

USE OF AMENDMENTS IN PITS AND LAGOONS FOR REDUCING AMMONIA, ODOR AND SLUDGE¹

Sanjay Shah, Extension Specialist, Biological and Agricultural Engineering Department, NC State University, Raleigh, NC 27695-7625

Background

Anaerobic (absence of air or oxygen) bacteria play an important role in breaking down the hog waste (urine, feces, wasted feed, etc.) into simpler organic and inorganic compounds in the pits and lagoons. However, this also results in the production of many organic gases, also called volatile organic compounds (VOCs) as well as inorganic gases (e.g., ammonia, hydrogen sulfide). Many of these gases, individually or in combination with other gases, produce objectionable odors. Schiffman et al. (2001a) identified 331 VOCs in hog waste that contribute to odors. As the population of NC grows and subdivisions are being built closer to hog farms, odors can result in friction between hog producers and homeowners. Some manure gases can also affect the health of the hogs and workers at high concentrations. Jones et al. (1997) showed that ammonia concentrations in the 10 to 15 ppm range reduced resistance to infection in hogs. Ammonia has been identified as an air pollutant of major importance at the large scale as it contributes to formation of very fine particulate matter that can cause (and increase) respiratory diseases and haze (NRC, 2003). Hence, the US EPA is considering regulating emissions of not just ammonia but also other air pollutants from animal agriculture under the Clean Air Act as well as other laws. Dietary manipulation (e.g., reducing crude protein), technology (e.g., spraying oil in the houses), management (e.g., regular wash-down of pens), or amendments can be used to reduce production of odorous gases in hog facilities. Amendments can also reduce sludge levels in the lagoon thereby requiring sludge removal at greater intervals. This paper focuses on amendments (additives) for use in hog house shallow pits and lagoons because they can improve productivity and air quality and reduce sludge levels in lagoons.

Amendments

Amendments for reducing sludge levels and/or improving air quality by reducing emissions of ammonia, H₂S, and VOCs from hog house shallow pits and lagoons can be classified into the following categories: (1) pH modifiers, (2) digestive amendments, (3) disinfectants, (4) oxidizing agents, (5) adsorbents, (6) enzyme inhibitors, (7) saponins from Yucca, and (8) masking agents and counteractants (McCrary and Hobbs, 2001). A single amendment is unlikely to provide benefits for multiple gases (or reduce odor) and in fact, may increase the emission of one gas while reducing the emission of another. Similarly, an amendment that may be effective in improving air quality may be ineffective in reducing sludge levels. Amendments that have shown potential in the lab or field in improving air quality in hog production are listed in Table 1; Table 2 provides information on costs and sources of some

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promising amendments. The different categories of amendments are discussed with emphasis on those products that were evaluated in scientific studies and are currently available.

(1) pH modifiers: Changing the acidity (PH) of the waste can result in biochemical changes that can increase or decrease formation of certain gases. Increasing the pH using alkaline material like burnt lime (CaO) or slaked lime (Ca(OH)₂) to values greater than 12 can destroy odor producing organisms. But large amounts of lime are required (for lagoon application) and they also increase ammonia emissions. Further, alkaline material will also increase sludge levels in the lagoon. Acidifiers, material that reduce pH, are generally effective in reducing ammonia emissions. Adding acids, acid forming salts, and labile (unstable) carbon can reduce the pH (increase acidity) of the waste, resulting in more of the ammoniacal (ammonia plus ammonium) nitrogen being in the form of ammonium rather than ammonia. The acidity also creates unfavorable conditions for the bacteria and enzymes that contribute to ammonia formation. While many acids are effective, they are either too expensive (Hendriks and Vrielink, 1997) or pose safety concerns. Labile carbon sources will stimulate anaerobic microbes in the waste to produce organic acids, reducing the waste pH (McCrorry and Hobbs, 2001) ; however, they are expensive and will increase solid levels in the waste. Acid forming salts such as aluminum chloride and aluminum sulfate (alum), though not as effective, are safer to use and less expensive than acids. Alum, though effective in reducing ammonia in broiler houses, is not recommended in hog production because it increases H₂S emission (Smith et al., 2001). Aluminum chloride solution added to shallow pits at 0.75% concentration reduced ammonia concentrations by 52% for 42 days (Table I) in the hog house (Smith et al., 2004). The aluminum chloride solution (5%) can be sprayed beneath the slats over the pit liquid with a plastic spray system (to prevent corrosion), or metered into the flush tank for flushing systems at 1 oz per gallon of fresh waste. While aluminum chloride may not help with other odorous gases, it will conserve N and reduce soluble P in the waste (Smith et al., 2001). However, the volume of waste to be handled will be increased; while dissolved solids content may be increased slightly, total solids are likely to be reduced due to dilution. Adding an acidifier directly to the lagoon to reduce ammonia emissions may be uneconomical because large quantities of acidifier will be required because of the effluent's buffering capacity. Any acidic material will corrode metals and concrete so care should be taken to spray the acidic solution directly onto the waste which will rapidly buffer its acidity.

(2) Digestive amendments: Digestive amendments may contain a mix of bacteria and/or enzymes that may break down the odorous compounds in the waste, and thus, improve air quality and perhaps, reduce solid levels. Some manufacturers claim that their products reduce ammonia emissions by converting the ammonium to organic N. However, only some digestives (see Table 1: Zhu et al., 1997; Chastain, 2000 ; Heber et al., 2002; Schneegurt et al., 2005) showed varying levels of success in improving air quality or reducing solids ; in many other studies, they failed (e.g., Williams and Schiffman, 1996; Warburton et al., 1980). Among amendments evaluated recently (Table 1), Bio-Kat looks promising since it improved air quality, reduced total solids, and improved hog performance at the farm scale (Schneegurt et al., 2005). There are some reasons for the inconsistent performance of digestive amendments. Depending on the types of bacteria and/or enzymes in an amendment, that formulation may reduce the concentrations of only one or two compounds and if those compounds are not the main sources of odor, the amendment will not reduce odor (Ritter , 1989). If a digestive amendment is designed to work in deep pits where waste is cleaned out every 6 months, it may not work in pit recharge systems that are emptied every week. Also,

bacteria in the amendment may not survive in the waste management system (Ritter, 1989). Finally, since the manufacturer may not provide the exact mode of action of a proprietary product, researchers may be unable to provide the optimum conditions to maximize the effectiveness of that product or improve it.

(3) Disinfectants: Unlike digestive amendments, disinfectants can reduce odor by killing all bacteria in the waste. Some disinfectants that have been used for odor control in waste management include orthodichlorobenzene, chlorine, hydrogen cyanamide, formaldehyde, paraformaldehyde, carvacrol and thymol. Orthodichlorobenzene, present in amendments such as Tee II and Ozene have shown mixed results (McCrary and Hobbs, 2001). Formaldehyde and paraformaldehyde reduced ammonia and H₂S formations by reducing bacterial populations (Ritter, 1981). Natural antimicrobials like carvacrol and thymol were very effective in stopping production of certain odorous compounds in the lab for 2 months (Table 1) (Varel, 2002) but they are expensive (Table 2) and toxic. While disinfectants may reduce odor, ammonia and H₂S emissions, generally, frequent applications would be required; they are also unlikely to reduce solid levels in the waste. Hence, they are neither practical nor economical for use at the farm scale (McCrary and Hobbs, 2001).

(4) Oxidizing agents: Oxidizing agents such as potassium permanganate, hydrogen peroxide, and ozone reduce odors not just by oxidizing odorous organic compounds into less odorous products but also by destroying odor producing bacteria, including those that produce H₂S and ammonia. In theory, oxidizers should also decrease solid levels in waste; however, additional work is needed in this area. Potassium permanganate and hydrogen peroxide were effective at concentrations of 500 ppm in reducing short-term odor from hog waste (Cole et al., 1976). Govere et al. (2005) also reported that hydrogen peroxide and calcium peroxide, singly or in combination with minced horseradish roots (containing the enzyme peroxidase) were effective in reducing odor (Table 1). The enzyme-oxidizer combination (particularly using calcium peroxide) was more effective than either the enzyme or oxidizer used alone (Govere et al., 2005). Ozone reduced odor and sulfide levels in hog manure for up to 3 weeks (Wu et al., 1999); ozone will also not increase the volume of waste unlike potassium permanganate or hydrogen peroxide. Hydrogen peroxide is effective but it breaks down rapidly and is corrosive at concentrations exceeding 8% (in water). Hence, potassium permanganate is probably preferable even though its crystals are corrosive and it is a strong oxidizer. Using both these oxidizer solutions for treating waste would increase the volume of waste. Overall, oxidizers can be effective and economical in improving air quality in hog production. The costs of some oxidizers are compared in Table 2.

(5) Adsorbents: Unlike digestive amendments that absorb and chemically transform the odorous compounds, adsorbents bind odorous compounds on their surfaces. Adsorbents, such as zeolite (a type of silicate material found naturally), usually clinoptilolite, and Sphagnum peat moss have been used for improving air quality in hog production. Zeolite can bind ammonium and thus reduce ammonia volatilization. While Portejoie et al. (2003) reduced ammonia emissions from hog slurry in the lab by using a zeolite cover, its application over lagoons would be difficult. While applying zeolite in pits may reduce ammonia emissions, it would be difficult to apply and it would increase total solids in the waste. McCrary and Hobbs (2001) reported that use of zeolite will likely have limited effect on odors. While peat moss can reduce ammonia emission from lagoons, large quantities have to be applied and they have to be oven dried to at 221 F to make them float. Hence,

adsorbents may not be effective in improving air quality in liquid waste management systems.

(6) Enzyme inhibitors: In hog production, the most effective enzyme inhibitors that can impact air quality are those that inhibit the enzyme urease, thereby, preventing or reducing the speed at which urea (from animal urine) converts into ammonia. There may be other inhibitors that might impact other odorous gases. However, since inhibitors are expensive and require repeated applications, they are neither economical nor practical in hog production (McCrory and Hobbs, 2001). They are unlikely to reduce solids in waste.

(7) Saponins from Yucca: Saponins from Yucca, a desert plant, likely bind or convert ammonium into organic-N, thereby, reducing ammonia emissions (McCrory and Hobbs, 2001). Amon et al. (1995) showed that De-odorase®, a product containing Yucca when fed to hogs and added to waste, reduced ammonia levels by 26% though it had no impact on odor (Table 1). A review of studies using Yucca indicated that they were inconsistent in reducing ammonia levels (McCrory and Hobbs, 2001). They may slightly increase solids in waste.

(8) Masking agents and counteractants: While a masking agent covers the objectionable odor with a more pleasant one, a counteractant neutralizes the odor. Both compounds are usually made from a mixture of aromatic oils. Pine oil in Pine-Sol at concentrations of 1 to 2 quarts per 4,000 gallons of liquid dairy manure added into the slurry tank reduced the offensiveness of odor during land application (Georgia Extension). Since the natures of hog and dairy wastes are different, it is unclear how effective these masking agents will be with hog waste. There is need to evaluate the impact of low-cost, easily available masking agents such as pine oil compounds on odors during land application of hog waste. These chemicals are unlikely to reduce solids in waste.

Summary

Many manufacturers claim that their amendments are effective in reducing emissions of ammonia, H₂S, and VOCs from hog waste; others also claim that their products may further reduce solids in the waste. However, few of those products have been evaluated in scientific studies and even fewer have been found to be effective in improving air quality in scientific studies. An amendment that might work in one situation may not perform well in another. Some amendments that have been shown to be effective and are currently available in the market are discussed here. Hence, some amendments mentioned in this paper may no longer be available and other effective amendments may not be included in this paper. Based on the review of scientific literature, hog producers in North Carolina and the Southeastern US may wish to consider the following recommendations with regard to amendments.

1. Ammonia reduction inside the houses is a priority both for improving animal health and reducing emissions (due to regulatory reasons). Acidifiers like aluminum chloride solution sprayed in the pits will not only reduce ammonia levels inside the houses but also soluble P levels in the effluent, reducing potential for water pollution. While adding acidifiers to the lagoon may provide some benefits, it will be much more expensive than applying in the pits. Further acidifiers applied in the pits will provide residual benefits in the lagoon. Acidifiers will increase volume of waste slightly. While increased N analysis of the waste increases its fertilizer value, it may also increase the acreage required to dispose of the waste.

Acidifiers are more expensive than some digestive amendments but slightly cheaper than oxidizers.

2. Digestive amendments are more likely to perform in a narrower range of conditions than acidifiers or oxidizers; however, compared with other types of additives, they are the most likely to reduce solids in the waste. Adding digestive amendments to the flush tank will likely be more beneficial in flush systems. Spraying digestive amendments in the house will be more beneficial in pit recharge or pull-plug systems where the waste stays in the house for a longer period of time. Digestives vary widely in price.

3. Oxidizers such as potassium permanganate have been shown to be effective in reducing odor intensity and improving odor quality and may help in reducing ammonia and H₂S levels. Spraying oxidizer on the liquid surface beneath the slatted floors may improve air quality inside the houses. Oxidizers seem to be more expensive than some digestive amendments but less expensive than all others.

4. If using multiple amendments, contact the manufacturers to confirm that they do not react with one-another to reduce the effectiveness of one or more compounds, or create toxic byproducts.

5. While new products are entering the market rapidly, less effective products may be taken off the shelf or sold under a different name. Manufacturers may also modify their products, thereby, requiring a different dosage. If a product showed promise in a scientific study, it may perform better than the one evaluated only by its manufacturer. Products with moneyback guarantees may be more reliable.

6. Be very careful when handling amendments. Read all manufacturers guidelines on how the product should be used and handled. Obtain material safety data sheets (MSDS) for each product that is used. Be very conscientious about using personal protective equipment (e.g., gloves).

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Table 1. Summary of recent studies on amendments that were effective in improving air quality and reducing solids in hog waste management

Author/s and [amendment type]	Scale; waste management system; duration	Amendment and dosage	Key results	Comments
1. Aron et al. (1995) [Saponin]	House; shallow pit and lagoon; 60 days	Deodorase ¹ added to feed and added in shallow pits (6.2 grams per day)	Ammonia concentration 11.8 ppm in control versus 8.8 ppm in treated rooms (26% reduction); odor concentration unaffected	Weight gain was not affected by Deodorase
2. Williams and Schiffman (1996) [Multiple types]	Lab; fresh slurry	Odor counteractant ² (natural oils), 125 ppm; digestive deodorant ³ (microorganisms and enzymes), 500 ppm; potassium permanganate (PP), 14000 ppm; Sphagnum peat moss (SPM), 7500 ppm; and chemical deodorant ⁴ (inorganic compounds), 5000 ppm	PP improved odor quality and reduced odor intensity; counteractant improved odor quality; all other amendments were ineffective	Field scale testing required
3. Hendriks and Vrieling (1997) [pH modifier]	House; deep pit and slurry tank; 8 months	AMGUARD ⁵ (organic acid) added to reduce slurry pH to 3.5 units; labile C added as milled wheat (3 lb/pig-week) and heated potato starch (2.7 lb/pig-week) to produce lactic acid; no control treatment	3.2 lb-ammonia emitted per pig place/yr (42% reduction) with AMGUARD and 3.0 lb-ammonia emitted per pig place/yr (45% reduction) with labile C	Producer estimated amendments cost NLG ⁶ 28, 42, and 21 per pig place per year for organic acid, milled wheat and potato starch, respectively
4. Hendriks et al. (1997) [Digestive]	House; deep pit; 22 months	A total of 10 lb of amendment ⁷ (mixture of enzymes, bacteria, yeast, and mold) added to pit 1 ft by 6.6 ft	Ammonia emission per unit live weight of animal was reduced by an average of 30% (0 to 51%) over four measurement periods	Producer estimated amendment cost BEF ⁸ 1.00 per sold pig
5. Zhu et al. (1997) [Multiple types]	Lab; deep pit waste; 35 days	MPC ⁹ , Bio-Safe, Shac ¹⁰ , and X-Stink ¹¹ (enzymes and microbes), Shac ¹⁰ (enzyme), X-Stink ¹¹ (aerobic bacteria), and CPPD ¹² (chemical oxidizing agent)	MPC, Bio-Safe, Shac, and X-Stink reduced odor thresholds by 83-87%, while CPPD reduced odor threshold by 58%; MPC and Bio-Safe reduced total volatile solids	Ammonia and H ₂ S reductions not determined due to low levels; X-Stink and CPPD reduced pH
6. Wu et al. (1999) [Oxidizer]	Lab; fresh and stored manure 21 days	Ozone applied at 0, 0.25, 0.5, 0.75, and 1 ppm to manure	Ozonation at 0.5 ppm reduced odor to acceptable level even after 3 weeks of storage; ozonation reduced sulfide levels rapidly	Total cost \$2.65 per 100 gallons ⁶
7. Chastain (2000) [Digestive]	Lab; recharge pit; 6 days	Bio-Safe ¹³ (enzymes and microbes) mixed with effluent at zero, 67, 100, and 200 ppm	100 ppm amendment reduced odor by 36%, 100 and 200 ppm were no different	Unclear how ammonia volatilization increased despite reduced pH
8. Heber et al. (2002) [Digestive?]	House; deep pit; 6 months	0.44% Allisance ¹⁴ sprayed to achieve concentration of 300-350 ppm in waste	24% reduction in treated buildings compared with untreated buildings; however, 20% waste dilution in treated buildings not considered	Not cost-effective considering modest reduction and considerable additional investment
9. Varel (2002) [Disinfectants]	Lab; fresh hog waste in jars; 56 days	Natural antimicrobials carvacrol and thymol in dosages of 2.5 ppm; also other dosages and combinations of the two compounds	Stopped production of odorous compounds	Odor not measured; also suppressed anaerobic bacteria and fecal coliform
10. Smith et al. (2004) [pH modifier]	House; pit recharge; 42 days	Aluminum chloride added to pits at zero, 0.25, 0.5, and 0.75% of manure volume	Reduced pH and ammonia concentration with higher concentrations more effective; at 0.75% concentration, ammonia emission from pit was 52% compared with control over 42 days	Phytase treatment results not reported; use of aluminum chloride also reduced soluble P in waste (Smith et al., 2001)
11. Schaegeert et al. (2005) [Digestive]	Shallow pit & lagoon; 71 days for houses & 51 days for lagoon	Five barn pits sprayed with Bio-Kat ¹⁵ to concentrations of 0, 0.5, 1, 5, and 2 ppm; lagoon sprayed at 0, 3, and 10 days; additional Bio-Kat applied to lagoon to maintain 1 ppm until day 51	Ammonia concentration in barn decreased with increasing Bio-Kat dosage; ammonia concentration in 2 ppm barn was 50% of 0 ppm barn after 71 days; ammonia, total N, and total solids concentrations decreased in lagoon receiving Bio-Kat	Hog losses and antibiotics use decreased in treated barns
12. Govere et al. (2005) [Enzyme and oxidizers]	Lab; slurry tank; 3 days	Mined borendish roots (HR; enzyme) (10% weight/volume of waste), calcium peroxide (CP; 1872 and 2448 ppm), hydrogen peroxide (HP; 1156, 1768, and 2312 ppm) - HR only, oxidizer only, and combination of enzyme and one oxidizer	HR and HP reduced odor intensity and unpleasantness some though HR+HP was more effective; HR+CP more effective than HR+HP at same concentrations	Authors emphasize use of amendments just prior to land application; longer term odor suppression unclear; impacts of higher solid content on application unclear

¹Proprietary names

²Names not disclosed

³Netherland guildler (€) (euro) = NLG 2.2 in Nov. 2001]; as of July 2006, €1 = \$1.26

⁴Belgian franc (€) = BEF 40.35 in Nov. 2001]

⁵Bio-science Environmental Services, the manufacturer of MPC reported that it was a mixture of enzymes and bacteria and was being sold currently as 104-E

⁶€0.38 per 100 liters (€) = \$1.84 as of July 2006)

Table 2. Cost of using some potentially promising amendments and their sources

Amendment, category	Source	Dosage per 100 gallons of fresh waste ¹	Cost to treat 100 gallons of fresh waste ² , \$	Comments
Aluminum chloride solution, acidifier	Kemiron (800-879-6353)	34 lb of 5% solution	2.10 ³	Based on study #10 in table 1; 28% solution diluted to 5% on the farm
104-E, digestive	Bio-Science (866-463-2511)	3.33 gallons	73.50 ³	Based on study #5 in table 1; MPC has been renamed 104-E
Shac Manure Digester, digestive	Shac Environmental Products (888-533-4446)	0.008 gallons	0.30	Based on study #5 in table 1;
Bio-Kat, digestive	NRP Inc. (954-970-7753)	0.0002 gallons	0.90 ⁴	Based on study #11 in table 1; average of 12 oz (\$65/gallon) needed to treat waste from 1,000 hogs in wean to finish operation
Carvacrol, disinfectant	Sigma Aldrich (800-325-3010)	2.1 lb	70 ³	Based on study #9 in table 1; liquid has to be diluted in ethanol prior to addition to waste due to low water solubility
Ozone, oxidizer	Based on design by Wu et al. (1999)	0.00005 lb	2.65 ⁵	Based on study #6 in table 1; for farm with 13,400 lb live weight (e.g., 89 150-lb finishers) at 1999 prices
Potassium permanganate, oxidizer	Ohio Pure Water Company (888-644-6426)	1 gallon of 5% solution	2.40 ³	Based on study #2 in table 1; crystals (0.44 lb) dissolved in 1 gallon water to form 5% solution
Hydrogen peroxide (H ₂ O ₂), oxidizer	DFWX Company (903-496-2813)	1 gallon of 5% solution	3.00 ³	Based on study #12 in table 1; 35% H ₂ O ₂ diluted to 5% solution on the farm

¹Assumed that 1,000 lb of live weight produces 90 lb or 10.8 gallons of fresh waste with no recharge or flush liquid volume considered. Dosages are meant for addition in the pits; for addition to the lagoon, the manufacturer should be contacted.

²Freight prices, when not provided, are approximate. Actual total cost will vary widely based on the size of the order as well as fuel prices; for example, Victor Johnson of Kemiron reported that price of aluminum chloride range from \$0.15/wet lb for a 46,000-lb truck load to \$0.35/wet lb of 2,650 lb of tote (6 September 2006)

³Price of amendment only

⁴To treat shallow pits not lagoon

⁵Total cost (1999 prices)