NATURAL RESOURCES CONSERVATION SERVICE
VIRGINIA ENGINEERING DESIGN NOTE #591 (DN-591)
AMENDMENTS FOR TREATMENT OF AGRICULTURAL WASTE

Chemical or biological additives are used as amendments for the treatment of agricultural waste such as manure, process wastewater, and storm water runoff from lots or other high intensity use areas. This is done by altering the physical and/or chemical characteristics of the waste stream. Purposes for doing this include improving or protecting air quality, water quality, or animal health or altering the consistency of the waste stream to facilitate implementation of a waste management system.

This practice does not include amendments added to the animal feed.

Background

For most farming operations, the dominant agricultural waste is animal manure and urine and associated materials such as bedding, washwater, or runoff. This material is typically spread on farm fields as a fertilizer. As excreted by poultry, the ratio of nitrogen (N) to phosphorus (P) is about 3:1. When these numbers are adjusted to show the plant-available values, the ratio is closer to 1:1. If the waste is not used immediately, some of the nitrogen volatilizes and is lost to the atmosphere as ammonia. At the time of application, the N:P ratio is about 0.5:1. The N:P ratio is different for different animals but the principle is the same.

If this waste is applied at rates required to meet plant needs for nitrogen, the amount of phosphorus is about twice as much as the plant needs. If the waste is applied at a rate that meets the phosphorus need, then nitrogen is under-applied and supplemental nitrogen fertilizer is needed. For many years, farmers in Virginia applied manure in sufficient quantities to meet the nitrogen requirements of the plants. This resulted in a buildup of soil phosphorus to excessive levels. Water moving across the surface or through soils can remove both soluble (dissolved) and particulate (eroded soil particles) forms of soil phosphorus. The transport of particulate and soluble phosphorus can increase the concentration of bioavailable phosphorus in surface waters such as streams, rivers, lakes, and oceans. Algal blooms in the Bay and the resulting deterioration of the water quality have been linked to this process.

To address this concern, Virginia farmers with animal operations are now required to have nutrient management plans that are based on phosphorus. Supplemental nitrogen applications are made, as needed. However, this means that less litter can be applied per acre. This is of particular concern on farms with large animal to acre ratios. Amendments to treat poultry waste can be used to increase the amount of nitrogen in the poultry litter. Some of these amendments also bind the phosphorus into a non-soluble form that is not plant available. In many cases, use of these amendments makes it possible to increase the amount of litter applied to the field

Poultry

For poultry operations, there are both air quality and water quality considerations. In a poultry house, the uric acid and organic nitrogen in poultry manure and spilled feed are converted to

ammonium by microbes in the litter. Depending on the moisture content, temperature, and acidity of the litter, a portion of the ammonium will be converted to ammonia. High temperatures and high pH (alkaline conditions) increase the rate of conversion. Since high ammonia levels are linked to poor bird health and a loss of profits, it is to the grower's benefit to keep ammonia levels as low as possible. Typically this is done by venting the ammonia gases to the atmosphere. This can cause odor complaints. Also, venting the ammonia also vents heat. In the winter, heating costs increase when the house is ventilated to reduce ammonia.

Ammonia released into the atmosphere affects water quality when precipitation transports the ammonia into the water. One way to reduce this effect is to suppress the conversion of ammonium to ammonia. This can be done by applying amendments to the litter which lower the pH. This increases the fertilizer value of the litter by keeping more nitrogen in the plant-available ammonium form. Lower heating and ventilation costs, improved bird health, and fewer odor complaints are added benefits. The environmental benefits are improved air quality and a decrease in the amount of supplemental nitrogen needed on crop fields. There are additional benefits to fish health since ammonia is toxic to fish.

Cattle and Swine
Amendments for cow and hog manure are on the market. If you need to know more about them, please contact the NRCS Environmental Engineer.

Types of poultry litter amendments and their performances
Five types of amendments are available to manage ammonia in poultry litter: acidifiers; alkaline material; adsorbers; inhibitors; and microbial and enzymatic treatments.

Acidifiers
This type of amendment creates acidic conditions (pH less than 7) in the litter, resulting in more retention of nitrogen as ammonium rather than ammonia. The acidity also suppresses the bacteria and enzymes that contribute to ammonia formation, resulting in reduced ammonia production.

Alkaline materials
Materials such as agricultural lime ($CaCO_3$), hydrated or slaked lime ($Ca(OH)_2$), or burnt lime (CaO) increase litter alkalinity (to a pH greater than 7) and convert more of the ammonium in the litter into ammonia gas. Combining ventilation and heating with the application of alkaline material between flocks can lead to the venting of large amounts of ammonia, which will result in lower ammonia levels later when the chicks are placed in the house. Adding alkaline materials may also reduce soluble phosphorus levels in the litter. When this method is used, ammonia is released into the atmosphere and the fertilizer value of the litter is decreased. The released ammonia decreases air quality, increases odors, and adds nutrients to the surface water when the ammonia gas comes in contact with water. In addition, if the alkaline material is not used up during the layout period between flocks, ammonia levels in the house may increase when fresh manure is added to the litter.

Adsorbers
Naturally occurring materials like clinoptilolite (a type of zeolite, a natural clay mineral) and peat tend to adsorb ammonia (bind on the surface instead of absorb). However, results are mixed for clinoptilolite with some researchers reporting large increases in ammonia levels and others having modest declines. The use of peat as litter decreases ammonia levels but is unlikely to be cost-effective when compared to the use of wood shavings or other easily accessible materials.

Inhibitors
Inhibitors slow the conversion of uric acid and urea to ammonia by inhibiting enzymes and micro-organisms. Inhibitors are currently too expensive and too easily broken down to be practical or economical to growers.

Microbial and enzymatic treatments
This treatment consists of adding beneficial microbes and enzymes that create the right environment in the litter to convert uric acid and urea rapidly into ammonia. Venting the produced ammonia during layout will result in lower ammonia levels when the chicks are placed in the house. Company research indicates reduced ammonia levels, improved bird weight, and reduced mortality and crust loads. However, these claims have not been validated by independent research at this time. Also, venting ammonia into the environment degrades air quality.

Summary - poultry litter amendments
There are many production benefits to the use of amendments to poultry litter and, for this reason, they are commonly used in many places. However, there are air and water quality benefits that can be gained also. Acidifiers, the most widely used type of amendment, lessen ammonia levels by converting ammonia to ammonium. Reducing ammonia losses will also improve the fertilizer value of the litter. Odor complaints from neighbors may be reduced. Nitrogen loading to surface water will also be reduced when ammonia production is suppressed.

The three most common acidifers, alum, PLT, and Klasp, have similar effects on ammonia suppression when applied at similar rates. Alum and Klasp also have the effect of chemically binding phosphorus in a non-soluble form. This limits the amount of soluble phosphorus in the soil and in runoff water, which limits leaching to groundwater and phosphorus loading to streams. Poultry Guard is also an acidifier but research by Delaware NRCS has found this product to be less effective than the ones mentioned above at achieving the desired air and water quality improvements.

When litter is treated with one of these products, it affects the nutrient content of the litter. In most cases, litter can be applied at higher rates that more closely address the nitrogen needs of the crop without adversely affecting the phosphorus levels in the soil. Treated litter should be tested to determine the land application rates needed to meet the Nutrient Management Plan.

The properties of the three primary products used for air and water quality improvements are listed in Table 4 of the Virginia Conservation Practice Job Sheet (VA-591-JS) *Amendments for Treatment of Poultry Wastes*. A summary of the properties of the acidifiers and alkaline materials is listed in Table 1.

Table 1. Properties of acidifiers and alkaline materials.

Active Ingredient	**Effects on Litter Nutrients**	**Mode of Action**	**Precautions**	**Other effects**
Acidifiers				
Alum. Aluminum sulfate **Al^+ Clear** [$Al_2(SO_4)_3 \cdot 14H_2O$], Liquid Al^+ Clear A7 Acid + Liquid Alum – 7% H_2SO_4 + 36% $Al_2(SO_4)_3$-$14H_2O$	Increases ammonium nitrogen. Decreases water-soluble phosphorus in the soil but does not affect the total phosphorus in the soil. Soluble and total phosphorus in runoff water are reduced because some of it has precipitated out. There are reduced concentrations of arsenic, copper, iron, and zinc. No effects on soluble aluminum, potassium, or sodium. Calcium and magnesium concentrations increased.	Lowers litter pH thereby conserving ammonium-N. Aluminum binds phosphorus, reducing its immediate availability to crops.	No known limitations of this practice when the alum is applied at reasonable rates. Excessive amounts of alum (more than 30% by weight) would lower the pH and increase the phosphorus availability. There is no reason to apply alum at this rate commercially.	* Reduces phosphorus runoff from fields by 75%. * Reduces pathogen numbers. * Bird health and performance improves with decreases in ammonia. * Better worker environment and less facility corrosion. * Less air pollution. * Fewer odor complaints. * Reduced ammonia gas generation will reduce energy costs. * May be able to apply treated litter at higher rates. * More balanced fertilizer. * Improved water quality by reducing potential of phosphorus and heavy metals to reach streams.
Klasp™ ferric sulfate [$Fe_2(SO_4)_3 \cdot NH_2O$];	Ammonium nitrogen will increase in the litter to the extent that ammonia gassing is reduced. Water-soluble phosphorus will be bound by the iron in the soil but does not affect the total phosphorus in the soil. Soluble and total phosphorus in runoff water are reduced because soluble phosphorous is bound in an iron precipitate. Bound iron will eventually become available as	Lowers litter pH thereby reducing ammonia off-gassing. The ferric iron in **Klasp™** binds phosphorus, reducing its immediate availability to crops. There is evidence that continued use of **Klasp™** on built up beds will reduce the available moisture in the litter which can limit microbiological growth.	No known limitations of this practice when **Klasp™** is applied at recommended and reasonable rates. Excessive and un-commercial applications would eventually lower the litter pH and increase the phosphorus availability.	* Bird health and performance improves with decreases in ammonia. * Better worker environment and less facility corrosion. * Reduced ammonia gas generation will reduce energy costs. *** Klasp™** binding with phosphorous can reduce phosphorous leaching from fields and polluting streams

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	phosphorous is released over time. Availability of soluble forms of arsenic and other metals should be reduced. No effects on soluble aluminum, potassium, or sodium			* Drier litter can reduce pathogen numbers. * **Klasp**™ may be applied to litter at higher rates to achieve enhanced treatment effects. * Fertilizer N value enhancements are possible. * Improved water quality by reducing potential of phosphorus and heavy metals to reach streams. * Less air pollution and fewer odor complaints.
Other Iron-containing amendments—ferrous sulfate [$FeSO_4 \cdot 7H_2O$]; ferric chloride ($FeCl_3$); and ferrous chloride ($FeCl_2 \cdot 2H_2O$)	Increases ammonium-N. Decreases water-soluble phosphorus, but does not affect total phosphorus.	Lowers litter pH thereby conserving ammonium-N. Iron binds phosphorus, reducing its immediate availability to crops.	Iron toxicity to poultry is possible with high application rates of ferrous sulfate products.	* Bird health and performance improves with decreases in ammonia. * Better worker health conditions. * Less air pollution. * Fewer odor complaints. * Reduced energy costs. * More balanced fertilizer.
Phosphoric acid	**Increases water-soluble phosphorus** and total phosphorus and ammonium.	Decreases litter pH thereby conserving ammonium-N. Adds phosphorus directly as component of active ingredient.	The phosphorus content of litter is becoming the nutrient which most limits land application. Adding phosphorus to the litter will increase the number of acres needed for land application. **Not recommended where phosphorus loading is a concern.**	* Bird health and performance improves with decreases in ammonia. * Better worker health conditions. * Less air pollution. * Fewer odor complaints. * Reduced energy costs. * More balanced fertilizer.
Weak acids – oxalic,	May increase ammonium nitrate	Decreases litter pH thereby	None cited.	* Bird health and performance

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propionic, citric, or boric acid	in litter. Substantial changes in water-soluble phosphorus are unlikely.	conserving ammonium-N.		improves with decreases in ammonia. * Better worker health conditions. * Less air pollution. * Fewer odor complaints. * Reduced energy costs. * More balanced fertilizer.
Poultry Guard™ -- Acidified clay; 36% sulfuric acid (H_2SO_4) soaked in a type of clay	Increases ammonium-N. Effects on loss of phosphorus and soluble metals was not evaluated. However, it is unlikely to be as effective as alum in reducing the loss of phosphorus and soluble metals because of its chemical composition.	Decreases litter pH thereby conserving ammonium-N.	None cited.	* Bird health and performance improves with decreases in ammonia. * Better worker health conditions. * Less air pollution. * Fewer odor complaints. * Reduced energy costs. * More balanced fertilizer. * Reduced pathogens.
Poultry Litter Treatment (PLT) – 93% sodium bisulfate ($NaHSO_4$)	Increases ammonium-N. Effects on loss of phosphorus and soluble metals was not evaluated. However, it is unlikely to be as effective as alum in reducing the loss of phosphorus and soluble metals because of its chemical composition.	Decreases litter pH thereby conserving ammonium-N.	None cited.	* Bird health and performance improves with decreases in ammonia. * Better worker health conditions. * Less air pollution. * Fewer odor complaints. * Reduced energy costs. * More balanced fertilizer. * Reduced pathogens.
Alkaline Materials				
Limestones – calcitic ($CaCO_3$) or dolomitic	Little effect on water-soluble phosphorus or ammonium content	Litter alkalinity is increased to a pH greater than 7. Large	Liming value of litter should be taken into account when	* May reduce soluble phosphorus levels.

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($CaCO_3$ & $MgCO_3$)	of the litter. Increases liming value of litter.	amounts of ammonia are released during the layout period. Limited increase in litter pH and soluble calcium occurs because of low solubility of limestone. Sometimes included in products with iron-containing treatments or alum to prevent excessive decrease in pH.	applied to cropland. If liming is needed, then the use of lime-containing litter may be beneficial. However, indiscriminate use of lime-containing litter on cropland not needing liming may cause excessively high soil pH levels and micronutrient values in some soils. Magnesium may also become limiting in soils when calcium-only liming materials are used repeatedly.	* May increase energy costs at time of application. * Ammonia is released into the atmosphere. * Fertilizer value is reduced. * May cause increase in odor complaints. * May increase ammonia in house if the limestone is not completely used up during the layout period.
Quick lime (CaO) or slaked lime [$Ca(OH)_2$]	Decreases water-soluble phosphorus, but does not affect total phosphorus. Increases liming value of litter. Ammonium levels in the litter may be unchanged, increase or decrease depending on amount added.	Increases litter pH and adds calcium, resulting in calcium phosphate formation.	Liming value of litter should be taken into account when applied to cropland. If liming is needed, then the use of lime-containing litter may be beneficial. However, indiscriminate use of lime-containing litter on cropland not needing liming may cause excessively high soil pH levels and micronutrient values in some soils. Magnesium may also become limiting in soils when calcium-only liming materials are used repeatedly. The phosphorus in the litter will become available to the crop after incorporation into	* May increase energy costs at time of application. * Ammonia is released into the atmosphere. * Fertilizer value is reduced. * May cause increase in odor complaints. * May increase ammonia in house if the limestone is not completely used up during the layout period.

Active Ingredient	Effects on Litter Nutrients	Mode of Action	Precautions	Other effects
			the soil and pH decreases.	

References

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