Reduction of Ammonia Emission from Stored Laying-hen Manure Using Topically Applied Additives: Zeolite, Al^{+}Clear, FERIX-3 and PLT

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Species: Poultry (Laying Hens)
Use Area: Manure storage
Technology Category: Chemical Amendments
Air Mitigated Pollutants: Ammonia

Description:

Ammonia (NH_3) emissions from animal feeding operations not only reduce the fertilizer nitrogen (N) value of the manure, but also contribute to environmental pollution. Hence, cost-effective means to reduce NH_3 loss associated with animal housing, manure storage and land application will have positive economic and environmental impacts.

Laying hen manure in commercial egg production is typically either accumulated in the lower level of high-rise (HR) houses or removed from manure-belt (MB) cage houses to a manure storage facility one to seven times a week. Various mechanisms are involved in conserving N in poultry manure during storage, such as immobilization of ammonium (NH_4^+) through addition of easily decomposable, N-poor materials, adsorption of NH_4^+ and NH_3 onto amendments, and regulation of manure pH (Kirchmann et al., 1989).

Mitigation Mechanism:

Natural zeolite [(Na_4K_4) (Al_8Si_{40}) $O_{96}\cdot 24H_2O$] is a cation-exchange compound that has a high affinity and selectivity for NH_4^+ ions due to its crystalline, hydrated properties resulting from its infinite, 3-dimentional structures (Mumpton et al., 1977). It has been used as an amendment to poultry litter, in anaerobic digesters treating cattle manure, in composting of pig slurry and poultry manure, as an air scrubber packing material to improve poultry house environment. Specific research findings include trapping of > 90% of N loss during 13-d composting of pig slurry by placing 12% (by weight) zeolite and chopped straw mixture in the air stream (Bernal et al.,1993); 44% reduction in NH_3 loss during 56-d composting of poultry manure with a surface application of 38% (by weight) zeolite (Kithome et al., 1999); and 22%–47% reduction in NH_3 emissions over 4-d storage of slurry dairy manure when mixed with 2.5%–6.25% (by weight) zeolite (Milan et al., 1999).

Ammonia volatilization stems from microbial decomposition of nitrogenous compounds, principally uric acid, in poultry manure. Manure pH plays a key role in NH_3 volatilization in that NH_3 generation tends to increase with increasing manure pH. Uric acid decomposition is favored under alkaline (pH>7) conditions, and the effect of uricase—the enzyme that catalyzes uric acid breakdown reaches maximum at pH of 9. Consequently, NH_3 emissions can be inhibited by acidulants that lower manure pH and reduce conversion of NH_4 to NH_3. The acidulants also inhibit bacterial and enzyme activities that are involved in the formation of NH_3, thus reducing NH_3 production. Liquid Al^{+}Clear and dry granular Al^{+}Clear (aluminum sulfate), FERIX-3 (ferric sulfate) and PLT (sodium bisulfate) are acidulants that, when hydrated, produce hydrogen ions (H^+) that attach to NH_3 to form NH_4. As a result of the reaction, the amount of NH_3 emitting from the manure is reduced, thereby reserving the N content of the manure. Al^{+}Clear and PLT had been applied to poultry litter to control NH_3 volatilization (Moore et al., 1995; 1996; Armstrong et al., 2003). FERIX-3 usually is used for industrial and municipal water and wastewater treatment over a wide pH range for color, organics, phosphorous, heavy metal, arsenic and bacteria removal, turbidity, chemical oxygen demand (COD) or biological oxygen demand (BOD) reduction and enhanced coagulation.

Applicability:

Manure in MB houses drops onto a belt beneath cages and is frequently removed from the house, say, 1 to 7 times per week. The removed manure could be transported and stored in manure storage before it is land-applied or composed. NH_3 emission from manure storage primarily depends on the manure handling practices. The manure surface exposed to the air should be limited to control the NH_3 emission. The following practices are suggested to reduce emissions: 1) reduce the surface area of manure piles; 2) keep adding new manure on the old manure pile; 3) keep the temperature of manure storage low if possible. In addition, using topically applied additive can mitigate the NH_3 emission in the manure storage. This publication covers the testing results of using zeolite, Al^{+}Clear, FERIX-3, and PLT as the agents of topical application on nearly fresh laying-hen manure in storage.

Limitations:

Since Al^{+}Clear, FERIX-3 and PLT all have low pH, care must be taken in the material handling (i.e., wearing gloves and eye protection) and to reduce potential corrosion to building components.

Cost:

Table 1 lists the cost comparison of dry Al^{+}Clear, FERIX-3 and PLT, with different application rates. Table 2 lists the costs of the 48.5% liquid Al^{+}Clear and Zeolite. Three application rates for liquid and dry Al^{+}Clear, FERIX-3, PLT, and Zeolite were tested. Since the NH_3 emission reduction from two of the three application rates for Al^{+}Clear, FERIX-3, and PLT had no difference, the costs of higher application rate are not listed for the comparison. The costs listed do not reflect the delivery costs. Because these additives could be applied with the same or similar methods, the comparison does not include the application cost either. The costs of the additives are based on the 50 lb/pack prices of 2008.

Ability of the additives to reduce emissions decreases over time. The costs of the topical application of the agents at end of the 7th day was as following: A) 1.56, 1.81 or 1.83 cent/ft^2-10% NH_3 reduction, respectively, for zeolite applied at 0.6, 1.3, or 1.9 lb/ft^2 (3.1, 6.3, or 12.5 kg m^{-2}); B) 0.25 or 0.36 cent/ft^2-10% NH_3 reduction, respectively, for liquid Al^{+}Clear applied at 0.2, or 0.4 lb/ft^2 (1, or 2 kg m^{-2}) of manure surface area; C) 0.36 or 0.49 cent/ft^2-10% NH_3 reduction, respectively, for dry granular Al^{+}Clear applied at 0.1 or 0.2 lb/ft^2 (0.5 or 1.0 kg m^{-2}); D) 0.46 or 0.42 cent/ft^2-10% NH_3 reduction, respectively, for FERIX-3 applied at 0.1 or 0.2 lb/ft^2 (0.5 or 1.0 kg m^{-2}); and E) 0.45 or 0.60 cent/ft^2-10% NH_3 reduction, respectively, for PLT applied at 0.1 or 0.2 lb/ft^2 (0.5 or 1.0 kg m^{-2}).

Table 1. Comparison of costs and NH_3 emission reductions (mean ± standard deviation) of topical application of Granular Al+Clear, FERIX-3, PLT and Zeolite at different rates on reduction of ammonia emission from stored laying hen manure

		PLT		FERIX-3		Granular Al^{+}Clear	
Appl.Rate	kg/m^2	0.5	1	0.5	1	0.5	1
	lb/ft^2	0.1	0.2	0.1	0.2	0.1	0.2
Cost	Cent per ft^2	2.5	4.9	1.9	3.8	2.3	4.5
	$ per m^2	0.26	0.53	0.21	0.41	0.24	0.48
Cost, cent/ft^2/10% of NH_3 reduction	Day 1	0.29	0.60	0.22	0.43	0.26	0.50
	Day 2	0.28	0.58	0.22	0.43	0.25	0.50
	Day 3	0.28	0.57	0.22	0.44	0.25	0.50
	Day 4	0.30	0.56	0.22	0.44	0.26	0.50
	Day 5	0.34	0.56	0.25	0.44	0.27	0.50
	Day 6	0.38	0.56	0.32	0.43	0.30	0.49
	Day 7	0.45	0.60	0.46	0.42	0.36	0.49

Table 2. Costs and NH_3 emission reductions (mean) of topical application of Liquid Al+Clear and Zeolite at different rates on reduction of ammonia emission from stored laying hen manure

		Liquid Al^{+}Clear		Zeolite		
Appl.Rate	kg/m^2	1	2	3.1	6.3	12.5
	lb/ft^2	0.2	0.4	0.6	1.3	1.9
Cost	cent/ft^2	1.6	3.2	5.6	11.2	16.8
	$/m^2	0.17	0.34	0.6	1.2	1.8
Cost, cent/ft^2/10% of NH_3 reduction	1	0.17	0.35	0.85	1.23	1.75
	2	0.17	0.34	1.04	1.32	1.73
	3	0.19	0.34	1.19	1.45	1.73
	4	0.20	0.34	1.30	1.56	1.73
	5	0.21	0.34	1.40	1.65	1.75
	6	0.23	0.34	1.47	1.72	1.79
	7	0.25	0.36	1.56	1.81	1.83

Implementation:

Eight emission vessels were designed and built for the study (fig. 1). The vessels were placed in an environmentally-controlled room that was kept at a constant temperature of 23°C (73°F). A flow rate of 3 LPM was introduced into each vessel, resulting in an air exchange rate of 11 air changes per hour (ACH). During each trial, new batch of hen manure was collected and mixed before it was randomly assigned to the eight emission vessels. Manure samples with an initial weight of 2.5 kg were used as the experimental units. The 2.5 kg sample was placed in a 3.8-liter (1-gal) container (surface area of 0.02 m^2) that was further placed inside the 19-liter (5-gal) emission vessel.

Figure 1. Emission vessels system used to evaluate efficacy of various manure treatment agents to reduce ammonia emissions from manure storage.

Two vessels were used as controls (i.e., no additives). The five additives tested included natural zeolite, two forms of Al^+Clear (48.5% liquid and dry granular), FERIX-3, and PLT. The additives were topically applied to the manure samples at three dosages of low, medium, or high that corresponded to 2.5%, 5% or 10% of the manure weight (3.1, 6.3 or 12.5 kg/m^2 manure surface area) for zeolite; 1, 2, or 4 kg/m^2 manure surface area for liquid Al^+Clear; and 0.5, 1.0, or 1.5 kg/m^2 for granular Al^+Clear, FERIX-3, and PLT. Two or three trials were conducted to obtain four or six replicates of each treatment. Each trial lasted 7 days.

The NH_3 emission reductions with the medium dosages were in the range of 62% to 93% while NH_3 emission reductions with the low dosages varied from 36% to 82% (Table 3). The NH_3 emission reductions with high dosage were up to 94% during 7-d period. The result shows that there were no significant difference between the high dosage and medium dosage for liquid and granular Al^+Clear, FERIX-3, and PLT after the 7-d storage period ($P=0.5$) (Table 3).

Table 3. NH_3 emission reductions (mean ± standard deviation) of topical applied Zeolite, liquid Al^+Clear, granular Al^+Clear, FERIX-3 and PLT at different rates at the end of the 7-d storage period

Additives	Application dosage		
	Low	Medium	High
Zeolite	36±10% [a]	62±7% [b]	92±2% [c]
48.5% Liquid Al^+Clear	63±11% [a]	89±5% [b]	94±2% [b]
Granular Al^+Clear	81±10% [a]	93±1% [b]	94±2% [b]
FERIX-3	82±5% [a]	86±5% [b]	87±1% [b]
PLT	74±8% [a]	90±3% [b]	92±1% [b]

Table 4. Comparison of NH_3 emission reductions (mean ± standard deviation) of topical applied granular Al^+Clear, FERIX-3 and PLT at different rates at the end of the 7-d storage period

		PLT		FERIX-3		Granular Al^+Clear	
Appl. Rate	kg/m^2	0.5	1	0.5	1	0.5	1
	lb/ft^2	0.1	0.2	0.1	0.2	0.1	0.2
Day	1	86±2%	81±3%	87±3%	89±2%	89±1%	91±1%
	2	91±1%	85±2%	88±3%	89±1%	90±1%	91±1%
	3	89±1%	87±3%	88±3%	87±1%	91±1%	89±1%
	4	82±5%	88±3%	86±1%	86±2%	90±1%	89±1%
	5	74±10%	88±2%	77±6%	86±2%	87±2%	90±2%
	6	65±14%	87±2%	60±16%	88±1%	77±5%	91±2%
	7	56±18%[a]	81± 2%[b]	42±26%[a]	90±1%[b]	63±8%[a]	92±3%[b]

The granular Al^+Clear, FERIX-3, and PLT were selected to compare the NH_3 emission reduction rate over a 7-d storage period. In each trial, two vessels were used as controls and two dosages (0.5 and 1.0 kg/m^2) of Al^+Clear, FERIX-3, and PLT were applied to the remaining six vessels. During the first 3-d period, there was no difference in NH_3 emission reduction rates among all applications. NH_3 emissions of the low application rate vessels started to increase on 4^{th}, 4^{th}, and 5^{th} d for PLT, FERIX-3, and Al^+Clear, respectively (fig. 2). At the end of the 7-d period, the NH_3 emission reduction rates from all vessels with 1.0 kg/m^2 application rate were the same (88%), and they were significantly higher than the reduction rates with the 0.5 kg/m^2 rate (Table 4). There was no significant difference in the reduction rates among the three additives with 0.5 kg/m^2 application rate after 7-d period.

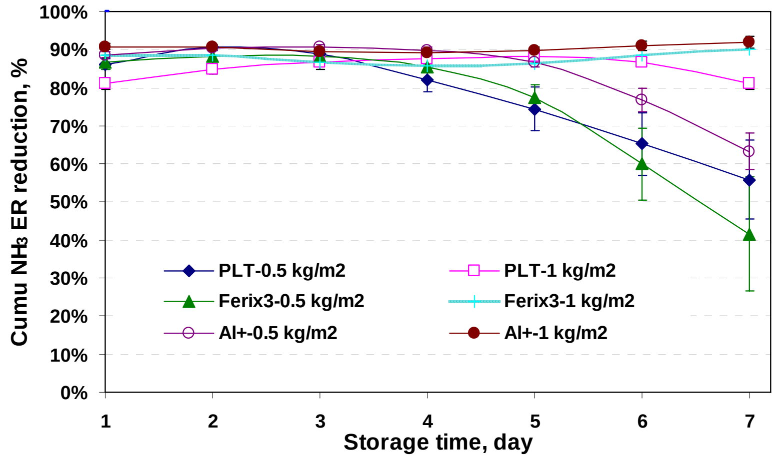

Figure 2. Ammonia emission reductions of ventilated storage of laying hen manure with different rates of topical application of granular Al^+Clear, FERIX-3, and PLT.

Technology Summary:

Ammonia emission from manure storage may be controlled by using physical, chemical and/or biological methods. In this study, five treatment agents, including zeolite, 48.5% liquid Al^+Clear (aluminum sulfate), granular Al^+Clear (aluminum sulfate), granular FERIX-3 (ferric sulfate), and PLT (sodium bisulfate) were topically applied to stored nearly fresh laying-hen manure. Each agent was tested at three application rates, i.e., low, medium and high. The results show that there were no significant difference between the high and medium dosages for Al+Clear, FERIX-3, and PLT after the 7-d storage period. Reduction of NH_3 emission by the topical application of the agents over a 7-day manure storage/testing period was as following: A) 36%, 62% or 92%, respectively, for zeolite applied at 3.1, 6.3, or 12.5 kg m^{-2} (0.6, 1.3, or 1.9 lb/ft^2); B) 63% or 89%, respectively, for liquid Al^+Clear applied at 1, or 2 kg m^{-2} (0.2, or 0.4 lb/ft^2) of manure surface area; C) 56% or 81% respectively, for dry granular Al^+Clear applied at 0.5 or 1.0 kg m^{-2} (0.1 or 0.2 lb/ft^2); D) 42% or 90%, respectively, for FERIX-3 applied at 0.5 or 1.0 kg m^{-2} (0.1 or 0.2 lb/ft^2); and E) 74% or 90%, respectively, for PLT applied at 0.5 or 1.0 kg m^{-2} (0.1 or 0.2 lb/ft^2).

Additional Resources:

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Acknowledgments:

Funding for this study was provided in part by the U.S. Poultry and Egg Association and is acknowledged with gratitude. The experimental equipment was procured with partial funds from the College of Agriculture and Life Sciences Air Quality Research Initiative.

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As published in the proceedings of:

MITIGATING AIR EMISSIONS FROM ANIMAL FEEDING OPERATIONS CONFERENCE

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