How much does my farm emit?

OVERVIEW:

Air emissions from animal feeding operations (AFOs) are receiving increasing attention because of concerns related to human and animal health, nuisance and contributions to climate change. All of these concerns lead to the unavoidable question: how much of a pollutant of interest is emitted from a livestock farm?

Authors:

- Zifei Liu
- Wendy Powers

Reviewers:

- **Kevin Janni, Ph.D., P.E.,** Professor and Extension Engineer, Department of Bioproducts and Biosystems Engineering, University of Minnesota
- **Teng Teeh Lim, Ph.D., P.E.,** Assistant Professor, Extension Agricultural Engineer, Commercial Agriculture Program, University of Missouri

What emissions are of interest and why?

Odors

Odors are often a concern for AFO. According to the Michigan Department of Agriculture Right to Farm Environmental Complaint Response Program, the total number of odor complaints from 2007 to 2009 was 175, which exceeded the number of surface water complaints (150). Odors from animal farms are by-products of microbial decomposition of manure and other organic matter. While little is known about the connection between odor and human health, in general, people have a natural aversion to manure odors and at some point may decide that farm odors are a nuisance. Farm odors are comprised of over 200 different chemicals (odorants), including volatile organic compounds (VOC), ammonia (NH3) and hydrogen sulfide (H2S). Odors also include an undetermined number of additional compounds at very low concentrations that cannot be detected with current technologies. These compounds interact with each other in unpredictable ways, and it is extremely difficult to quantify their contributions to odor. The most practical way of measuring odor is still utilizing the human noses and standardized olfactometry evaluation standards.

Ammonia

Ammonia is a gas emitted from AFOs because of the relatively inefficient conversion of feed nitrogen (N) into animal product (meat, egg, and/or milk). The efficiency of N retention in animal production may range from 20 to 40% (Rotz, 2004). Thus, a considerable amount of N is excreted and converted to NH3 by a combination of hydrolysis, mineralization, and volatilization. Atmospheric NH3 is an important pollutant due to its impact on ecosystems. Deposition of NH3 can lead to over enrichment of nutrients and cause eutrophication of surface waters. Ammonia gas can react in the atmosphere with other gases to form fine particulates (ammonium (NH4+) aerosols), which are a health concern. The residence time of NH3-NH4+ in the atmosphere is on the order of days, and they can be transported hundreds of kilometers (NRC, 2002). Therefore, a regional-scale perspective is necessary when considering the environmental effects of NH3.

Hydrogen sulfide

Hydrogen sulfide (H2S) is produced by decomposition of animal manure whenever there are sulfur compounds, anaerobic conditions and sufficient moisture. It is of interest mainly because of health concerns. It is an extremely toxic

MICHIGAN STATE UNIVERSITY | Extension

and irritating gas at high levels, and has a generally objectionable rotten egg odor. Workplace concentration limits of 10 ppm are recommended (NIOSH, 1977). There is also possible chronic health impact from low, long-term exposure. Odors of H2S become detectable in concentrations as low as 0.5 ppb (NRC, 2003).

Particulate matter

Particulate matter (PM), or dust, is of interest because of its health and environmental concerns. The PM emitted from AFOs is highly complex in size, physical properties, and composition. For regulatory purposes, airborne particulates are commonly classified into PM10 (≤10 μm in diameter) and PM2.5 (≤2.5 μm in diameter). Coarse particles (2.5-10 μm in diameter) tend to be deposited in the upper airways of the respiratory tract, whereas fine particles (PM2.5) can reach and be deposited in the smallest airways (alveoli) in the lungs. AFOs can contribute coarse particles directly through animal activity and animal housing ventilation units, and they can also contribute fine particles as the result of a secondary formation process (gas-to-particle conversion, see section on 'Ammonia'). The primary concerns of airborne particles are related to haze/visibility and health effects.

Greenhouse gases

Greenhouse gases (GHG) in the atmosphere can delay heat on the Earth's surface from being lost to space like the glass walls of a greenhouse do ('greenhouse' effect), and contribute to global climate change. The GHGs that are emitted from activities related to animal agriculture include carbon dioxide (CO2), methane (CH4), and nitrous oxide (N2O). The CO2 generated by agriculture is often considered to be biogenic in nature or "carbon neutral" (as contrast to CO2 from fossil-fuel combustion, which adds new carbon to the atmospheric-biospheric circulation system), and therefore sometimes is excluded or deferred in accounting of total GHG emissions.

The effects of airborne pollutants differ in their potential severity and the spatial scales, as elaborated in Table 1. For example, the effects of odor are of interest mainly at local level, while NH3 has relevant impacts mainly on a regional-scale perspective.

How much is emitted?

The challenges

As AFOs increase in size, they have the potential to emit significant quantities of air pollutants. Ammonia emissions from AFOs have been estimated to account for 71% of total man-made NH3 emissions in the US based on EPA's National Emission Inventory estimates (EPA, 2004). Practices to control NH3 emissions from animal agriculture have received considerable attention. The Food and Agriculture Organization of the United Nations (FAO) estimated that the global animal agriculture sector is responsible for 18% of global, human-induced GHG emissions (FAO et al., 2006). However, Pitesky et al. (2009) discredits the FAO claim and reported that only 3% of all GHG emissions in the US can be attributed to livestock production, according to a study of EPA et al. (2009).

Accurate quantification of each AFO's emissions and evaluation of their impacts is not an easy task, because: (1) air emissions from individual farms can vary depending on many factors, such as the species, the number of animals, animal size, animal age, type of feed, manure handling and storage systems, ventilation methods, design and age of structures, farm management and mitigation practices, and climate; (2) direct measurements of AFO emissions are expensive and difficult considering the many uncontrollable factors that may affect measurements, and industry-wide, standard methods to accurately estimate AFO emissions are still under development; and (3) scientific understanding of AFO air emissions and their effects requires the expertise of many disciplines (animal nutrition, agricultural engineering, waste management, atmospheric chemistry, meteorology, air monitoring, toxicology, etc.), and there are very limited research quantifying these effects.

Emission factors

Many local, state, and federal agencies rely on emission factors to develop emission inventories. EPA defines emission factor as the mass of the pollutants emitted per animal unit (AU) per year and they are usually derived from calculations based on measured data. The emission factor for an AFO represents the sum of the annual mean emission rates from housing, manure storage/treatment and

Table 1. Potential Importance of AFO Emissions at Different Spatial Scales (adapted from NRC, 2003)

Emissions	*Global & Regional*	*Local & Property Line*	*Primary Effects of Concern*
Odor	Insignificant	Major	Nuisance, quality of life
VOC	Significant	Minor	Odorous, ozone formation
NH_3	Major	Minor	Atmospheric deposition
H_2S	Insignificant	Significant	Odorous, health
PM	Insignificant	Significant	Health, haze

land application. Emission factors are based on average annual conditions and typically a composite of various animal sizes and types for a particular animal species. Some emission factors currently used in the U.S. are based on those developed for Europe. And many of those emission factors were developed from measurements taken over short periods of time, during which the weather, operating conditions and animal size may not represent the annual average conditions. Also, there are many data gaps on emission factors for subsets of animal species and different production management systems.

The National Air Emissions Monitoring Study (NAEMS)

AFOs are subject to permitting requirements under the Clean Air Act as well as reporting requirements under the Comprehensive Environmental Response, Compensation, and Liability Act and the Emergency Planning and Community Right-to-Know Act if their emissions reach specified thresholds. In order to ensure compliance with these requirements and create a national methodology for estimating AFO air emissions, EPA developed the NAEMS under the Air Compliance Agreement with 2,600 participating AFOs. The NAEMS began in June 2007 to measure air emissions at 24 sites (including all major types of swine, dairy and laying hen facilities) in nine states over a two-year period. Measurements of air emissions included: PM, NH3, H2S and VOC. Within 18 months of the study's completion, EPA was to develop and publish air emission estimating methodologies for types of facilities included in this study. Table 2 presents estimates of AFO emissions from animal houses summarized from the NAEMS report. Data from other literatures were used to fill gaps that were not covered by the NAEMS.

Implications

The raw data collected in the NAEMS, along with data from published scientific journals suggest that there is considerable variation among types of farms (swine, dairy, laying hen, and broiler chickens) and even within a specific type of farm. For example, a 3000 cow dairy farm may emit NH3 from 33 lb/day to 374 lb/day; a 9600 head finishing swine site may emit NH3 from 142 lb/day to 179 lb/day; a 500,000 laying hen barn may emit NH3 around 315 lb/day (manure belt system) or from 699 to 1233 lb/day (high rise system). The Emergency Planning and Community Right-to-Know Act (EPCRA) and the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) required reporting of NH3 and H2S emissions exceeding 100 lb/day. Efforts to regulate air emissions from agricultural sources have been confounded by a lack of information. On Dec. 18, 2008, EPA published a final rule that clarified the limited exemption for air emissions from AFOs. There will be increasing liability for not complying with EPCRA following the effective date (Jan. 20, 2009) announced by EPA. Based on currently available data (house emissions only), the farm sizes that may trigger the need for a farm to report under EPCRA (based on NH3 emission threshold: 100 lb/day) were estimated as following (The sizes of farm that may trigger the reporting need can be smaller than the following numbers when houses are not the only emission source in farm).

- Sows: 1500-7000 head
- Finishing swine: 5400-6800 head
- Dairy: 800-9100 head
- Beef: 200-600 head
- Layers: 41000-160000 head
- Broilers: 85000-96000 head
- Turkeys: around 46000 head

Factors affecting AFO emission

Air emissions from AFOs depend on manure characteristics and how the manure is managed. Emission rates are generally dependent on several factors: whether the manure is handled in a wet or dry state, the presence of an aerobic or anaerobic microbial environment, manure pH and temperature, manure storage time, and the precursors present in the manure (e.g., nitrogen, or sulfur). Wet manure handling systems usually have higher emissions of VOC, H2S and CH4 due to the anaerobic environment, while dry manure handling systems have higher emissions of PM and N2O (EPA, 2001). Higher temperature and longer manure residence time can increase emissions significantly. Higher pH (>7) of manure can result in higher emissions of NH3, while lower pH (<7) can raise emissions of H2S. The NRC (2003) recommended that process based models should be used with mass balance constraints for N-containing compounds, CH4, and H2S to identify, estimate, and guide management changes that influence emissions. Several emission models have been developed to estimate NH3 emissions from AFOs (Ni, 1999; Zhang et al., 2005).

Emission control practices

Proper management and maintenance practices are essential for controlling AFO air emissions. These practices include: adherence to proper nutrient management plans, improved nutrient uptake efficiency and preventing feed spoilage, proper ventilation, drainage and manure removal systems, adhering to loading rates for anaerobic lagoons, regular cleaning of buildings, and quick disposal of mortalities. Stockpile size should be minimized, and if possible, long-term stockpiling of manure should be avoided. Odor decreases exponentially with distance. Establishing a sufficient distance between AFO facilities and neighbors with consideration of prevailing winds can be an effective way to minimize odor nuisance. Also, many odorous compounds are carried on dust particles and therefore, strategies to reduce odors are often related to strategies that reduce dust emissions.

Practices to reduce AFO emissions require a whole-farm approach. The AFOs often include at least 3 emission sources within the operation: a housing facility, a manure storage system, and a land application site. The potential control practices for reducing emissions from these 3 sources are summarized in Table 3. These control practices have varying cost and effectiveness, and some may need more economic or regulatory incentives to be widely adopted on AFOs.

Table 2. Estimates of AFO emissions from animal houses

Species	NH_3		H_2S		PM10		VOC		CH_4		N_2O	
	g/d-head	lb/yr-head	g/d-head	lb/yr-head	g/d-head	lb/yr-head	g/d-head	lb/yr-head	g/d-head	lb/yr-head	g/d-head	lb/yr-head
Swine									5.4-58[e]	4.3-47[e]	0.16-0.4[e]	0.13-0.32[e]
(Sow gestation)	6.5-29.4[a] (13-35%)*	5.2-23.7[a]	0.3-8.5[a] (13-77%)*	0.2-6.8[a]	0.28-0.48[a] (16-35%)*	0.22-0.39[a]	1.8-7.2[a]	1.4-5.8[a]				
(Farrow)	1.9-10.0[a] (28-77%)*	1.5-8.0[a]	3.8-7.6[a] (28-77%)*	3.1-6.1[a]	1.17-1.67[a] (30-67%)*	0.94-1.34[a]	10.4-12.1[a]	8.4-9.7[a]				
(Finishing)	6.7-8.4[a] (12-18%)*	5.4-6.8[a]	0.23-0.85[a] (13-18%)*	0.19-0.68[a]	0.18-0.29[a] (12-17%)*	0.14-0.23[a]	0.6-5.5[a]	0.5-4.4[a]				
Dairy	5.0-56.5[a] (7-28%)*	4.0-45.5[a]	0.9-4.9[a] (7-22%)*	0.7-3.9[a]	0-10.3[a] (8-49%)*	0-8.29[a]	12-197[a]	9.7-158[a]	379[d]	305[d]	16[d]	13[d]
Beef	73-218[b]	59-175[b]	2.1-3.8[b]	1.7-3.1[b]	4.0[g]	3.2[g]	Neg.[g, **]	Neg.[g, **]	98-231[d]	79-186[d]	11-15[d]	9-12[d]
Layers									0.01-0.04[e]	0.008-0.032[e]	0.05-0.06[e]	0.04-0.05[e]
(High rise)	0.63-1.12[a] (6-26%)*	0.51-0.90[a]	0.001[a] (12-14%)*	0.0008[a]	0.016-0.038[a] (9-29%)*	0.013-0.031[a]	0.03-0.34[a]	0.02-0.27[a]				
(Manure belt)	0.28[a] (21%)*	0.23[a]	0.002[a] (17%)*	0.0016[a]	0.008-0.025[a] (22%)*	0.006-0.020[a]	0.03-0.04[a]	0.02-0.03[a]				
Broilers	0.47-0.54[a] (17%)*	0.38-0.43[a]	0.003[a] (18%)*	0.0024[a]	0.044-0.045[a] (15%)*	0.035-0.036[a]	0.10-0.13[a]	0.08-0.10[a]	0.02[e]	0.016[e]	0.03-0.10[e]	0.02-0.03[e]
Turkeys	0.98[g]	0.79[g]	0.004[e]	0.0032[e]	0.03-0.8[g]	0.02-0.64[g]	Neg[g, **]	Neg.[g, **]	0.23-0.26[e]	0.19-0.21[e]	0.14-0.15[e]	0.11-0.12[e]

[a] data was adapted from the NAEMS report (2007-2009). Available at http://www.epa.gov/airquality/agmonitoring/data.html. Accessed on Oct. 2011.

[b] data was adapted from the USDA-CSREES-funded project, "Air Quality: Reducing Emissions from Cattle Feedlots and Dairies," between the years of 2003-2008. Available at http://www.michigan.gov/documents/deq/deq-ess-cafo-worksheet-beefemissions_266548_7.pdf. Accessed on Oct. 2011.

[c] Laguë et al. (2002).

[d] Phetteplace et al. (2001).

[e] unpublished data from MSU (personal communication from Wendy Power's research group).

[g] data are adapted from EPA (2001).

* Uncertainties were calculated based on measurement errors (observed bias and precision from zero/span check) of concentrations and airflows.

** Neg. represents that no emission or negligible emission was observed.

Table 3. Potential emission control practices for AFOs

Source or Location	*Control practices*
Housing facilities	Frequent manure removal (belt transport, scrape or flush) Using bedding/dry manure systems instead of liquid manure systems Chemical additives on animal litter Ration/diet manipulation Oil sprinkling Exhaust air treatment (biofilters, wet scrubbing, etc.)
Manure storage facilities	Using various types of covers (straw, cornstalks, or synthetic) to reduce emissions Urine/feces segregation Proper aeration Biological treatment Acidification
Land application	Direct injection (liquid manure) or rapid incorporation (by plowing or similar techniques) into soil

Conclusion

Determination of AFO emissions and evaluation of their impacts are active areas of research in the US. The NAEMS presented quality-assured emission data and promoted a national consensus on methods and procedures for measuring AFO emissions. Many factors can affect AFO emission rates from an individual farm. Proper management and maintenance practices are essential for controlling of air emissions from AFOs. The raw data collected during the NAEMS, along with data from published scientific journals suggest that there is considerable variation between types of farms and even within a specific type of farm. The size of farms that may be regulated to report emissions was estimated based on these data.

REFERENCES:

EPA. 2001. Emissions from animal feeding operations, EPA Contract No. 68-D6-0011. Available at www.epa.gov/ttn/chief/ap42/ch09/draft/draftanimalfeed.pdf. Accessed on Nov, 2010.

EPA. 2004. Estimating ammonia emissions from anthropogenic nonagricultural sources. Draft final report. Emission inventory improvement program. Available at http://www.epa.gov/ttnchie1/eiip/techreport/volume03/eiip_areasourcesnh3.pdf. Accessed on Nov, 2010.

EPA, L. Hockstad, and M. Weitz. 2009. Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990–2007. Environmental Protection Agency, Washington DC; 430-R-09-004.

FAO, H. Steinfeld, P. Gerber, T. Wassenaar, V. Castel, M. Rosales, and C. de Haan. 2006. Livestock's Long Shadow. Food and Agriculture Organization of the United Nations. Available at http://www.fao.org/docrep/010/a0701e/a0701e00.HTM. Accessed on Nov, 2010.

Laguë, C., T.A. Fonstad, A. Marquis, S.P. Lemay, S. Godbout, R. Joncas and R. Lagacé. 2002. Greenhouse Gas and Odour Emissions from Swine Operations in Québec and Saskatchewan: Benchmark Assessments. Progress report submitted to the Climate Change Funding Initiative in Agriculture program.

National Institute for Occupational Safety and Health (NIOSH). 1977. Criteria for a Recommended Standard -- Occupational Exposure to Hydrogen Sulfide (DHEW/NIOSH Pub. No. 77-158). Cincinnati, OH: National Institute for Occupational Safety and Health.

National Research Council (NRC). 2002. The Scientific Basis for Estimating Air Emissions from Animal Feeding Operations. Washington, D.C.: National Academy Press.

National Research Council (NRC). 2003. Air Emissions from Animal Feeding Operations, Current Knowledge, Future Needs. Washington, D.C.: National Academy Press.

Ni, J. 1999. Mechanistic models of ammonia release from liquid manure: a review. J. Agric. Engng Res. 72, 1-17.

Phetteplace, H.W.; D. E. Johnson and A. F. Seidl. 2001. Greenhouse gas emissions from simulated beef and dairy livestock systems in the United States. Nutrient Cycling in Agroecosystems. 60: 99–102.

Pitesky, M.E., K.R. Stackhouse, and F.M. Mitloehner. 2009. Clearing the air: livestock's contribution to climate change. Adv. Agronomy. 103:1-40.

Rotz, C.A. 2004. Management to reduce nitrogen losses in animal production. J. Anim. Sci. 82:E119-E137.

Zhang, R. H., T. R. Rumsey, J. R. Fadel, J. Arogo, Z. Wang, G. E. Mansell, and H. Xin. 2005. A process-based ammonia emission model for confinement animal feeding operations: Model development. In Proc. 14th Intl. Emission Inventory Conf. Research Triangle Park, N.C.: U.S. EPA, Office of Air Quality Planning and Standards.

Produced by ANR Communications.
[Print line goes here]