Use of Sodium Bisulfate to Reduce Ammonia Emissions from Poultry and Livestock Housing

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Species: Poultry (broiler, layer & turkey), cattle, and horses
Use Area: Animal Housing
Technology Category: Chemical Amendment
Air Mitigated Pollutants: Ammonia & Volatile Organic Carbons

Description:

Ammonia (NH_3), volatile organic compounds (VOCs) and greenhouse gases (GHG) of animal manure origin are produced by microbial activity on the nitrogen and carbon compounds not utilized by the animals for either maintenance or growth and excreted in the feces and /or urine (Carey, et al., 2004; Mutlu, et al. 2005). The release of ammonia from animal manure is dependent upon the amount of ammoniacal nitrogen present, pH, surface area, temperature, and the amount of urease present (Mutlu, et al., 2005; Gay and Knowlton, 2005). Therefore, for any emissions intervention to be effective, it must exploit at least one of these avenues to prevent NH_3 release into the atmosphere (Jongebreur and Monteny, 2001). VOCs are mostly derived from the bacterial degradation of manures soon after excretion (Mitloehner, 2005). Decreasing the bacterial activity in freshly excreted manures should then reduce the production & subsequent emissions of VOCs.

Ammonia emission from animal housing is calculated by multiplying ammonia concentration by airflow. Research and extensive commercial application show that the use of Sodium Bisulfate reduces ammonia emissions two ways: by reducing ammonia flux from the surface of the poultry litter and by reducing ventilation rates. The amount of emissions reduction can be tailored to a specific location by varying the rate, timing, and surface area of SBS application. Other documented benefits are as follow:

- Fuel savings through reduced ventilation
- Improved bird performance i.e. weight, feed conversion, and livability
- Improved animal welfare through better air quality and paw quality
- Reduced respiratory lesions
- Reduced Salmonella & campylobacter incidence of broilers
- Fly control in layer, equine, and calf housing
- Reduction in environmental mastitis
- Substantial return on investment.

Mitigation Mechanism:

Sodium bisulfate (SBS) is a dry, granular acid salt that has been used for many years as a pH reducer in a variety of agricultural, industrial, and food applications. The anti-bacterial properties of sodium bisulfate have been exploited in its application as a toilet-bowl sanitizer (i.e. EPA Reg. #1913-24-AA) and as a preservative in EPA method #5035 “Closed-System Purge-and-Trap & Extraction for Volatile Organics in Soil & Waste Samples,” to prevent microbial activity leading to VOC release. These properties along with the safety and ease of use of SBS have led to its use for ammonia binding (Fig.1) and bacterial reduction in poultry, dairy, and equine manure and bedding materials (Ullman, et al., 2004; Blake and Hess, 2001; Sweeney, et al., 1996; Harper, 2002). The use of SBS reduces ammonia emissions two ways: by reducing ammonia flux from the surface of the poultry litter and by reducing ventilation rates. Sodium bisulfate is hygroscopic. As water is adsorbed into the SBS bead from the humidity in the air, the SBS is dissolved into its Na^+, $H^{+,}$ and $SO_4^=$ constituents.

100 lbs. Of SBS Binds 14 lbs. NH_3				
2 $NaHSO_4$	+ 2NH_4OH $\longrightarrow$	$(NH_4)_2SO_4$	+ Na_2SO_4	+ 2H_2O
100 lbs.	29 lbs.	55 lbs.	59 lbs.	15 lbs.

Figure 1. Binding of Ammonia by SBS to produce Ammonium Sulfate

The hydrogen ion reduces the pH of the litter and protonates the ammonia molecule. The resulting ammonium is then bound by the sulfate component. This formation of ammonium sulfate is non reversible therefore the nitrogen in the litter is not released as the pH increases (Ullman, et al., 2004). The sodium and hydrogen ions of SBS exert negative pressure on the bacterial populations of the litter; decreasing total aerobic population counts 2-3 logs (Pope and Cherry, 2000). This may also serve to decrease urease concentration in the litter for additional ammonia reductions

(Ullman, et al., 2004). Once the ammonia concentration at bird level has been reduced, the poultry houses can be minimally ventilated for relative humidity control as they were designed rather than over-ventilated for NH_3 removal (Czarick and Lacey, 1998). In an ongoing emissions study being conducted at North Carolina State University, the value of whole house application and higher rates of application of SBS on reducing emissions are being demonstrated. In houses using an industry standard rate of 75-lbs/1000 sqft, emissions from brood chamber only application totaled 32.52 kg-NH3 per house for the 14 day brooding period compared to 23.96 kg-NH3 for a whole house application at the same rate for the same time period. Houses receiving 150-lbs of SBS per 1000 sqft in a whole house application had an average total emission for the 14-day brooding period of only 4.9-kg of ammonia.

Applicability:

Sodium bisulfate is suited to a wide variety of animal housing types. SBS has been used successfully in commercial applications in dry litter in both broiler, turkey, and layer facilities, deep bedding of horses, swine, and cattle, and free-stall and dry lot dairy housing systems. Due to the safety of SBS, it can be broadcast in the presence of animals at any time during production unlike most other amendments. This flexibility allows for each operation to tailor SBS usage rate and application timing to meet its unique needs. Any application scheme of SBS will reduce interior ammonia and ventilation rates, thereby reducing ammonia emissions. Specific application rates and application timing are necessary for reduction of food-borne pathogens and fly control purposes.

Reduction of ambient ammonia levels in broiler housing has been demonstrated in a variety of studies. Ammonia levels were 90% lower post PLT application with an average of 6.2 PPM of NH_3 in the treated houses and 62.3 PPM in the control houses. Two weeks after application, the ammonia levels in the treated houses were still reduced by 50% compared to control houses. Two hundred commercial broiler houses were studied in Delaware and Maryland by Terzich (1997) with 100 houses treated with PLT® and 100 houses serving as control. Ammonia levels averaged 127 PPM pre-treatment and were all 0 PPM post-treatment (Table 1). Consequent to the improved air quality, bird performance was significantly improved in the treated houses with better mortality rates, average weights, average daily gain, and percentage of respiratory lesions at processing compared to controls. Fuel usage was also reported to be 43% less in the treated houses. At a cost of $120/house for the PLT® litter treatment, the resulting production increases and fuel savings provided the producer with a substantial return on investment that would support increased

Table 1. Average ammonia levels and litter pH values in 100 houses in which litter was treated with sodium bisulfate compared with 100 houses that were untreated controls.

		Pre-Treatment	Post-Treatment	Time (weeks)						
				1	2	3	4	5	6	7
Ammonia (PPM)	Treated	127	0	0	5	8	15	19	20	18
	Control	119	119	125	125	138	114	128	98	97
Litter pH	Treated	8.5	1.7	2.1	3.4	4.5	5.0	5.5	5.9	6.4
	Control	8.9	8.9	8.7	9.1	8.5	9.3	8.6	8.1	8.9

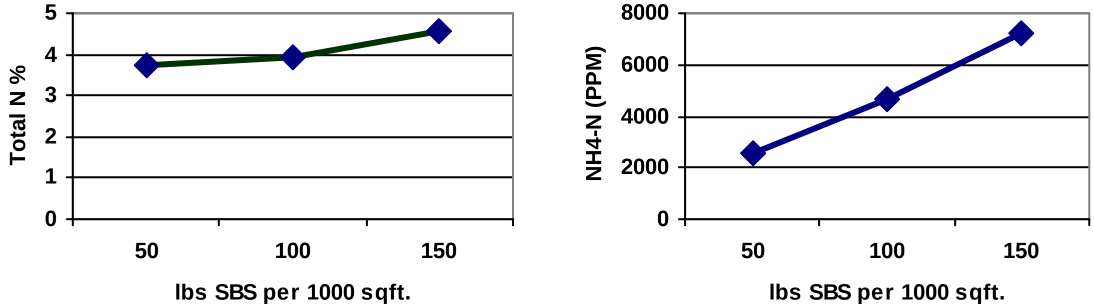
PLT addition rates to maximize ammonia emissions reductions while maintaining producer profitability. Similar ammonia results and improvements in respiratory health through the use of PLT have also been reported (Terzich et al, 1998; Terzich et al, Apr 1998).

By converting ammonia into ammonium sulfate, the use of SBS increases fertilizer value of litter and displaces phosphorus resulting in improved nitrogen to phosphorus ratio. In a study at the University of Georgia, a linear increase is evident in both N and NH_4-N retained in the litter as the amount of PLT applied is increased (Fig. 3 & 4).

Similar results were observed in a commercial egg layer high-rise house where the higher rate of PLT showed the most consistent decrease in ammonia emissions (Patterson et al, 2006). As in the UGA study, manure ammonium (NH_4^+) nitrogen and P_2O_5 were positively altered by treatment group with the high-rate treatment group having the highest level of retained nitrogen and the lowest level of P_2O_5 (table 2).

Limitations:

Sodium bisulfate is only limited by the amount of product applied. Because of the hygroscopic nature of SBS, greater longevity of ammonia reductions will occur at interior housing humidity of 75% or less. This is consistent with the normal and proper ventilation of poultry houses for relative humidity control.



Figures 3 & 4. Amount of retained Total Nitrogen and NH4-N in broiler litter after three flocks of SBS usage on re-used litter.

Table 2. Commercial Layer Manure Analysis after 8 PLT® treatments over a 45-day period

Treatment	Total N (lbs/ton)	NH_4-N (lbs/ton)	Total Phosphate (P_2O_5) (lbs/ton)
Control	38.37[b]	11.08[c]	71.63[a]
PLT-150	40.50[ab]	13.75[b]	62.38[b]
PLT-300	46.08[a]	17.06[a]	55.48[c]
P-value	0.0551	<0.0001	0.0004

Cost:

Multiple field demonstrations of PLT litter amendment use in commercial poultry complexes have also documented the economic benefits of using PLT® litter acidifier. Two field demonstrations completed in 1999 are discussed here.

A commercial broiler complex in the Southeast raising both a large (7.0 lb. or 3.2 kg) and small (4.5 lb. or 2.05 kg) bird evaluated the economic and performance benefits of using litter amendments from January – August 2000. Contract growers were given a choice of either using PLT® or an alum litter amendment (Al+Clear, General Chemical Corp., Parsippany, NJ) at the rate of 2.27 kg/9.29m^2 (50 lbs. /1000 sq ft) in the brood chamber (10,000 sq ft). Eighty-seven percent of the big bird growers and eighty-two percent of small bird growers chose PLT. The remaining thirteen percent of the big-bird and eighteen percent of the small-bird growers chose to use alum in an identical manner to the PLT. A total of 43.9 million birds were evaluated in this demonstration. The variety of housing and management types were similar between the treatment groups. Both the small and large bird groups raised on PLT substantially out performed the birds raised on alum (table3). In a complex of this size, the general rule of thumb used in the U.S. poultry industry is that an improvement in feed conversion of 0.01 lbs. of weight gain / lb. of feed consumption is worth $1 Million per year (Agrimetrics Associates, Inc., Midlothian, VA). The large birds raised on PLT had a feed conversion improved by 0.02 and the feed conversion of the small birds was improved by 0.04 over the birds raised on alum. This reduced performance shown by the birds raised on alum is consistent with production losses due to ammonia exposure reported in the literature (Miles, et al., 2004). This resulted in a net return of $2.7 million /yr over the cost of PLT ($305,000) on improved feed conversion alone in that complex. Additional economic benefit would have also been realized by the grower and the poultry integrator from the increases in weight and livability observed in this trial. Similar results were achieved in another complex in the South-Central part of the U.S. where the same rate of PLT application was compared with untreated litter (table 4). The economic viability of the use of PLT for reducing ammonia emissions is the reason why so many poultry growers have voluntarily adopted this BMP.

Sodium bisulfate costs $0.50/kg ($0.23/lb) and the use of a commercial applicator is approximately $40-45 per house. SBS is safe enough to be applied by the farmer or poultry grower. No additional house preparation is necessary for application. Fuel savings in the first 2-3 days recoup the cost of SBS and its application. Improvements in feed conversion, weight, livability, and paw quality all provide substantial additional return on investment.

Table 3. Production Data from Southeast Commercial Broiler Complex for all flocks raised on either SBS or alum from January-August 2000.

Bird Size	Performance Parameter	SBS	Alum
Large (7.0 lb/3.2 kg)	Total Number of Birds	19, 086, 816	2,846,212
	Livability (%)	88.86[1]	87.66
	Feed Conversion	2.27	2.29
	Weight (lbs)	6.92	6.81
	Condemnation (%)	1.77	2.11
Small (4.5 lb/2.05 kg)	Total Number of Birds	18,091,297	3,869,792
	Livability (%)	93.2	92.06
	Feed Conversion	2.05	2.09
	Weight (lbs)	4.52	4.5
	Condemnation (%)	1.07	1.99

[1] Includes Three flocks with livability <20% due to an ice storm and subsequent roof collapse

Table 4. Production data from South-Central Commercial Broiler Complex for all flocks raised on either SBS or untreated litter from October, 1999-March, 2000.

Performance Parameter	Untreated Control	SBS-Treated
Total Number of Birds Placed	9,101,579	9,921,203
Age (days)	40	39
Weight (lbs)	3.87	3.88
Livability (%)	96.73	96.84
Condemnation (%)	0.34	0.32
Feed Conversion	1.87	1.85

Implementation:

The rate and timing of SBS application are dependent upon the type of housing to be treated, the age of the bedding material in the house, and the age of the animals being housed. Application rates begin at 0.32 kg/m^2 (50-lbs/1000 sqft) for new bedding and litter up to 3-4 flocks old. As the bedding material ages or the manure load increases, the application rate is increased accordingly. Rates of 0.64-0.96 kg/m^2 (100-150-lbs/1000 sqft) are commonly used in commercial field applications. The two drivers of ammonia release from the litter or bedding material are temperature and surface area. Because there is no choice but to have the proper floor temperatures to brood chicks, surface area of the litter particles needs to be minimized to reduce ammonia release from the litter. The amount of SBS needed for a particular grow-out is dependent on the amount of ammonia in the litter and how readily that ammonia is released. The older the birds raised on a farm and the higher the number of flocks raised on the litter, the more fecal material that is present. In other words, 3 flock litter from a house of 45-day-old 1.8-kg birds will have much less ammonia in it than 3 flock litter from a house of 4.2-kg roasters. Also, litter that has been aggressively handled and has maximum surface area will release far more ammonia than litter that has been crusted correctly. Because the amount of amendment used has to be matched to the ammonia load in a particular location, it is important to follow the manufacturer's recommendations when deciding upon the correct rate to use for a specific location and animal type.

In poultry housing, SBS is routinely applied prior to bird placement using a broadcast spreader of some type. Both professional application with a truck mounted spreader and hand application with a push spreader are used depending on farmer preference. Applications in the presence of animals are often done for bacterial or fly control purposes. Because of the safety and efficacy of SBS, producers have maximum flexibility to meet their needs.

Technology Summary:

Sodium bisulfate reduces ammonia and VOC emissions from animal housing areas. SBS binds ammonia converting it to ammonium sulfate thereby retaining nitrogen and increasing fertilizer value of the litter. Total phosphorus is reduced through dilution. Fuel savings and increased animal performance and welfare are realized allowing the mitigation to pay for itself. Research and commercial field studies indicate a 60-90% reduction of ammonia flux form the bedding surface. Application rates vary from 0.32-1.95 kg/m2 depending on the litter age and concentration of manure in the bedding. Sodium bisulfate costs $0.50/kg ($0.23/lb) and the use of a commercial applicator is approximately $40-45 per house. SBS is safe enough to be applied by the farmer or poultry grower. No additional house preparation is necessary for application. Fuel savings in the first 2-3 days recoup the cost of SBS and its application. Improvements in feed conversion, weight, livability, and paw quality all provide substantial return on investment. Additional benefits include reduced incidence of food-borne pathogens, fewer respiratory lesions and ascites, and improved paw quality.

Additional Resources:

SBS & Horses http://www3.vet.upenn.edu/labs/equinebehavior/publixs/Papers/96effect.pdf
Ammonia & Foals http://animalscience.ag.utk.edu/horses/pdf/foalammo.pdf
Sodium Bisulfate as a Litter Treatment http://www.aces.edu/pubs/docs/A/ANR-1208/

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As published in the proceedings of:

MITIGATING AIR EMISSIONS FROM ANIMAL FEEDING OPERATIONS CONFERENCE

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