Technologies for Odor Control in Swine Production Facilities

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Introduction

Odor complaints are a major environmental challenge for the swine industry. Swine odors generate due to anaerobic decomposition of manure, and from feed materials and wastewater. They are emitted from manure handling, storage, and treatment facilities, as well as swine buildings themselves. Although little is known about the connection between odor and human health, people generally have a natural aversion to manure odors. Swine odors may become a nuisance that interferes with the neighbor's quality of life and property values of nearby communities. Increasingly stringent regulations of odor levels and air emissions can be a limiting factor in the growth of the industry.

Constituents of swine odors

Odors from swine facilities are the human olfactory response to a complex mixture of various odorous gases (odorants), which comprise hundreds of chemicals, including volatile organic compounds (VOC), ammonia (NH_3), hydrogen sulfide (H_2S), etc. (Table 1).

Quantifying the contributions of each odorant to the overall odor intensity is difficult, and their contributions do not accumulate in an additive manner. Odor Units (OU) can be used to describe odor concentration; one OU/m^3 is defined as the amount of odorant(s) in one cubic meter of air at the odor detection threshold. The numerical value of the odor concentration is equal to the dilution factor that is necessary to reach the odor threshold. Most gaseous odorants can be absorbed in and carried by airborne dust in swine buildings, and thus can travel long distances and be re-emitted from the dust.

Ammonia can create strong odors near the manure storage, but it is usually quickly diluted as it travels due to its high volatility. Hydrogen sulfide is an extremely toxic and irritating gas at high levels, and has a generally objectionable rotten-egg odor. Compared to NH_3, H_2S concentrations are generally low in swine houses, but when the manure is agitated, high quantities of H_2S can be released.

A number of factors affect odor control in swine production facilities.

Table 1. Concentrations of odor, VOC, NH_3 and H_2S at the edge of swine facilities in literature

	Odor	VOC	NH_3	H_2S
Median	120 OU/m^3	50 µg/m^3	6 ppm	20 ppb
Range	40 to 960 OU/m^3	1 to 27,700 µg/m^3	0.3 to 16 ppm	2 to 115 ppb

Data are adapted from results of a meta-analysis of air emissions from swine production facilities in North America, part of which is published in Liu and Powers (2013).

Best practices for odor control

Proper management and maintenance practices are essential for odor control in swine production facilities. Many practices that help control odor also improve indoor air quality, thus improving health and productivity for both workers and animals.

Regular cleaning of facilities. Manure and feed particles can attach to floors, walls, equipment, and pigs. Regular and thorough cleaning of all surfaces that may have exposed organic material can reduce odor source. Designing the building and all facilities for easy cleaning is important. Smooth surfaces and easy access to all building areas for cleaning is helpful. Quick disposal of mortalities, adhering to proper manure removal plans and preventing water and feed waste are also important to reduce odor sources.

Ventilation. If buildings are kept clean, the next factor for odor control in swine facilities should be effective ventilation. A proper setting of the minimum ventilation rate is one of the first steps for maintaining a healthy environment for pigs and workers. Minimum ventilation rates should be increased as the pigs gain weight.

Floor design. Floor design has a large impact on dust and odor levels in swine houses. Solid concrete floors with scrapers or small flush gutters have more wet, manure covered surfaces, and tend to emit more odorous compounds than slatted floors. Many swine facilities use either fully slatted or partially slatted floors to allow liquids to drain through to a manure pit or gutter. Hoop swine housing systems with bedding have been shown to have higher NH_3 and H_2S emissions.

Drainage and manure removal systems. Good drainage of manure through a slatted floor reduces odor sources by decreasing the area of waste exposed to ventilation air. Lodging of manure between slats should be minimized. Drainage properties are influenced by slat design, width of openings, and material characteristics such as roughness and porosity. Replacing concrete slats with cast iron, metal or plastic slats has been shown to reduce NH_3 production. Smooth floors have lower emissions. A partially slatted floor with reduced slurry pit area is known to have lower NH_3 emission than a fully slatted floor. A typical flat-scraper system consists of a shallow slurry pit with a horizontal scraper under the slatted floor, but the surface area under the slat is a large emitting area. Pit flushing has been shown to reduce NH_3 emission significantly compared to static pits.

Frequent manure removal. How often and well manure is removed from swine facilities greatly influences the amount of odor generated from swine facilities. Frequency and cleaning ability of the flushing water both have a great impact; for example, frequent flushing for short periods is more effective than prolonged but less frequent flushing. Using fresh water instead of recycled water can further reduce emissions.

Manure storage. Reducing the manure surface area and minimizing air circulation at the manure surface can reduce emissions. Altering the pit design to use sloped pit walls or manure gutters could reduce the manure surface area. The depth of the slurry channels also affects air movements over the slurry surface. A deeper channel has lower emissions. Cooling the floor of the slurry channel also can reduce emissions. Loading rates for treatment lagoons should adhere to proper recommendations.

Technologies for odor control

During the last two decades, various mitigation technologies have been evaluated to reduce odor emissions from swine production facilities. Approaches to control odor and air pollutants can be classified into three categories: ration/diet modification, manure treatment, and capture/treatment and dispersion of emitted gases. Each of these mitigation approaches includes several specific technologies (Table 2).

Diet modification

Reducing dietary crude protein (CP) content can result in reduced excretion of excess nutrients such as nitrogen (N) and can reduce NH_3 and odor emissions from manure. To avoid overfeeding nutrients and enhance nutrient use in animals, dietary composition should be well balanced by matching dietary nutrients with pigs' requirements.

A low-CP diet can be used without effect on animal performance by supplementing with synthetic amino acids (AA) to provide the limiting nutrients in the diet. Up to 40 percent reduction in swine N excretion and a reduction of manure pH have been reported by reducing dietary CP content and supplementing AA. Reduction in urinary N and manure pH both favor reduction in NH_3 emissions. Reducing dietary CP content and supplementing synthetic AA have been shown to be effective in reducing NH_3 emissions from swine operations, but whether these adjustments control odor is uncertain. For every percentage point reduction in dietary CP content (e.g. 14 percent vs. 15 percent dietary CP concentration), a 10 percent reduction in NH_3 emissions from manure can be expected.

Feed additives can be used to increase the digestibility and absorption of nutrients and to influence N excretion

Table 2. Summary of technologies for odor control in swine production facilities

	Technology	Effectiveness	Cost			Comments
			Installation ($ per pig space)	Operation ($ per pig produced)	Overall	
Ration/ diet modification	Low CP content diets and/or feed additives	Moderate	—	<$0.50[a]	Low	Use of synthetic amino acids to reduce diet CP and cost is well established, and is a common industry practice; should be considered as a BMP.
Manure handling and treatment	Solid-liquid separation	Moderate	$22–$27[b]	$2–$3[b]	Moderate to high	More research is needed to develop practical techniques for immediate separation of solids from freshly excreted manure.
	Storage additives	Uncertain	$1.20[c]	$0.50[c]	Moderate	Only works for a short period or specific odorants; need further research to improve reliability.
	Impermeable storage covers	High	$6–$32[d]	-	Moderate	A venting system and a support structure may be needed.
	Permeable storage covers	Moderate	$0.60–$5[d]	-	Low to moderate	Effectiveness highly dependent on how the cover is managed.
	Anaerobic digestion	High	$22–$150[e, f]	-	High[g]	Not economically feasible for small operations; has problem of NH_3 inhibition; has more potentials through co-digestion.
Air treatment	Oil spraying	Low to moderate	~$6[e]	~$0.70[e]	Moderate	Create slick flooring for pigs and people; health concern on oil misting.
	Biofilters	High	$4–$11[e]	$0.05–$0.10[e]	Low to moderate	A promising technology; need careful maintenance.
	Wet scrubbers	Moderate	~$40[e]	~$2[e]	Moderate to high	Need treatment for wastewater; effectiveness on odor depends on solubility of odorants.
	Vegetative environmental buffers	Low to moderate	~$1[h]	$0.05–$0.20[h]	Low	Decreases direct visual viewing of facilities; may decrease natural ventilation in summer; requires planning and time.

Note: CP = crude protein; BMP = best management practices.

[a] Depends on price of synthetic amino acids; the cost of low CP diets sometimes can be lower than regular diets.

[b] Based on a gravity screen system or a gravity belt thickener system; from Walker and Wade. 2009. *Comparison of the effectiveness and economic costs of two production scale polyacrylamide assisted solid/liquid separation systems for the treatment of liquid swine manure*. Appl Eng Agric. 26(2): 299-305.

[c] Based on addition of a commercial manure additive (Alliance); from Heber et al., 2000. *Effect of a manure additive on ammonia emission from swine finishing buildings*. Trans ASABE. 43(6):1895-1902.

[d] Calculation was based on assumption of 2.1 m^2 lagoon area per pig space; adapted from Stenglein et al., 2011. *Covers for mitigating odor and gas emissions in animal agriculture: an overview*. eXtension. Air Quality Education in Animal Agriculture. *http://www.extension.org/sites/default/files/Covers%20overview%20FINAL_1.pdf.*

[e] Data were adapted from resources of eXtension. Available online at *http://www.extension.org/pages/23980/technologies-for-mitigating-air-emissions-in-swine-production*

[f] Calculation was based on installation of an anaerobic digestion system for a capacity of 4,000 pigs.

[g] Cost effectiveness depends on the value of energy recovery from biogas.

[h] Data were adapted from Iowa demonstration cooperators.

and pH of manure. Addition of fermentable carbohydrates can shift N excretion from urine (quickly degradable urea) to feces (slowly degradable microbial protein) and lower feces pH. Addition of acidifying salts can lower urinary pH. These strategies can be combined with a low-CP diet to further reduce NH_3 emission. To reduce odor emissions, dietary sulfur-containing AA should be minimized to meet the recommended requirements. In recent years, co-products of ethanol such as dried distillers grain with solubles (DDGS) have been used to replace a portion of the grain in swine feed. Increased DDGS content in diets can result in increased odor, NH_3, and H_2S emissions.

Manure handling and treatment

Solid-liquid separation of manure is a physical means to reduce odor by mechanical or gravitational separation of solids from liquid manure. Separated liquid will have lower biodegradable organic matter for anaerobic degradation, and separated solids will have much smaller volumes and air-manure contact surface, reducing odor emissions. The N in urine is mainly in the form of urea, and it is converted into volatile NH_3 after it is in contact with feces containing urease. If urine-to-feces contact is reduced, NH_3 formation will be reduced. Effectiveness of solid-liquid separation on odor reduction is highly variable, depending on the time between excretion and separation, and the separation efficiency. Solid-liquid separation should occur within 10 days of manure excretion to prevent decomposition of fine manure particles, and to minimize odor emissions ideally should occur immediately after manure is excreted. Separation is challenging once the feces and urine have been mixed. Common separation units include gravity settling/sedimentation and mechanical screening, which require additional space and maintenance. More research is needed to incorporate the concept of solid-liquid separation into planning and design of the manure handling systems.

Storage additives have been proposed to be added to the manure storage pit, or sprayed on the manure to control odors. Common additives include biological additives such as enzymatic or bacterial products that alter the decomposition so that odorous compounds are not generated; chemical additives such as acid and disinfectants; oxidizing agents; and adsorbent and masking agents. Biological additives are usually odorant-specific, and one additive is not suitable for all odorants. Chemical additives are often effective only for a short period of time, requiring frequent applications and becoming costly. Use of adsorbent and masking agents has had limited success in reducing odors.

Storage covers are being used to reduce odors from liquid manure storage structures and lagoons. Covers are usually classified as permeable [e.g., straw or Geotextile® (a synthetic permeable cover), or both], or impermeable (plastic, concrete, or wood). Both permeable and impermeable floating covers decrease odor emissions by decreasing the solar radiation and direct wind velocity that transports odor constituents. Some permeable covers are thought to act as biofilters on the top of stored liquid manure. Floating permeable covers are simple and inexpensive (\$0.03 to \$0.09/ft^2 for straw, \$0.09 to \$0.22/ft^2 for Geotextile®) but they degrade in a relatively short time period (2 to 6 months for straw due to saturation and sinking; 3 to 5 years for Geotextile®). The performance of straw covers depends on the straw's ability to float on the surface. Buoyancy or support is essential if consistent performance is required. Impermeable covers have higher capital costs (\$0.30 to \$1.40/ft^2) and have a life expectancy as long as 10 years. Impermeable covers usually require a venting system to avoid pressure buildup under the cover due to production of manure gases, and require a system for removing rain and snowmelt. Covering lagoons may also reduce evaporation, requiring either more frequent irrigation pumping or greater lagoon volume.

Anaerobic digestion is a widely applied technology for stabilization of organic waste and production of biogas. It is one of the most effective end-of-pipe methods of reducing odor and air pollutants from swine manure. Anaerobic digestion has been shown to reduce odor emissions effectively. Due to high cost, anaerobic digestion generally is not economically feasible for small operations. Cost effectiveness of anaerobic digestion is dependent on the value of energy recovery from biogas; such as through a contract with an electrical utility company. The high content of NH_3 has been a limitation for digestion of swine manure. Co-digestion of manure with carbon-based substrates recently has renewed interest in enhancing the biogas production efficiency and economic viability of anaerobic digestion.

Air treatment

Oil spraying or sprinkling on floor and pen surfaces at regular intervals reduces dust levels in swine buildings and can reduce odor. However, problems such as oils transforming into a gum and plugging irrigation sprinklers have been observed during manure application. Smaller facilities could apply the oil with a hand sprayer. The oil needs to be applied at low pressure to form relatively large droplets and avoid formation of a fine mist that gets into the worker's and animal's respiratory systems.

Biofilters are made of moist, porous material with a large surface areas in which microorganisms can grow and break down odorants when contaminated air passes through. If properly designed and maintained, biofilters can reduce up to 90 percent of emissions of odor, NH_3, and H_2S from ventilation fan exhausts. Biofilter media moisture content and empty bed residence time (EBRT) are the most important design and operation parameters. A 5-second EBRT has been recommended for adequate odor and H_2S reduction from swine facilities. Desirable media properties include high moisture-holding capacity, and high pore space to maximize EBRT and minimize pressure drop. Examples of biofilter media include peat, soil, compost, wood chips, sawdust, straw, or a combination of different materials.

Performance of biofilters depends on microbial activity, which is complicated and is influenced by temperature, nutrient availability, moisture, pH, and airflow rate. Design and operational parameters such as selection of packing material, maintaining optimum moisture content, weed control, and assessing pressure drop are critical to efficient operation of the biofilters.

In general, recommended operating conditions for biofilters are: moistures of 40 to 65 percent, temperature of 77 to 122°F, and media porosity of 40 to 60 percent. Maintaining operating conditions with a supply of moisture and energy source is important. More than 90 percent of biofiltration problems were attributed to media drying. Horizontal media beds or vertical media beds can be used, depending on surface area and space availability. Leaving the biofilters open to the atmosphere helps reduce pressure drops. Up-flow open biofilters can be constructed at a relatively low initial cost for minimum airflows. Higher construction and operating costs occur if biofilters are designed for high airflows. Pressure drops of less than 60Pa and media depth of 0.25 to 0.45m have been suggested to maintain reasonable fan ventilation efficiency and to prevent excessive drying.

Wet scrubbers have been developed for removing dust and air emissions from ventilation fan exhausts. A scrubber consists of a reactor with a filter made from an inert material (e.g., plastic) with large surface area. The filter is moistened with a sprayer or sprinkler system. Usually, portion of the used water is recycled and the rest is replaced with new water. Exhaust air is forced through the filter to ensure good contact between air and water. The simplest scrubber uses only water, while acid can be added into the recirculated water to improve reduction of NH_3 and make an acid scrubber. Acid scrubbers can reduce 70 to more than 90 percent NH_3, but they are much less effective in reducing typical odors. Effectiveness in reducing NH_3 depends on the amount of acid used and the contact time allowed between air and liquid, while effectiveness in reducing odor also depends on the solubility of odorants.

Wet scrubbers have great potential for adaptation to existing swine facility ventilation fans because they do not cause excessive backpressure to the fans and do not significantly reduce building ventilation airflow. One option to decrease operation costs is to clean only part of the outgoing air, especially for the limited number of days of maximum ventilation. The wet scrubbers can be optimized to benefit both emissions and indoor air quality, and it may also help cooling the air. Removed liquid may be used as a liquid fertilizer.

Vegetative environmental buffers (VEBs) can be established by planting trees around swine facilities. VEBs are thought to reduce dust and odor in two ways. First, VEBs work as a windbreak, enhancing vertical air mixing that results in more dilution and slowing air movement that results in more deposition of dust. Second, VEBs reduce odor and dust as living bio-filters through interception and retention of dust, and adsorption and break down of odor components. The waxy leaf surface area has an affinity for N-based chemicals. VEBs have been shown to reduce downwind concentrations (up to 50 percent reduction in NH_3 and dust, up to 85 percent reduction in H_2S, and 6 to 66 percent reduction in odor). Effectiveness and costs are highly variable and depend on site-specific design. The most effective reduction occurs just beyond the VEBs.

Greater species diversity and a combination of plant growth rates are recommended to make a robust and mature VEB system. A row spacing of 16 to 20 feet is recommended by the Natural Resource and Conservation Service. Appropriate site preparation is critical to the long-term health of tree plantings and contributes to lower tree mortality and faster tree growth. Many problems of VEBs (e.g. high tree mortality) were due to inadequate site preparation. Design of VEBs should consider air circulation near and through animal houses. VEBs are gaining popularity as a promising strategy for mitigating dust, odor, NH_3, and H_2S from farms. Additional advantages of VEBs include visual screen (aesthetics value), improved neighbor relations, and increasing effectiveness over time. The main barrier to adoption of VEBs is lack of technical guidelines.

Odor dispersion and separation distances

Odor decreases exponentially with distance. Properly siting new swine facilities and establishing a sufficient distance between these facilities and neighbors with consideration of prevailing winds can effectively minimize odor nuisance, although this method may not be applicable for existing facilities. Under stable atmospheric conditions (e.g., during the evening hours with calm wind), odor can travel long distances, but generally few swine facilities generate odor that travels more than half a mile. The ideal separation distance between a swine facility and the nearest neighbor to avoid odor nuisance is somewhat subjective. Odor dispersion is a complex process and odor modeling tools are being developed to aid in the siting of new facilities and the expansion of current production sites. Consider the direction of prevailing winds, distance to neighbors, topography, and presence of natural windbreaks when siting new facilities. When planning a new facility in hilly areas, choose a site that is not up-slope from close neighbors to avoid downhill air drainage carrying odors to neighbors.

Summary

The practices and technologies discussed vary in costs and effectiveness. Some have not been evaluated thoroughly, and some may need more economic incentives or regulatory compliance requirements to be widely adopted. Odor reduction research from swine operations is ongoing, and many new technologies are being developed. No single method will completely eliminate odors from swine facilities. When trying to control odor and air pollution, consider the whole farm system and a combination of different practices and technologies to be more effective. Care must be taken to select technologies that are compatible with the management capabilities of the operation to prevent potential failure due to mismanagement.

Take home messages

- Many odorous compounds are carried on dust particles and, therefore, strategies to reduce dust emissions contribute significantly for odor control.
- If urine and feces don't come in contact with each other, NH_3 formation will be greatly reduced.
- H_2S is an extremely toxic and irritating gas at high levels. Although the H_2S concentrations are generally low in swine facilities, a high quantity of H_2S can be released when the manure is agitated.
- When controlling odor and air pollutions, consider the whole farm system and a combination of different methods.

Resources and references

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