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Identification and evaluation of smell emissions from agriculture

Application of chemical sensor arrays

Around farms there is an increasingly emerging problem of smells affecting people living in the vicinity. An evaluation of this nuisance has only been possible up until now through using the human nose. In that this olfactory method has many deficits such as lack of reproducibility, subjectivity, high personnel costs, or also the dependence on the level of sensitivity able to be produced on the day in question by the tester, a system is now developed where smell can be measured by an apparatus.

Presented here are the methods involved and the documentation of first quantitative results which confirm the suitability of the system used.

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Because of increasing housing density and also growing expectations regarding the quality of air, the identification of unwanted smells around farms has become a challenge that can no longer be ignored. Thus there's a necessity for the development of a system for objective smell measurement.

Olfactory

Up until now different methods have been used for measuring smells (*table 1*). The olfactory approach is currently the standard technique for measuring air pollution in units of smell, and therefore effect-associated units.

The following utilisation areas are thus covered [1 to 4]:

- Definition of the smell substance concentration in the context of emissions as well as their influences
- Investigation of the smell thresholds of individual substances and substance mixes

The procedure involves the diluting of smell samples. The diluted samples are given to a sampling panel. It is decided by the panel at what point of dilution a smell can still be identified in the added air. This threshold is defined as a smell unit (GE) for the smell in question:

Smell threshold: 1 GE
Recognition threshold: 3 to 5 GE

It has been agreed within the guidelines [1 to 4] to test all smells present in the total group. A CEN norm [6] which should replace the current national guidelines but which is, however, only in planning at the moment, uses once again other values. In this case n-butanol is to be used for the testing of the groups.

Multisensor-array

Structure

The main part of the equipment used comprises three sensor chambers each with six metal oxide sensors, one temperature sensor and one moisture sensor. A substance flow regulator and a pump are applied to precisely control the volume flow through the sensor chambers. This system ensures the precise dosing of the sample and the reproducibility of the resultant measurements. A pre-activated valve controls whether a sample is to be processed or whether the sensors are to be rinsed with pure air.

Methods	Utilisation	Deficits
Human nose and olfactory	Hedonistic evaluation	Subjective interpretation of smells
GC-MS	Smell identification and definition using comparative substances	No recording of total impression of the smell
Multisensor-arrays	Recording of total impression of smell	Results of sensor ageing

Table 1: Common methods for odour measurement

If a sample containing reduced substances is channelled over the sensors these react to this with the chemically absorbed oxygen under return of electrons on the conductivity band of the semi-conductor. Through this, its resistance is altered. This resultant resistance alteration is registered as a measurement signal.

The small selectivity represents advantages for this application in that only through certain evaluation algorithms can it be used.

Evaluation algorithms

Only one value per sensor and measurement can be used for the evaluation. This means that for each of the 18 sensors there is a measurement value.

Finally, the individual measurements are processed via various evaluation algorithms in order to form the single measurements into groups. Through the 18 sensor values an 18-dimensional zone is created. Through this it is possible to transfer through mathematical conversion the sensor signal from one sensor into the sensor signal of another sensor. This is what the PCA model attempts, in the 18 dimensional zone there lies a two-dimensional level (formation of the characteristic zone) so that this creation contains as much original information as possible.

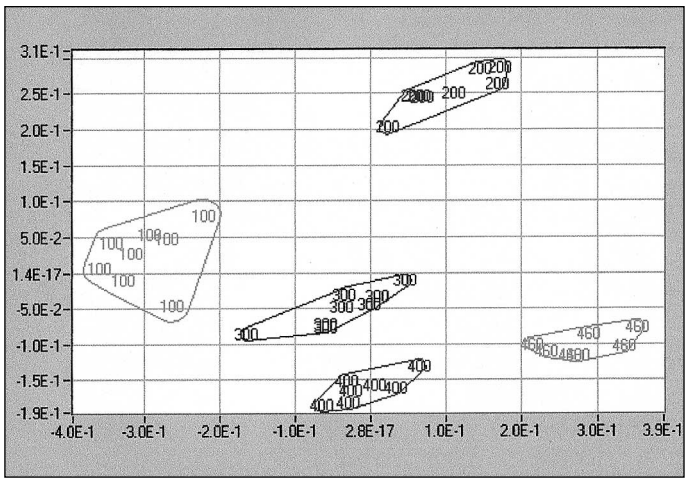

Fig. 1: PCA-plot for different concentrations of n-butanol (100 ppb, 200 ppb, 300 ppb, 400 ppb, 460 ppb)

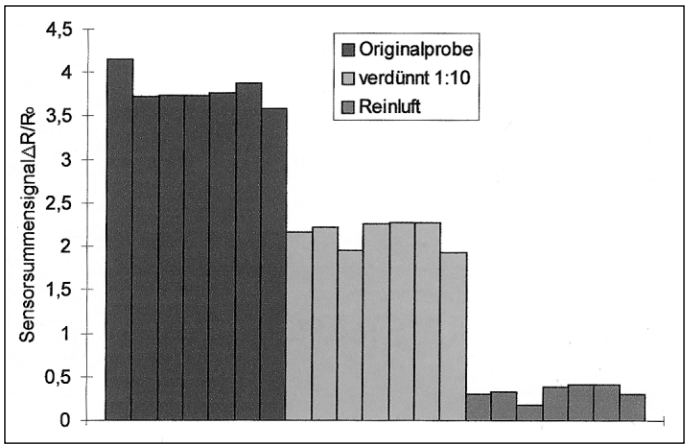

Fig. 2: Results of the MSA measuerements fom different concentrations of piggery air

Comparison of sensitivity of olfactory and multisensor-array in the measurement of n-butanol

In the chapter on olfactory certain limits which apply to an olfactory group are defined for the smell ability of sampling panels regarding n-butanol. Similar concentrations were produced in a gas mix station and filled in sample bags. These sample bags were tested via the multisensor-array. The appropriate characteristic zone is illustrated in *figure 1*.

The figures gave the concentrations of n-butanol in ppb. Through PCA-analysis, a separation of the various concentrations take place. This order of separation is not, however, according to the value of the concentrations. This can be explained, as described in the previous chapter, in that this representation is produced only through a transformation of a higher dimensional zone to a two-dimensional zone. If another transformation is used, then the representation is altered.

If one compares this result with that of the olfactory group it shows that the multisensor-array with regard to n-butanol follows the guidelines for an olfactory group. The sensitivity, visible through the concentration graduations, is notably higher than results that can be achieved by samplers.

Comparison of the sensitivity of olfactory and multisensor-array with farm smells

If multisensor-array is to be applied for classifying smell emissions then it must be as sensitive as the human nose with regard to real smells. For this comparison, samples of actual smells from a pig house were used.

An original sample from a naturally-ventilated feeding pig unit was transformed to a 1/10 dilution in a gas mix station. The original sample and the dilution were first of all given to the olfactory group in triplicate. In the case of the undiluted sample, the samplers A, B, C and D were relatively in agreement in determining a smell substance concentration of 167 GE/m^3. Sampler E determined in this case a concentration of 54 GE/m^3. With the original probe, the average value determined by the whole group was 144 GE/m^3. The diluted sample was subsequently tested. Sampler A determined a smell substance concentration of 31 GE/m^3 and with this (31 GE/m^3 : 170 GE/m^3 = 0.18) nearest to the dilution of 0.1. The samplers B, C, and D a trend was visible of an, on average, smaller concentration in the case of the diluted samples. The values, however, at 0.3, 0.6 and 0.8 were increasingly further away from the actual dilution value. In fact sampler E determined with the diluted sample a higher smell substance concentration (74 GE/m^3) than determined by him for the original sample (54 GE/m^3).

According to VDI guideline 3881, pages 1 to 4 [1 to 4] only the result of the whole olfactory group can be applied for the actual evaluation. In this case a dilution relationship of (80 GE/m^3 : 144 GE/m^3= 0.55) was determined. With regard to the entire group the trend of a smaller concentration in the diluted sample can be recognised. However, the exact definition of the concentration differences was not possible.

The same samples and their dilution, as in the above olfactory measurements, were presented for multisensor-array testing. Here, seven repeat measurements were carried out in each case. The relative concentrations were measured with the help of the sensor composite signal. For this, the maximum reactions of the sensors are totalled. Additionally, the composite signal is applied with pure air.

The original sample gave measurement values between 4.1 ΔR/R0 and 3.5 ΔR/R0, on average a sensor composite signal of 3.8 ΔR/R0. With the 1/10 diluted sample, notably smaller reactions were measured. In this case, as with the olfactory measurements, no overlapping of the measurement results between the original sample and the dilution took place. On average, a value of 2.1 ΔR/R0 was determined.

The advantage of the multisensor-array measurements compared with those of the olfactory approach mainly lies in the higher reproducibility and the dependability of the individual measurement results from that.

Calibration function of the multisensor-array for emissions from pig and cattle housing

In order to achieve the target of defining smell dimension, the data of the olfactory system and that of the sensor measurements were run together. A correlation was established between the olfactory-determined smell units and the sensor signals over the sensor total signal [6, 7]. Two preliminary calibration functions were able to be established, differing from one another in their gradient. This difference is explained by the differing compositions of the respective samples.

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