\*Symptomatic Effects of Exposure to Diluted Air Sampled from a Swine Confinement Atmosphere on Healthy Human Subjects.*** Susan S. Schiffman, Clare E. Studwell, Lawrence R. Landerman, Department of Psychiatry, Duke University Medical Center and Katherine Berman, and John S. Sundry, Department of Medicine, Duke University Medical Center **Environmental Health Perspectives • VOLUME 113 | NUMBER 5 | May 2005**

*Abstract:* Aerial emissions from a swine house at North Carolina State University's field laboratory were diluted to a level that could occur at varying distances downwind from a confined animal feeding operation (CAFO) both within and beyond the property line, and these emissions were delivered to an environmental exposure chamber. The study design consisted of two 1-hr sessions, one in which 48 healthy human adult volunteers were exposed to diluted swine air and another in which they were exposed to clean air (control). Objective measures of

blood pressure, temperature, heart rate, respiratory rate, lung function, nasal inflammation, secretory immunity, mood, attention, and memory were correlated with objective measures of air quality. Ratings of perceived (self-reported) health symptoms were also obtained. The mean levels of airborne constituents in the swine air condition were hydrogen sulfide (24 ppb), ammonia (817 ppb), total suspended particulates (0.0241 mg/m<sup>3</sup>), endotoxin (7.40 endotoxin units/m<sup>3</sup>), and odor (57 times above odor threshold). No statistical differences on objective measures of physical symptoms, mood, or attention resulted from the 1-hr exposure to swine emissions in the environmental chamber when compared with clean air for healthy human volunteers. However, subjects were 4.1 ( $p = 0.001$ ) times more likely to report headaches, 6.1 ( $p = 0.004$ ) times more likely to report eye irritation, and 7.8 ( $p = 0.014$ ) times more likely to report nausea in the swine air (experimental) condition than in the control condition. These results indicate that short-term exposure in an environmental chamber to malodorous emissions from a swine house at levels expected downwind can induce clinically important symptoms in healthy human volunteers.

***\*Aerosols Emitted from a Livestock Farm in Southern Germany,***  
**Journal Water, Air, & Soil Pollution, Publisher Springer Netherlands**  
**ISSN 0049-6979 (Print) 1573-2932 (Online), Issue Volume 154, Numbers 1-4 /**  
**May, 2004 DOI 10.1023/B:WATE.0000022962.65942.4b Pages 313-330**  
**Springer Link Date Tuesday, November 02, 2004. Gerhard Lammel,**  
**Friedhelm Schneider, Erika Brüggemann, Thomas Gnauk, Andreas Röhrl**  
**and Paul Wieser**

*Summary:* This paper reported on a study of the atmospheric aerosol produced on a farm directly on farm, downwind, and in the background with the aim to characterize the aerosol physically and chemically and to determine the source, i.e. chicken, cattle or pig farming. The study encourages a systematic characterization of aerosols emitted from livestock operations in future studies of similar kind.

***\*Hazardous substances emergency events in the agriculture industry and related services in four mid-western states. Berkowitz Z, Orr MF, Kaye WE, Haugh GS. J Occup Environ Med. 2002 Aug 44 (8):714-23.***

*Abstract:* Analysis of Hazardous Substances Emergency Events Surveillance data reported from 14 participating states between 1993 and 1998 found that acute releases are seasonal. This seasonality was more prevalent in four Midwestern states during April-June and coincided with their planting season, suggesting an association of these releases with the agricultural industry. A more detailed analysis of events related to this industry in these states found that ammonia was the chemical most frequently released, and ammonia related events resulted in a significantly higher number of evacuations than all

other events (OR = 10.7, [5.25-22.28]). A logistic regression model to identify risk factors for an event with victims found an increased risk for: (1) events with ammonia during April-June (adjusted OR = 3.57, [2.09-6.09]); (2) events in fixed-facilities during April-June (aOR = 3.74, [2.01-6.95]); and (3) events with multiple substances (aOR = 2.33, [1.05-5.17]). The most common causes for the events were equipment failure and operator error. Resulting injuries were mainly respiratory, ocular, and traumatic, and included six deaths. Employing more stringent safety measures and educating employees and the public about the health hazards involved with agricultural chemicals may reduce injuries and help contain costs associated with the releases.

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

*Abstract:* High-density concentrated animal feeding operations (CAFOs) have become an increasing source of concern with respect to their impact on health, the environment, and quality of life in the communities in which they are located. A growing body of literature has identified a number of potential adverse effects, including the development of anti-microbial resistance patterns, groundwater contamination, and occupational respiratory disease. The odor associated with CAFOs has had a detrimental effect on the quality of life of rural residents, and there may also be associated adverse health effects. Physicians in rural areas may be asked to assess patients with concerns related to neighboring CAFOs and may be drawn into a political battle regarding the authorization of the development of additional CAFOs. This article reviews current research on the community, environmental, and occupational health effects associated with high-density animal production facilities. It also discusses recommendations for evaluating patients affected by CAFO odors and steps to decrease occupational and community exposure.

**\*Emergency planning and the acute toxic potency of inhaled ammonia. Michaels, R. A. (1999). *Environmental Health Perspectives*, 107(8), 617-627.**

*Abstract:* Ammonia is present in agriculture and commerce in many if not most communities. This report evaluates the toxic potency of ammonia, based on three types of data: anecdotal data, in some cases predating World War 1, reconstructions of contemporary industrial accidents, and animal bioassays. Standards and guidelines for human exposure have been driven largely by the anecdotal data, suggesting that ammonia at 5,000-10,000 parts per million, volume/volume (ppm-v), might be lethal within 5-10 min. However, contemporary accident reconstructions suggest that ammonia lethality requires higher concentrations. For example, 33,737 ppm-v was a 5-min zero-mortality value in a major ammonia release in 1973 in South Africa.

Comparisons of secondary reports of ammonia lethality with original sources revealed discrepancies in contemporary sources, apparently resulting from failure to examine old documents or accurately translate foreign documents. The present investigation revealed that contemporary accident reconstructions yield ammonia lethality levels comparable to those in dozens of reports of animal bioassays, after adjustment of concentrations to human equivalent concentrations via U.S. Environmental Protection Agency (EPA) procedures. Ammonia levels potentially causing irreversible injury or impairing the ability of exposed people to escape from further exposure or from coincident perils similarly have been biased downwardly in contemporary sources. The EPA has identified ammonia as one of 366 extremely hazardous substances subject to community right-to-know provisions of the Superfund Act and emergency planning provisions of the Clean Air Act. The Clean Air Act defines emergency planning zones (EPZs) around industrial facilities exceeding a threshold quantity of ammonia on-site. This study suggests that EPZ areas around ammonia facilities can be reduced, thereby also reducing emergency planning costs, which will vary roughly with the EPZ radius squared.

**\*Swine CAFO Odors: Guidance for Environmental Impact Assessment Region 6 U.S. EPA. Prepared by Lee Wilson and Associates, September 30, 1996.**

*Summary:* This report utilized existing literature to summarize the current understanding of swine odors and addressed the need to evaluate swine CAFOs to understand how swine odors are generated, what their impacts can be, and how proposed CAFOs may or may not be designed to abate potential odor impacts.

**\*Concentrated Animal Feeding Operations (CAFOs), Assessment of Impacts on Health, Local Economies, and the Environment with Suggested Alternatives. Institute of Science, Technology and Public Policy. Online.**  
[http://www.istpp.org/pdf/istpp\\_cafo.pdf](http://www.istpp.org/pdf/istpp_cafo.pdf)

**\*Medical Evaluation and Risk Assessment, Industrial Swine Operation and Community Health Effects, CEFEQ. Online.**  
<http://www.cefeo.org/medicalriskassess.htm>

**\*Symptomatic Effects of Exposure to Diluted Air Sampling of Swine Confinement Atmosphere of Health Human Subjects, Goliath. Online.**  
[http://goliath.ecnext.com/coms2/gi\\_0199-4363473/Symptomatic-effects-of-exposure-to.html](http://goliath.ecnext.com/coms2/gi_0199-4363473/Symptomatic-effects-of-exposure-to.html)

**\*Strategy for Addressing Environmental and Public Health Impacts from Animal Feeding Operations, EPA. Online.**  
<http://www.epa.gov/npdes/pubs/astrat.pdf>

**\*Neighboring Health and Large-Scale Swine Production, National Ag Safety Database, USDA. Online.**

<http://www.cdc.gov/nasd/docs/d001701-d001800/d001764/d001764.html>

## **II.F.1 Research on CAFO emissions**

**\*National Air Emission Monitoring Study. A. Herber. Agricultural and Biological Engineering, Purdue University. R. Gran, Agronomy, Purdue University. W. Robrage, North Carolina State, L. Wang. North Carolina State. C. Gooch. Cornell University, K. Casey. Texas A&M University, L. Jacobson. University of Minnesota, J. Koziel. Iowa State University, F. Mitloehner. University of California-Davis, R. Zhang. University of California –Davis, P. Ndegwa. Washington State University. Compiled in: Western Dairy Air Quality Symposium, Sponsored by Western States Dairy Producers Trade Association. Palms Casino Resort. Las Vegas, Nevada. April 26-27, 2007.**

*Summary:* The main objectives of the NAEMS are:

- Determine whether individual farms are likely to emit particulate matter (PM) and volatile organic compounds (VOCs) in excess of applicable Clean Air Act Thresholds.
- Determine whether individual farms are likely to emit NH<sub>3</sub> and/or H<sub>2</sub>S in excess of applicable Comprehensive Environmental Response, Compensation and Liability Act (CERCLA) and Emergency Planning and Community Right-to-Know Act (EPCRA) reporting requirements.
- Form a database with which new studies of emissions and control technologies can be compared, and from which emission estimation methodologies can be developed.

**\*Methane Emissions from Cattle. K. A. Johnson and D. E. Johnson, Departments of Animal Science, Washington State University, Pullman Washington and Colorado State University Fort Collins, Colorado**

*Abstract:* Increasing atmospheric concentrations of methane have led scientists to examine its sources of origin. Ruminant livestock can produce 250 to 500 L of methane per day. This level of production results in estimates of the contribution by cattle to global warming that may occur in the next 50 to 100 year to be a little less than 2%. Many factors influence methane emissions from cattle and include the following: level of feed intake, type of carbohydrate in the diet, feed processing, addition of lipids or ionophores to the diet, and alterations in the ruminal microflora. Manipulation of these factors can reduce methane emissions from cattle. Many techniques exist to quantify methane emissions from individual or groups of animals. Enclosure techniques are precise but require trained animals and may limit animal movement. Isotopic and nonisotopic tracer techniques may also be used effectively. Prediction equations based on fermentation

balance or feed characteristics have been used to estimate methane production. These equations are useful, but the assumptions and conditions that must be met for each equation limit their ability to accurately predict methane production. Methane production from groups of animals can be measured by mass balance, micrometeorological, or tracer methods. These techniques can measure methane emissions from animals in either indoor or outdoor enclosures. Use of these techniques and knowledge of the factors that impact methane production can result in the development of mitigation strategies to reduce methane losses by cattle. Implementation of these strategies should result in enhanced animal productivity and decreased contributions by cattle to the atmospheric methane budget.

***\*Odor Emissions and Chemical Analysis of Odorous Compounds from Animal Buildings. L.D. Jacobson, J. A. Koziel, S. J. Hoff, A. J Heber, and D. B. Parker. Agricultural Emissions, Workshop on Agricultural Air Quality, Washington D.C. June 2006***

*Summary:* This study will supplement the National Air Emissions Monitoring Study (NAEMS) with comprehensive measurements of odor emissions from eight separate animal buildings in the U.S. Investigators in this project will add odor emission measurements to the NAEMS, and will include both standard human sensory and chemical methods to gain both quantitative and qualitative understanding of odor emissions from animal buildings.

***\*Odorous VOC emissions from beef feedlots. K. Casey, D. Parker. Texas A&M University. Compiled in: Western Dairy Air Quality Symposium, Sponsored by Western States Dairy Producers Trade Association. The Orleans Hotel & Casino. Las Vegas, Nevada. March 21-22, 2006.***

*Summary:* This paper proposes studying odorous volatile organic compounds from beef feedlots. Beyond determination of emission rates, the project will elucidate the effect of common management practices on emission of odorous compounds.

***Air Quality research investments at the Cooperative State Research, Education, and Extension Service. R. Knighton, USDA-CSREES. Compiled in: Western Dairy Air Quality Symposium, Sponsored by Western States Dairy Producers Trade Association. The Orleans Hotel & Casino. Las Vegas, Nevada. March 21-22, 2006.***

*Summary:* This paper describes and quantifies funding mechanisms used by CSREES, current air quality investments, and provides a listing of projects that relate specifically to dairies, discussion of recent requests for applications of the National Research Initiative Air program. Additionally, a geographical depiction of special research grants in response to atmospheric deposition of NH<sub>4</sub> and non-attainment areas of PM is provided.

***Process-based farm emission model for estimating gas emissions from California dairies.*** A. Rotz, USDA Agricultural Research Service, University Park, PA, University of California AT Davis, The Pennsylvania State University, National Dairy Environmental Task Force. Compiled in: **Western Dairy Air Quality Symposium, Sponsored by Western States Dairy Producers Trade Association. The Orleans Hotel & Casino. Las Vegas, Nevada. March 21-22, 2006**

*Summary:* This paper describes the Facility Gaseous Emission Model being developed to meet the need for a process-based modeling approach for estimating farm emissions and the effects of management on these emissions. The primary objective is to create a relatively simple and easy to use software tool that predicts each of the major gaseous emissions from dairy farms on both a daily and annual basis. The model will be validated against data gathered over a two year period through the monitoring of dairies throughout the United States. The research will also be used to create a research tool for evaluating the interaction between gas emissions and other farm processes including water quality impacts and farm profitability. The model will be made available to other researchers and educators working on whole-farm impacts of technologies and strategies used to reduce environmental impacts from dairy farms.

***Process-based farm emission model for estimating gas emissions from California Dairies.*** R. Zhang, F. Mitloehner. University of California Davis, A. Goldstein, University of California Berkley. Compiled in: **Western Dairy Air Quality Symposium, Sponsored by Western States Dairy Producers Trade Association. The Orleans Hotel & Casino. Las Vegas, Nevada. March 21-22, 2006.**

*Summary:* The purpose of this research is to enhance the scientific understanding of volatile organic compounds in dairy feed and manure sources and the processes that control their production and emission; it will facilitate the design of technologies for reducing emissions, and deliver a computer model that can estimate or predict the emission rates of various VOCs under different farm management and environmental conditions. Specifically, the following tasks are to be performed:

- Develop and refine gas sampling and measurement techniques for quantifying the VOCs produced and emitted from dairy feed silage and manure sources.
- Quantify the generation and emission rates of VOCs from silage and manure under different management and environmental conditions.
- Develop mathematical relationships to calculate the generation and emission rates of VOCs from feed silage and manure sources as functions of manure characteristics and environmental conditions.
- Using measurement and other data, develop and populate a process-based computer model that can predict the emission rates of VOCs from different dairy feed silage and manure sources.
- Perform preliminary validation and tuning of the modeling results using

available dairy measurements.

***Quantifying ammonia emissions from California dairies.*** C. Krauter. California State University, Fresno, B. Salas, Applied Geosolutions, C. Li. University of New Hampshire. Compiled in: Western Dairy Air Quality Symposium, Sponsored by Western States Dairy Producers Trade Association. The Orleans Hotel & Casino. Las Vegas, Nevada. March 21-22, 2006

*Summary:* This paper reports preliminary ammonia emissions data from dairy manure applications collected during the winter of 2005/2006 for a project to calibrate a computer simulation model of carbon and nitrogen biogeochemistry for California dairy systems. Emissions will be monitored using a USEPA Emission Isolation Flux Chamber. Future sampling will be conducted during the Spring and Fall months, and application of dry manure from scraped corrals or solids separation processes will be monitored in addition to the injection and liquid effluent flood applications.

***Developing and applying process-based models for estimating GHG and air emissions from California dairies.*** W. Salas. Applied Geosolutions, LLC, University of New Hampshire, University of California at Davis, California State University at Fresno, University of California at Riverside. Compiled in: Western Dairy Air Quality Symposium, Sponsored by Western States Dairy Producers Trade Association. The Orleans Hotel & Casino. Las Vegas, Nevada. March 21-22, 2006

*Summary:* This paper discusses project parameters for developing a biogeochemical process-based tool for quantifying air emissions from California dairies, to be made adoptable in other regions based on local soils, climate, and manure management conditions and practices.

***Air emissions from dairy CAFOs: multi-scale measurements and process based modeling.*** N.M. Marcillac, N.p. Hanan, T. Lee, R.F. Follet, T. L. Stanton, J.L. Collett, and D.E. Johnson. Compiled in: Western Dairy Air Quality Symposium, Sponsored by Western States Dairy Producers Trade Association. The Orleans Hotel & Casino. Las Vegas, Nevada. March 21-22, 2006.

*Summary:* In this paper, there is a proposal for a study aimed at quantifying emissions of ammonia, ammonium, nitric acid, methane, carbon dioxide, and nitrous oxide from multi-component dairy systems. It examines spatial, diurnal and seasonal variability. The goal of the project is to develop and test process based estimations of CAFO air emissions.

***\*Modeling the source of emissions from animal feeding operations.*** W. Powers. Iowa State University. Compiled in: Western Dairy Air Quality Symposium, Sponsored by Western States Dairy Producers Trade Association. The Orleans Hotel & Casino. Las Vegas, Nevada. March 21-22, 2006.

*Summary:* This study by Iowa State University proposes to collect baseline data for broiler chickens, growing pigs, and lactating dairy cows for emissions associated with animal feeding operations. Data will be collected to complement efforts by the National Research Council Committee on Animal Nutrition to use a mass balance approach, abased on nutrient inputs into animal feeding operations. The study will also identify recommendations for addressing emissions from animal feeding operations and be used to develop an interactive model for the purpose of site-specificity, and measures will address the diet variation that occurs nationwide.

***Comparison of monitoring techniques to quantify nitrogen and sulfur emissions from dairy wastewater lagoons and open feeding areas.*** R. Sheffield, University of Idaho. Compiled in: **Western Dairy Air Quality Symposium, Sponsored by Western States Dairy Producers Trade Association. The Orleans Hotel & Casino. Las Vegas, Nevada. March 21-22, 2006.**

*Summary:* The paper describes a study, which proposes to evaluate the differences between field-based monitoring methods being used to quantify nitrogen and sulfur emissions from dairies. The study will focus on identifying the differences between monitoring methods and how such assessments could be accurately done in the future.

***\*Ambient H<sub>2</sub>S Concentrations near Swine Barns and Manure Storages,*** Published by the American Society of Agricultural and Biological Engineers, St. Joseph, Michigan [www.asabe.org](http://www.asabe.org) Citation: Paper number 024059, 2002 ASAE Annual Meeting. Authors: José R. Bicudo, David R Schmidt, Carrie L. Tengman, Larry D. Jacobson.

*Abstract:* This paper summarizes results obtained from eight different swine farms that were monitored continuously for hydrogen sulfide (H<sub>2</sub>S) during different periods of time in 1999, 2000, and 2001. Continuous measurements of H<sub>2</sub>S were carried out with single point monitors, which use a photo-optic system to measure gas concentrations based on 15- minutes averages. Weather parameters, including rainfall, air temperature, relative humidity, wind speed and direction, and solar radiation were also monitored. H<sub>2</sub>S concentrations as high as 450 ppb were recorded about 5 m downwind of a deep-pitted finishing barn. On the other hand, average H<sub>2</sub>S concentrations measured about 15 m from deep-pitted wean-to-finish barns were between 4 and 6 ppb only. Manure storages were found to cause a larger impact on ambient H<sub>2</sub>S than animal barns. Data from nursery farms showed lower H<sub>2</sub>S concentrations than finishing farms, but storage basins were covered with straw or natural crust. A distinct diurnal variation in ambient H<sub>2</sub>S was reasonably well correlated with air temperature and relative humidity.

**\*Concentrated Animal Feeding Operations (CAFOs), Assessment of Impacts on Health, Local Economies, and the Environment with Suggested Alternatives.** Institute of Science, Technology and Public Policy. Online. [http://www.istpp.org/pdf/istpp\\_cafo.pdf](http://www.istpp.org/pdf/istpp_cafo.pdf)

**\*Medical Evaluation and Risk Assessment, Industrial Swine Operation and Community Health Effects, CEFEQ.** Online. <http://www.cefeo.org/medicalriskassess.htm>

**\*Symptomatic Effects of Exposure to Diluted Air Sampling of Swine Confinement Atmosphere of Health Human Subjects, Goliath.** Online. [http://goliath.ecnext.com/coms2/gi\\_0199-4363473/Symptomatic-effects-of-exposure-to.html](http://goliath.ecnext.com/coms2/gi_0199-4363473/Symptomatic-effects-of-exposure-to.html)

**\*Strategy for Addressing Environmental and Public Health Impacts from Animal Feeding Operations, EPA.** Online. <http://www.epa.gov/npdes/pubs/astrat.pdf>

**\*Neighboring Health and Large-Scale Swine Production, National Ag Safety Database, USDA.** Online. <http://www.cdc.gov/nasd/docs/d001701-d001800/d001764/d001764.html>

## II.F.2 Research on CAFO impacts

***\*Monitoring and modeling of emissions from concentrated animal feeding operations: overview of methods.*** B Bunton, P O'Shaughnessy, S Fitsimmons, J Gering, S Hoff, Me Lyngye, PS Thorne, J Wasson, and M Werner. *Environmental Health Perspectives.* 115(2) 303. 2007.  
*Summary:* Provides recommendations for further research.

***\*Health effects of airborne exposures from concentrated animal feeding operations.*** Heederik, D., Sigsgaard, T., Thorne, P. S., Kline, J. N., Avery, R., Bonlokke, J. H., et al. (2007). *Environmental Health Perspectives,* 115(2), 298-302.

*Abstract:* Toxic gases, vapors, and particles are emitted from concentrated animal feeding operations (CAFOs) into the general environment. These include ammonia, hydrogen sulfide, carbon dioxide, malodorous vapors, and particles contaminated with a wide range of microorganisms. Little is known about the health risks of exposure to these agents for people living in the surrounding areas. Malodor is one of the predominant concerns, and there is evidence that psycho-physiologic changes may occur as a result of exposure to malodorous compounds. There is a paucity of data regarding community adverse health effects related to low-level gas and particulate emissions. Most information comes from studies among

workers in CAFO installations. Research over the last decades has shown that microbial exposures, especially endotoxin exposure, are related to deleterious respiratory health effects, of which cross-shift lung function decline and accelerated decline over time are the most pronounced effects. Studies in naive subjects and workers have shown respiratory inflammatory responses related to the microbial load. This working group, which was part of the Conference on Environmental Health Impacts of Concentrated Animal Feeding Operations: Anticipating Hazards-Searching for Solutions, concluded that there is a great need to evaluate health effects from exposures to the toxic gases, vapors, and particles emitted into the general environment by CAFOs. Research should focus not only on nuisance and odors but also on potential health effects from microbial exposures, concentrating on susceptible subgroups, especially asthmatic children and the elderly, since these exposures have been shown to be related to respiratory health effects among workers in CAFOs.

***\*Modeling and Regulating Ammonia Emissions. N. Hutchings, H. Fagerli, W. Asman, T. Misselbrook, R. Pinder, and J. Webb. Agricultural Emissions, Workshop on Agricultural Air Quality, Washington D.C. June 2006***

*Summary:* This study proposes to develop, under the auspices of the Nordic Council of Ministries, a model to be incorporated into the framework of the UN Convention on Long-Range Transboundary Pollution (CLTRP). The model would improve the temporal resolution of ammonia emission estimates. A second objective is to use the model the effect of a range of ammonia abatement measures that either are, or could be a part of, the regulation of agricultural ammonia emissions.

***\*Photochemical ozone formation potential of agricultural VOC sources. P.G. Green. University of California, Davis. Compiled in: Western Dairy Air Quality Symposium, Sponsored by Western States Dairy Producers Trade Association. The Orleans Hotel & Casino. Las Vegas, Nevada. March 21-22, 2006.***

*Summary:* The project seeks to improve current understanding of the photochemical ozone formation potential in the unidentified fraction of VOC from agricultural sources.

***\*Health effects from breathing air near CAFOs for feeder cattle or hogs. Von Essen, S. G., & Auvermann, B. W. (2005). Journal of Agromedicine, 10(4), 55-64.***

*Abstract:* There is concern that livestock operations for fattening cattle and raising hogs known as concentrated animal feeding operations (CAFOs) release substances into the air that have negative effects on the health of persons living nearby. These substances include dust containing endotoxin and other microbial products as well as ammonia,

hydrogen sulfide and a variety of volatile organic compounds. Odors from these farms are considered offensive by some neighbors. A variety of medical complaints are reported to be more common in those people who live near CAFOs for raising hogs than in people without this exposure. Respiratory health effects, including symptoms of pulmonary disease and lung function test result abnormalities, have been described in workers employed in CAFOs where hogs are raised. Health effects after inhalation exposure of neighbors to substances released into the ambient air from these farms is less well characterized. It must be noted that CAFO workers may differ from neighbors in terms of their exposures and general health status. The presence of dust and other substances from cattle feedlots also causes some neighbors to voice concerns about the impact on their health but this exposure has been studied less extensively than exposure to substances released from CAFOs where hogs are raised. Further research needs to be done to look for measurable health effects attributable to living near all CAFOs in order to better understand the impact of these farms.

***\*Public health concerns for neighbors of large-scale swine production operations. Thu, K. M. (2002). Journal of Agricultural Safety & Health, 8(2), 175-184.***

*Abstract:* This article provides a review and critical synthesis of research related to public health concerns for neighbors exposed to emissions from large-scale swine production operations. The rapid industrialization of pork production in the 1990s produced a generation of confined animal feeding operations (CAFOs) of a size previously unseen in the U.S. Recent research and results from federally sponsored scientific symposia consistently indicate that neighbors of large-scale swine CAFOs can experience health problems at significantly higher rates than controlled comparison populations. Symptoms experienced by swine CAFO neighbors are generally oriented toward irritation of the respiratory tract and are consistent with the types of symptoms among interior confinement workers that have been well documented in the occupational health literature. However, additional exposure assessment research is required to elucidate the relationship of reported symptoms among swine CAFO neighbors and CAFO emissions.

**\*Potential Environmental Impacts of Animal Feeding Operations, EPA. Online. <http://www.epa.gov/agriculture/ag101/impacts.html>**

**\*Risk Management Evaluation for Concentrated Animal Feeding Operations, EPA. Online. <http://www.epa.gov/nrmrl/pubs/600r04042/600r04042.pdf>**

## II.H. Other Comprehensive Studies

\*Ammonia Workshop, Oct 22-24, 2003, Washington, D.C., in conjunction with the annual National Atmospheric Deposition Program (NADP) meeting. NOAA. Online. <http://nadp.sws.uiuc.edu/nh4ws>

\*The Purdue Agricultural Air Quality Laboratory, PAAQL. Online. <http://cobweb.ecn.purdue.edu/~odor/NAEMS/>

\*National Air Emissions Monitoring Study, EPA. Online. <http://www.epa.gov/agriculture/airmonitoringstudy.html>

\*Animal Feeding Operations Air Quality Compliance Agreement Sheet, EPA. Online. <http://www.epa.gov/compliance/resources/agreements/caa/cao-fcsht-0501.html>

\*The Scientific Basis for Estimating Air Emissions from Animal Feeding Operations, Interim Report, National Research Council Interim Report, EPA. Online. <http://www.epa.gov/ttn/chief/ap42/ch09/draft/interimanimalfeed.pdf>

\*EPA Collaborates with Farmers on the First Nationwide Study of Air Emissions from Animal Feeding Operations, EPA. Online. <http://yosemite.epa.gov/opa/admpress.nsf/bd4379a92ceceeac8525735900400c27/123eb5c154ff33b0852572fa00594518!OpenDocument>

## III. Emissions Reduction Strategies

***\*Air Quality Extension and Education: Enhanced Learning Opportunities for Addressing Air Quality Issues in Animal Agriculture.*** R. Stowell, D. Schulte, R. Koelsch. University of Nebraska, R. Sheffield. University of Idaho, E. Wheeler. Pennsylvania State University, K. Janni. University of Minnesota. Compiled in: Western Dairy Air Quality Symposium, Sponsored by Western States Dairy Producers Trade Association. Palms Casino Resort. Las Vegas, Nevada. April 26-27, 2007.

*Summary:* The purpose of the project is to provide targeted information and training regarding air quality to professionals who interact with livestock and poultry producers and, in a coordinated effort, to develop learning modules.

Project objectives included:

- Provide and make readily usable a modular curriculum complete with educational materials on air quality to pre-professionals and livestock and poultry producers.
- Expand professional and pre-professional access to researchers and leading national air quality experts.
- Provide access to timely, research-based information and educational

materials on air quality in animal agriculture.

- Provide coordinated, focused air quality education and training, actively engaging professionals and pre-professionals in experiential learning.

Anticipated products include:

- Curriculum materials associated with learning modules on priority air quality topic areas
- Bi-monthly Web casts to capture knowledge of national experts and cutting-edge research
- Web page for 24/7 access to information and educational reference materials
- Annual workshops for engagement and focused training of students and professionals

**Western Region Dairy Odor and Air Quality Education. P. Ndegwa (Washington), R. Sheffield (Idaho), Mike Gamroth (Oregon), Robert Hagevoort (New Mexico), Frank Mitloehner (California). Compiled in: Western Dairy Air Quality Symposium, Sponsored by Western States Dairy Producers Trade Association. Palms Casino Resort. Las Vegas, Nevada. April 26-27, 2007**

*Summary:* The goal of the project is to reduce the environmental impacts of dairy farming in the West so as to promote the guaranteed sustainability of the milk and cheese industry in the region. The specific objective of the proposal is to train Agricultural Professionals across the dairy producing regions in the West on best management practices (BMPs) available to dairy producers for the mitigations of air quality degradation. The educational program will address regulatory issues on federal and state levels, and is multi-state, multi-disciplinary to provide a unified approach to providing education to the dairy industry. The project is also expected to serve as a quasi-pilot educational program and will provide other interested agricultural professional educators with a template to conduct similar programs elsewhere in the nation. Program material developed under this program will be available on the web to project participants, extension educators, and to the public.

***\*Ammonia emission controls as a cost-effective strategy for reducing atmospheric particulate matter in the Eastern United States. Pinder, R. W., Adams, P. J., & Pandis, S. N. (2007). Environmental Science & Technology, 41(2), 380-386.***

*Abstract:* Current regulation aimed at reducing inorganic atmospheric fine particulate matter (PM<sub>2.5</sub>) is focused on reductions in sulfur dioxide (SO<sub>2</sub>) and oxides of nitrogen (NO<sub>(x)</sub> = NO + NO<sub>2</sub>); however, controls on these pollutants are likely to increase in cost and decrease in effectiveness in the future. A supplementary strategy is reduction in ammonia (NH<sub>3</sub>) emissions, yet an evaluation of controls on ammonia has been limited by uncertainties in emission levels and in the cost of control technologies. We use state of the science emission

inventories, an emission-based regional air quality model, and an explicit treatment of uncertainty to estimate the cost-effectiveness and uncertainty of ammonia emission reductions on inorganic particulate matter in the Eastern United States. Since a paucity of data on agricultural operations precludes a direct calculation of the costs of ammonia control, we calculate the "ammonia savings potential," defined as the minimum cost of applying SO<sub>2</sub> and NO<sub>(x)</sub> emission controls in order to achieve the same reduction in ambient inorganic PM<sub>2.5</sub> concentration as obtained from a 1 ton decrease in ammonia emissions. Using 250 scenarios of NH<sub>3</sub>, SO<sub>2</sub>, and NO<sub>(x)</sub> emission reductions, we calculate the least-cost SO<sub>2</sub> and NO<sub>(x)</sub> control scenarios that achieve the same reduction in ambient inorganic PM<sub>2.5</sub> concentration as a decrease in ammonia emissions. We find that the lower-bound ammonia savings potential in the winter is \$8,000 per ton NH<sub>3</sub>; therefore, many currently available ammonia control technologies are cost-effective compared to current controls on SO<sub>2</sub> and NO<sub>(x)</sub> sources. Larger reductions in winter inorganic particulate matter are available at lower cost through controls on ammonia emissions.

***\*Are Algae the Solution to Wastewater Nitrates? Arizona State University. Online. [http://asunews.asu.edu/20080125\\_algae](http://asunews.asu.edu/20080125_algae)***

*Summary:* Researchers at Arizona State University say algae may be at least part of the solution in dealing with wastewater from livestock operations. By running wastewater through bioreactors that contain algae, they produce isolated algal blooms that do not disrupt anything around them. The algae then gobble up nitrogen and phosphorus. The ASU scientists can then harvest the algae for a variety of possible uses.

***\*Effects of Reduced Crude Protein on Gaseous Emissions and Swine Performance. W. Powers, S. Z. Bastyr, R. Angel, T. Applegate, and B. Kerr. Agricultural Emissions, Workshop on Agricultural Air Quality, Washington D.C. June 2006.***

*Summary:* The objective of this study was to evaluate pigs that were fed either a typical industry diet or one of two diets that contained decreasing crude protein levels by supplementing with amino acids. Animal performance and gaseous emissions were measured and emissions reductions were documented.

***Effect of the installation of an anaerobic digester on farmstead ammonia, hydrogen sulfide and VOC emissions. R. Sheffield. University of Idaho. Compiled in: Western Dairy Air Quality Symposium, Sponsored by Western States Dairy Producers Trade Association. The Orleans Hotel & Casino. Las Vegas, Nevada. March 21-22, 2006.***

*Summary:* The paper presented information on a project funded by the Idaho Department of Agriculture and Idaho Dairymen's Association to evaluate the emissions of odor and air quality pollutants across the farmstead.

***Reducing ammonia emissions from dairy waste using enhanced oxygen immobilized-cell biotechnology.*** P. Ndegwa. Washington State University. Compiled in: Western Dairy Air Quality Symposium, Sponsored by Western States Dairy Producers Trade Association. The Orleans Hotel & Casino. Las Vegas, Nevada. March 21-22, 2006.

*Summary:* This paper describes reducing ammonia emissions from dairy waste using enhanced oxygen immobilized-cell biotechnology. The overall objective of this research is to develop a cost-effective biological nitrification-denitrification process to enhance adoption of this technology as a control method to mitigate emissions of ammonia from AFOs.

***Emissions of ammonia and greenhouse gases from dairy operations.*** S. Chen, P. Ndegwa. Washington State University. . Compiled in: Western Dairy Air Quality Symposium, Sponsored by Western States Dairy Producers Trade Association. The Orleans Hotel & Casino. Las Vegas, Nevada. March 21-22, 2006.

*Summary:* The goal of this research was to elucidate the impact of the anaerobic digestion technology in the mitigation of emissions of ammonia and greenhouse gases on a typical dairy operation.

***\*Source reduction and mitigation strategies for air emissions from turkeys, laying hens, and growing cattle.*** W. Powers, J.R. Russell. Iowa State University, T. Applegate. Purdue University. Compiled in: Western Dairy Air Quality Symposium, Sponsored by Western States Dairy Producers Trade Association. The Orleans Hotel & Casino. Las Vegas, Nevada. March 21-22, 2006.

*Summary:* The purpose of the study was to evaluate the effect of diet modification on the emission of ammonia, hydrogen sulfide, nitrogen oxides, methane and volatile organic compounds. Specific objectives were to:

- Identify promising feed strategies
- Establish emission data for air contaminant emissions generated from dairy operations
- Evaluate mitigation strategies that involve both dietary changes as well as post-excrement manure/litter storage techniques.
- Application of findings to mass balance model
- Dissemination of information gained through development of decision-making tools.

***Developing effective manure treatment technologies for reducing emissions from manure storages.*** R. Zhang, F. Mitloehner. University of California Davis, J. McGarvey. USDA Agricultural Research Service. Compiled in: Western Dairy Air Quality Symposium, Sponsored by Western States Dairy Producers Trade Association. The Orleans Hotel & Casino. Las Vegas, Nevada. March 21-22, 2006.

*Summary:* The purpose of the research was to address increasing public concerns over air emissions from dairy operations by developing effective

mitigation technologies for reducing gaseous emissions from manure storages. Six-month experimental results showed that both anaerobic digestion and aerobic treatment had significant effects on the reduction of VOCs, VFAs, NH<sub>4</sub>, and H<sub>2</sub>S in Manure storages. The research also concluded that anaerobic process performed significantly or moderately better than aerobic process on the reduction of these gases in terms of mass of individual gas per mass of volatile solid fed. Detailed microbial analysis was also performed to elucidate the effects of process conditions on the microbial community, which are responsible for gas production.

***Bacterial population dynamics during waste treatment and subsequent storage in simulated wastewater holding lagoons.*** J. McGarvey. USDA/ARS, F. Mitloehner, R. Zhang. University of California at Davis. Compiled in: **Western Dairy Air Quality Symposium, Sponsored by Western States Dairy Producers Trade Association. The Orleans Hotel & Casino. Las Vegas, Nevada. March 21-22, 2006.**

*Summary:* The study examined aerobic and anaerobic digestion techniques used to treat dairy waste before storage in simulated holding tanks. Results showed that aerobic digestion altered the bacterial population structure the greatest, while anaerobic digestion resulted in fewer differences, and storage without treatment resulted in the least amount of change. Statistical analysis of the libraries revealed that the waste contained the greatest amount of microbial diversity and that anaerobic treatment resulted in the greatest amount of diversity loss followed by no treatment and aerobic treatment.

***\*Managing Manure to Improve Air and Water Quality.*** M. Aillery, N. Gollehon, R. Johansson, J. Kaplan, N. Key, and M. Ribaud. A Report from the Economic Research Service, USDA. September 2005. [www.ers.usda.gov](http://www.ers.usda.gov).

*Summary:* This report assesses the potential economic and environmental tradeoffs between water quality policies and air quality policies that require the animal agriculture sector to take potentially costly measures to abate pollution. This report also analyzes the potential implementations of adding air quality regulations to existing Clean Water Act regulations in the Chesapeake Bay watershed, where a limited land base increases producers' costs of meeting manure management requirements.

**An Assessment of Technologies for Management and Treatment of Dairy Manure in California's San Joaquin Valley. San Joaquin Valley Dairy Manure Technology Feasibility Assessment Panel. December 2005.**

*Summary:* The Dairy Manure Technology Feasibility Assessment Panel was created in February 2005 to evaluate technologies that have a potential to improve the management and treatment of dairy manure in the San Joaquin valley. This panel evaluated each technology for its environmental and economic performance, based on information supplied by each technology vendor, and considered the quality of supporting data and the development status of the

technology.

***Liquid and Atmospheric Ammonia Concentrations from a Dairy Lagoon during an Aeration Experiment*, Atmospheric Environment 38 (2004) 1523–1533. Authors: Brian Rumburga,\* , Manjit Negera, George H. Mounta, David Yongea, Jenny Filipya, John Swainb, Ron Kincaidb, Kristen Johnson, Laboratory for Atmospheric Research, Department of Civil and Environmental Engineering, Center for Multiphase Environmental Research, Washington State University, Pullman, WA 99164-2910, USA Department of Animal Sciences, Washington State University, Pullman, WA 99164-6351, USA. Received 17 June 2003; accepted 24 November 2003**

*Summary:* Ammonia emissions from agriculture are an environmental and human health concern, and there is increasing pressure to reduce emissions. Animal agriculture is the largest global source of ammonia emissions and on a per cow basis, dairy operations are the largest emitters. The storage and disposal of the dairy waste is one area where emissions can be reduced, aerobic biological treatment of wastewater being a common and effective way of reducing ammonia emissions. An aeration experiment in a dairy lagoon with two commercial aerators was performed for 1 month. Liquid concentrations of ammonia, total nitrogen, nitrite and nitrate were monitored before, during and after the experiment and atmospheric ammonia was measured downwind of the lagoon using a short-path differential optical absorption spectroscopy (DOAS) instrument with 1 ppbv sensitivity. No changes in either liquid or atmospheric ammonia concentrations were detected throughout the experiment, and neither dissolved oxygen, nitrite nor nitrate could be detected in the lagoon at any time. The average ammonia concentration at 10 sampling sites in the lagoon at a depth of 0:15 m was 650 mg l<sup>-1</sup> and at 0:90 m it was 700 mg l<sup>-1</sup> NH<sub>3</sub>-N. The average atmospheric ammonia concentration 50 m downwind was about 300 ppbv. The 0:90 m depth total nitrogen concentrations and total and volatile solids concentrations decreased during the experiment due to some mixing of the lagoon but the 0:15 m depth concentrations did not decrease indicating that the aerators were not strong enough to mix the sludge off the bottom into the whole water-column.

***\*Livestock ammonia management and particulate-related health benefits. McCubbin, D. R., Apelberg, B. J., Roe, S., & Divita, F., Jr. (2002). Environmental Science & Technology, 36(6), 1141-1146.***

*Abstract:* agricultural operations are the largest source of ammonia emissions in the United States and contribute to the formation of ammonium nitrate and ammonium sulfate, two prevalent forms of fine particulate matter. Researchers have found an association between fine particulate matter and a variety of adverse health effects, including premature mortality, chronic bronchitis, hospital admissions, and asthma attacks. Management practices that reduce ammonia emissions may decrease adverse health effects, resulting in significant economic benefits. We estimated the impact of a variety of emission

controls, including diet optimization, alum, and incorporation of manure into the land. The results suggest that relatively modest management policies can have a significant impact on fine particulate formation in the atmosphere. Because of the heterogeneous nature of particulate matter, a key question is the importance of particulate matter size and composition. To the extent that ammonium nitrate and ammonium sulfate contribute to adverse health effects, ammonia management may have significant health implications. Our results suggest that a 10% reduction in livestock ammonia emissions can lead to over \$4 billion annually in particulate-related health benefits.

***Guidance for Evaluating Surface Water Quality Improvements Resulting from Dairy Waste Best Management Practices.*** P. J. Picket. Washington State Department of Ecology Environmental Investigations and Laboratory Services Program, Watershed Assessments Section. January 1996. Publication No. 96-300.

*Summary:* This document provides a general overview of the most significant considerations to be included in the design of a dairy waste Best Management Practices (BMP) evaluation study, and points the direction to more detailed information. It emphasizes the importance of developing a comprehensive project plan, careful planning of the monitoring surveys, and evaluating both the BMP implementation and the water quality affected by BMPs.

***\*Evaluation of potential environmentally superior technology for volatile organic compounds (VOCs) measurements at the EST farms and conventional farms.*** V.P. Aneja, J. Blunden, W. A. Lonneman. (Date and publication source not provided.) North Carolina State University report.

*Summary:* Study to connect VOCs to odor. Did not specify type of operations from which samples were taken.

**\*Vegetative Environmental Buffers to Mitigate Odor and Aerosol Pollutants Emitted from Poultry Production Sites.** Workshop on Agricultural Air Quality, Iowa State University. Online.

[http://www.ncsu.edu/airworkshop/Best\\_Management\\_Practices.pdf](http://www.ncsu.edu/airworkshop/Best_Management_Practices.pdf)

**\*Managing Manure to Improve Air and Water Quality, USDA Economic Research Report 9:** Aillery, Gollehon, Johansson, et al.

**\*Strategy for Addressing Environmental and Public Health Impacts from Animal Feeding Operations,** EPA. Online.

(<http://www.epa.gov/npdes/pubs/astrat.pdf> )

## **OTHER STUDIES**

**\*Combined animal feeding operations, ODA .** Online.

[http://oregon.gov/ODA/NRD/cafo\\_front.shtml](http://oregon.gov/ODA/NRD/cafo_front.shtml)

**\*External Costs of Agricultural Production in the United States, Erin M. Tegmeier and Michael D. Duffy, Dept. of Economics, Iowa State University. Online.**

[http://www.nrem.iastate.edu/class/assets/For460-560/History%20of%20agriculture%20in%20the%20US%20an%20intro,%20Land%20use%20change,%20and/Tegtmeier%20and%20Duffy\\_2004.pdf](http://www.nrem.iastate.edu/class/assets/For460-560/History%20of%20agriculture%20in%20the%20US%20an%20intro,%20Land%20use%20change,%20and/Tegtmeier%20and%20Duffy_2004.pdf)

**Three Mile Canyon Farms, Sustainable dairy practices. Online.**  
[http://www.threemilecanyonfarms.com/our\\_best\\_practices/sustainable\\_dairy\\_practices.html](http://www.threemilecanyonfarms.com/our_best_practices/sustainable_dairy_practices.html)