

Significant Odor Reduction from a Highly Efficient Micro-ecosystem™ based on Biofiltration

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Species: Swine
Use Area: Animal Housing
Technology Category: Biofilter
Air Mitigated Pollutants: Ammonia, Hydrogen Sulfide, Particulate matter, Odor

Description:

Swine facilities produce an organic by-product (manure) that has become increasingly vital to crop production and nutrient management. This organic liquid is usually stored in a pit directly underneath the housing facility or adjacent to the facility in a lagoon or formed structure. The storage and subsequent breakdown of this material causes gases and odorous particulate matter to be released into the ambient air affecting air quality in and around these facilities (Lee et al., 2006). Exhaust fans are most often employed to remove these gases from underneath a housing facility. Odorous emissions are a composite of organic compounds, ammonia, hydrogen sulfide, and particulates (Wood, S.L., et al., 2001). Research findings by Green et al. (2005) have demonstrated significant reduction in hydrogen sulfide and ammonia emissions utilizing biofiltration.

Odor Cell Technologies LLC, (OCT) has developed hybrid odor cells that synergistically combine the principles of biofiltration with technology that maintains optimal environmental conditions creating a micro-ecosystem within the cells.

This technology uses above ground cells which contain an organic media, pine bark, to establish this aerobic micro-ecosystem. Pockets of anaerobic activity that are inherent in traditional biofilters are not a factor in the odor cells (Cundiff et al., 2003). These cells attach to pit exhaust fans individually which allows for flexibility based on actual run-time calculations (Figure 1). The cells are connected to a water source where hydration cycles can be programmed through the use of timers and rain sensors (Figure 2). Maintenance and physical inspection can be easily done by adding media to the cell and lifting the top panel to observe the point of contact within the capture chamber.



Figure 1. Installation of an odor cell



Figure 2. Mature odor cell with hydrator

In addition to reducing odorous emissions, other benefits of the technology are:

- Capture of particulate matter which reduces the transfer distance of odor
- Improved air quality within a rural setting
- Environmentally friendly filtering medium
- Aesthetically appealing and visible odor reducing technology
- Addresses a wide variety of ventilation emissions
- Requires no upgrades to existing ventilation fans
- No shutters required on minimum ventilation fans
- No static pressure variability on fans from ambient winds/snow
- Microbial conditions easily monitored and maintained

Mitigation Mechanism:

The biological activity within the odor cells creates a micro-ecosystem that is actually a network of microorganisms interacting with a feedstock of emissions provided by the exhaust fans. These exhaust emissions actually supply nutrients to the microbes and they in turn break down the emissions thereby removing the undesirable characteristics. Microorganisms play a vital role in the normal biological cycles by converting organic compounds into elemental components (Shareefdeen, et al., 2005).

Creation and maintenance of a viable micro-ecosystem is a prominent feature of the odor cell technology. Enhancing conditions to promote maturity of the micro-ecosystem is a priority during the initial startup of the odor cells. The following principles are integral to the efficiency and performance of the odor cells:

1. Physical entrapment of particulates (Figure 3).
2. Timely and quantified hydration that stimulates and maintains microbial activity (Figure 4).
3. Rapid development and maintenance of a micro-ecosystem (Figure 5).



Figure 3. Non-hydrated filter after 4 months of operation.



Figure 4. Hydration delivery system.



Figure 5. Microbial activity present during winter months.

The biological workhorses of this network are heterotrophic aerobic bacteria. They are a highly nutritionally diverse group of organisms which use a broad range of enzymes to chemically break down a variety of organic materials. Bacteria are single-celled and structured as rod-shaped bacilli, spherical-shaped cocci, or spiral-shaped spirilla. The characteristic earthy smell of soil is caused by actinomycetes, organisms that resemble fungi but actually are filamentous bacteria. In the filtering media, fungi break down tough debris such as cellulose allowing bacteria to continue the decomposition process. Fungi can breakdown organic residues that are too dry, acidic, or low in nitrogen for bacterial decomposition. Most fungi are classified as saprophytes because they live on dead or dying material and obtain energy by breaking down organic matter. Yeasts and molds (fungi) are present in acceptable levels to provide secondary support for breaking down organic compounds (BBC Laboratories, 2005). Each microorganism community interacts with unique and specific families of organic and inorganic substances surrounding it such as ammonia, hydrogen sulfide, and volatile organic compounds. The microbial community becomes more diverse and can accommodate an even wider range of emissions as it matures.

There are distinct phases within the growth of microorganisms (Figure 6). The log phase or exponential phase features rapid cell division and growth. The stationary phase marks conditions when viable count remains constant as the number of new cells counterbalances the number of dying cells. The log decline phase is characterized by a decrease in the viable population count. When the nutrient supply is a limiting factor, the microorganisms enter into the endogenous respiration phase. Reproductive growth is curtailed and some cells change to a dormant state (sporulation). Other organisms simply self-destruct. Total absence of a nutrient source will lead to massive cell death. OCT's selected media, pine bark, has a built-in "seed stock" of bacteria that can grow rapidly under the right conditions. Table 1 illustrates the growth of specific microbes within the pine bark at different time intervals.

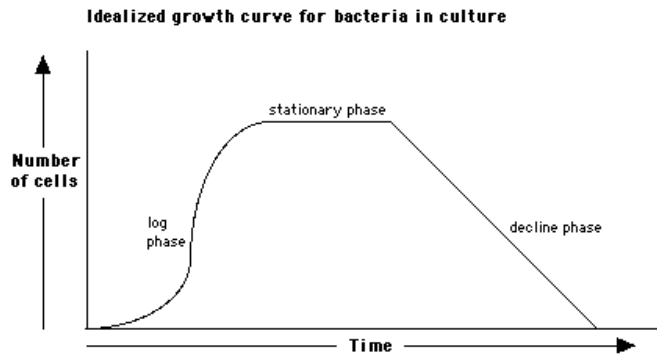


Figure 6. Growth of a microbial population.

Table 1. Growth of specific microbes at different time intervals.*

Duration	Organism	Level Found (cfu/g)**	Testing Method
Virgin Bark	Aerobic Plate Count	390,000 cfu/g	FDA III
	Mold	720 cfu/g	FDA XVIII
	Yeast	14,000 cfu/g	FDA XVIII
60 Day Bark	Aerobic Plate Count	1,100,000,000 cfu/g	FDA III
	Mold	770,000 cfu/g	FDA XVIII
	Yeast	Not Detected	FDA XVIII
180 Day Bark	Aerobic Plate Count	1,280,000,000 cfu/g	FDA III
	Mold	160,000 cfu/g	FDA XVIII
	Yeast	88,000 cfu/g	FDA XVIII

*Analysis conducted by Midwest Laboratories.

**Units are expressed in colony forming units per gram of substrate.

Heterotrophic bacteria are well within an adequate range of organisms necessary for a viable micro-ecosystem (100 million to 10 billion colony forming units per gram (cfu/g) (BBC Laboratories, 2005). As the aerobic micro-ecosystem matures, more species of microorganisms become active adding to the diversity of microorganisms available for breakdown of undesirable odors. Additionally, bacteria secrete distinctive enzymes that break down waste and toxins into simpler compounds that the bacteria can utilize as a food source. Enzymes respond to similar conditions that are present in a flourishing microbial population. Thus, environmental conditions that promote microbial growth and function mutually support active enzyme activity.

Consistency of the media is fundamental to the odor cell efficiency. Testing of the pine bark media yields a consistent porosity of 60%-62% (Nicolai, R. et al., 2001). The slowing of the air through the bark allows particle deposition within the media. The unique physical integrity of the pine bark allows particles to be entrapped in "micro-caverns" within the bark. Microbes can then breakdown these particulates over time. The microbes act as a "self-cleaning" mechanism for the odor cells. The porous layered structure of the bark results in much more surface area being exposed to exhaust emissions. Table 2 reports the effectiveness of the odor cell in reducing particulate emissions.

Table 2. Effectiveness of odor cells in reducing dust emissions.*

Duration**	Total dust inside	Concentration Inside	Total dust outside	Concentration Outside	% Reduction
24 hours	2.68 mg/filter	0.93 mg/m ³	0.10 mg/filter	0.035 mg/m ³	96.24%
48 hours	2.65 mg/filter	0.46 mg/m ³	0.34 mg/filter	0.059 mg/m ³	87.27%

*Analysis of samples conducted by Test America, Cedar Falls, Iowa

**Samples were collected December 18-20, 2007. Minimum ventilation fan (5700 cfm), 835 head present averaging 122.7 kg (270 pounds).

Optimal populations of microbes thrive in a 50% moisture content of the media. However, microbes can function in varying degrees in a 30%-65% range (Cundiff et al., 2003). An additional benefit of timely hydration is that the moisture

can interact with gaseous emissions such as ammonia and hydrogen sulfide. This damp environment simulates a “scrubbing” action on these substances. Figure 7 illustrates typical ammonia reduction of the odor cells as the micro-ecosystem matures.

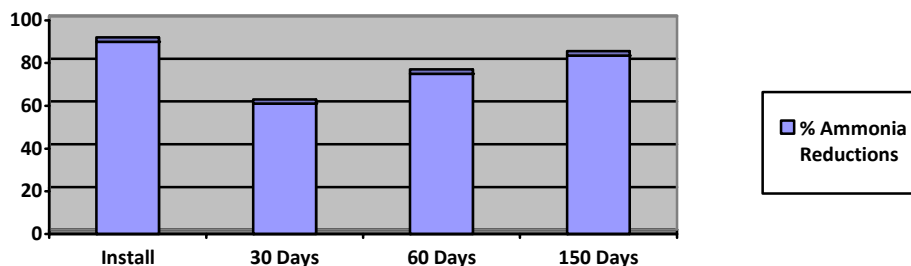


Figure 7. Ammonia reduction with maturation of the odor cell.

Applicability:

Odor cell technologies are effective at mitigating odor emissions in swine housing systems that employ direct-drive, pit exhaust fans in a range of 1500-10,000 cfm. Knowledge of the ventilation system’s operational goals is essential in evaluating odor cell size and maximizing its capabilities. The considerations that need to be identified are:

- Identify minimum ventilation fan(s)
- Know the desired ventilation rate/pig space
- Establish the run-time requirements of each state of ventilation

Limitations:

Bio-filtration is most effective on organic compounds and particulate matter. It relies on a constant feedstock supply (air emissions) utilizing organic material as the filtering medium. Maintenance of the moisture level between 30% and 65% is critical to an active microbial population. The static pressure load on common fans is between .05 and .08 inches of water when pine bark is used. This load must be accounted for in calculating ventilation requirements, but allows implementation of the technology in most existing CAFO’s without changing the ventilation system dramatically. Table 3 and Figures 8 and 9 illustrate the static pressure load on a 10-inch odor cell. The recommended media characteristics have been examined for several years. The selection of the media must meet three criteria: (1) consistent porosity (2) slow degradation rate, and (3) porous structural makeup. The recommended pine bark meets all three criteria. Substitution of media that do not meet all three criteria is not recommended.

Table 3. Typical static pressure load on a 10-inch odor cell.

Age of cell	Head pressure (inches of water)
30 days	0.050
90 days	0.044
150 days	0.061

Total pressure of the system (Vacuum + Head pressure) was .09 to .1 inches of water. The odor cell pressure on the ventilation fan was between .04 and .06 inches of water.

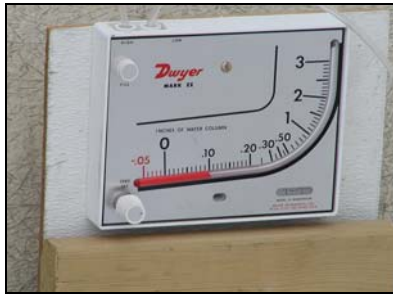


Figure 8. Dwyer manometer



Figure 9. Head and vacuum testing

Cost:

Table 4 presents costs that would be expected using a 1200 head mechanically ventilated finishing unit with 6 pit fans:

Table 4. Estimated costs of a 1200 head finishing building.

Quantity	Description	Cost/unit	Total
6	Odor Cells (10 inch)		
	Internal/External Hydrators	\$1650.00	\$9900.00
6	Initial Bark Fills	\$125.00	\$750.00
6	Rock Base Pads	\$20.00	\$120.00
1	Hydrator Delivery Package includes: 60 feet ½ inch braided hose, 2 valves, Timer, control box, 600 feet ¾ inch pvc pipe		<u>\$360.00</u>
		Total	\$11130.00
Shipping	\$1.45/loaded mile (Spring 2008)	250 miles	\$362.50
Optional items			
1	Rain Sensor	\$55.00	(\$55.00)
1	Manometer	\$50.00	(\$50.00)
6 Installations	Install and Fill Odor Cells	\$50.00/cell	(\$300.00)

Assuming a 20-year life for a finishing building, this equates to \$.48 per pig space for fixed costs. Assuming 2.6 turns per year over 20 years, the cost per pig produced would be \$.18 for fixed costs. Operational and maintenance costs assuming a complete media change every 5 years would be \$.14 per pig space and \$.05 per pig produced. Labor is optional in this cost estimate. Odor Cell Technologies LLC usually demonstrates the proper installation of 1 odor cell at no charge. The implementation is quite straight forward and most site managers select to do the installation themselves. A turnkey installation quote can be supplied upon request. (Pricing is subject to input cost increases due to market volatility and fuel surcharges).

Implementation:

Once a producer has determined their ventilation requirements, he/she may elect to phase in technologies appropriate to odor mitigation goals and budget limitations. The more aggressive odor cells (10-inch) are generally placed on minimum ventilation fans with less aggressive cells implemented on subsequent stage fans based on run-time criteria. Other considerations include Iowa State University's air modeling, proximity to neighbors, predominant wind direction, proximity to public areas such as towns, parks, and nearby public roads. Additional federal, state, and local ordinances or site requirements such as Minnesota's OFFSET (Jacobsen et al., 2002) need to be a part of the odor management plan. Figure 9 illustrates the different levels of technologies that may be used.



Figure 9. (Left-to-right) Minimum, Stage 2, and Stage 3 implementations.

The design of the odor cells allows visual inspection of the condition of the bark. At least 6 inches of media may be consumed before additional media is required. This can be easily observed through visual inspection of settling.

Normal maintenance usually includes the topping off of the cells in the spring and the fall. It is important to note that too much water affects microbial growth as well as too little. If too little moisture is present, microorganisms will sense that the environment is not conducive to growth and vitality and will go dormant. Too much water will result in accelerated decomposition of the bark and decrease the useful life of the media. The measurement of the moisture content of the media is easily monitored by visual inspection and physical handling of the media. Visual inspection includes observing dark “streaks” which are resident microbe colonies and probing the bark with one’s finger to feel dampness. Individual bark pieces can be evaluated by observing how the pieces respond to bending. If the bark “snaps” when broken (similar to a potato chip) it is on the low end of the moisture range and would require more watering. Ideally the bark will be pliable and flexible to bending. It is important to note that the media is to be “damp”, not wet. Most of the watering use will occur between the months of April through September/October. It is recommended that hydration cycles be repeated with greater frequency and less duration during these months. Large amounts of water are not required for hydration. The goal is to maintain 50% moisture content in the media. Most times this is a function of replacing the normal evaporation rates. Through the use of a timer, the hydrators can be programmed to maintain optimal conditions for the microorganisms to grow. Normal rainfall provides natural hydration and can substitute for normal hydration cycles. Rain sensors that override normal hydration cycles are very effective in preventing over-hydration. Since the odor cells are above ground, excess water does not build up within the media.

The main water nozzles on the hydrator are located on the outside of the odor cells and can be visually observed. In addition, an internal nozzle can be observed by lifting the center panel to check the spray pattern. Delivery of water to the filters is a site-specific choice of the facility owner. Options may include laying pvc pipe above ground, shallow trenching of irrigation tubing, dedicated internal/external lines, or ordinary garden hoses.

Technology Summary:

Odor Cell Technologies LLC has created a patented technology that significantly reduces odors commonly found in and around swine production facilities. Through the implementation of odor cells, odorous gases and particulate matter can be biologically broken down and reduced at the point source. Reducing the transfer distance of these odors improves air quality to the surrounding community. Peak efficiency of the odor cells is easily maintained by accessible monitoring of the conditions within the cell. Adaptability to ventilation requirements, flexibility in design, simplicity of installation, low maintenance and durability make this technology a sensible way to address odor issues. For approximately \$.62 per pig space an effective odor mitigation strategy can be implemented that is environmentally friendly, aesthetically appealing and cost effective.

Acknowledgements:

Odor Cell Technologies LLC would like to recognize our best advocates - our customers. They are truly pioneers in air mitigation. Their feedback has been a valuable asset to our company. Many of their down-to-earth suggestions have been instrumental in refining our technologies.

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