

Long-term performance of biofilters for odour control on pig farms

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Abstract

The growth of pig industry has caused a great problem of undesirable odours, particularly in and around production buildings, storage areas and when the pig manure is spread. Among manure treatment options, organic bed biofiltration represents a very promising technique for the deodorization and treatment of pig manure.

Research and development work to optimize the BIOSOR™-Manure, a biofiltration process for simultaneously treatment of liquid and gaseous effluents on pig farms, have been realized on the site of a piggery (Île d'Orléans, Québec, Canada) using a 560 m³ biofiltration system.

The results obtained show that the BIOSOR™-Manure process is an efficient, simple and performing technology bringing a global solution to odours pig manure problems. Actually, the process reduce over 95% the polluting load from the gas of the pig farm (NH₃, H₂S), the BIOSOR™-Manure process eliminates over 80% the odour intensity coming from the production installations, the storage, the transportation and the spreading of the manure.

Introduction

The porcine production industry is grappling with a growing problem associated with the odour pollution that it generates, which currently represents the most blatant non-point source pollution management problem. Even though there are over 150 volatile combinations in pig manure (Merkel *et al.*, 1969; Schaeffer *et al.*, 1977; Yasuhara *et al.*, 1983), the main components are methane, carbon dioxide, ammonia and hydrogen sulphide (Lee, 1976; McQuitty *et al.*, 1983; Lasbleiz, 1989). According to their detection limit and their olfactory character, ammonia and hydrogen sulphide have been identified as being good indicators to monitor odours emanating from the treatment of pig manure (Pain *et al.*, 1990, Martin and Laffort, 1991). Considering the intensity and duration of the odours, the proposed weighting of odour sources for Québec, Canada is 20% for the building, 10% for the storage, 5% for the collection and 65% for the spreading (O'Neill and Stewart, 1985; Héduit, 1989; Buelna *et al.*, 1993).

Increasingly stringent environmental standards, constantly growing public awareness of environmental problems and the conflicts associated with living with unpleasant odours, have led to enhanced research into various alternatives for treating pig manure in different countries. One alternative, the organic bed biofiltration is a very promising technology for the deodorization and treatment of liquid and gas effluents in reducing the overall odour problem at the farm (building, storage, spreading).

The biofiltration by organic media is a simultaneous AIR/WATER treatment process (Buelna, 2000; Buelna *et al.*, 1998) for the global management of porcine production effluents. The principle consists of passing the liquid (manure) and gas (foul air) effluents through an organic media biofilter (mixture of peat moss, woodchips, etc.). As a pollutant removal agent, the organic media can act in two ways, as a natural resin able to fix several types of pollutants and/or as support for various types of micro-organisms capable of degrading the retained substances. These pollutants are degraded into CO₂ and H₂O

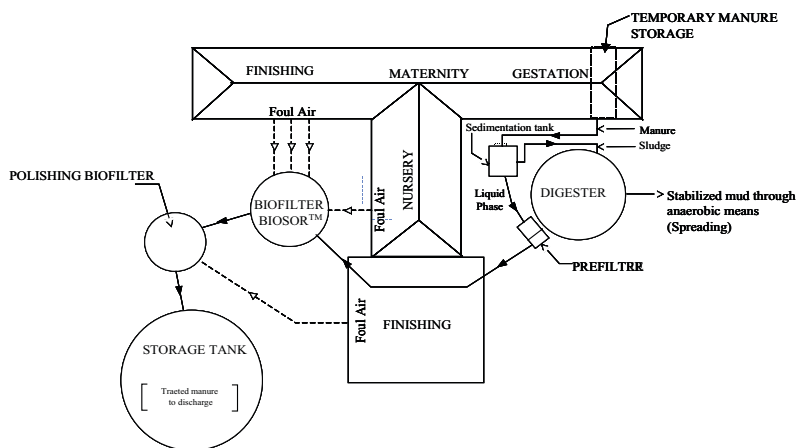
due to the microbial activity (Bélanger *et al.*, 1987). The constituents of the organic media, particularly the lignin and organic acids, possess numerous polar functional groups: alcohols, phenols, aldehydes, ketones, acids, ether. This polar character gives it a good adsorption capacity for organic molecules and transition metals (Coupal and Lalancette, 1976). Adsorption properties can also be linked to the presence of a porous structure, conducive to physical adsorption (Tinh *et al.*, 1971).

Given the potential of this technology, large scale research and development work has been conducted on a 150 sows farrow-to-finish operation on Île d'Orléans (Québec, Canada) using an industrial biofiltration system of 560 cubic metres total volume (primary biofilter: 400 cubic metres, polishing biofilter: 160 cubic metres). This work aimed to demonstrate the overall efficiency of biofilters to reduce odours in terms of manure produced and foul air coming from the livestock buildings.

The results obtained during the long-term monitoring of the technology's purifying performance (6 years), show that the system installed on the farm offers a purifying efficiency of over 95% for NH₃. The measured elimination performances exceed 99% for H₂S. System efficiency is maintained at around 80% - 85% for odour intensity reduction. Moreover, foul air and raw manure from the livestock buildings, considered to be annoying, indeed unacceptable, are deodorized to reach an acceptable level after they pass through the biofilter.

This results show that the BIOSOR™-Manure process is a simple and efficient treatment system adapted to the needs of agricultural enterprises, which is a substantial asset for the evolution of the sustainable development of this industry.

Figure 1: Diagram of BIOSOR™-Manure (Porcherie Orléans inc.)



Materials and methods

An industrial biofiltration system was designed, built and implemented to treat the liquid and gas effluents of a 150 sows farrow-to-finish operation (about 3,000 pigs produced per year). The system was designed to simultaneously treat up to 12 cubic metres/d of manure and 15,000 cubic metres/h of foul air. Figure 1 shows that the pig manure is treated by first separating the liquid and solid parts in a sedimentation tank and a 1,200 cubic metres digester (existing storage tank reused for the needs of the system). The system stabilizes and deodorizes the sludge (20% of the total volume of the manure) through anaerobic

digestion. The residual liquid fraction (80%) is directed to a protection prefilter. This fraction is then pumped to the surface of a 400 cubic metres primary biofilter composed of a multi-layer organic bed non inoculated (70% woodchips, 30% peat moss). In order to reach a degree of purification to consider discharge to the environment, the waters are finally directed into a 160 cubic metres polishing biofilter (non inoculated, 70% woodchips, 30% peat moss). The treated water is stored in an existing tank (2,600 cubic metres) before being used to wash the gutters or for irrigation. The foul air from the production building is directed to the base of the two biofilters to perform a counter-current treatment.

Measuring Purification Efficiency

We have used two complementary approaches to determine the deodorization performance of the biofiltration system. The first is the classic physicochemical analysis to evaluate the concentration of ammonia (NH₃) and hydrogen sulphide (H₂S), the two main compounds responsible for the odours. The second is olfactometry, a sensory analysis method that calls upon a jury to quantify the perceived odours. Ammonia, hydrogen sulphide and odour intensity (olfactometry) were subject to rigorous monitoring to establish the deodorization performance of the biofiltration system.

Analytical Approach. The sampling method selected to characterize the foul air from the buildings housing the pigs is a selective sampling device by family of components (Le Cloirec *et al.*, 1991). This technique consists of trapping the volatile components to be dosed with specific reactivities. The ammonia trapped in the form of ammonium ions in the hydrochloric acid solution is dosed by colorimetry using the Nessler reactive according to the AFNOR NFT 90.15 norm. The sulphated components are quantified by iodometric dosage according to the SMEWW – 4500 S²-F Iodometric Method (APHA *et al.* 1995).

Sensory Approach. To perform the sensory analysis of the gas effluents, it was used the TECNODOR™, dynamic dilution olfactometer based on the principle of the suprathreshold measure (Ref.: ASTM E544 American standard, VDI 3882 German standard and AFNOR X43-103 French standard). The TECNODOR™ is a mobile machine that allows *in situ* measurement. The principle consists of having a jury of at least four people smell the odour to be evaluated. The intensity of the perceived odour is then compared with the intensity provided by a specific concentration of a reference substance (1-butanol) generated by the olfactometer. The intensity of the ambient odour is then expressed as an equivalent ppb of 1-butanol. For the comparative olfactometrical analysis of the liquid (raw and treated manure), we used a dynamic flux chamber (Eklund, 1992; Gholson *et al.*, 1991) that channels the fumes and prevents their dispersion in the ambient air when the olfactometric measure is taken.

In addition to measuring the intensity of the perceived odours, we have also evaluated the hedonic character of the perceived odours, i.e. the degree of acceptability experienced by each jury member upon exposure. To do this, we used the method suggested by Martin and Laffort (1991) which consists of determining the Odour Nuisance Index (ONI).

Results and discussion

Performance of the Elimination of Ammonia and Hydrogen Sulphide

Table 1 shows the results obtained for the determination of ammonia concentrations (NH₃) and hydrogen sulphide (H₂S) present in the foul air of the livestock buildings and when it comes out of the biofilters (averages for six years).

The increased concentrations in biofilter entries observed in the fall are caused by a decrease in the farm's ventilation rates. This operation is performed in order to comply

with minimum ventilation rate criteria for the winter. This rate is completely taken up by the biofilter supply fans.

Table 1: Elimination of Target Compounds (NH₃ and H₂S)

Period	Compounds	Average Concentration (ppmv)		Elimination Performances (%)
		Biofilter entry	Biofilter exit	
Summer	NH ₃	2.35	0.11	> 95
	H ₂ S	0.034	undetected	> 99
Fall	NH ₃	6.72	0.07	> 98
	H ₂ S	0.186	undetected	> 99

Ammonia is the compound with the highest concentrations varying between 2.3 and 6.7 ppmv. Even though they appear weak, the hydrogen sulphide concentrations measured in the foul air (0.03 to 0.19 ppmv) are nevertheless higher than the perception threshold for this compound (Le Cloirec *et al.*, 1991).

The system maintained purifying efficiencies greater than 95% for NH₃ during six years of operation. The measured elimination performances exceed 99% for H₂S.

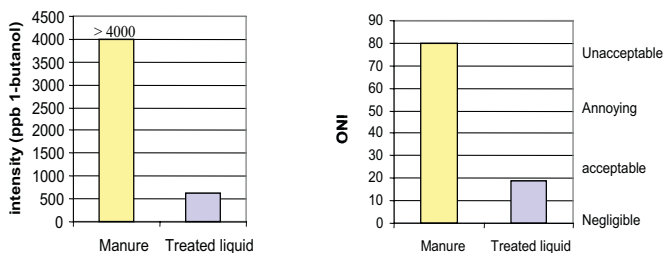
Odour Reduction (Foul Air in the Livestock Buildings)

The results of the sensory measures show a net difference between the foul air and the treated air. This difference essentially resides in the intensity of the perceived odour and the level of discomfort felt by the jury. Table II reveals that the farm's ambient air is characterized by a strong intensity qualified as annoying, even unacceptable. The air that comes out of the biofilter provides a slight olfactory sensation that is deemed acceptable. Moreover, the air treated by biofiltration has an odour described as being like a wetland (characteristic odour of peat moss). The biofilter therefore has a dual role: it breaks down the pollutants from the farm (NH₃ and H₂S) and it gives the gas stream an acceptable odour. System efficiency is maintained at around 80% - 85% for the reduction in odour intensity. This reduction was not affected by winter time and summer time temperatures (-25°C ; +25°C) and the load applied to the biofilter.

Table 2: Characteristics of Odours Measured upon Entering and Exiting the Biofilter

Period	Average Odour Intensity (ppb 1-butanol)		Reductio	Period	Odour Nuisance Index (ONI)	
	Biofilter Entry	Biofilter Exit			Biofilter Entry	Biofilter Exit
Summer	5,270	850	84%	Summer	Annoying	Acceptable
Fall	12,170	2,200	82%	Fall	Unacceptable	Acceptable

Figure 2. Sensory Measures Carried Out on the Liquid Fraction (Raw Manure and Treated Liquid)



Olfactometric Measures on the Liquid Fraction (Treated and Untreated Manure)

The results of the sensory measures also show a net difference between the raw manure and the treated manure. Figure 2 reveals that the biofiltration system reduced the odour intensity by over 4,000 ppb of 1-butanol to about 600 ppb of 1-butanol. In addition, the raw manure qualified as unacceptable is deodorized to reach an acceptable level after passing through the biofilter. The odour of the treated water that comes out of the biofilter also has a wetland smell (peat moss).

Conclusion

The results obtained during this project reveal that the BIOSOR™-Manure biofiltration process represents a solution to the overall problem of porcine farm odour. Its dual role enables the biofilter to break down pollutants from the farm and provide treated foul air and manure with an acceptable odour (peat moss).

The passage of gas effluents in biofilters reduces (> 95%) the concentration of target compounds (NH₃ and H₂S) present in the foul air of livestock buildings. Moreover, sensory measures show that the biofilter reduces the intensity (> 80%) of odours generated by livestock production activities and the management of manure (buildings, storage, transportation and spreading).

The sensory analysis method used (TECNODOR™ olfactometer) resulted in an *in situ* evaluation of the sensation actually perceived (intensity) by integrating the hedonic aspect (pleasant or unpleasant character) of the odour.

In light of these results, there is no doubt that the biofiltration process represents a rugged, simple and efficient technology to solve the overall environmental problem associated with unpleasant odours generated by the management of pig manure. The biofiltration system is installed directly on the producer's pig farm with no impact on production control while recuperating existing storage reservoirs. This technology now makes it possible to reconcile people's environmental concerns with the pork industry's potential for growth.

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