INDOOR AIR QUALITY

Controlling Ammonia Gas In Swine Buildings

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Ammonia is the most important gas healthwise found in swine buildings on a day-to-day basis because it can occur at levels high enough to be an irritant to the respiratory system. The recommended maximum gas concentrations suggested by OSHA (25 ppm) are much higher than those suggested by agricultural scientists in Europe (10 ppm).

Many studies have been done over the last several years in Europe and North America to see what can be done to reduce indoor levels of ammonia gas through building design and management practices, Table 1. From these studies, it doesn't seem like any single solution will do the job satisfactorily. Ammonia gas can be significantly reduced if the right things are done simultaneously with available methods and management practices that involve ventilation, manure management, building hygiene, and feed management. Implementing these strategies for ammonia reduction in swine buildings may also reduce other manure gases and odors.

Ventilation
Since additional airflow reduces contaminant levels, ammonia control should be considered when choosing the minimum ventilation rate. Proper ventilation will also require uniform distribution of fresh air into the room. Air circulation fans or distribution ducts improve the mix of indoor air during the winter. Air speeds across manure-covered surfaces should be minimized since the amount of ammonia gas given off by manure is increased with air speed. In one experiment with 165 lb pigs, increasing the air change rate from 2 to 4 air changes per hour increased the quantity of ammonia released from 250 to 350 mg/hour.

The design, location, and management of ventilation inlets can affect air speeds across the floor and over the pit surface. Make sure the inlets are working properly. Most incoming air jets in cold weather should travel across the ceiling first and then down to the floor. By that time, the speed of the fresh air is quite low. Exposed purlins and ceiling fixtures can prematurely detach an air jet from the ceiling and direct it down to the floor at relatively high air speeds. Air inlets that direct incoming air down the wall can therefore increase ammonia emissions into the room.

Ventilation fans that exhaust air directly from the pit reduce manure gas concentrations in the room. When measurements of hydrogen sulfide were taken with pit ventilation during manure agitation, the concentrations were around 150 ppm under the floor and only about 5 ppm above the floor. Without pit ventilation, gas concentrations in the occupied parts of the room would have been dangerously high.

Air exhaust from the pit is not likely to increase air velocities across the manure surface unless it is within two or three diameters away from the discharge hole in a duct or the exhaust fan. Do not overfill a pit under slotted floors—leave at least 12 inches between the bottom of slat supports and the top of the manure.

There will be some ammonia in the room even with well-designed pit ventilation, because ammonia offgassing will also come from urine and manure that accumulates on the slats and other room and equipment surfaces. In some cases, the pit contributes only a minor portion of total ammonia gas. Keep bedding, animal pens, and feeding areas dry to slow down manure decomposition. Ventilate to dry wet areas quickly or add new bedding.

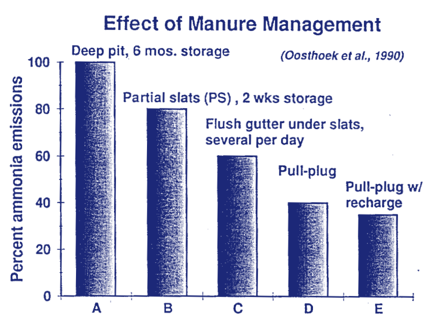
Make sure fresh air doesn't enter the building through the manure pit, e.g. through uncovered pump-out ports. This may happen with wind-induced back pressure on the pit ventilation fans, especially variable-speed pit fans which are extremely vulnerable to wind at low speeds, e.g. < 50% of maximum. Include an air trap in drain lines to reduce backdraft of manure gases from an outside storage.

Another situation which probably occurs more frequently is ventilation air entering and leaving the pit. High speed air, in spite of pit ventilation, will "scour" ammonia gas into the room. Reduce the speed of air entering the pit to avoid this problem. For this reason, duct-type pit ventilation is probably more effective than fans only.

Wet scrubbing reduced ammonia levels by 40% in recent tests. Air was forced up through a shaft filled with thousands of small pieces of inert plastic, against a downward flow of water. It also removed a significant amount of dust particles, bacterial and fungal spores,
and carbon dioxide. Scrubbers can also remove more than 90% of odorous gases; however, the technique is relatively expensive at the present time.

Manure Management
To reduce ammonia levels, avoid storing manure in the building for long periods. The rate of ammonia released from manure increases for storage times longer than about one day. However, there are no further reductions in ammonia release rates for less than one day because so much comes from dirty surfaces (slats, floor, animals, etc.). Ammonia production peaks at three days and again at 21 days. Frequent manure removal helps maintain low ammonia gas levels. Removing manure frequently to reduce ammonia is more effective with poultry than with swine because ammonia formation takes place mainly from the swine's urine. This occurs so rapidly that cleaning intervals in swine buildings would have to be at least half-hourly and the urine, in particular, would have to be removed as completely as possible. This can be done efficiently only with flushing systems since surface scrapers always leave behind a film of urine on the surface, from which emission takes place. European researchers are developing gutter scrapers that automatically separate the liquid from the solids.

Figure 1



Effect of five different manure collection systems on ammonia emissions (Oosthoek et al., 1990).

Researchers in The Netherlands compared the relative ammonia emissions for five different manure collection systems, Figure 1. Total slotted floors with deep pit and long-term storage generated the most ammonia gas. The building with a partially slatted floor and manure pit produced 20% lower ammonia emissions. A partly-slatted floor combined with a sloping floor under the slats from which manure was flushed several times a day was 30% below that for a deep pit. Greater emission reductions were achieved when manure was collected under the slatted floor in about 4 inches of flushing water so manure that falls into liquid and solids are submerged. If the mixture was regularly pumped out and replaced by new flushing liquid (as in pit recharge), the reduction was 60%.

Using the "pull plug with recharge" or "fill and empty" principle of manure removal, the reduction increased to 70%. In this last case, pipes were laid under the floor of the manure pit leading to the outside manure storage. Inlets to these drain pipes were placed at regular intervals in the floor. The drains could be closed with plugs, shut-off balls, or gate valves. When opened, the slurry or flushing liquid flowed out without significant surface turbulence into the outside liquid manure storage. The openings are then closed and new flushing liquid added to the pit. The results of these tests agree with Canadian researchers who stated that there is no advantage to continuous flow gutters, flush gutters, or scraped gutters over fill-and-empty gutters in terms of ammonia production.

Treatment of liquid manure pits to reduce offgassing will have one of the following objectives: (1) to develop an aerobic system, (2) to enhance anaerobic conditions, or (3) to stop microbial activity. Aerobic systems involve the use of aeration pumps and continual agitation, and have high energy and maintenance costs. Additionally, restarting aeration following repairs of the system can cause acutely toxic conditions by stripping out anaerobic gases that have built up in the manure.

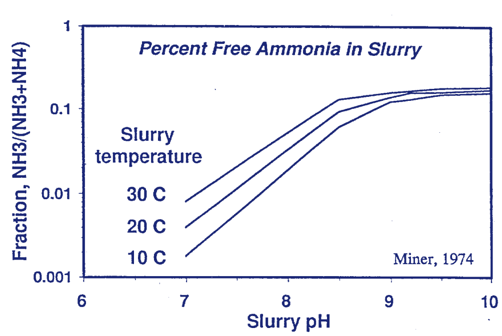
Proper conditions in the pit for anaerobic conditions will reduce the build-up of both solids and toxic gas. Anaerobic conditions are difficult to attain because the loading rates, solids content, ammonia content, buffering capacity, and temperature must all be favorable. Attaining anaerobic conditions is most probable in farrowing buildings where the loading rate is relatively low.

Adding water to the pit reduces ammonia concentration in the slurry by enhancing anaerobic conditions and diluting the concentration of urine. Table 2 shows that manure composition (solids vs. liquid) has a great effect on ammonia emissions.

Microbial activity (and thus gas production) can be retarded by lowering manure pH by adding acidic chemicals. However, reducing microbial activity enhances solids buildup and retards waste stabilization. This increases the potential of water pollution upon land application.

Ammonia is highly water-soluble and can largely remain in

Figure 2

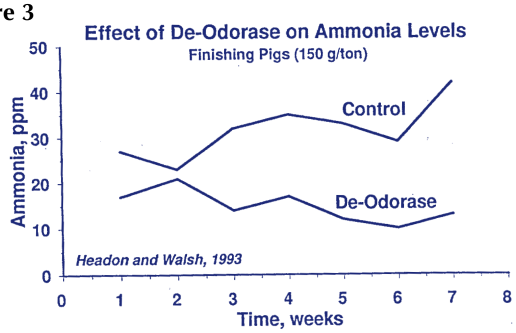


Effect of pH and slurry temperature on the potential for release of ammonia from manure (Miner,1974).

the water in the dissociated form as ammonium. Only that part which is present in the unionized form can become volatile and be released as a gas. The proportion of volatile ammonia to total ammonia concentration in stored manure is a function of manure pH and temperature. The higher the manure pH, the more ammonia is present in the manure in volatile form. Figure 2 shows the relationships between pH, temperature and the potential for release of ammonia gas. The greatest increase in ammonia release occurs at high temperatures between a pH of 7 and 10. Only small quantities are released at a pH<7. Hardly any measurable amounts of free ammonia are present when pH$\leq$4.5 is maintained. Manure pit pH can be lowered by adding nitric acid. Other acids that can be used are hydrochloric acid, sulfuric acid, and phosphoric acid, but nitric acid is the most popular since the other acids affect manure quality. An even distribution of acid is needed and it will increase the nitrogen content of the slurry. Be very cautious in handling concentrated acids.

Chelated copper-sulfate solutions are used to slow down gas-producing bacteria. Other chemicals which are sometimes added to pits include paraformaldehyde, superphosphate, phosphoric acid, and acetic and propionic acid. Crystalline hydrated aluminosilicates (zeolites) are sometimes added to adsorb ammonia in the pits.

Figure 3



Effect of yucca extracts on ammonia gas in a finishing building (Headon and Walsh, 1993).

Well-managed and sufficient amounts of straw bedding will reduce ammonia gas inside the building more than any other solid manure management system. However, the overall emissions to the outside atmosphere are the same due to higher losses during storage and spreading. More dust is found in the building with straw, and fungal spores will dominate airborne microorganisms. The Dutch developed and tested a manure removal system for partially-slotted floor swine buildings in which straw bedding is used in the sleeping area of the pens. A filter net installed beneath the slats collected the solid manure and straw, but allowed the urine and waste water to drain into the pit. Both fractions were daily removed from the barn. Odor was reduced by 50% in the building with the manure solids separation system compared to a similar building with under-slat manure storage.

Building Hygiene

Good building hygiene reduces ammonia emissions by reducing the amount of manure-covered surface area. This includes the pig's skin. The warm body of an animal, when covered with wet manure, makes an area of accelerated bacterial growth and ammonia production which is quickly vaporized into the air by body heat. Keep pigs clean and dry.

Feed Management

Phase feeding with addition of synthetic amino acids can reduce ammonia emissions, Table 3. Less manure through more efficient feed utilization by the animal is a side benefit on top of the nutritional benefits.

Substances added to the slurry (2 oz/100 ft^3 slurry at a cost of $114/gal) or to the feed to reduce the release of ammonia from the manure have not yet been tested over long periods and their effectiveness is still debated. Substances added to the feed appear to have a greater effect than slurry additives. It is very difficult to compare and evaluate reports about the use of these substances since there is presently no established test procedure for them.

Feed additives based on yucca extracts are incorporated in the feed at low levels (4 oz/ton, costs about $10.50/lb). The additional costs are about $1.35-$1.50/ton of grow-finish diets. Yucca extracts bind ammonia and prevents its release. Ammonia levels are reduced by 1/3 to 1/2 according to recent tests, Figure 3.

Table 1. *Summary of strategies to reduce ammonia concentrations in swine buildings.*

1. Ventilation System

A. Increase airflow ratew
B. Modify and control air distribution
   1. Reduce air speeds across manure-covered surfaces
   2. Prevent air from entering room from pit by
      a. Exhausting air from the pit
      b. Slowing down inside air as it enters the pit
      c. Preventing outside air from entering the pit
C. Wet scrub recirculating air (future method)

2. Manure Management

A. Remove manure from building more frequently
B. Separate solids and remove urine (urine contains 2/3 of total ammonia
C. Submerge solids (ammonia is strongly absorbed by water)
D. Treat pit manure
   1. Develop aerobic conditions (expensive, but very effective)
   2. Enhance anaerobic conditions (difficult)
   3. Inhibit microbes (increases outdoor pollution)
      a. Slow down gas-producing bacteria
      b. Reduce or increase manure pH
   4. Bind ammonia gas with yucca extracts
E. Use adequate bedding, e.g. straw, with solid manure systems
F. Maintain good building hygiene
G. Keep animals clean and dry

3. Feed Management

A. Use phase feeding with synthetic amino acids
B. Add yucca extracts to feed to reduce ammonia levels in manure

Table 2. *Volatilization of ammonia from various compositions of stored bovine manure at 30 C.*

Percentage Composition of Manure			Ammonia release
Feces	Urine	Water	(µg)NH3/h
100%	-	-	3.2
-	100%	-	426.0
50%	50%	-	120.0
75%	25%	-	16.0
75%	-	25%	3.4
50%	-	50%	6.6
25%	-	75%	9.7
5%	-	95%	2.2

Table 3. *Nitrogen in slurry of finishing pigs.*

Feeding regime	Slurry Nitrogen
	(lb/pig)
1-phase	10.6
2-phases	9.7
3-phases	9.2
3-phases + amino acids	6.2

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