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Chemo-sensitometry and odour measurement

The state of electronic olfactometry

Chemo-sensitometry measurement systems which in a very general sense imitate the biological sense of smell have been introduced under the description of „electronic noses“. Although such systems do not, in the main, analyse odour characteristics but rather compositions of gaseous mixtures, they are also applied in electronic olfactometry.

This report discusses the background and the problems of their application and transfer into odour measurement. In this context the methods used up until now have not proved detailed enough. Perspectives and research targets for further developed are identified.

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The promise inherent in the term „electronic nose“ is so far not realisable. The analogy to the biological sense of smell is limited to the first stage of smell appreciation in the form of many sensors with unspecific reactions. Thus such systems cannot develop the functionality of a sense of smell.

The description „electronic nose“ has therefore mainly given way to the more neutral and appropriate description chemosensor array [1]. Typical area of use for the commercially available systems is therefore not really odour measurement, but instead recognition of chemical characteristics contained in the gaseous parts of samples. „Chemical imaging“[2] describes this type of investigation.

There does exist, however, considerable interest in using chemosensor array for measuring odours, from which improved objectivity and continuous long-term observations are expected [3].

Basics of measurement procedure

Chemosensor arrays are arrangements of gas sensitive sensors coupled through different data processing methods. The preferred sensors for chemosensor arrays react not to individual gases but instead to classes of material, to precise chemical functionalities or form parameters. As a whole, therefore, the sensor reactions represent different aspects of the material being sampled. In this way, the sensor array achieves a universality of measurement which, in association with intelligent data processing, allows it to deliver information on mixes of gaseous material and, above all, enables these to be differentiated from one another.

Odour material

Odour constituents are part of all gaseous material in the atmosphere. The signalling role of odours as far as living organisms are concerned has led to only information-carrying material being filtered out for recognition. From the chemical standpoint there results irritating differences in odour thresholds concerning chemically similar materials which is connected to this high degree of selection and filtering.

Chemo-sensitometry evaluates chemical differences. In most cases chemically similar materials lead to similar sensor reactions. This behaviour is shown especially by sensors of chemosensor arrays adjusted to limited selectivity.

Reaction of array to odour-carrying air mixes

The reaction of an array to material mixes is a superposition of individual reactions. *Figure 1* shows the reaction of six sensors to a mix of five materials. Each sensor shows a different size of signal comprising the sensor reactions to the individual materials. The sensor does not differentiate between odour-active and odour-neutral materials.

The individual sensor reactions are described in general by formula 1 through which two parts can be formally differentiated:

$$S_1 = a_{1,0} + a_{1,1}c_1 + a_{1,2}c_2 + \ldots + a_{1,n}c_n + a_{1,n+1}c_{n+1} + \ldots + a_{1,m}c_m \qquad (1)$$

The concentrations c_1 to c_n in this context cover the odour-active components, c_{n+1} to c_m the odour-neutral components.

The physiological-olfactometric reaction to a material mix is only caused by the odour-active components.

Measuring odour strength

Continual monitoring of odour sources is required for investigating odour strengths. The reference factor of odour strengths comes from the value of the odour unit per volume (GE/m^3) determined by graduated dilution of samples. It represents the physiological effect of the odour material mixing.

Two materials (or material mixes) with the same odour strength in GE/m^3 generally show different real concentrations because of different odour thresholds in the content material.

The resulting odour impression from several materials is not the sum of the individual impressions. A multiplicity of phenomena such as mutual masking and strengthening allows no conclusion from chemical composition regarding odour impression.

Using sensor total signals

The standard way of dealing with such problems is the empirical data assessment and the seeking of correlations with which the relationship between odour impression and mix composition can be determined. A series of trials [3, 5, 8, 9, 11, 12, 13, 14, 15, 16] have followed this path and through comparative olfactometric measurements – with simultaneous application of chemosensors – determined correlations between the sensor signals and the odour strengths.

With the exception of the sources [13,14] all points in the use of a total signal are the same, developed from the signals from individual sensors. This total signal is carried out against the measured odour strengths and this allows the determination through linear regression of the sought for relationship between sensor signals and odour strength. The total signal from n sensors is calculated by assumption of linear performance curves to

Gleichung einsetzen

(2)

As shown in formula 2 the total signal behaves as the signal of a single sensor with „determined" characteristics of all totalled sensors. Through differing sensitivity of the sensors for different materials, the total signal shows a broad testing capability.

Determining correlations between odour and sensor signals

It is reported in the published literature [16] that the identified correlations have application in each case only with very precise odour sources and thus own correlations for every source must be used in each case. Making this more difficult is the fact that the correlations have proved not to be stable over longer recording periods [13, 14].

Thus a glance at the existing and basic data for such correlations is interesting. The biological odour sources are substrates where, through biochemical processes, odour materials are produced and released. The component mix is dependent on the biochemical condition. An odour source within a ventilated building is shown in *figure 2.* Such configurations appear with enclosed composting or in livestock housing or storage facilities. Within buildings, odours are released and carried by air currants. The concentration of the odour material c_i is calculated from the relationship of the releasing mass current $\dot{m}_i$ and the air volume current $\dot{V}$

$$c_i = \dot{m}_i / \dot{V} \qquad (3)$$

An assumption is important for further argumentation. With coupled existence of the odour material in the biochemical processes the relative relationship of the components are altered and, with that, the mixture composition with the process condition (see also *figure 6* in LANDTECHNIK-NET). With composting it is, therefore, determined by degree of rotting, within livestock housing by the age of animals or from the composition of the feed. With processes that progress or change slowly the odour mix also changes slowly.

The release $\dot{m}_i$ of a given odour material mix can change through exterior parameters, e.g. the development of the compost, the animal activity, or the factors that influence the material transformation such as temperature and air overflow. Additionally, the diluting air volume current alters, through the ventilation system (or in the case of naturally ventilated sources the wind situation).

The collection of data for a correlation between odour strengths was carried out within a limited period of time during which different odour strengths were received together with the simultaneously recorded sensor signals. According to the above assumptions, similar odour materials were anyway involved but, and this was the important aspect, at different dilutions. Alterations in volume current as well as material release led to differing dilutions and the associated alterations of the sensor signal.

The given correlations are therefore an impression of a graduated dilution and give no characteristics associated with the odour.

Above all, the non-active odour components also assist the measurement signals [18] which results in the paradoxical situation of a correlation between odour strength and sensor signal also being received when the sensor is meant to be completely insensitive to the odour-active components.

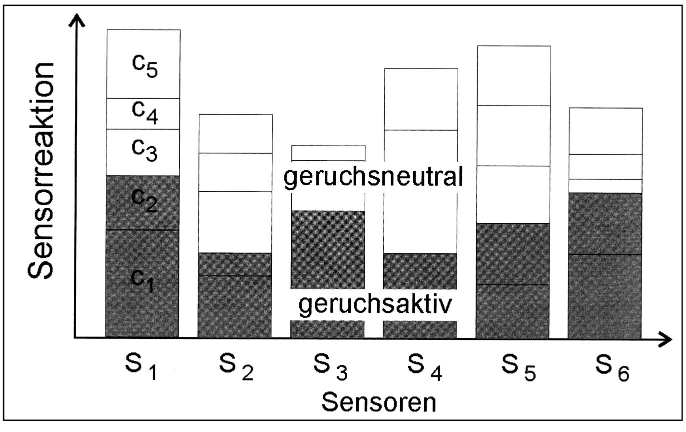

Fig. 1: Proportion of odour active and neutral components at the sensor signal.

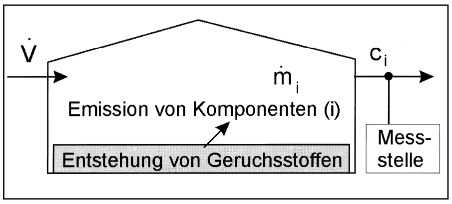

Fig. 2: Release and dilution of odour materials.

Summary and outlook

The problem of investigating odour strength using chemo-sensitometry measurements can be regarded as unsolved.

The methods described above did not achieve the required target for two reasons:

1 The often-used total sensor signal reduced the chemosensor array to the functionality of a single sensor. With that, the potential possibilities of the chemosensory measurement system were not used.

2 The related correlation to odour strength is an expression of a hidden dilution series and allows no transfer onto other odour mixtures. Correlations of this type can also be received with suitable individual sensors or with FID technique (Flame ionisation technique) [10]

The primary aim in the development of chemosensory odour measurement must be the development of an evaluation method, which has been adjusted to meet the problems, and adjusted to meet the characteristics of the interaction of chemo-sensitometry with the realities of odour identification. The applied methods must exploit all the information contained in the sensor signal and calculate using statistical data analysis.

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