# Testing of a Developed Multigas Sensor System for Outdoor Odour Nuisance Monitoring

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***Abstract*—This work presents the testing of a developed electronic nose for outdoor odour nuisance monitoring. The sensor system consists of a sampling system, a measuring cell equipped with commercially available low-cost gas sensor elements and a data acquisition system. The sensor testing showed that the developed prototype is able to distinguish, identify and partially quantify individual odorous substances like ethanol, ammonia and hydrogen sulphide. Ethanol and ammonia could even be detected below or near their odour threshold.**

***Keywords-electronic nose; outdoor odour; machined olfaction; sensor testing.***

## I. INTRODUCTION

Odour nuisances in outdoor air, e.g., caused by emissions from industrial or agricultural facilities into the environment, can seriously affect the well-being and health of residents. For the detection and evaluation of the outdoor odour immission, i.e. at a point of exposure to the residents, olfactometric methods exist, which are based on the human sensory perception of trained examinants forming a so-called qualified panel [1][2]. However, the relevance and the degree of odour nuisances are often difficult to assess, as they are only recorded and evaluated by persons with individual subjective olfactory perception, in a short time interval and in a limited spatial resolution. Therefore, olfactory measurements, even though performed with trained examiners, are subject to considerable standard deviations and measurement uncertainties. The application of an objective sensor-supported measurement method - machined olfaction - as a supporting and complementary method is consequently of great interest.

In a Moroccan-German research project, such a tool in the form of a multi-gas sensor system, also known as an electronic nose, shall be developed and tested under laboratory and field conditions. In addition, measurement strategies for odour monitoring in the outdoor air are to be derived from the tests.

This paper presents the results of a proficiency test of the developed prototype under laboratory conditions for a selection of odorants and is organised as follows. In section II the used materials and methods are described. Section III obtained results are presented and discussed. Conclusions of the investigations are given in section IV.

## II. MATERIALS AND METHODS

### A. Electronic Nose

The prototype of the electronic nose [3] consists of a 270 $cm^3$ measuring cell equipped with six commercially available solid-state metal oxide semiconductor gas sensor elements (MQ-3, -4, -5, -8, -9, -135, Winsen Electronics Technology Co., Ltd, Zhengzhou, China) for the differentiation, identification and quantification of gaseous substances, as well as a temperature (LM35DZ, Texas Instruments, Dallas, USA) and a relative humidity sensor (HIH 4000, Honeywell International Inc., Morristown, USA). For data acquisition, a multifunction data I/O device (NI USB-6212, National Instruments, Austin, USA) with 16 bit analog to digital converters is employed, which transfers the data to a PC running a LabVIEW graphical user interface. Sampling can be performed either indirectly via a micro pump and 2 $dm^3$ Tedlar® bags (TB) or directly at a gas flow rate of 250 $cm^3$ $min^{-1}$.

### B. Feature extraction and pattern recognition

To derive evaluable information from the complex sensor responses of the electronic nose, characteristic features were extracted from the measurement signals of each gas sensor. These are: the initial conductance ($G_0$), the steady-state conductance ($G_S$), the dynamic slope of the conductance (dG/dt) and the area under curve (A). Based on these features, a Principal Component Analysis (PCA) was performed for dimension reduction.

### C. Test gas generation

For sensor testing, the Gas Mixing System (GMS) of the accredited test laboratory for the testing of sensors for determining the composition of non-explosive gas mixtures of BAM was used. The method bases on dilution of gas streams. The traceability is given by the usage of certified test gases from gas cylinders, calibrated thermal mass flow controllers into a zero-gas stream of known composition. In addition, volatile organic compounds (VOC) or volatile inorganic compounds can be added traceable to the mass into the gas stream via a liquid evaporator or a permeator.

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### D. Sensor testing

The basic requirements for the behaviour of the employed sensor elements were tested by exposure to individual test gases from gas cylinders containing:

- Ethanol with a volume fraction of 483 $cm^3\ m^{-3}$ (ppm),
- Ammonia with a volume fraction of 28.86 ppm and
- Hydrogen sulphide with a volume fraction of 11.13 ppm

in synthetic air. Different volume fractions were adjusted with the GMS of BAM by adjusting the mixing ratio. Sampling was performed both indirectly via TB and directly from the test gas stream (without the micro pump).

In the further course of the sensor testing, the response to a mixture of the mentioned test gases, artificial odour of a pig farm, which is commercially available as "PigOdour" (Olfasense, Kiel, Germany), and components identified via Gas Chromatography–Mass Spectrometry (GC-MS) from outdoor odour samples in morocco collected by Tenax® TA filled thermal desorption (TD) tubes are tested under variable climatic conditions. After passing the laboratory tests, the performance of the electronic nose is tested in the field.

## III. Results and Discussion

Figure 1 shows the PCA plot resulting from the extracted feature datasets of the measurements of ethanol, ammonia ($NH_3$) and hydrogen sulphide ($H_2S$) for indirect (a) and direct sampling (b) together with the blank value of the corresponding sampling system.

For indirect sampling, the cluster of the blank value measurement overlaps with the odorant measurements in the lower volume fraction range (3 ppm of ethanol, 7.3 ppm of $NH_3$ and 0.1 ppm as well as 1 ppm of $H_2S$). The measurements of the remaining test gas concentrations could be well separated by PCA.

With direct sampling, a better separation of the clusters is achieved than with indirect sampling. Only the clusters of the blank value measurement overlap with the measurements of 0.1 ppm and 1 ppm of $H_2S$.

Especially at low odorant concentrations as it is to be found in outdoor air, the use of TB is only suitable to a limited extent since the material act both as a sink and, in the case of inadequate cleaning, as a source of VOC. In this study, *N*,*N*-dimethylacetamide and phenol were determined as main contaminants of the TB via TD GC-MS.

## IV. Conclusion

This paper describes the need for traceable test gas generation methods for testing of this developed multi gas sensor device (electronic nose).

With very simple and cost-effective gas sensors, which are applicable in products for citizen science, it is possible to differentiate, identify and partially quantify odorous substances with good discrimination strength within short measuring times.

For the considered outdoor air application, a direct sampling and thus a portable measuring device is essential. A corresponding adaptation of the measuring system is planned.

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In memoriam of Dr. Thomas Hübert.

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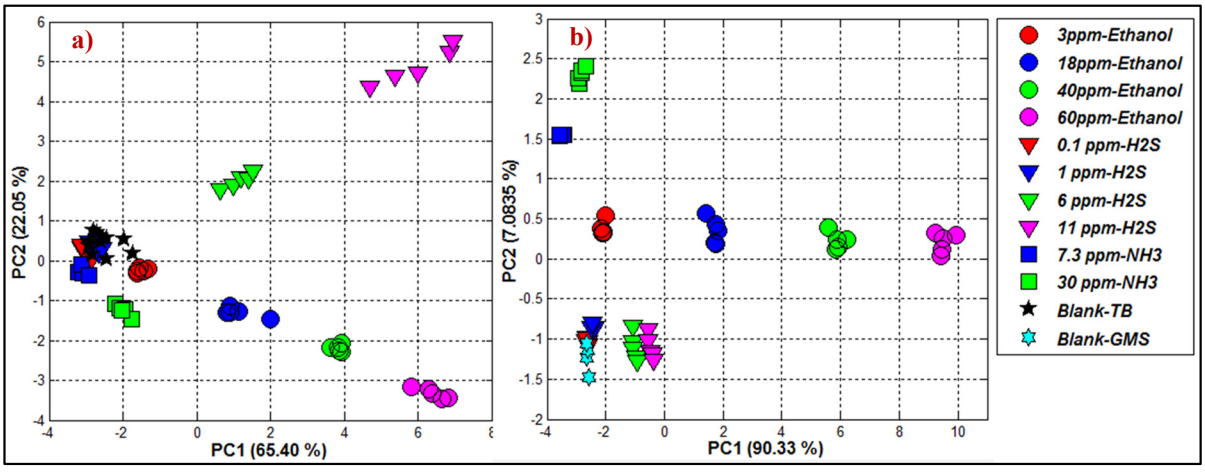


Figure 1. PCA plot performed on measurements of ethanol, $H_2S$ and $NH_3$ with the electronic nose: a) indirect sampling, b) direct sampling.

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