

RAPP Technology for Control of Gas and Odor from Swine Manure Pits

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Species: Swine
Use Area: Manure Storage, Manure Treatment
Technology Category: Chemical Amendment
Air Mitigated Pollutants: Odor, Ammonia, Carbon Dioxide, Sulfur Dioxide

Description:

This paper presents the results of a laboratory study of a new manure treatment method, patented by Rapp Technology, to reduce gas and odor emissions from swine manure. The study followed the National Pork Producers Council (NPPC) protocol previously used in testing 35 commercially available pit additives in 2000. Six manure reactors, three treated and three controls, were used to simulate the deep manure pit and were tested side by side for 49 days. Test results showed that, relative to the controls, emissions of ammonia, carbon dioxide, and sulfur dioxide from the treated reactors were reduced by 93% ($P < 0.05$), 83% ($P < 0.05$), and 84% ($P < 0.05$), respectively. Emissions of hydrogen sulfide were 39% less than the controls, but the difference was not statistically significant ($P > 0.05$). The odor concentration was significantly reduced ($P < 0.05$) from 2772 ± 184 to 1857 ± 420 OU/m³ (OU = odor unit) with the air inlet at 568 ± 71 OU/m³ in one set of valid samples. In addition to mitigating air emissions, the technology also caused a significant increase in total and ammonium nitrogen in the treated manure relative to untreated manure accompanied by a significant decrease in total phosphorous.

In the previous test of 35 pit additives by the NPPC, the best reductions of ammonia and hydrogen sulfide emissions were 15% ($P > 0.05$) and 47% ($P > 0.05$), respectively. None of the 35 pit additives study showed a statistically significant reduction in odor concentration (Heber *et al.*, 2001). Thus, the Rapp Technology presented in this paper was more effective for air pollution abatement.

Mitigation Mechanism:

The Rapp pit treatment technology consists of two component parts. The first part is an oil cover floating on the surface of the manure slurry to slow the rate of volatilization of the offensive molecules. The oil cover allows excrement to drop through it. The second component part is an alkaline solution, which is injected beneath the cover. This solution contains NH₃ (a base) that neutralizes the volatile fatty acids and phenols in the slurry to their ammonium salts. Such salts are more prone to stay in the aqueous slurry because they are more water-soluble and less volatile than the original acids. Keeping these acids out of the air decreases the stench. Moreover, there is an added benefit accompanying neutralization of the slurry. In anaerobic environments, certain anaerobes (acetogens) chemically change the long-chain fatty acids (which are non-volatile and insoluble in water) found in manure solids into shorter-chain fatty acids (which are more volatile and water soluble) such as those on the list of compounds most responsible for the offensive odor of manure (Zahn *et al.*, 2001). This chain length reduction generates an odor, which can persist if the digestion process stops at this stage due to excessive acidity destroying other anaerobes (methanogens), which would otherwise complete the digestion process. The complete digestion process converts the volatile fatty acids into odorless gaseous compounds (carbon dioxide and methane). Thus, adding an alkaline solution to the slurry neutralizes the volatile fatty acids keeps them in solution, and promotes their removal through complete digestion.

Applicability:

This technology was designed for deep manure pits. During the laboratory study to simulate the deep pit, liquid swine manure collected from a finishing operation was tested at Purdue University in manure reactors, made from 38-cm diameter, 122-cm tall PVC pipes that had removable sealing caps (Figure 1). Following initial filling with 75 L of manure, to a depth of 66 cm, swine manure was added weekly for five weeks starting on day 6. Each reactor received 5.8 L of liquid swine manure, which was equivalent to 5 cm manure in each reactor during the weekly addition. The reactors were ventilated with clean room air of 7 L/m during the test. Concentrations of gases, including ammonia, hydrogen sulfide, sulfur dioxide, and carbon dioxide in the inlet air and reactor exhaust air were measured with gas analyzers continuously for 10 min each reactor. The inlet air and exhaust air were sampled twice for odor measurement with a trained odor panel using a dynamic olfactometer.

The oil cover used in this study was provided commercially (Custom Formulating & Blending, Bristol, IN). The oil was a petroleum product (325 SSU) that is considered agriculture oil, and can be used in crop production applications. The

addition of the oil to the three treated reactors occurred only on day 0. Each reactor received 1.5 L of oil, or a 1.3 cm thick oil cover, which was poured onto the surface of the manure (Figure 2). Three other untreated reactors were used as controls.

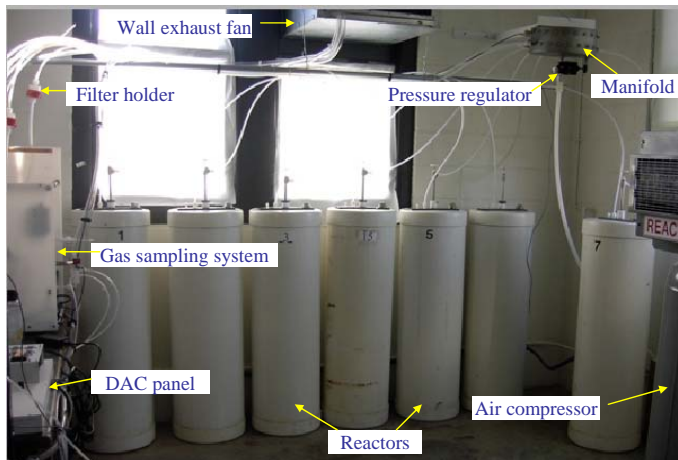


Figure 1. Reactor setup in the test room. Reactor 7 was a spare.

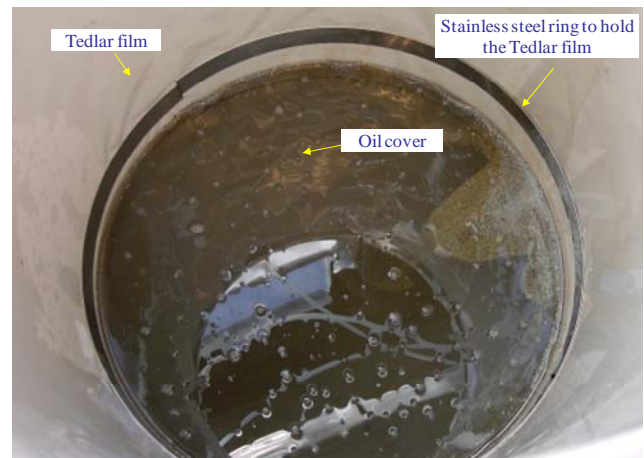


Figure 2. Oil cover formed inside one of the treated reactors on day 0.

The neutralizer used in this study was also provided by Custom Formulating & Blending, Inc, Bristol, IN, and formulated by Rapp Technologies, Athens, Illinois. The neutralizer was added to the bottom of the reactor through the pH probe and neutralizer addition assembly, using a 30-mL syringe. A total of six neutralizer additions occurred over the duration of the study, on days 0, 2, 6, 37, 44, and 48. The initial addition of neutralizer to each of the treated reactors on day 0 was 288 mL. On days 2, 6 and 37, each reactor received 144, 60 and 30 mL of neutralizer, respectively. The fourth addition occurred on day 44 with 60, 30, and 0 mL of neutralizer to reactors 2, 4, and 6, respectively. The final neutralizer of 30 mL was added on day 48 to each of the treated reactors. The air supply was shut off during this procedure, and all ports were open to allow the neutralizer to flow into the manure.

The study results showed that the emission rates of ammonia and carbon dioxide from the treated reactors were reduced by 93% ($P < 0.05$) and 83% ($P < 0.05$) compared with control reactors, respectively. These reduction rates were much higher than any previous tests of manure additives reported in the literature. The treatments also reduced sulfur dioxide emissions by 84% ($P < 0.05$). These results showed that the oil cover was very effective in reducing gas emissions from simulated deep manure pits. The treated reactors also showed 39% lower hydrogen sulfide emission rates than the controls. However, the reduction was not statistically significant, due to large variations caused by hydrogen sulfide burst releases (Ni *et al.*, 2000). Two valid odor samples at the end of the test showed reduction of odor concentration for the treated reactors. The odor concentration for the last sampling, which also had double size sample numbers, was statistically significant ($P < 0.05$). The odor concentration for the control reactors, treated reactors, and air inlet were 2772 ± 184 , 1857 ± 420 , and 568 ± 71 OU/m³, respectively.

Figure 3 presents daily mean ammonia emission rates from the two groups of reactors. Because of the constant air supply to the reactors, the daily mean gas concentration patterns were similar to the emission rate patterns. Figure 4 presents daily means of carbon dioxide emissions from the two reactor groups. Although all the reactors experienced a general increase in emission rates from the start to the end of the test, the changes were relatively small before the third weekly manure addition on day 27, when manure with high dry matter (DM) content was introduced into the reactors. The variations of carbon dioxide emissions within the groups were less than those of hydrogen sulfide and sulfur dioxide. Figures 5 and 6 plot the daily mean emission rates of hydrogen sulfide and sulfur dioxide from the two groups of reactors from day 14 to the end of the test. During this period, hydrogen sulfide emissions from the control and treated reactors demonstrated a strong fluctuation pattern. In Figures 3 to 6, arrows indicate manure addition days and diamond arrows indicate neutralizer addition days.

Table 1 lists manure analysis results at the end of the study before and after thorough agitation of the manure. The treated reactors had higher TKN ($P < 0.05$), NH₄-N ($P < 0.05$), and lower P ($P < 0.05$) as compared with the control reactors. Both the control and treated reactor samples had higher DM after agitation as compared with those before agitation. The agitation of the treated reactors caused significant increases ($P < 0.05$) in TKN and NH₄-N, while there was only a numerical increase ($P > 0.05$) in TKN and NH₄-N for the control reactors after agitation. An apparent reason for the difference before and after the agitation was that the manure with higher DM settled at the bottom of the reactor before and was more evenly distributed following the agitation. Therefore, the characteristics of the agitated manure samples better represented the actual mean values.

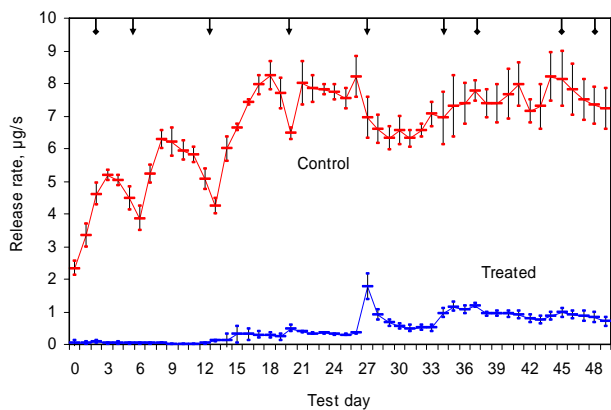


Figure 3. Daily mean ammonia emission rates and 95% confidence intervals from the two reactor groups.

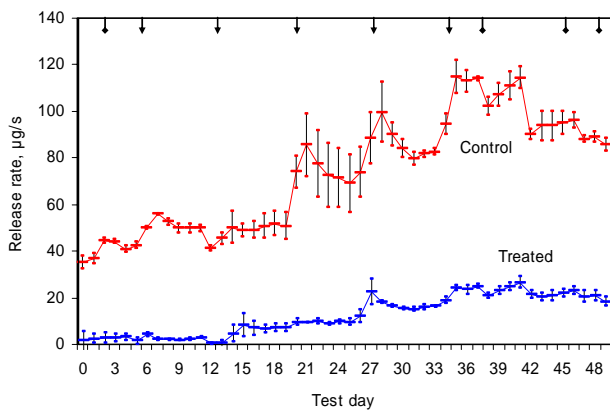


Figure 4. Daily mean carbon dioxide emission rates and 95% confidence intervals from the two reactor groups.

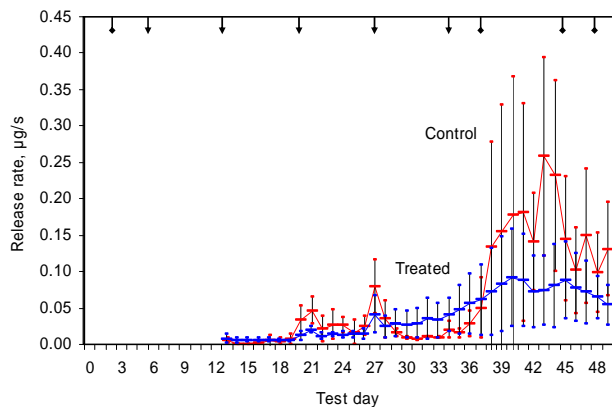


Figure 5. Daily mean hydrogen sulfide emission rates and 95% confidence intervals from the two reactor groups.

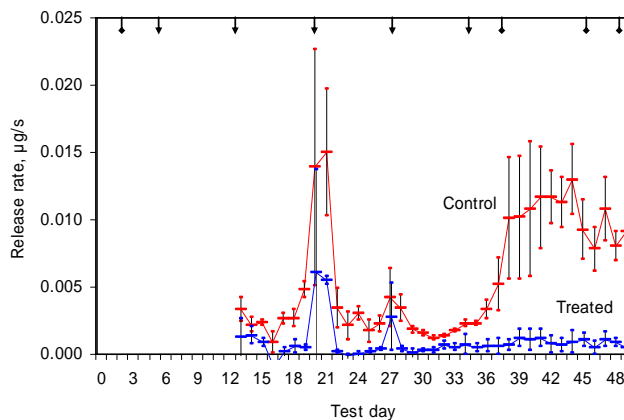


Figure 6. Daily mean sulfur dioxide emission rates and 95% confidence intervals from the two reactor groups.

Table 1. Characteristics of reactor manure on day 49 (mean 95%±confidence interval)

| | Before Agitation | | After Agitation | |
|--------------------------|------------------|-----------|-----------------|-----------|
| | Control | Treated | Control | Treated |
| Sample n | 3 | 3 | 3 | 3 |
| DM, % | 0.72±0.02 | 0.73±0.05 | 0.87±0.02 | 0.81±0.02 |
| TKN, mg/L | 1852±127 | 2207±67 | 2010±64 | 2396±30 |
| NH ₄ -N, mg/L | 1774±114 | 2115±153 | 1902±121 | 2286±56 |
| P, mg/L | 132±3 | 106±7 | 202±8 | 184±3 |
| pH | 8.2±0.2 | 8.0±0.02 | 8.1±0.07 | 8.0±0.01 |

Limitations:

The oil cover floats on top of the liquid manure and creates a barrier for reducing gas and odor emissions. It works well for accumulated liquid manure such as the manure in pits. It is not suitable for applying on the manure on the barn floors. The effect of neutralizer on emission reduction could not be differentiated from the effect of oil cover in the lab test. Future high quality field studies are needed to optimize the application method, including the application of neutralizer, and to achieve maximum reduction with minimum costs.

Cost:

During the lab test, the oil and the neutralizer (both provided by Custom Formulating & Blending, Bristol, IN) cost \$1.13 and \$ 0.67 per reactor, respectively. According to Juergens Environmental Control (Carroll, Iowa) for field application of the neutralizer, the fixed cost of the system for 1000 to 8000-pig finishing operations averages \$2.50 - \$5.00 per pig per 3 year term (shipping and labor not included). The annualized cost of neutralizer operating averages \$0.01 per pig per day.

Implementation:

This technology is a combination of manure coverage and manure amendment or additive. Because of using oil as the liquid barrier on top of manure, the cover allows manure to drop through the cover and is effective in reducing gaseous compounds from releasing from manure. The implementation of the oil cover is simple and does not require special equipment. Oil is biodegradable and easy to obtain.

According to Juergens Environmental Control (Carroll, Iowa), the implementation of neutralizer needs special equipment. The blended neutralizer solution with a proprietary formula is stored in a 5500-gallon poly storage tank near an 8 ft x 8 ft x 8 ft utility shed. The neutralizer solution tank is operated by a computer in the utility shed. PVC piping is plumbed from the storage tank to the main manifold located outside of the barn or manure storage station. The manifold has injectors placed at uniformly distributed areas in the manure pit. The computer is programmed to inject the solution six times a day for two seconds, pumping 1.34 gallons into the pit each time. Daily usage is subject to barn size.

Technology Summary:

This gas and odor reduction technology consists of (1) an oil cover that is floating on the surface of the manure slurry to slow the rate of volatilization of the odorous molecules. The oil cover allows excrement to drop through with only a brief disturbance of the cover, (2) an alkaline solution, which is injected beneath the oil to alter the chemical reaction in the manure. The laboratory study demonstrated significant reduction of ammonia, carbon dioxide, sulfur dioxide, and odor from the treated reactors. Compared with previously tested commercial manure additives, this technology is more effective in mitigating gas and odor emissions from simulated deep manure pits.

Acknowledgments:

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