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Review

Odour sampling. 2. Comparison of physical and aerodynamic characteristics of sampling devices: A review

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Abstract

Sampling devices differing greatly in shape, size and operating condition have been used to collect air samples to determine rates of emission of volatile substances, including odour. However, physical chemistry principles, in particular the partitioning of volatile substances between two phases as explained by Henrys Law and the relationship between wind velocity and emission rate, suggests that different devices cannot be expected to provide equivalent emission rate estimates. Thus several problems are associated with the use of static and dynamic emission chambers, but the more turbulent devices such as wind tunnels do not appear to be subject to these problems. In general, the ability to relate emission rate estimates obtained from wind tunnel measurements to those derived from device-independent techniques supports the use of wind tunnels to determine emission rates that can be used as input data for dispersion models.

Keywords: Odour; Emission; Wind tunnel; Chamber

1. Introduction

Estimation of rates of emission of volatile materials from area sources such as anaerobic treatment ponds, feedlot pads, compost windrows and municipal wastewater works is a complicated process. Conceptually, two basic processes may be used:

1. Device-independent micrometeorological techniques, where the emission rate is calculated from concentrations measured across the plume of emitted material and local meteorological data, specifically wind velocity profile data (e.g. (Yamulki et al., 1996; Christensen et al., 1996; Denmead et al., 2000; Magliulo et al., 2004; Kim et al., 2005)), and
2. A sampling device, where a chamber, hood or wind tunnel, is deployed on an emitting surface. The device may be static (sealed or vented) or flushed with contaminant-free carrier at a known velocity or flow rate. The emission rate is calculated as the product of concentration and airflow through the device (e.g. (Raich et al., 1990) (Eklund et al., 1985; Gholson et al., 1991; Fukui and Doskey, 1996; Conen and Smith, 1998; Peu et al., 1999)).

In principle, similar techniques may be used to estimate odour emission rates. The entire process comprises: collection of representative odour samples; measurement of flushing rates within the sampling device (if used) or measurement of ambient meteorological conditions (for device-independent methods); determination of odour concentration in the sample using dynamic olfactometry, and calculation of odour emission rates using the concentration

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and flushing rate data or meteorological conditions at the time of sampling. In the case of odour, however, the high cost of odour assessment limits the number of samples that can be realistically analysed. This effectively precludes micrometeorological measurement techniques, which necessitate the collection of a substantial number of samples across the downwind odour profile.

The entire odour sampling and assessment process was recently reviewed (Environmental Protection Agency, 2001; Gostelow et al., 2003). In the former review the benefits and disadvantages of micrometeorological, wind tunnel, static- and dynamic-hood sampling procedures were tabulated in some detail, together with the potential application of all techniques. While the technical and methodological difficulties associated with wind tunnels appeared to be least, the authors held back from recommending the use of any specific device for sample collection. It should be noted that the use of any device to collect a sample of odorous air is likely to disturb the emitting surface and thereby the true emission rate.

In Australia, a range of wind tunnels and emission chambers have been used to collect odour samples from area sources at intensive livestock farming operations. Regulatory agencies in Australia have developed odour management policies for these facilities based on data derived from a number of these devices (Streeten and McGahan, 2000; Skerman, 2000; McGahan et al., 2000; Environment Protection Authority, 2001). Accordingly, separation distances and odour impact criteria vary according to the regulatory jurisdiction. This situation arose in part from the very different numeric values obtained from use of the various emission chambers or wind tunnels. This creates difficulties for industries that operate across State lines in Australia, who may have quite different license conditions for equivalent operations in different States. These apparent anomalies are difficult to comprehend by the general community, thereby creating difficulties for the various regulatory agencies and producers. Recently the Australian beef cattle feedlot industry facilitated an investigation to reconcile the use of these two sampling devices for odour sampling (Meat & Livestock Australia (MLA) and the Australian Feedlot Producers Association (ALFA), 2002; Nicholas et al., 2004). The results of this research confirmed that two sampling devices commonly used in Australia for estimating odour emission rates from area sources provide quite different results.

The situation is even more confusing if the scientific literature is consulted. While mass transfer processes have been extensively investigated and described, little guidance is provided in the selection and operation of sampling devices to obtain meaningful emission rate estimates. Review of the literature reveals a wide range of devices that may be used to collect samples of volatile chemicals from liquid and soil surfaces. With the possible exception of measurements of emission rates for mercury (Gustin and Lindberg, 2000) and major atmospheric gases (Wanninkhof et al., 1985; Clark et al., 1995; Crusius and Wanninkhof, 2003), limited comparison of data derived from different sampling devices has taken place. Accordingly, limited data and information exists to guide practitioners in the selection and operation of sampling equipment. Currently, even less information exists to guide practitioners in the selection and use of the most appropriate odour sampling equipment.

This review identified some of the devices used to collect samples of volatile material emitted from solid and liquid surfaces. The physical dimensions and typical operating conditions of these devices were summarized, providing an overview of the wide range of sizes and operating conditions. Examination of a few representative examples from the literature in more detail identified some of the practical issues and limitations posed by each device. Consideration of the fundamental principles underlying the mass transfer process provided guidance regarding selection of sampling equipment. Finally, information from the literature was used to justify the selection of wind tunnels for estimating odour emission rates.

2. Odour as an "analyte"

This aspect was recently discussed (Hudson and Ayoko, accepted for publication), where it was established that "odour" is a complex mixture of many organic and some inorganic chemicals. For example, up to 330 different chemicals belonging to a range of chemical classes including volatile fatty acids, aldehydes and ketones, nitrogen heterocycles, reduced sulphur compounds and phenols, were identified in odour samples derived from piggeries and beef feedlot operations (O'Neill and Phillips, 1992; Schiffman et al., 2001; Wright et al., 2005). As a sample material, odour therefore represents an uncontrolled mixture of chemicals of different classes and quite different physical and chemical properties. Caution is therefore required when selecting a sampling technique to ensure that discrimination is minimized and that the sample is truly representative of the ambient odour composition. This is particularly important when the key odorants associate with intensive livestock-raising are considered. Zahn et al. (2001) generated an artificial piggery odour using 19 specific odorants. It was possible to develop an odour prediction model using nine of these compounds – acetic, butyric, isobutyric, valeric and heptanoic acids, phenol, 4-methylphenol 4-ethylphenol and 3-methylindole. These odorants all have relatively small values of non-dimensional Henry constant. Wright et al. (2005) identified 4-methylphenol, 2′-aminoacetophenone, isovaleric acid and 4-ethylphenol as the most significant odorants downwind from a major piggery. Neither Zahn et al. (2001) or Wright et al. (2005) identified hydrogen sulphide, mercaptans or other reduced sulphur compounds as significant odorants associated with intensive livestock facilities.