CHEMICAL ENGINEERING TRANSACTIONS, Volume 15, 2008
Edited by Renato Del Rosso

Continuous online odour measurements

PD Dr. Peter Boeker*“, Dipl.-Phys. Torsten Haas*#, PD Dr. Bernhard Diekmann*,
Prof. Dr.-Ing. Peter Schulze Lammers*
* Department of agricultural engineering, University of Bonn
# Physics Department, University of Bonn
“ AltraSens, Bonn
Nussallee 5, D-53115 Bonn

Attention to odour as an environmental nuisance has been growing as a result of increasing industrialisation. Therefore many sensors and methods to detect or to analyse odour were developed since the last years. In this contribution the concept and application of an odour measurement method with a chemosensor system in combination with olfactometric reference measurements is described. The chosen exemplary measurements were carried out behind a charcoal filter from a waste incineration plant. The measurement period was three months. During that period the course of the odour emission was measured and calculated online. The method of online odour measurement was successful and has shown the efficiency of detecting a filter breakthrough. Since 3 years the odour measurement system is now working continuously under rough industrial conditions.

1. Introduction

Odour nuisances are increasingly polluting the environment, which leads to conflicts with residents living close to agricultural or industrial facilities. A reliable identification of offensive odour nuisance and an effective method for odour reduction require an accurate measuring technique for odour presence and odour intensity. With an electronic odour measurement system (OdourVector™) and a special technique of data analysis, it is possible to measure odour continuously at different emission sources. The odour measurement system OdourVector was already successfully tested on odours from purification plants, composting facility (Yuwono 2003) industrial processes (Boeker 2003), exhaust air systems and odours from sewage systems (AltraSens2008). The main subject of this paper is to explain the functionality of odour measurement with OdourVector. At last the online monitoring of a charcoal odour filter at an incineration plant is presented as an example of the application of the OdourVector measurement system.

2. Framework and methods of odour measurement

Although the chemosensor system seems to be working in technical analogy with the human sense of smell there are some important differences which are leading to problems. The differences between the biological sense of smell and the technical realisation of the sensor-array-based measurement systems are fundamental.

The important problems of odour measurement are still (Boeker 2003):

- Gas-sensors are unable to distinguish between odorous gases and odourless gases.
- The sensory properties of the chemosensors are changing after some time because of ageing and drift.
- Wrong or inappropriate methods of measuring and data analysis lead to incorrect results.

Therefore, the correct odour measurement requires consideration of the following main rules of odour detection:

- A meaningful selection of the sensor's coating. The sensor should be non-selective but enough sensitive to comprise many different odour components (Horner 1990).
- High stability of the sensor by keeping its calibration and quantifying odour emission.
- Application of a special method depending on the measuring conditions.

The methods of measuring odours are quite complex. Many non-odorous gases produce high signals, and some extremely odorous gases at very low concentrations are producing only very small or almost no signals (Boeker 2003). In the decision tree in Fig 1 the different possibilities are shown. Under the conditions of case 1 and 2 a real odour measurement is possible. In both cases the odorous gases are measured directly, in case 2 the interfering concomitant gases are suppressed by technical means. Case 3 and 4 refer to an indirect odour measurement. Although in case 3 no direct measurement of odorous gases takes place, the correlating odourless gases are measured, giving a measurement on the condition of this correlation. Case 4 is similar; the dominant odourless concomitant gases correlate with the main odour compounds. The cases 5 and 6 refer to conditions without the possibility for odour measurement. In both cases the correlation to the odour is missing, thence the measurement systems only gives information about irrelevant odourless gases, leading to false positive or false negative results respectively.

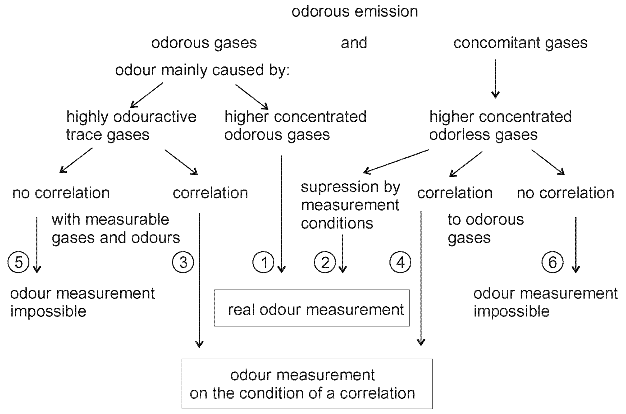

Fig. 1: Decision tree for the possibility of odour measurements

Therefore, it is not possible to determine the odour impression of a certain gaseous atmosphere only by means of a chemical measuring system. The odour measurements must take place in two stages. The first stage is to analyse the composition of the odour emission in a predefined odour space. In the second stage the intensity of this emission will be calculated. Before that the measurement system has to be trained for the particular odour emission. During the calibration the chemical measurements are carried out parallel to olfactometric reference measurements. Olfactometry is a standardised procedure for odour measurements and it is based on experimental evaluation of the odour impression by a group of humans. Unfortunately this procedure has a high amount of measurement uncertainty (Maxeiner 2003, 2006; Boeker 2007). A result of a mathematical Monte-Carlo-simulation of olfactometric measurements is presented in figure 2. The structure of the simulation is identical to the process of an olfactometric measurement. The simulation is based on EN 13725. The simulation show an inherent error (2σ) up to 4,5 db, which means an error band between one third and the threefold of an actual measured value. In reality, as proven by round robin tests, the measurement uncertainty is even higher. Under these difficult conditions, the following methodology of the data evaluation must be used, in order to avoid errors in the calibration procedure of the odour measuring systems. The chemical measurements define regions of chemically matching emissions (classes) at the chemical odour space of the measurement system. These odour classes can be separated with the principal component analysis, PCA (Pardo 2002).

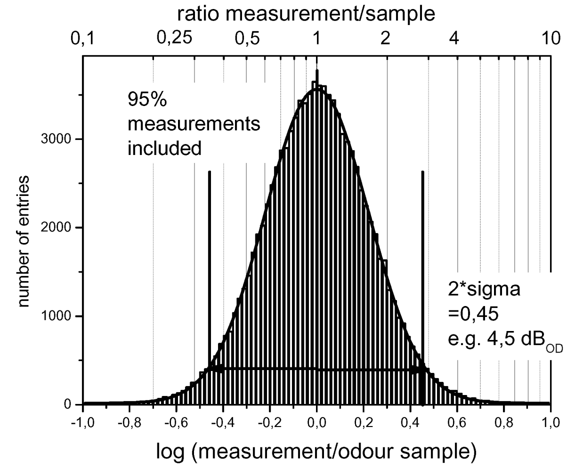

Fig. 2 Result from the Monte-Carlo-simulation of olfactometry.

After the calibration the following measurements are classified to the predefined odour classes by use of a distance criterion such as the mahalanobis distance.

For each individual odour class olfactometric data is acquired, from which a calibration function is calculated in order to determine the odour strength. According to the developed methodology it is finally possible to calculate the spectrum of odour intensity from the chemical sensors using all calibration functions. The whole process of a measurement with OdourVector is illustrated in Figure 3.

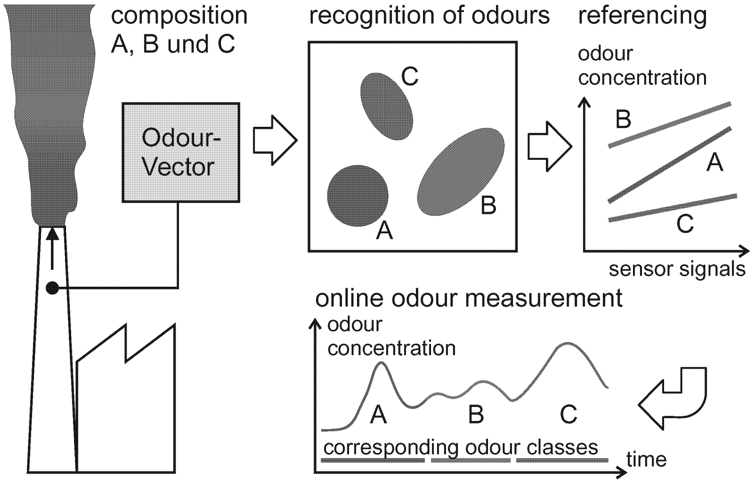

Fig. 3 Process of measurement with the OdourVector chemosensor system

3. The OdourVector measurement system

The OdourVector™ measurement system consists of an array of chemical sensors based on oscillating quartz crystals. The crystals are covered with special coatings that absorb gas molecules. The chemical load of the coating increases the effective mass and thus the oscillation frequency of the sensor changes accordingly. This frequency changes are recorded with the system, which is also the core principle of the method. The change of frequency follows the Sauerbrey-formula. This formula shows a linear correlation between the frequency shift and the change of mass. This type of chemosensor is called as quartz-microbalance-sensors (QMB or QCM). A combination of 6 QMB sensors with different coatings makes it possible to get an individual pattern of the odour sample. An integrated pre-concentration unit (absorbent Tenax™) enhances the sensitivity of the measurement, reduces interferences and renders a highly stable measurement mode possible. Via GSM-modem a remote control and the delivery of online and collected date is implemented. In order to collect reference odour samples in sample bags the OdourVector can automatically activate a sample system at high emission levels and send a SMS via the GSM-modem. By this means the referencing procedure is much more effective than the collection of samples at fixed time intervals.

4. Application of the odour measurement methodology

The OdourVector was used several months under industrial conditions on a waste incineration plant with the aim to detect the breakthrough of the odorous gases behind the active charcoal odour filter. The measurement results are presented in the figure 4 und 5. The figures shows different sensor patterns which are also used for identification of the breakthrough. With olfactometric reference data the measurement system was calibrated. The calibration function is applied in figure 5 to calculate the actual odour concentration from the sensor signals and the patterns. The high degree of correlation between the calculated odour and later control measurements is obvious in figure 5.

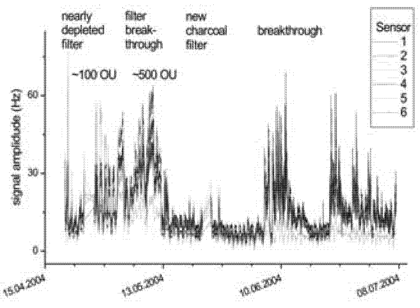

Fig. 4: Signal amplitude (frequency difference between reference and desorption phase) of OdourVector behind a charcoal odour filter recorded over three months.

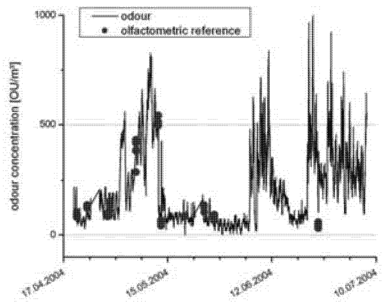

Fig. 5: Odour concentration (OUE/m³) during the three month measurement phase compared to olfactometry references

To illustrate the difference of the several samples figure 6 shows a PCA plot of selected data from the result of the measurements in figure 4. The data are separated in three different regions (classes) in the chemical space. The left class represents the pattern of a new filter. The right class appears when the filter is depleted and the odour is no longer reduced from the charcoal. The middle class corresponds to a changeover pattern. This means that the process of a filter depleting starts with the left pattern, then the pattern changes to the middle class and at least the pattern ends with a filter breakthrough which is indicated by the right class.

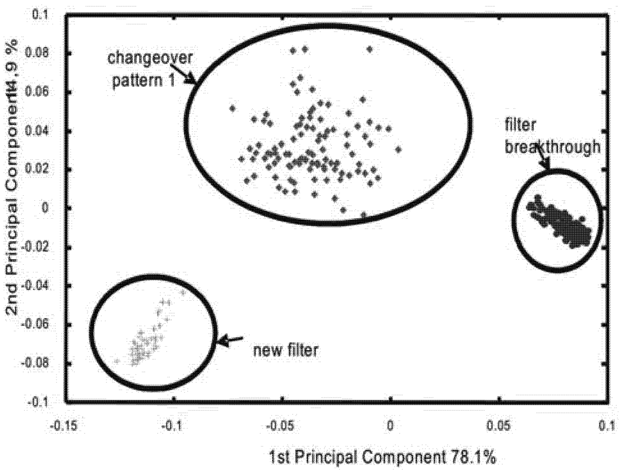

Fig. 6: PCA Plot of measurements results at a waste incineration plant.

Consequently there are two indicators for a filter breakthrough:

- The first indicator is the odour concentration itself and
- The second is the pattern of a filter breakthrough.

High odour concentration may mean a depleted filter. The advantage of this indicator is that it has a simple and robust mathematic analysis. The second indicator should be independent from sensor amplitude which can be an advantage for this method. For other application it is necessary to combine both methods to get full and correct information about the odour.

5. Outlook

The OdourVector system has been installed permanently after the measurements presented here. It is now working since nearly 3 years, supervising the odour filters of the waste incineration plant. Since then approximately 50.000 odour measurement cycles have been carried out with the odour measurement system.

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