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Non-specific conducting polymer-based array capable of monitoring odour emissions from a biofiltration system in a piggery building

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ABSTRACT

A commercial non-specific gas sensor array system was evaluated in terms of its capability to monitor the odour abatement performance of a biofiltration system developed for treating emissions from a commercial piggery building. The biofiltration system was a modular system comprising an inlet ducting system, humidifier and closed-bed biofilter. It also included a gravimetric moisture monitoring and water application system for precise control of moisture content of an organic woodchip medium. Principal component analysis (PCA) of the sensor array measurements indicated that the biofilter outlet air was significantly different to both inlet air of the system and post-humidifier air. Data pre-processing techniques including normalising and outlier handling were applied to improve the odour discrimination performance of the non-specific gas sensor array. To develop an odour quantification model using the sensor array responses of the non-specific sensor array, PCA regression, artificial neural network (ANN) and partial least squares (PLS) modelling techniques were applied. The correlation coefficient (r^2) values of the PCA, ANN, and PLS models were 0.44, 0.62 and 0.79, respectively.

1. Introduction

Odour emissions from intensive livestock facilities are a source of contention in many rural areas. Under certain conditions odour emissions have been known to affect neighbours and communities at distances of a kilometre or more from the odour source. One of the odour control technologies that have been shown to be both economical and effective is a biofilter. Biofiltration can reduce odour and hydrogen sulphide emissions from livestock and poultry facilities by as much as 95% and ammonia by 65% [1]. This method of odour control has been used in industry for many years and was recently adopted for use in piggery and other livestock systems.

Biofilters are designed to remove contaminants from the air, and all operate on the same basic principle [2–4]. They contain a packing medium (filter bed) where micro-organisms reside in thin layers of moisture around the media particles forming a biofilm. As contaminated air is passed though the packing medium, organic compounds are absorbed into, and adsorbed onto the biofilm layer where microbial action oxidises them into less harmful or less odorous products. These products are primarily water, carbon dioxide, inorganic salts, some volatile organic compounds (VOCs) [1] and microbial biomass.

When considering applying a biofilter system in a field situation, it is necessary to evaluate the system objectively in terms of its odour control efficiency, in a reliable and repeatable manner. Previous studies of intensive livestock odours have generally used olfactometry to measure concentration, intensity and offensiveness. However, there are several disadvantages associated with the olfactometric technique including expense of operation and difficulty of collecting representative samples [5].

Gas chromatography–mass spectrometry (GC–MS) assists identification and concentration measurement of volatile compounds present in odorous air samples discharged from the biofilter. Odour analysis using a GC–MS identified 168 odorous chemical compounds from the air samples collected in and around animal housings [6]. However, the concentration of odours is difficult to measure using GC–MS because many chemical compounds are present at very low concentrations and the concentration of each component is continuously changing. Work has been performed to correlate complex odours to concentrations of single components such as ammonia and hydrogen sulphide. However, no such correlation is yet apparent [7].

Recent developments in the non-specific gas sensor array (*i.e.* electronic nose) technology and modern pattern recognition

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techniques, including chemometrics and bio-mimetic algorithms, provide opportunities to extend the scope of odour measurement. A feature that distinguishes an electronic nose from other instruments used for odour measurement is the ability of its sensor array to respond differently to various odours. Each odour may contain hundreds, sometimes thousands, of different VOCs. Classical spectrometry analytical methods such as GC–MS are able to identify and measure individual odorous chemical compounds in an odour sample. On the other hand, the electronic nose reacts to the 'total odour sample' like a human nose. The human olfactory sensing system does not separate individual chemicals in the sample as part of an assessment process. The odour is assessed and identified using our brain (*i.e.* odour recognition from memory).

Researchers have identified that a non-specific gas sensor array was able to quantify odours in the field and to discriminate between odours from different sources [8–17]. The lack of reproducibility of sensors could be compensated using a flexible calibration and recognition tool based on neural networks [18]. Researchers have proved that an artificial neural network (ANN) can simulate non-linear relationships observed in human perceptions such as taste and odour and thus, is able to be used to develop prediction models from the relationships [19]. Improved statistical methods were also used to discriminate between various VOCs derived from car components from datasets collected using a non-specific sensor array system [20].

Furthermore, there have been approaches to obtain relationships between electronic nose output and odour concentration determined by dynamic olfactometry using different pattern recognition algorithms [21–24]. In these trials, the odour concentrations of samples not used to train an electronic nose could be accurately determined using an ANN approach. Although errors associated with olfactometry were identified as a constraint to improving the accuracy of odour concentration determination, it was shown that ANN algorithms significantly improved the model's ability to predict new samples than using alternative linear and non-linear multivariate modelling techniques. In these approaches, reliable olfactometry data is highly important because ANNs are trained not only using the sensor outputs of an electronic nose but also the odour concentration results from olfactometry. Chemometric methods have also proven useful for developing odour prediction models, especially where a limited number of calibration data are available [23].

In this study, a commercial non-specific gas sensor array system was evaluated in terms of its capability to monitor the odour control performance of the biofilter system that was developed to treat odorous air sourced from a commercial piggery building. The electronic nose used (AromaScan A32S) includes an array of conducting polymer sensors, which are appropriate for the assessment of odour emissions from intensive livestock industries because of their sensitivity to volatile chemicals found in such odours. The electronic nose system was able to provide qualitative information (*i.e.* discriminate between samples from different sources) and predicted odour concentrations using a model based on results from olfactometry.

2. Materials and methods

2.1. Biofiltration system

A multi-component biofiltration system comprising a biofilter and humidifier was constructed as shown in Fig. 1. A fan was positioned at the outlet of the system to generate airflow. Gas samples were collected from the inlet ducting, humidifier-to-biofilter ducting and outlet ducting (as indicated in Fig. 1). These gas samples were analysed for determining odour concentration using dynamic olfactometry and the AromaScan^{TM} (AromaScan plc., Crewe, UK).

2.1.1. Biofilter vessel

The biofilter vessel was constructed using a 2720 l polyethylene rainwater tank (Duraplas^{TM} 600U/R, diameter 1400 mm, height 1970 mm). The filter material loaded into the biofilter comprised a mixture of *Callistris glaucophylla* (white cypress pine) woodchips and screened compost made of pig manure. The woodchips and

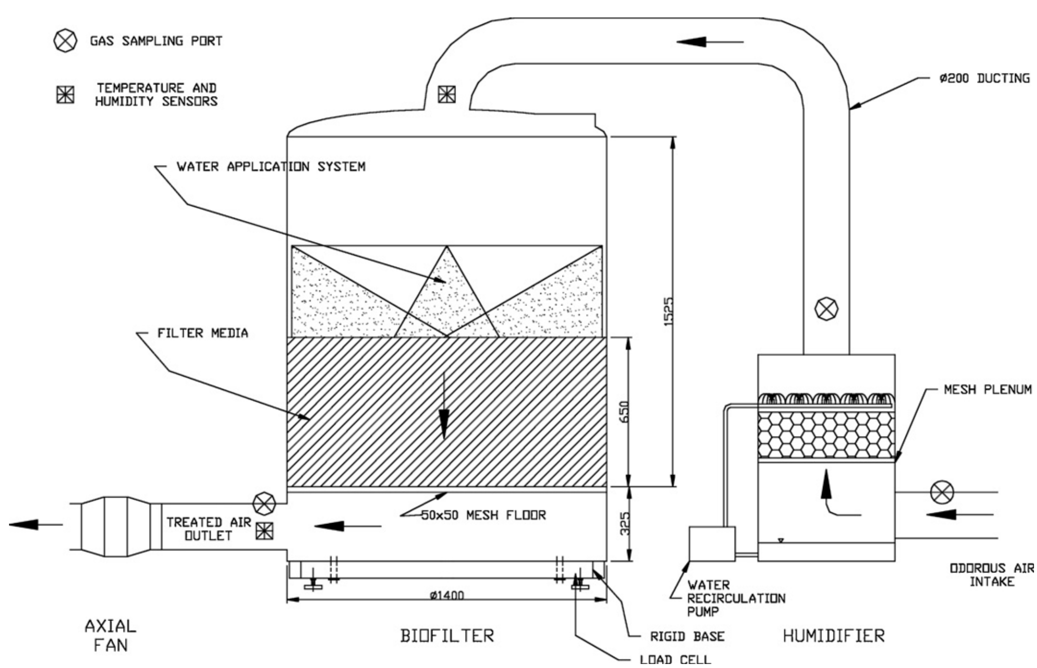

Fig. 1. Schematic of biofiltration system, showing humidifier, biofilter and axial fan.