AIR QUALITY

Airborne Emissions Sources and Management on Animal Agriculture Production Systems

AIR QUALITY EDUCATION IN ANIMAL AGRICULTURE

Mitigation Strategies: Air Emissions

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This publication discusses airborne emissions from animal operations that can have negative effects on the environment and human health. Identifying emissions sources and developing mitigation practices can help combat these effects.

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Overview

Every state in the United States has animal agriculture production. The type and size of animal agriculture operations vary widely. USDA census data from 2007 showed a continuing trend toward fewer mid-sized operations, and more small and very large farms. Animal agriculture production practices vary with operation size and by location. Production practices and operation size impact airborne emissions, the number of emitting sources, the amount emitted, and the practicality of mitigation practices.

This publication describes ways for livestock operations owners and managers to identify important air emissions sources, assess factors and management practices that impact emissions, and develop self-monitoring, mitigation, and communications plans.

Animal operations, manure treatment facilities, and waste storage facilities can be sources of gases and particulate matter (PM) emissions. Hundreds of gases can be emitted from animal operations and some are odorous. Potentially hazardous gases emitted from animal operations include ammonia (NH_3) and hydrogen sulfide (H_2S). Greenhouse gases emitted include carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O). Some emitted gases react in the atmosphere to produce fine particulates that contribute to haze and impair visibility. PM emissions can include biological particles (e.g., viruses, bacteria, endotoxins, fungal spores, mycotoxins, parasites, and pollens), inorganic particles, and organic particles (e.g., feed, skin, fecal particles). Aerosols is a term used to describe solid and liquid particles in the air (*Figure 1*).

Figure 1. Animal operations can be sources of gas and particulate matter (PM) emissions. (Source: USDA Natural Resource Conservation Service)

Table 1. Partial list of potential gas and particulate matter sources and practices of animal agriculture operations

Source/Practice	**Potential emissions**
Animals	PM, odors, and gases
Open lots or feedlots	PM, odors, and gases
Manure collection, transport, treatment and storage facilities, including litter, bedded packs, scrape alleys, slatted floors, manure pits and tanks, anaerobic lagoons, aerobic lagoons, and manure storage basins or tanks	PM, odors, and gases
Manure agitation and mixing	Gases and aerosols
Land application	PM, odors, and gases
Animal buildings	Ventilation exhaust carrying PM, odors, and gases
Feed storage and processing	VOC and PM
Bedding	PM
Animal mortalities	Odors and gases
Spilled and wash water	Odors and gases
Unpaved (gravel) roads	PM
Disinfectants, vehicles, building materials	VOC, nitrogen oxides (NO_x), and PM

PM: particulate matter; VOC: volatile organic compound

Animal operations can be sources of gas and particulate matter emissions. Gases of primary interest include those that are odorous (hydrogen sulfide, ammonia, volatile organic compounds) and greenhouse gases (methane and nitrous oxide).

Gas and PM emissions from animal operations can have negative environmental and health impacts locally, regionally, and globally. Large particles and aerosols have a local impact because they settle out of the air near the source. Very small particles can have local and regional impacts because they can travel great distances before settling out or being scrubbed out of the air. Odors have a local impact. Gases that react in the atmosphere usually have regional impacts while greenhouse gases have global impacts because they can remain in the atmosphere for a very long time — enough time to travel around the world multiple times.

The health impacts of gases and PM emitted from animal agriculture operations continue to be a research area. The impacts can vary depending on the exposure, which can range from intense (i.e., high concentration) for a short time period (e.g., seconds and minutes) to low-level (i.e., low concentration) for extended time periods (e.g., years or a lifetime). Local, state, and federal regulations may attempt to address impacts from gases and PM ranging from nuisance concerns to human health and environmental impacts.

People, animals, and environments that may be impacted by airborne emissions from animal operations can be called receptors. An inventory of potential local receptors (e.g., nearby neighbors, public areas, schools, roads, and towns) can help identify who and what may be impacted by emissions from your operation and the need for mitigation to reduce the impacts.

Regulations can vary widely depending on local and regional conditions and whether the animal operation is in or near an area that does not meet the National Ambient Air Quality Standards (NAAQS) or a specially protected area (e.g., national parks). States with areas that do not meet NAAQS must develop state implementation plans (SIP) that describe actions to be taken to bring the area into attainment; meeting the NAAQS. States and local units of government may enact additional regulations regarding odors and other airborne emissions that animal operations must meet. Owners and managers of animal agriculture operations are responsible for checking with local, state, and federal environmental regulatory agencies to determine which regulations apply to their operation.

Airborne Emissions Sources

Animal agriculture operations have sources and management practices that affect air emissions. An inventory of potential sources and practices can help owners and managers to assess them and consider effective mitigation practices. *Table 1* lists some sources and the gases or PM emitted. Gases of primary interest include those

Table 2. Factors affecting gas and particulate matter emissions, dispersion, and impacts

Factor	Observations
Number of animals and total quantity of manure, total volatile solids	Emissions generally increase with animal number, total manure quantity, and total manure volatile solids.
Animal species	Nitrogen and moisture content vary with animal species, bedding, manure handling, treatment, and land application method.
pH	pH affects the partitioning between NH_3 and H_2S and their ionized forms (NH_4^+ and HS^-). NH_4^+ and HS^- are nonvolatile.
Animal productivity	High and low producing animals emit at similar rates so emission rates per pound of milk or meat produced are usually less for high producing animals.
Building size	Emissions generally increase as building size and animal numbers increase.
Building design	Emissions generally reduce by reducing emitting surface areas, temperature, and ventilating rates.
Open lot size	Emissions generally increase as open lot size and animal numbers increase.
Manure storage size and time	Emissions generally increase as manure storage size, emitting surface area, and time manure is stored increase.
Manure treatment	Aerated manure is generally less odorous but emits more ammonia. Anaerobic manure emits more odors. Anaerobic digestion usually reduces odor and greenhouse gas emissions if well managed.
Solid manure moisture and oxygen content	Dry solid manure is generally more aerobic and emits fewer odors and CH_4 but more N_2O. Wet solid manure can be anaerobic and emit more odors and CH_4.
Type of land application	Surface-applied manure can emit more than manure injected or incorporated immediately after application.
Distance to receptor	For odors, greater distance between animal operations and receptors generally provides more time for odors to dilute to below detectable levels.
Wind speed and direction	Wind direction impacts the direction emissions go and increased wind speed helps disperse odors. Windy and dry weather conditions may increase PM emissions during and after land application.
Ambient temperature	Higher temperatures favor microbial activity and gas volatility.
Sunny conditions	Sunny conditions help disperse airborne gases and particulate matter vertically in the atmosphere away from ground level receptors.
Terrain	Valleys, hills, and mountains can impact how emitted gases and particulate matter move downwind.
Diet and feed management	Diet and feed management can be used to reduce emissions without impairing performance. By balancing amino acid composition of the diet, odor emissions can be reduced.
Location and management	Owners and operators can locate and manage animal agriculture operations to reduce emissions and address local community concerns through awareness and adaptation of effective mitigation practices.

that are odorous plus H_2S, NH_3, CH_4, N_2O, and volatile organic compounds (VOCs). PM can include pieces of hair or feather, dander, dried manure, feed, bedding, and other biological particles.

A comprehensive inventory of potential sources (i.e., building, open lot, road, feed processing center, manure storage unit, ventilation exhaust) and daily or seasonal management practices (i.e., manure solid separation, pumping, or manure storage agitation) that can emit odors, gases, or particulate matter can help identify the most important sources. A list of important sources may help prioritize sources to mitigate to reduce emissions and improve air quality.

A systems approach must be used to avoid implementing a practice that reduces emissions at one place on the agricultural operation but increases them at another place.

Factors Affecting Gas and Particulate Matter Emissions and Dispersion

Numerous factors and practices impact the amount and type of gases and PM that are emitted, their dispersion, and downwind impacts. Factors that influence emissions include: 1) diet and feed management, 2) manure management system, 3) animal building design and management, 4) land application, and 5) environmental conditions. Gas emissions depend in part on whether microbial breakdown occurs under aerobic or anaerobic conditions, and manure storage time and temperature. PM emissions depend on whether the manure is handled wet or dry. A partial list of factors that affect gas and PM emissions and dispersion is in *Table 2*. These factors and practices can be used to suggest mitigation practices to consider.

A systems approach must be used to avoid implementing a practice that reduces emissions at one place on the operation but increases emissions at another place. For example, covers on manure storage facilities can retain ammonia and hydrogen sulfide in the stored manure, but the gases can be emitted during agitation and land application. Windbreak walls can be used to increase the mixing of clean air and emitted gases and dilute the gases, but the walls do not reduce emissions. The relation between factors, emissions, and impacts is not always known; care must be used when extrapolating limited data.

Air Emissions Management

Owners and managers of animal agricultural operations may choose to manage emissions beyond the regulated requirements to minimize the impact of their operations on the community, region, or globe. Several steps can help owners and managers manage emissions:

1. Identify emissions sources at or near an operation by walking through the operation and creating a list of sources and what is being emitted using *Table 1*. Information about animal numbers, building dimensions, lot sizes, ventilating rates, manure storage characteristics, and sizes could be collected to characterize emissions. The odor offensiveness of each source also should be noted.

2. Identify the location and type of receptors near an operation and where manure is land applied. Receptors include people on public roads, neighboring residences, cities and towns, schools, parks, and other public lands. Receptors experiencing repeated exposure to airborne emissions may incorrectly assume that emissions are always at detectable levels.

3. Use wind rose information to identify which receptors are expected to be downwind of the operation or land application sites. Wind roses for many locations are available online from the Natural Resources Conservation Service (NRCS) at *http://www.wcc.nrcs.usda.gov/climate/windrose.html*.

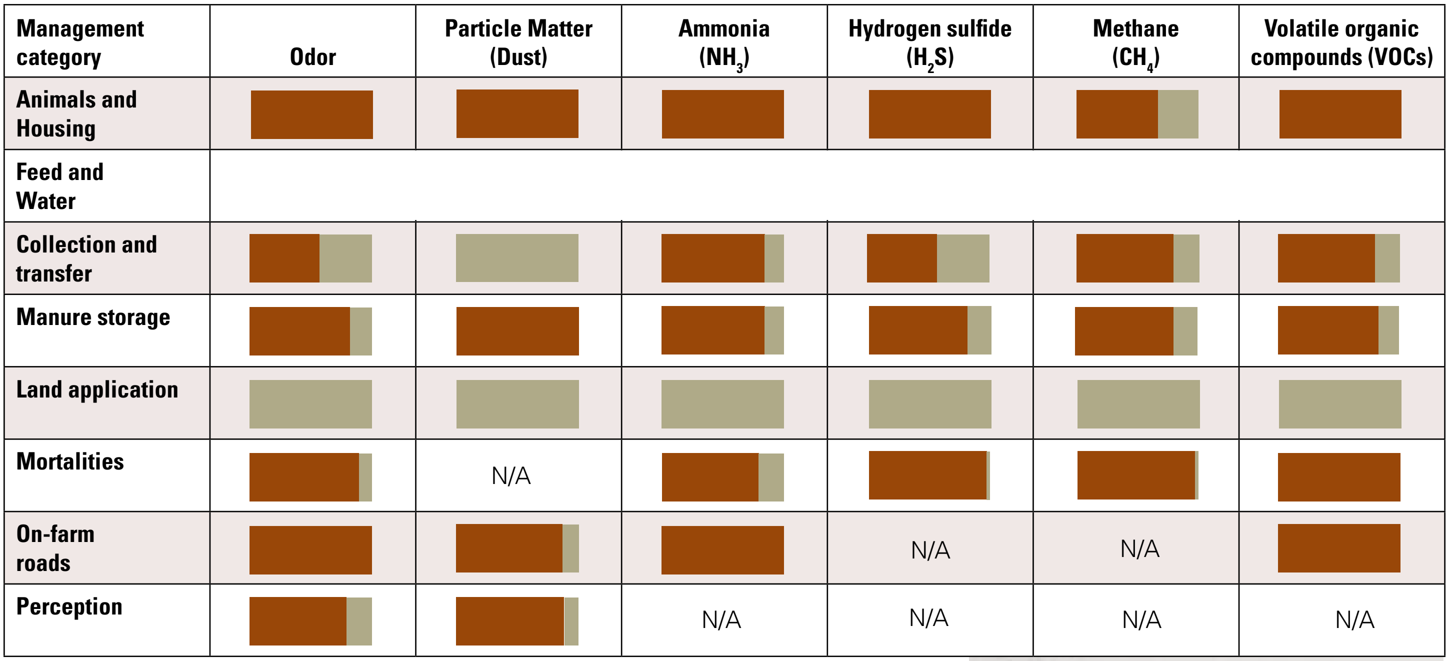
4. Develop a standardized method to measure gas and PM emissions. Various measurement tools are available. Gas and PM samples may be collected from sources of concern and sent to a laboratory for further analyses.

5. Be aware that gas and PM emissions change as a function of daily, seasonal, and climatic variation as well as management practices.

6. Develop effective and applicable control technologies for animal buildings, open lots, manure handling and storage facilities, land application, and animal mortalities. Technologies that increase dispersion of gases also may be used.

Identifying emissions sources and receptors can help assess the potential local impact of an operation. Owners of operations with sources likely to impact many receptors may want to assess their practices to identify ones to modify to reduce emissions.

Figure 2. An example of a National Air Quality Site Assessment Tool report for a beef cattle operation. The brown area represents the relative effectiveness of current management practices. The tan area in each bar represents room for improvement.



National Air Quality Site Assessment Tool (NAQSAT)

An online tool, the National Air Quality Site Assessment Tool (NAQSAT) for Livestock Production Systems, was developed to help owners and operators of animal agriculture operations assess practices that affect air emissions. The tool helps owners and operators identify opportunities to reduce emissions. NAQSAT is available online at *http://naqsat.tamu.edu/*.

NAQSAT considers the influence of diet and feed management; animal housing and management; manure handling, storage, and application practices; mortality management; and internal and nearby road management practices on air emissions. Practices that may not influence emissions but may affect relationships with neighbors are considered and scored separately. Results provide owners and managers with information regarding the extent to which effective practices are being implemented within specific areas and where improvements can be most beneficial. NAQSAT was based on the most accurate, credible data available at the time of its development. It was designed for use by livestock and poultry producers and consultants to provide information and education only. The tool does not provide emissions data and/or regulatory guidance. NAQSAT results outline the degree to which management practices used on an individual operation minimizes air emissions, given the current understanding of the role of management practices and mitigation options on air emissions.

Owners and managers of animal operations may want to establish a protocol for monitoring emissions or receptor site conditions. Training and practice will produce more consistent assessments of self-monitoring.

Monitoring Emissions and Odor Complaints

Owners and managers of animal agricultural operations may want to establish a protocol for monitoring emissions or receptor site conditions (*Figure 3*). This monitoring may include scheduled drives around the operation perimeter, public roads, or visiting receptor sites with a notebook for recording the date, time, location, and the strength and characteristics of odors or other emissions detected. When self-monitoring, it is important to do the monitoring before being exposed to strong odors or other emissions from the operation or other activities. Training and practice will produce more consistent assessments.

Establishing good communications and relations with neighbors and community members can be beneficial. Neighbors and community members can help monitor odors and emissions and provide an informal way to assess emissions. Livestock owners and managers also may want to develop a standard operating procedure for receiving and addressing odor or emission complaints. Complaints should be investigated as soon as possible. Weather conditions, receptor location, farm activities, and potential emissions sources at the time of the event may help owners understand what caused the event and help formulate changes to avoid future complaints. Courteous and respectful communications about a complaint and potential plans of action, if needed, may help mitigate the complaint and enhance community relations.

Mitigation Practices

If owners and managers wish to reduce emissions, they may want to investigate effective research-based mitigation practices. Several mitigation practices are summarized in fact sheets available on the Livestock and Poultry Environmental Learning Center Air Quality website at *http://www.extension.org/pages/15538/air-quality-in-animal-agriculture.* Numerous methods can reduce gas and PM emissions. One effective method to reduce emissions from animal buildings is to remove manure frequently. Another approach may be to check weather forecasts and not apply manure when the wind is blowing toward neighbors or other nearby receptors. A list of control approaches are given in Table 3. NAQSAT may help owners and managers assess the impact of different mitigation practices and the consequences of the change of practice. Not all practices are appropriate in every situation.

Figure 3. A protocol for regular monitoring of odors and other emissions can help a farm establish correlations between certain activities or weather conditions and neighbors likely to be affected. Identifying these patterns can allow farms to initiate proactive communication or mitigation or implement corrective actions more quickly. (Source: USDA Natural Resources Conservation Service)

Table 3. Gas and PM control approaches, and their potential benefits

Control approaches	Observations and comments
Prompt manure and animal mortality removal and disposal	Prompt removal of manure and animal mortalities reduces emissions and odors.
Bedded solid manure	Well-bedded solid manure has less gas emissions than liquid systems but PM may be higher.
Water and vegetable oil application	Controls PM as well as gas emissions. Floors and other building surfaces become oily.
Chemical additives	Consistent effectiveness of chemical additives is not proven.
Ozone added to the building air	A powerful oxidizer and antimicrobial, but it is very toxic and corrosive.
Diet manipulation	Reducing protein content helps reduce NH_3 and other nitrogen-containing compound emissions, but it may affect animal productivity and feed costs.
Wet scrubbers or washing walls	Reduce gas and dust emissions. Used with mechanically ventilated systems.
Biofilters	Effectively reduce gas emissions. Used with mechanically ventilated systems. Limited use for naturally ventilated systems.
Windbreak walls	Helps to dilute gases and enhance dispersion.
Natural windbreaks	Similar to windbreaks. Esthetic. It takes time to establish.
Covers	Synthetic impermeable covers or straw/cornstalks covers can be used. Covered manure can create anaerobic conditions and increase NH_3, H_2S, CH_4, and odorous VOC emissions during agitation and land application.
Solid separation	Reduces the organic load of anaerobic lagoons. Does not have a significant impact on air quality.
Aeration	Reduces odor and gas emissions. Expensive, requires very large amounts of energy.
Composting	Separated solid manure and animal mortalities can be composted. If well managed, composting reduces gas emissions and kills pathogens.
Anaerobic lagoons	Bacterial populations and manure loading need to be in balance to be effective.
Anaerobic digesters	Help reduce gas emissions and can provide heat and electricity. Requires intense management.
Manure additives	Chemical additives can be used to control pH, chemical oxidation, precipitation, and adsorption. More studies and development are needed.
Direct injection during land application	Direct injection under soil helps to reduce gas and PM emissions
Rapid cultivation after land application	If direct injection is not possible (e.g., solid manure), rapid cultivation after application is suggested.
Watch weather forecast	Do not spread manure on windy days. Avoid land application ahead of rain that is expected to produce runoff. Rain after land application may reduce PM emissions.

The Livestock and Poultry Environmental Learning Center Air Quality website has information on several mitigation practices that owners and managers may want to review prior to implementing a practice.

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