A Surface Aeration Unit for Odor Control from Liquid Swine Manure Storage Facilities

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Species: Swine, Dairy, and Poultry
Use Area: Manure Storage
Technology Category: Aeration
Air Mitigated Pollutants: Odor

Description:

Odors generated from anaerobic lagoons have been a long-term issue that has been studied for years but without effective techniques in place to deal with it. The failure in controlling odors emitted from such manure storage structures has caused numerous lawsuits and soured the relationship between animal farmers and their neighboring residents. With the mounting pressures from the public and regulatory agencies, the sustainability and productivity of animal producers using lagoons for manure storage will be jeopardized and social ties strained if acceptable levels of odor reduction are not achieved.

Past research results have indicated that aeration can be an effective tool for odor control (Pain et al., 1990; Sneath et al., 1992; Zhang and Zhu, 2005; Williams et al., 1984; Williams et al., 1989; Zhang et al., 2004). Under aerobic conditions, biodegradable organic materials such as swine manure can be oxidized into stable inorganic end products by aerobic bacteria (Westerman and Zhang, 1997). The nitrogenous compounds in manure are oxidized to nitrite and then to nitrate, enabling the management of excess nitrogen as di-nitrogen (N_2) gas through localized denitrification (Burton et al., 1993). In addition, odorous compounds such as sulfide and mercaptan are also decomposed to form odorless sulfate (Westerman and Zhang, 1997). Work by Williams (1984) quantified the relationship between the offensiveness of odor and the volatile fatty acids (VFAs) concentration in treated pig slurry, a major group of odorous compounds that can be controlled by aerobic treatment. Williams et al. (1984, 1989) also showed how the return of an offensive odor in stored aerobically-treated liquid manure, indicated by the increase in VFA content, was determined by the aerobic treatment regime that the manure had undergone prior to storage. All this information clearly demonstrates that aeration (aerobic treatment) has been proven an effective technique in manure odor control. As such, treatment technologies based on this principle need to be developed and put in use for animal producers to conquer the intractable odor issue.

Mitigation Mechanism:

An anaerobic lagoon, if functioning properly, will usually not produce significant odors. However, due to management problems, many anaerobic lagoons are overloaded so the normal anaerobic digestion process is disrupted and odorous compounds, such as volatile fatty acids, sulfides, indoles, and other odorous substances, are produced in large quantities as a result. These compounds find their way to the atmosphere by surface emission, which can actually be effectively contained by lagoon covers. Using the same concept, a surface aeration unit is developed and aimed at aerating the top liquid in a lagoon to create an oxygenated layer that functions just like a cover to reign in the emission of odors from the lagoon surface. In this paper, such a surface aeration system, composed of a venturi air injectors complex which was tested in both lab- and field-scale experiments for its effectiveness and efficiency in transferring oxygen into the liquid under aeration, is presented. Unlike physical covers, the aerated liquid layer on the surface of a lagoon forms an intangible biological cover that can decompose the odorous compounds before they gain access to the atmosphere, leading to reduced odor emissions.

Applicability:

This technology is best suited for any open liquid manure storages including lagoons, ponds, and earthen storage basins for odor control, regardless of animal species such as swine, poultry, and dairy operations as long as an open liquid manure storage structure is used in the manure handling and storage system. The technique will not be feasibly applied to in-barn manure storages, such as deep pits, because of the potential for increased ammonia emission during the aeration treatment, leading to deterioration of indoor air quality. Figure 1 shows a sketch of the surface aeration system in a manure lagoon and figure 2 is a photo of the installation of a pilot scale unit on a swine manure lagoon in Minnesota during the experiment. A snapshot of the aerator module complex made of six venturi air injectors is presented in figure 3.

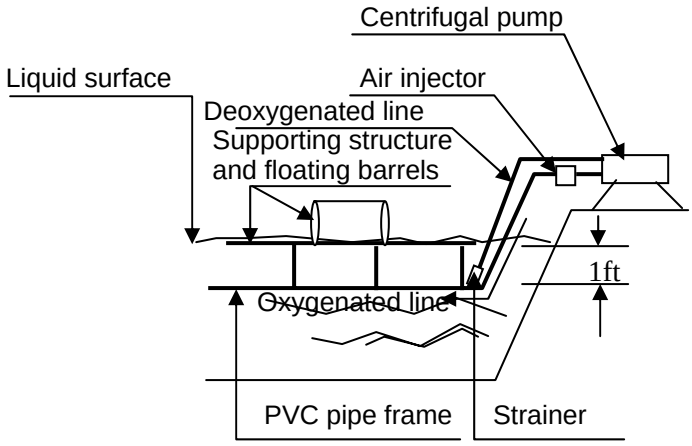

Figure 1. Schematic of a section of the aeration apparatus

Figure 2. The aerator module in the field test

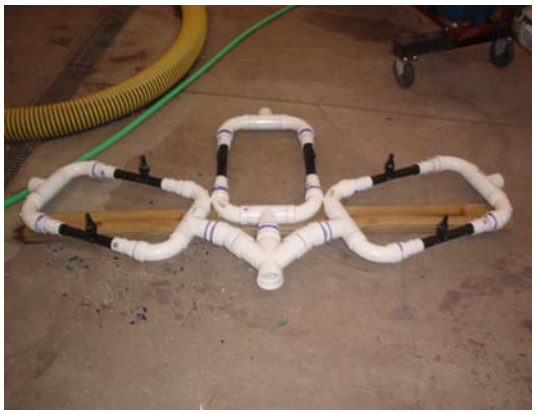

Figure 3. The configuration of the aerator module

As said early, surface aeration is to create an aerated layer in the top lagoon liquid that functions like a biological cover to prevent the odorous compounds from going airborne, thus reducing the quantity and intensity of odor generated by the manure lagoon. Since it is an invisible cover, the additional benefit of this technology may lie in the savings in labor and material costs in constructing and/or placing (replacing) physical covers.

Limitations:

This technology is not meant to completely eliminate odor emission from manure storage facilities due to the fact that it is not expected to function like an impermeable physical cover. Therefore, users of this technology will still see odors emanated from the liquid manure storages, but at a significant reduced level. In addition, the system can work all-year around in warm climate zones after initial installation; however, the piping structure has to be removed from the liquid to avoid damage potentially caused by water freezing during winter in the northern states of the country and replaced into the liquid in late spring or early summer when the lagoon water thaws. In this case, the implementation of the technology may encounter some level of inconvenience.

Cost:

The capital cost of this surface aeration system is relatively inexpensive and all the venturi air injectors are commercially available (under $200/each). For a one-acre lagoon, a total of 18 air injectors are needed, which amounts to about $3,600. Three pumps (1.5 horsepower each) will also be needed (alternatively one 4.5 horsepower pump can be used, too) for the establishment, adding another $1,000 to $1,500 into the budget. The piping structure will cost about $500 in materials and $5,000-$7,000 in construction and installation. In summary, the equipment cost including materials and installation may be anywhere between $10,000 and $15,000 for a one-acre size lagoon.

As for the running cost, the electricity outlay is relatively minimal. For a 4.5 horsepower pump running 24 hours a day and 365 days a year, the power consumption will be 4.5 hp x 0.75 kW/hp x 24 h/day x 365 day/year = 29,565 kWh. Assuming the price per kWh being at $0.07, the total annual cost for the operation will be 29,565 kWh x $0.07 = $2,070. Considering the particular lagoon where this system was experimented, the production facility has a capacity

of 4,000 head finishing pigs, which means that a total of 10,000 pigs could be produced each year, given a yearly production cycle of 2.5. Thus, the treatment cost per pig marketed is only about 21 cents. In addition, the proposed surface aeration system is literally maintenance free with limit needs in checking the functionality of the pumps and strainers.

Implementation:

Information reported here concerning the use of the developed surface aeration technique to control odor emission from liquid manure storages is based on data from a study performed on an actual swine manure lagoon located in Nicollet County in Minnesota. The lagoon, an earthen structure of about 1 acre surface area, receives manure from 4 barns housing finishing pigs all year around. The surface aeration apparatus was designed to cover about 1/3 of the lagoon surface with the uncovered area being used as the control. Since the experiment was conducted in Minnesota, the unit could only be operated between late spring and early fall and was taken out of water afterwards to avoid piping freezing issues. This project is part of a large effort funded by the USDA National Research Initiatives Air Quality Program (project title: A Field-Scale Surface Aeration System to Control Odor from Open Liquid Manure Storage Facilities; Agreement Number: 2006-55112-16639) in developing and evaluating a cost-effective surface aeration system to control odor and gas emissions from liquid manure storage facilities.

Before the field scale surface aeration structure was actually built, an extensive lab-scale experiment aimed at developing an efficient aerator module was carried out at the University of Minnesota Southern Research and Outreach Center at Waseca. The outcome of the numerous lab experiments is the completion of the design of the aerator module currently used in the field experiment. This aerator module has significantly increased the aeration efficiency without increasing the power consumption, leading to the establishment of an aerated layer in top lagoon liquid with a constant level of dissolved oxygen of greater than 0.3 mg/L at a depth 6” from the liquid surface. According to the data collected in last summer, the aerated liquid layer, as expected, worked effectively as a biological cover that prevented odorous compounds from escaping from the liquid, hence the reduction of odor emissions. Based on the air samples collected from both the treated and control areas from the experimental lagoon and analyzed at the Olfactometry Lab in the Bioproducts and Biosystems Engineering Department at the University of Minnesota, the reduction in detection odor threshold has reached about 67% shortly after the start of the aeration operation. More field tests have been arranged and a full evaluation of the system in terms of manure odor control from the same lagoon will be conducted in the coming summer. It is expected that, upon completion of the study, the technology will become mature and ready for adoption by animal producers using lagoons or other open manure storages to reduce odor emissions from their operations.

Technology Summary:

Aeration is a proved technology to reduce odor from animal manure storage facilities. However, the scarce use of this technology by animal producers largely hinges on its prohibitive capital and running costs. To overcome this concern, partial aeration, such as surface aeration, can be an alternative to full aeration to save power usage. The developed surface aeration system that employs a specially designed aerator module that can effectively transfer air into liquid at minimal electricity consumption has been demonstrated in this paper according to field test data and proved to be able to significantly cut down on the odor strength (in odor detection threshold) emitted from the lagoon. The surface aeration system can be run all year around in warm climate zones but can only be operated part of the year in cold climate zones. The maintenance requirement is expected to be minimal and the capital cost for the system is estimated at between $10,000 and $15,000. The annual running cost of the presented surface aeration system is around $2,000 which results in a production cost of about 21 cents per pig marketed.

Additional Resources:

Interested readers may go to www.bbe.umn.edu and click on “publications and frequently asked questions” to get more information on aerobic treatment and surface aeration. An article about this topic also is included in the trade magazine “National Hog Farmer” (vol. 52, issue 12, p.27, 2007). The aerator development process can be found in an article published in a research journal “Applied Engineering in Agriculture” titled “Aerator Module Development Using Venturi Air Injectors to Improve Aeration Efficiency” (vol. 23, issue 5, pp, 661-667).

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