Review paper

Aerobic Biological Treatment of Animal Manure for Gaseous Emissions Control

Hong, J. Y.

Industrial Machinery Engineering Dept., Sunchon National University,
540-742 Sunchon, South Korea

INTRODUCTION

Animal manure is a highly biodegradable organic material. Depending on the presence or absence of oxygen in the manure, biological treatment process may be either aerobic or anaerobic. Under aerobic conditions, bacteria carry on respiratory metabolism to break down complex organic substances in the manure such as carbohydrates, proteins and fats into simple organic compounds, sugars and acids and then convert them into carbon dioxide and water without giving offensive odors.

Aerobic treatment process requires free molecular oxygen present in the environment. Under aerobic conditions, the nitrogen compounds are converted to ammonium by heterotrophic bacteria (which require nourishment from organic substances) and then oxidized by autotrophic bacteria (which obtain nourishment from inorganic matter such as ammonium) to nitrite and then to nitrate. Sulfur compounds in the wastes are converted to elemental sulfur or sulfate in the aerobic environment instead of odor-causing sulfide and mercaptan compounds in the anaerobic environment.

The degree of oxidation depends on the amount of oxygen provided and the reaction time allowed in the treatment process. When the aeration is terminated and the dissolved oxygen (DO) becomes absent, the environment is said to become anoxic if nitrate and sulfate are still present. Nitrate and sulfate can function as electron acceptors for facultative and anaerobic bacteria, the same as oxygen for aerobic bacteria, and are reduced to nitrogen gas and hydrogen sulfide, respectively.

The process for oxidizing ammonium into nitrate is called nitrification while the process for reducing nitrate into nitrogen gas is called denitrification. The combination of nitrification and denitrification will allow removal of

Corresponding Author: Hong, J. H. Industrial Machinery Engineering Dept., Sunchon National University, 540-742 Sunchon, South Korea, E-mail: jhhong@sunchon.ac.kr

nitrogen from animal manure.

Although aerobic treatment is an odorless process, the method is not widely accepted by animal producers because of the high operation cost associated with aeration. Nevertheless, some form of aerobic treatment would be a desirable alternative to intolerable odors, especially for the producers with a high risk of odor nuisance liability (Day and Arogo, 1993). Aerobic bacteria grow fast, producing a relatively large quantity of biomass that contains high levels of protein, and have been used as single-cell protein feed supplement.

The major aerobic treatment systems used for animal manure treatment are composting, oxidation pond (naturally aerated lagoon), aerated lagoon, oxidation ditch, aerobic sequencing batch reactor and autothermal thermophilic aerobic digestion system (ATAD).

The objective of this study was to review a current aerobic biological treatment methods on the animal manure for gaseous emission control.

1. Aerobic biological treatment systems

1) Composting

Composting is the aerobic biological degradation of animal manure by microorganisms under controlled conditions. In this process, an organic substrate is oxidized by mesophilic and thermophilic microorganisms for energy and growth.

The principle by-products of this conversion are metabolic heat, carbon dioxide and water. Under optimal conditions, nutrients are stabilized and odors are neutralized, yielding an end product of value to the animal producer. Although the process of biodegradation would occur naturally, composting involves varying degrees of control over the factors involved so that decomposition is accelerated. The composting of animal manure requires careful control of process parameters to ensure complete pathogen destruction and minimal ammonia and odor production.

There are many benefits of composting animal manure. The oxidation of carbon compounds and production of water has a net effect of reducing the volume and weight of the manure stock. If done properly, ammonia emissions can be minimized and odors controlled. The finished product has value to the farmers as a fertilizer, soil conditioner, or even a salable product. High enough temperatures can be achieved to kill most pathogens and weed seeds and plant diseases are suppressed. In some locations, farmers who compost may even be paid by their local municipality to compost community yard wastes in their pile. Although there are many advantages to composting, it is not without its drawbacks. These include monetary and labor costs, land requirements, potential nitrogen losses and possibly the need to market another product.

Intermittent aeration produced adequate composting while causing less emission of malodorous compounds (Elwell et al., 2004). Composting is an effective way for treating malodorous materials, and odor treatment such as manure compost biofilter in the process would make it more acceptable (Hong and Park, 2004).

2) Autothermal thermophilic aerobic digestion system (ATAD)

The ATAD processes also called liquid composting. It is a thermophilic aerobic treatment process treating wastes of 5~10% total solids in a continuous-flow system with a detention time of 6~14 days. The aeration tank is insulated to contain the heat generated from the aerobic treatment process and operates under thermophilic conditions (40~65°C). The ATAD process was studied in the 1960s and has been significantly developed since the mid-1970s. The benefits of this technology are high disinfection capability, low space and tankage requirement and a high treatment rate. The ATAD system is commercially available and has been successfully used for treating municipal wastewater sludge (EPA, 1990). It is a promising technology for treating concentrated animal manure for odor control and disinfection. Its capability of destroying pathogens will become more important to address the public health concerns associated with disposal of animal manure.

3) Oxidation ditch

An oxidation ditch is generally constructed in a large oval racetrack configuration. Cage rotors are partially immersed in the liquor; they provide aeration and circulate the ditch contents to keep the solids in suspension. The organic loading rate for an oxidation ditch for treating animal wastes is 550~700g BOD_5/m^3/day, approximately five times the loading rates used in municipal systems, and the rotor should be selected to provide an oxygenation capacity of twice the daily BOD_5 load and pumping capacity to maintain a ditch velocity of 0.3 m/s (NZAEI, 1984). With such aeration criteria, the electricity cost for running the rotors would be the same as for complete oxidation in a mechanically aerated lagoon. Due to prohibitive cost, the oxidation ditch has not been used in real animal farms, even though its effectiveness for animal manure treatment has been demonstated in previous research (Day and Arogo, 1993).

4) Aerobic sequencing batch reactor (Aerobic SBR)

Aerobic sequencing batch reactor is used for biological removal of nitrogen from the organic wastes. Intermittent aeration is used for achieving the nitrogen removal through nitrification and denitrification. Sequencing of aeration and no-aeration periods in a treatment reactor creates alternative aerobic and anoxic environments.

Aerobic treatment can effectively control the nature and quantity of nitrogen in the manure. Depending on the operating conditions, nitrogen can be conserved as ammoniacal nitrogen, lost via ammonia stripping during the aeration, oxidized to nitrate and conserved, or lost var. denitrification. Evans et al.(1986) found that when the aeration rate was low and DO in the liquid manure not detectable, the nitrogen remained in the forms of organic nitrogen and ammonia nitrogen for all the studied aeration treatments (0.5 to 15 day retention time) and temperatures (15 to 50°C). Up to 50% of organic nitrogen was converted to ammonia nitrogen and loss of nitrogen was mainly due to ammonia stripping. At high aeration rate when DO can be detected and was at least higher than 1 % of saturation, nitrification and denitrification occurs. It has been found that the sequencing batch treatment can remove up to 90~99.5 % convertible nitrogen in the manure (Fernandes et al., 1991; Svoboda, 1995).

5) Oxidation pond (Naturally aerated lagoon)

An oxidation pond is usually a shallow pond of 0.9~1.5 m depth and relies on wind for natural aeration and photosynthesis introduced by sunlight penetration to promote algae growth in the water to produce oxygen.

Oxidation pond is designed by the BOD loading rate (kgBOD_5/day/area). The recommended loading rates for different geographical areas are given in Agricultural Waste Management Field Handbook (USDA, 1992). The oxidation ponds require large surface areas. It is estimated that a 1,000 sow farrow-to-finish swine operation would require 340,000m^2 for the pond surface area if the pond is used for raw manure treatment. Therefore, oxidation ponds have not found wide applications among animal producers. Their use has been essentially limited to polishing the effluents from an anaerobic lagoon or other treatment units that have significantly reduced the BOD level of liquid manure. Moreover, oxidation ponds need warm, sunny weather to work well.

6) Mechanically aerated lagoons

A mechanically aerated lagoon uses a mechanical aerator to beat or blow air into the water, with a portion of the oxygen being dissolved. Because the aerated lagoon does not depend on wind and algae growth for the oxygen supply, the depth of the lagoon can be more than 1.5 m. Typical lagoons are 3~7.5 m deep. Therefore, the surface area of the lagoon can be much smaller than that of an oxidation pond for treating the same amount of wastewater. Various types of mechanical aerators are available for aerating lagoons. Cumby (1987) classified them into five major types based on their operation principles and presented their aeration efficiencies. Costs of aeration are directly related to the aeration efficiencies of the system.

More recent research has been focused on determining the minimal aeration requirement for acceptable odor control. A low level of aeration to maintain a DO level in the surface layer as low as 0.5 mg/L has been shown to be effective for odor control(Zhang et al., 1996). Surface aeration systems for deep anaerobic lagoons are currently under development.

CONCLUSIONS

Animal production systems vary widely in intensity, scale and sophistication and exist across a range of geographic and climatic conditions. Cost effective treatment technologies that can help dispose of manure safely with minimal environmental impact and generate recyclable wastewater will become more important for producers to meet the regulatory pressure and public demand for environmental protection and water resource conservation.

Composting produces stable and high quality soil amendment products from manure. Effective demonstration and education programs are needed to train the farms and entrepreneur composters about correct composting procedures and network development for feedstock resources.

Aeration is an energy-intensive biological treatment process. It is commonly used as a secondary treatment process following anaerobic digestion and/or solid-liquid separation. Its primary application in manure treatment will continue to be for odor control. Due to increasing concerns of ammonia emissions from animal manure, nitirfication of ammonia in the manure through aeration either for nitrogen conservation or for nitrogen removal will become an important area of research.

REFERENCES

1. Cumby, T. 1987. Areview of slurry aeration 3. Performance of aerators. Journal of Agricultural Engineering Research 36(3): 175-206.
2. Day, D. L. and Arogo, J. 1993. Biological and chemical treatment of animal manure. In: Meeting the Environmental Challenge, Proceedings of Environmental Sympsium, November 17-18, National Pork Producers Council, P.O.Box 10383, Des Moines, IA 50306,USA.
3. Elwell, D. L., Borger, D. C., Blaho, D. V., Fahrni, J. K., Keener, H. M. and Willett, L. B. 2004. Changes in concentrations of malodorous compounds during controlled aeration composting. Compost Science & Utilization 12(2):102-107.
4. Evans, M. R., Smith, M. P. W., Deans, E. A., Svoboda, I. F. and Thacker, F. E. 1986. Nitrogen and aerobic treatment of slurry. Agricultural Wastes 15:205-213.
5. Fernandes, L. E., McKyes, M., Warith, M. and Barrington, S. 1991. Treatment of liquid swine manure in the sequencing batch reactor under aerobic and anoxic conditions. Canadian Agricultural Engineering 3:373-379.
6. Hong, J. H. and Park, K. J. 2004. Wood chip biofilter performance of ammonia gas from composting manure. Compost Science & Utilization 12(1):25-30.
7. NZAEI. 1984. Agricultural Waste Manual. NZAEI Project Report No.32. December 1984. Lincoln College, Caterbury, New zealand: Agricultural Engineering Institute.
8. Svoboda, I. F. 1995. Nitrogen removal

from pig slurry by nitirification and denitrification. In: proceedings of 7th International Symposium of Agricultural and Food Processing Wastes (ISAFPW95), 24-33. ASAE, St. Joseph, MI. USA.

9. USDA. 1992. Agricultural Waste Management Field Handbook. United States Department of Agricultural, Soil Conservation Service.

10. Zhang, R. H., Yin, Y., Sung, S. and Dague, R. R. 1996. Anaerobic treatment of swine waste by the anaerobic sequencing batch reactor. In: Proceedings of the 51st Purdue Industrial Waste Conference. Ann Arbor Press Inc., Chelsa, MI. pp. 315-321.