

Reducing Ammonia Emissions from Poultry Litter with Alum

P. Moore¹, D. Miles¹, and R. Burns²
USDA Agricultural Research Service¹, Iowa State University²

Species: Poultry (Broiler Chicken and Turkey)
Use Area: Animal Housing
Technology Category: Chemical Amendment
Mitigated Air Pollutants: Ammonia

Description:

Ammonia emissions from poultry manure can cause several problems. Often ammonia concentrations in poultry rearing facilities reach very high levels, causing poor poultry performance (Carlisle, 1984). Anderson et al. (1964) showed that ammonia levels as low as 20 ppm compromised the immune system of chickens, making them more susceptible to diseases and damaged the respiratory system of the birds. Feed conversion and weight gains in poultry are also affected by high levels of ammonia (Carlisle, 1984). As a result of all these negative impacts on performance, Carlisle (1984) recommended ammonia concentrations in poultry barns be kept below 25 ppm. High levels of ammonia may also pose a risk to the health of agricultural workers in these facilities (Donham, 2000). In addition, ammonia releases from poultry facilities into the atmosphere can cause environmental problems, such as acid precipitation, fine particulate matter formation (particulate matter with an aerodynamic diameter less than ten microns in size), and nitrogen deposition into aquatic systems.

Because of the negative impact of high levels of ammonia on poultry growth (particularly at an early age), poultry growers often use litter amendments, such as dry or liquid acids, to reduce ammonia volatilization. Moore et al. (1995, 1996) found that aluminum sulfate (commonly referred to as alum) was more effective than other litter amendments for ammonia control. Subsequent work by Moore et al. (1999, 2000) showed that alum additions to commercial broiler houses reduced ammonia emissions for about four weeks, resulting in heavier birds with better feed conversion, lower mortality, and lower condemnation.

Benefits of treating poultry litter with alum include the following (Moore et al., 2003):

- Reduced ammonia levels improve bird performance and make a safer workplace (Moore et al., 2000, 2008),
- Lower litter pH results in reduced pathogen levels in the litter and on bird carcasses (Lines, 2002),
- Lower propane use during winter as a result of reduced ventilation for ammonia control (Moore et al., 1999),
- Reduced phosphorus runoff and leaching (Moore et al., 1999, 2000; Moore and Edwards, 2006),
- Reduced levels of heavy metals and estrogen in runoff (Moore et al., 1998, Nichols et al., 1997), and
- Crop yields are higher because alum-treated litter contains more nitrogen (Moore and Edwards, 2005).

Mitigation Mechanism:

Ammonia volatilization from manure is dependent on several variables, including manure pH, temperature, moisture content and in-house air velocity. Typically, untreated poultry litter has a high (basic) pH; often above 8. At this pH a large percentage of the inorganic nitrogen in litter is in the ammonia (NH₃) form. This form can become a gas and volatilize from the litter. When alum is added, it lowers the litter pH (makes it more acid) by providing a source of acidity or hydrogen ions (H⁺), which react with ammonia to form ammonium (NH₄⁺). Since ammonium is not volatile, the amount of ammonia emitted from the litter decreases. As long as the litter pH stays relatively low (less than about 7), ammonia emissions are controlled. The length of time the poultry litter pH is reduced and ammonia is controlled is dependent on the rate of alum used, with higher rates resulting in a longer period of ammonia control (Moore et al., 2008). The acidity generated by alum applications (lower litter pH) is also responsible for reduced pathogen numbers in alum-treated litter. Phosphorus runoff and leaching are decreased with alum because the aluminum from alum binds with phosphorus in the litter to make an aluminum phosphate compound which is far less subject to runoff or leaching.

Applicability:

This best management practice applies to all poultry operations that have dry litter (broiler, breeder and turkey houses). Typically alum is applied to litter between each flock of birds. If phosphorus control is desired, then the alum should be tilled into the litter to get good interaction of aluminum and phosphorus. There are three forms of alum that are commonly used; dry alum, liquid alum (48.5% alum) and high acid liquid alum (36.5% alum). High acid liquid alum

is preferred in situations where the litter is very dry, since it activates quickly, whereas dry alum is definitely preferred when litter moisture contents are higher. The two forms of liquid alum must be applied by a certified professional applicator, while dry alum may be applied by anyone.

Additions of alum to poultry litter, particularly at higher rates, has been shown to reduce ammonia concentrations by over 75% for the first two weeks of the flock, 50% the third week, 20-30% thereafter (Table 1). Addition of dry alum at the high and low rates reduced average weekly ammonia emissions by 47 and 35%, respectively, compared to the control barns (Table 2). The low rate of liquid alum only reduced average weekly NH₃ emissions by 26%, which indicates that dry alum is probably more effective. The ammonia concentration data reported here are similar to that reported by Moore et al. (2000), however, the reduction in ammonia emissions was not as great as found in earlier work. This is due to a difference in poultry management. Prior research conducted by Moore et al. (2000) utilized smaller birds (1.82 kg at market age) than the current study (2.72 kg at market age). Larger birds produce much more manure, hence more ammonia, which requires more acidity to keep it in the non-volatile ammonium form.

Table 1 – Average weekly ammonia concentrations (ppm) in poultry houses containing untreated and alum-treated litter (from Moore et al., 2008).

Treatment	Week 1	Week 2	Week 3	Week 4	Week 5	Week 6	Week 7	Average
High rate dry alum	9.4	8.5	20.9	25.9	27.0	26.1	20.1	19.7
Low rate dry alum	18.4	22.9	32.2	32.4	33.5	34.2	24.3	28.3
Low rate liq. Alum	14.0	19.8	30.0	28.5	33.6	25.8	23.3	25.0
Control	38.6	38.0	41.0	36.5	38.8	32.3	25.0	35.7

Table 2 – Average weekly ammonia emissions (kg NH₃/wk-house) in poultry houses containing untreated and alum-treated litter (from Moore et al., 2008).

Treatment	Week 1	Week 2	Week 3	Week 4	Week 5	Week 6	Week 7	Average
High rate dry alum	8.6	2.6	31.3	81.5	99.4	185.2	211.3	88.6
Low rate dry alum	15.7	19.0	43.0	91.7	91.8	170.4	259.5	98.7
Low rate liq. Alum	10.2	13.7	42.1	106.7	135.2	232.6	311.7	121.7
Control	45.0	45.9	58.8	115.9	134.7	227.7	314.3	134.6

Limitations:

When litter is treated with alum the litter pH decreases, which reduces ammonia volatilization. However, as broilers add more manure to the litter, the litter alkalinity uses up the acidity provided by the alum, causing the litter pH to increase with time. Hence, alum will lose its effectiveness over time. Since alum begins working as soon as it's applied, birds should be placed 2-5 days after application. Dry alum results in dusty conditions during application; as such, dust masks and goggles should be worn by applicators. Alum has a low pH and can be corrosive to handle, hence gloves should be worn. The cost of alum is variable, dependent upon proximity of the production facility to the supplier.

Cost:

As mentioned earlier, treating poultry litter with alum lowers ammonia levels in poultry rearing facilities and reduces pathogens in the litter and on birds. This results in a healthier environment for the bird, which results in better performance. It also reduces energy consumption, since less ventilation is required. The improvements in feed conversion, weight gains, mortality, condemnation, propane and electricity use, and nitrogen content in litter are shown in Table 3.

Table 3 – Summary of production parameters in alum-treated and untreated poultry houses for a flock of 20,000 broilers grown to 42 days of age. Taken from Moore et al. (1999).

	<u>Alum-treated houses</u>	<u>Control houses</u>
Propane use (L/flock)	3,020	3,357
Electricity use (kW/flock)	7,320	8,330
Weight gains (kg/bird)	1.73	1.66
Feed conversion (kg feed/kg bird)	1.98	2.04
Mortality (%)	3.90	4.20
Percentage of total bird weight rejected at processing (%)	1.50	2.00
Litter N content (%)	3.85	3.45

Each one of these parameters results in a monetary savings to either the grower or the integrator or both. The estimated savings associated with each parameter is shown in Table 4. The total savings to the integrator and the grower were estimated to be \$632 and \$308, respectively. The cost of energy, feed, poultry meat, and nitrogen have all increased since this work was completed. Hence, these benefits would be worth much more now. Likewise, the cost of alum has increased. When this work was done, alum cost approximately \$200/ton. The cost of treating a typical broiler house in this study was \$480, which included the spreading fee. Since the savings to the grower and integrator totaled \$940, the benefit cost ratio was 1.96. Currently, alum cost about \$350/ton.

Table 4 – Savings associated with alum to the integrator and grower per flock of broilers (20,000 four lb birds). Taken from Moore et al. (1999).

	<u>Integrator</u>	<u>Grower</u>
Lower propane use (assumed \$0.32/L)	0	107
Lower electricity use (assumed \$0.006/Kw)	0	6
Heavier birds (\$0.11/kg)	0	150
Improved feed conversion (\$0.001/point-lb bird)	480	????? ¹
Lower mortality (\$0.41/bird for integrator, \$0.35/bird for grower)	24	21
Higher percent total weight accepted during processing (\$0.32/lb)	128	0
Higher litter nitrogen content (assumed \$0.33/kg N)	<u>0</u>	<u>24</u>
Total Savings	\$632	\$308

¹The value of improved feed conversion to the grower varies from company to company.

Implementation:

The information in this report came from two different studies on the efficacy of alum to reduce ammonia emissions from commercial broiler farms (Moore et al., 1999, 2008).

Although alum can be applied to fresh bedding, it is typically applied to “used” bedding between each flock. If phosphorus control is also desired, then the alum should be tilled into the litter to allow optimum interaction between the aluminum in alum and phosphorus in the litter.

Alum application rates are dependent on the desired length of time that ammonia is to be controlled, with higher rates resulting in longer ammonia control. Recommended rates of alum vary from 0.045 to 0.09 kg/bird for an average sized

(1.82 kg) broiler (Moore et al., 2003, 2008). However, heavier birds result in higher manure production and more ammonia emissions. Therefore, when large birds are being grown, the final market weight of the bird should be considered when determining the alum application rate (0.025 to 0.05 kg alum/kg bird). Rates of 0.09 kg/bird have been shown to control ammonia for six weeks, while 0.045 kg/bird only controls ammonia for three weeks.

Reducing ammonia in poultry rearing facilities not only creates a safer environment for agricultural workers, it results in improved poultry performance. Improved weight gains, better feed conversion, lower mortality and condemnation rates have all been demonstrated in houses treated with alum. In addition, energy usage (propane and electricity) is reduced with alum because ventilation requirements are lower during winter months, as a result of lower ammonia levels. The fertilizer value of the manure is also improved, due to a higher nitrogen content, which results in higher crop yields. These agricultural benefits make this practice cost-effective. Environmental benefits of using alum include improved air quality (lower ammonia emissions), improved soil quality (lower levels of soluble phosphorus and reduced phosphorus leaching), and improved water quality (less runoff of phosphorus, estrogen and heavy metals). Hence, this is one of the few cost-effective best management practices that improves air, soil and water quality while enhancing poultry production and agronomic yields.

Technology Summary:

Alum additions to poultry litter reduce poultry house ammonia concentrations and emissions. Alum additions also result in decreased phosphorus runoff, improving water quality. There are three types of alum that can be used in poultry houses; dry, liquid and high acid liquid alum (this paper focuses on dry alum). Typically alum is not applied to fresh bedding material, but added to used bedding prior to each subsequent flock. Ammonia levels in poultry houses receiving alum have been shown to be reduced by over 75% for the first two weeks of the flock, 50% the third week, and 20-30% thereafter. However, the exact length of time that ammonia is controlled is dependent on the rate of alum application, with higher rates resulting in longer ammonia control. Recommended rates of alum vary from 0.045 to 0.09 kg/bird. However, these rates were based on broilers weighing 1.82 kg (4 lbs) at market age. Recently, more companies are growing larger broilers, which result in higher manure production and more ammonia emissions. Hence, for large birds the final market weight of the bird should be considered, with the corresponding range in alum application rates being 0.025 to 0.05 kg alum/kg bird. Alum application rates will be dependent on the desired length of time ammonia is controlled and whether or not controlling P runoff is desirable. Rates of 0.09 kg/bird have been shown to control ammonia for six weeks, while 0.045 kg/bird only controls ammonia for three weeks. Other benefits of alum include heavier birds, better feed conversion, lower condemnation rates and reduced propane use during cooler months as a result of lower ventilation needs. Crop yields are also higher with alum-treated litter because of higher nitrogen litter content. Phosphorus runoff and leaching are also reduced, improving water quality. The cost of alum is dependent upon both the chemical cost, the proximity of the production facility to the supplier, and the charge made by a third party to apply it (if applicable). In the economic evaluation made by Moore et al. in 1999, the cost of alum was \$0.26/kg alum applied (\$0.12/lb), which was equivalent to \$480 for a 1,459 m² house (16,000 ft²) treated with 1,816 kg alum(4000 lb). Savings to the grower and integrator from lower propane and electricity use, heavier birds, improved feed conversion and lower condemnation totaled \$940, resulting in a benefit cost ratio of 1.96. As a result of these benefits, currently 700-800 million chickens are grown with alum each year.

Additional Resources:

Treating Poultry Litter with Alum http://www.uaex.edu/Other_Areas/publications/PDF/FSA-8003.pdf

Treating Poultry Litter with Aluminum Sulfate http://www.sera17.ext.vt.edu/Documents/BMP_poultry_litter.pdf

Treating Broiler Litter with Alum <http://www.utextension.utk.edu/publications/infosheets/Pss318/PSS318.htm>

References:

- Anderson, D.P., C.W. Beard, and R.P. Hanson. 1964. The adverse effects of ammonia on chickens including resistance to infection with Newcastle Disease virus. *Avian Dis.* 8:369-379.
- Carlile, F.S. 1984. Ammonia in Poultry Houses: A Literature Review. *World's Poultry Science Journal.* 40 : 99-113.
- Donham, K.J. 2000. Occupational health hazards and recommended exposure limits for workers in poultry buildings. Pp. 92-109 In (J.P. Blake and P.H. Patterson, eds) *Proc. 2000 National Waste Management Symposium.* Auburn University Press, Auburn, AL.
- Line, J.E. 2002. *Campylobacter* and *Salmonella* populations associated with chickens raised on acidified litter. *Poultry Sci.* 81:1473-1477.
- Moore, P.A., Jr. and D.R. Edwards. 2005. Long-term effects of poultry litter, alum-treated litter and ammonium nitrate on aluminum availability in soils. *J. Environ. Qual.* 34:2104-2111.

- Moore, P.A., Jr. and D.R. Edwards. 2007. Long-term effects of poultry litter, alum-treated litter and ammonium nitrate on phosphorus availability in soils. *J. Environ. Qual.* 36:163-174.
- Moore, P.A., Jr., D.M. Miles, R.T. Burns, D.H. Pote, and W.K. Berg. 2008. Evaluation of ammonia emissions from broiler litter. ILES VIII Animal and the Environment Symposium, Foz do Iquazu, Brazil. (in press).
- Moore, P.A., S. Watkins, D. Carmen, P, DeLaune. 2003. Treating Poultry Litter with Alum. University of Arkansas Cooperative Extension Service. Available at: http://www.uaex.edu/Other_Areas/publications/PDF/FSA-8003.pdf. Accessed on January 14, 2008.
- Moore, P.A., Jr., T.C. Daniel, D.R. Edwards, and D.M. Miller. 1995. Effect of chemical amendments on ammonia volatilization from poultry litter. *J. Environ. Qual.* 24:293-300.
- Moore, P.A., Jr., T.C. Daniel, D.R. Edwards, and D.M. Miller. 1996. Evaluation of chemical amendments to inhibit ammonia volatilization from poultry litter. *Poultry Sci.* 75:315-320.
- Moore, P.A., T.C. Daniel, J.T. Gilmour, B.R. Shreve, D.R. Edwards, and B.H. Wood. 1998. Decreasing metal runoff from poultry litter with aluminum sulfate. *J. Environ. Qual.* 27:92-99.
- Moore, P.A., T.C. Daniel, and D.R. Edwards. 1999. Reducing Phosphorus Runoff and Improving Poultry Production with Alum. *Poultry Science* 78:692-698.
- Moore, P.A., Jr., T.C. Daniel, and D.R. Edwards. 2000. Reducing phosphorus runoff and inhibiting ammonia loss from poultry manure with aluminum sulfate. *J. Environ. Qual.* 29:37-49.
- Nichols, D.J., T.C. Daniel, P.A. Moore, Jr., D.R. Edwards, and D.H. Pote. 1997. Runoff of estrogen hormone 17 beta-estradiol from poultry litter applied to pastures. *J. Environ. Qual.* 26:1002-1006.

Point of Contact:

Philip Moore
 USDA/ARS
 Plant Sciences 115
 University of Arkansas
 Fayetteville, AR 72701
 USA
 479-575-5724
 philipm@uark.edu

As published in the proceedings of:
**MITIGATING AIR EMISSIONS FROM ANIMAL FEEDING
 OPERATIONS CONFERENCE**
 Iowa State University Extension
 Iowa State University College of Agriculture and Life Sciences
Conference Proceedings
Sponsored by:
 NRI Air Quality Extension & Education
 Iowa Farm Bureau Federation
 Iowa Egg Council
 Iowa Pork Industry Center
 Iowa Pork Producers Association
 U.S. Pork Center of Excellence