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The prevention of harmful gases and odours dispersion by biofiltration in the animal farm

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Abstract. Animal farms are have to be controlled regarding to environmental issues beacuse of their waste's effects. Dispersion of harmful gases and odour is some most important effect of animal waste. Decomposition of animal waste may cause dispersion of harmful gases such as ammonia, methane, carbon dioxide, hydrogen sulfide etc. and odours. Harmful gases and odours impact on human and animal welfare negatively. Biofiltration is a technique used to prevent the dispersion of harmful gases and odour on animal farms. Especially some animal production types such as swine and poultry farms may cause great problem in terms of harmful gases and odour, so biofiltration has been seen as an effective method treating polluted air in these farms. The process of biofiltration is conducted based on biological degradation of pollutants. The bed materials such as litter, mulch and woodchips etc. are used in biofiltration to ensure microbiological environment. In this study, it was purposed to give information about the biofiltration, its basic principles and usage on animal farms based on conducted researches.

Key words: animal waste, biofilters, treatment, environmental problems.

THE BASIC PRINCIPLES OF BIOFILTRATION IN ANIMAL FARM

Biofiltration is an effective method to treat ventilation air from mechanically ventilated livestock buildings. The ventilation air flows through a bed of biological material. Harmful gases are absorbed by cultures of microorganisms that grow within the bed. Two main design configurations for biofilters are that flat-bed type and a vertical biofilter. The flat-beds are easier to construct and cost less, but they occupy more space than the vertical biofilters. Vertical biofilters are more difficult to construct and biological material can settle, then it causes leaking problem. Vertical biofilters can be designed in multiple layers to reduce the effects of settling (Harmon et al. 2014).

Several technical factors should be considered in the designation and operation process of biofilter systems. These factors are biofilter media, moisture content, microorganisms, oxygen, temperature, pH, medium depth and pressure drops, nutrients, load of contaminant, toxic and inhibitory by products removal, dust and grease of contaminated air (Armeen, 2006).

Selecting suitable biofilter media has great importance to reach success in the biofilter systems. Desirable media properties include suitable environment for microorganisms depend on nutrients, moisture, pH and carbon supply, large surface area to maximize attachment area and sorption capacity, stable compaction properties to resist media compaction and channeling, high moisture holding capacity, and high porosity to maximize empty bed residence time (EBRT) and minimize pressure drop, low bulk density to reduce media compaction potential (Williams & Miller, 1992; Swanson & Loeher, 1997; Chen & Hoff, 2009). Comparison of media types is given in Table 1.

Table 1. Comparison of Media Type (Edwards & Nirmalakhandan, 1996; Devinny et al., 1999; Armeen, 2006)

Media Type	Advantages	Disadvantages
compost/peat	• high population of microorganisms • suitable for low concentration volatile organic compounds • low cost • high to medium nutrients • life time 2 to 4 years • high absorption of water	• compaction and channeling • limited buffer capacity • low biodegradation capacity
granular activated carbon packed bed	• high adsorption • good biomass adhesion • fast start up (adsorption) • suitable for high contaminant concentrations • high biodegradation capacity • life time more than 5 years	• high cost • difficult to clean due to adhesion • no nutrients
pelletized ceramic	• easy to clean • less expensive than activated carbon • high biodegradation capacity	• more expensive than compost or peat
perlite, and other inert materials	• high surface area • life time more than 5 years	• medium cost • no availability of nutrients

Generally organic materials such as bark mulch, woodchips, litter, wood shavings and compost are selected as biofilter media. These materials are inexpensive and can be easily supplied (Chen & Hoff, 2009). Also, some alternative media materials such as pine nuggets, lava rock, cedar chips and natural zeolite have been investigated for longer service and higher porosity (Luo & Lindsey, 2006; Janni et al., 2009; Akdeniz et al., 2011).

Media moisture content is a critical parameter for biofiltration systems. Researches indicate that 40% to 65% of moisture content are sufficient depend on media materials (Nicolai & Janni, 2001; Chen & Hoff, 2009). Temperature and pH should be controlled to optimize microbial activity in the media. The ideal operation temperature is between 30 and 40 °C (Yang & Allen, 1994). Williams & Miller (1992) suggested that the optimal pH is between 6 and 7.

Air pollutants are degraded by several groups of microorganisms. These are bacteria, fungi and actinomycetes. Bacteria have ability to degrading air contaminants faster. Fungi are more tolerant than bacteria to low moisture content and low pH of media, but they are more susceptible of low oxygen concentrations in the environment. Actinomycetes are similar to fungi, but they are small in size and are technically classified as bacteria. They have more tolerance to low moisture condition than bacteria. However, they have a low tolerance for acidic conditions. Fungi and actinomycetes are more active in the conditions of biofilters contain organic media with low moisture content (Metcalf & Eddy, 1991; Atlas & Bartha, 1993; Armeen, 2006).

Pressure drop should be considered when the biofilters are designed. Energy consumption is increased in the condition of high pressure drop (Yang et al., 2007). The biofilter media depth and air flow rate are primary factors to affect pressure drop and removal efficiency. Depths ranging from 0.3 to 1 m with most between 0.3 to 0.75 m have been generally used for on-site biofilters. Higher media depth can give good results based on removal efficiency but it may causes higher pressure drop. The media depth of 0.25 to 0.50 m has been recommended as optimal for agricultural biofilters (Chen & Hoff, 2009).

Some indicators such as empty bed residence time (EBRT), removal efficiency (RE) and elimination capacity (EC) are used to describe effectiveness of biofilter systems. EBRT can be calculated by dividing the volume of the biofilter media by the air flow rate. This indicator depends on the media depth, airflow rate, cross sectional area, porosity, physical properties of the media, mass loading and degradability of the odourants (Devinny et al., 1999; Armeen, 2006). 3–5 seconds of EBRT is sufficient for livestock facilities (Janni et al., 2011). The performance of a biofilter is often assessed by RE and it is defined as the fraction of contaminant removed. RE can be calculated by dividing the difference of inlet and outlet gas concentration by inlet concentration (Oliver, 2015) EC is the mass of contaminant that is degraded per unit volume of filter media per unit time (Devinny et al., 1999; Armeen, 2006).

THE OVERVIEW OF RECENT LITERATURES IN BIOFILTRATION

Martens et al. (2001) intended to determine the potential reduction of microbial bioaerosol, odour and ammonia emissions by biofilters in a pig facility. Five different media materials (Biochips, coconut-peat, wood-bark, pellets-bark and compost) were used in this study and the results showed obvious differences among media materials. Numbers of airborne cultivable bacteria were decreased by ca. 70 to 95% and the total counts of bacterial cells from ca. 25 to 90%. The total amount of fungal cells was reduced by at least 60%. Airborne endotoxins and MVOC (Microbial Volatile Organic Compounds) were effectively reduced by all filter materials to at least 90%. The mixture of chopped bark and wood had best performance compare than other media materials based on airborne endotoxins reduction and also the mixture of pellets and bark had best performance based on MVOC. The average odour reduction was between 40 and 83%. However, only Biochips slightly affected (8.4%) in the reduction of ammonia emissions.

Hong & Park (2004) investigated the influence of wood chip biofilter properties and the depth of biofilter on ammonia emission from composting manure. It was pointed out that ammonia emission was affected by the depth of biofilter media. Besides, optimum biofilter media depth was determined as 40 cm in a closed wood chip filter for allowable ammonia emissions.

Armeen (2006) aimed to determine designed a treatment system (a combination of biosrubbler and biofiltration) to reduce the NH_3 and H_2S compounds of polluted air from animal facilities and the effect of NH_3 and H_2S on biofilter performance. It was indicated that the best biofilter performance was reached by a mixture of polystyrene (75% by volume) and peat moss (25% by volume). It was pointed out that the removal efficiency was different between the bioscrubber with dilute sulfuric acid and the bioscrubber without acid. Sulfuric acid had positive effect on biofilter performance based on elimination of ammonia. Also, the ammonia concentrations significantly affected the EC, RE, and pH of the biofilters ($p < 0.05$). It was pointed out that the odour concentration was reduced 50% by bioscrubber and 72% by combination of bioscrubber and biofilter with no NH_3 injection

Luo & Lindsey (2006) assessed the effectiveness of biofilters, which contained different sizes of crushed pine bark or a mixture of zeolite and crushed bark to treat the exhaust gases from direct-fired meal dryers. Biofilter odour-removal efficiencies were measured between 80% and 99%. It was mentioned that the fine crushed bark biofilter generally is more effective than the coarse bark biofilter in reduction of odour concentrations. The additions of zeolite to the bark medium in the biofilter causes a very small decrease in odour-removal performance.

Lau & Cheng (2007) assessed the performance of a pilot-scale biofiltration system for treating odours from the exhaust air streams of a commercial duck farm building. The average odor removal efficiency of the biofilter system was found as 95 ± 3%.

Chen et al. (2008) developed a pilot-scale mobile biofilter contained two different types of wood chips (western cedar and hardwood) to reduce odour emissions from a deep-pit swine finishing facility in central Iowa. Volatile Organic Compounds were analyzed by a multidimensional gas chromatography-mass spectrometry-olfactometry system. As a result of this study, average reduction efficiency were found as between 76–93%. It is indicated that both type of chips had good performance for average reduction. Also, they had significant reductions in p-cresol, phenol, indole and skatole., On the other hand, it was pointed out that maintaining proper moisture content is more important than media depth and residence time.

Chen et al. (2009) tested two different types of wood chips (western cedar and hardwood) as media material to treat odor emissions from a deep-pit swine finishing facility in central Iowa. The results indicated that reduction of odour concentrations (average 70.1 and 82.3% for HW and WC, respectively) were considerably achieved by both types of chips. As a result of this study, average reductions of H_2S concentrations were found as 81.8 and 88.6% for HW and WC, respectively and of NH_3 concentrations were found as 43.4 and 74% for HW and WC, respectively.

Akdeniz et al. (2011) evaluated gas reduction efficiencies and gas reduction efficiencies of two alternative biofilter media (pine nuggets and lava rock) at three empty bed contact times (1, 3 and 5 s) and two moisture levels (82% and 90% relative humidity). It was pointed out that pine nuggets and lava rock can be accepted as alternative media types at %90 relative humidity and 5 s empty bed contact time to reduce hydrogen sulfide, total reduced sulfur, ammonia and greenhouse gas emissions. Also, they have lower pressure drop than wood chips biofilter. It was observed that odour was reduced up to 48% but it was not consistent.

Lei (2011) determined the optimal residence time of biofilters to ensure high reduction ammonia emission and low nitrous oxide production. Also, it was aimed to determine interaction between ammonia removal and nitrous oxide production. In this study a biofilter system was built and installed in front of a group of exhaust fans inside a broiler house. It was indicated that there was a linear relationship between the removal efficiency of ammonia and residence time ($p < 0.05$). While the average of nitrous oxide production rate were found as 3.92 ± 1.14 mg hr^{-1} at 20 sec residence time in low NH_3 concentrations, the average of nitrous oxide production rate in high NH_3 concentrations were found as 1.50 ± 0.40 mg hr^{-1} at 20 s residence time. At the end of the study, 50 sec residence time was recommended for high ammonia conditions.

Akdeniz & Janni (2012) evaluated biofilter media characteristics and NH_3, H_2S, SO_2, CH_4 N_2O reduction efficiencies from eight biofilters on four animal feeding operations. The biofilters were located on a dairy, a swine nursery, and two swine finishing farms. The result of study showed that the deep bed biofilters at the dairy farm, had the most porous media and lowest unit pressure drops and there was no N_2O generation in this biofilter. The highest H_2S, SO_2, NH_3 and CH_4 reduction efficiencies were measured from a flat-bed biofilter at the swine nursery farm. Whereas, the highest N_2O generation (29.2%) was also measured from this biofilter. This flat-bed biofilter media had the lowest porosity.

Oliver (2015) investigated spatial and temporal fungal dynamics in full-scale woodchip biofilters. It was pointed out that dynamics and potential abilities of fungi in biofilters treating livestock production emission can be used to guide the connection between fungi and biofilter function. It was mentioned that this relationship has potential to improving biofilter performance and better protect air quality.

CONCLUSIONS

The studies showed that contaminated air could be treated by biofilters at the high rate. But also, there are a number of subjects that could be improved in this system with regards to designation criteria, bed materials and relationship between microorganisms and the system.

In conclusion, biofiltration should be considered as a part of animal production facilities based on environmental impacts, human and animal welfares.

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