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Understanding Air Emissions from Animal Feeding Operations

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Animal feeding operations (AFOs) have long been associated with unpleasant odors. In past years, this has been an accepted fact of farming and has generally been accepted by neighbors. However, as animal production continues to evolve towards larger, more concentrated operations, odor emissions from AFOs have caused persistent public concern and complaints. In addition, dust and other gas emissions have also been a cause for environmental and health concerns. Therefore, air emissions have become a limiting factor for the viability and sustainability of large scale animal productions. A thorough understanding of air emissions from AFOs is necessary for the animal food production industry to effectively address these odor and air quality issues.

Natural air vs. "reality" air

Air, water, and food are three essentials of life. Natural, clean air in the atmosphere consists of 78% nitrogen, 21% oxygen, 0.9% argon, 0.03% carbon dioxide, and a small amount of other gases. Because of industrial, human, and animal activity, some chemicals, dust, and microorganisms are introduced into the air. In reality, the air we breathe is a mixture of natural, clean air and some amount of air pollutants.

Air emissions and air quality

Air emission is defined as, "any physical, chemical, biological or radioactive substance or matter that is emitted into the ambient air surrounding a property and contains air pollutants" (as defined in Section 302 of the Clean Air Act, as amended, 42 U.S.C, 7602). The air emission rate indicates how much air pollutant emissions are emitted into the ambient air within a certain time period. Air emissions directly affect the environment and potentially degrade air quality and may thereby affect health.

Air quality is the concentration of air pollutants in the ambient air. Air quality directly affects people and animal health.

Air emissions from animal feeding operations

The major air emissions associated with AFOs are

- gases (ammonia, hydrogen sulfide, nitrous oxide, methane, and carbon dioxide);
- particulate matter (PM);
- volatile organic compounds (VOCs);
- odor.

Gases

Ammonia (NH_3) is a colorless gas and has a sharp pungent odor detectable at 5 to 18 ppm (parts per million). It is lighter than air and highly soluble in water. It is released during animal excretions of urine, uric acid, and feces; from manure storage; and during manure decomposition. Ammonia comes from the inefficient conversion of feed nitrogen to animal products resulting in nitrogen excretion in feces, urine of pigs and cattle, and uric acid of poultry. Urea in urine can be rapidly hydrolyzed into ammonia and carbon dioxide at the presence of urease enzymes in feces. Uric acid can be degraded to ammonia and carbon dioxide as well. Undigested nitrogen in feces will be mineralized to ammonia.

Hydrogen sulfide (H_2S) is a colorless gas, heavier than air, and highly soluble in water. Hydrogen sulfide has the odor of rotten eggs, detectable at 0.7 ppm. It is generated from anaerobic microbial decomposition of sulfate and sulfur-containing organic matter in animal manure. Some natural water sources contain sulfate and hydrogen sulfide as well.

Nitrous oxide (N_2O) is a greenhouse gas. It results from the microbial processes of nitrification and denitrification of manure nitrogen. Through these processes ammonia is oxidized to nitrate and then nitrate is reduced to nitrous oxide and nitrogen gas (N_2, the form of nitrogen that naturally occurs in air). Nitrous oxide's potential to contribute to global warming is 296 times that of carbon dioxide.

Methane (CH_4) is a natural gas, odorless, and produced by microbial degradation of organic matters under anaerobic conditions. The primary source of methane in livestock operations is ruminant animals, which have a unique digestive process, enteric fermentation, through which a significant amount of methane is generated. Methane emissions also occur during the anaerobic microbial decomposition of manure. The way the manure is managed greatly affects the generation of methane. Liquid systems tend to produce more methane than aerobic solid waste systems. High temperature and moist conditions promote methane production. Methane is a greenhouse gas and can potentially contribute to global warming 23 times more than carbon dioxide.

Carbon dioxide (CO_2) is a part of natural air, odorless, and mainly caused by animal breathing and manure decomposition. Carbon dioxide is a greenhouse gas, which contributes to global warming.

Particulate matter (PM)—dust and liquid aerosols

Particulate matter is a generic term for a broad class of chemically and physically diverse substances that exist as discrete particles (liquid droplets or solids) over a wide range of sizes. Particulate matter is one of the six criteria pollutants regulated through National Ambient Air Quality Standards (NAAQS).

Dust is a common term for particulate matter generated though mechanical processes. Feed is usually the main component of dust in AFO buildings, but it also includes manure solids, dander, and feather and hair particles. Dust is generated through several mechanisms such as animal activity, building ventilation, entrainment of outside soil particles, and the manure drying processes. Liquid aerosol particles are also part of particulate matter and are generated through animal breathing, high pressure washing, and manure handling. Particulate matter absorbs odor and gases and carries bacteria, and thus can potentially be a transmitter of odor and diseases.

Particulate matter is classified as TSP, PM_{10} and $PM_{2.5}$ by the U.S. Environmental Protection Agency (EPA). TSP denotes total suspended particulates. PM_{10} and $PM_{2.5}$ denotes particulate particles with aerodynamic diameters less than 10 and 2.5 micron, respectively. Usually, particles with equivalent aerodynamic diameters less than 100 micron are airborne.

Generally, $PM_{2.5}$ is referred to as fine and $PM_{2.5–10}$ as coarse particles. Particles that are larger than 10 micron are called super coarse particles. Fine particles are of greater health concern because they can easily penetrate deep into human and animal respiratory tracts.

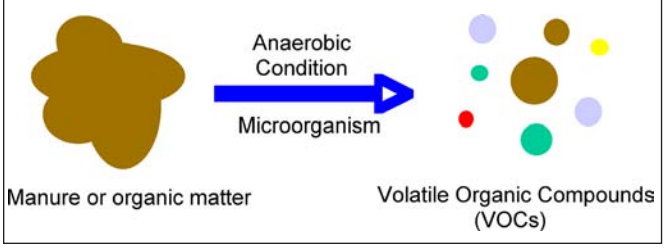
Volatile organic compounds (VOCs)

Volatile organic compounds are chemicals that easily vaporize at room temperature. Anaerobic decomposition and transformation of organic matter and animal waste generates a large number of volatile organic compounds. Volatile organic compounds that are associated with animal feeding operations include organic acids, nitrogen heterocycles, sulfides, amines, alcohols, hydrocarbons, and many more. Some volatile organic compounds are odorous and some are odorless.

Odor

Odor or unpleasant smell is usually associated with animal manure and organic waste decomposition under anaerobic conditions. Organic waste decomposition by microorganism generates a large number of the odorous volatile organic compounds (figure 1). Metabolic processes within the gastrointestinal tract of livestock also generate odor. Odor from confined animal facilities is not caused by a single chemical but rather the result of several gases and more than 330 odorous volatile organic compounds including ammonia and amines, volatile fatty acids, alcohols, and carbonyls, hydrogen sulfide, indoles, skatoles, mercaptans, and many more. Because of the vast number of compounds contributing odor, their individual contribution under various conditions is not yet clear.

Figure 1. Odor generation process (LPES, 2001).



Factors that affect odors are: air temperature, relative humidity, manure accumulation time, ventilation of the production buildings, weather conditions, and dust levels. These factors affect odor generation, transportation, and human perception. High temperatures speed biological processes and can increase odor emissions. High humidity and moisture levels promote anaerobic decomposition of organic compounds and in turn generate more odors. Manure accumulation time affects total odor generation. Weather conditions can affect the spread of odors. Ventilation systems in the production buildings reduce odor levels within the structure but convey them outside where dust, a major odor carrier, can distribute the odor further.

Air emission sources of animal feeding operations

Once we understand how air emissions are generated, it is clear that they are associated with many aspects of animal production including: the animals, feed, manure, and other organic materials. Therefore, air emissions from animal feeding operations are generated by three major sources: animal production facilities including animal buildings and open lots; manure treatment and storage facilities; and land application of animal manure (figure 2). Animal physical activities, feeding, and manure handling are likely the causes of dust and liquid aerosol emissions. Major gases, volatile organic compounds, and odor emissions are associated with manure storage, handling, and land application.

Why care about air emissions?

Air emissions contain air pollutants, which deteriorate air quality inside and outside of animal buildings when air is exhausted through a traditional air exchange process. Air quality inside animal buildings affects the health of animals and human workers and farmers depending on the levels of exposure. Exposure to an air pollutant is determined by the air pollutant

Figure 2. Sources of air emissions from animal feeding operations: (a) animal buildings, (b) manure storages, and (c) manure land applications.

(a) animal buildings

(b) manure storages

(c) manure land applications

concentration and the exposure time. Air quality beyond the property line affects the health of farm neighbors. Good air quality leads to healthier animals and farmers, more productive animal facilities, and happier neighbors.

Dust, ammonia, and hydrogen sulfide emissions from animal feeding operations have the greatest potential for health effects. Dust particles, especially fine dust particles, have significant health effects on humans because the particles can easily penetrate into the human respiratory system and decrease lung function and increase the rate of cardiovascular disease. These conditions can lead to increased rates of hospital admissions as well as mortality. Extensive research documents acute and chronic respiratory disease and dysfunction among workers in swine and poultry buildings from exposure to particulate and gaseous pollutants. Exposure to low levels of ammonia and hydrogen sulfide usually causes eye, nose, and throat irritation. Ammonia exposure level of 5000 ppm for 30 minutes can be fatal. A hydrogen sulfide exposure level of 1000 ppm will cause unconsciousness and death. During manure agitation, hydrogen sulfide levels can easily reach 1000 ppm, especially in the deep pit manure storage systems. OSHA limits occupational NH_3 and H_2S exposure limits to 50 ppm for an eight-hour work period.

The health effects of odorous volatile organic compounds from animal feeding operations are not fully understood and well documented. However, odor is a nuisance and affects the quality of people's life. For example, in North Carolina, a few people living near swine operations have reported an increased rate of headaches and mood changes.

In addition to the health effects, air emissions create significant environmental concerns. Ammonia emission causes environmental acidity, formation of small aerosol particles ($PM_{2.5}$), which affect atmospheric visibility and odor. Hydrogen sulfide emission also contributes to the formation of small particles. Dust and vapor aerosol particles directly contribute to visibility problems and haze formation. Nitrous oxide, methane, and carbon dioxide are all greenhouse gases that can absorb infrared radiation resulting in global warming.

Summary

The major air emissions associated with animal feeding operations are: ammonia (NH_3), hydrogen sulfide (H_2S), nitrous oxide (N_2O), methane (CH_4), carbon dioxide (CO_2), particulate matter (PM), volatile organic compounds (VOCs), and odor. The air emissions are generated by three major sources: animal production facilities including animal buildings and open lots; manure treatment and storage facilities; and land application of animal manure.

Air quality inside animal buildings affects the health of animals and farm workers depending on the levels of exposure. Ambient air quality around the farm affects the health of neighbors. Dust, ammonia, and hydrogen sulfide emissions from animal feeding operations have the greatest potential for health effects. Odor is a nuisance and affects the quality of life, but the health effects are not fully understood and well documented. In addition to the health effects, air emissions create environmental concerns, such as environmental acidity, atmospheric visibility, and global warming.

References

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