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ORIGINAL ARTICLE

An electronic body-tracking dog?

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Abstract The use of tracker dogs is the main method of finding hidden bodies, and in their search the dogs use typical scent patterns. "Electronic noses" can also be used to find and compare such patterns. Highly sensitive scent detectors have been successfully applied, e.g. in the examination of foodstuffs, in environmental tests and in material research. This study examined whether electronic sensors can be used to find bodies under outdoor conditions. The carcasses of two coneys were buried in soil at different depths. Over a period of 4 weeks, regular measurements were taken from the buried carcasses and from the control material. In addition, a "fingerprint" of the scent patterns was taken, and gas chromatography–mass spectrometry analyses were performed. Our findings indicate that it may be possible and viable to construct an "electronic body-tracking dog".

Keywords Electronic nose · Micro-array sensor · Decomposition odour · Forensic application · Discovering buried bodies

Introduction

Searching bodies in terrain, e. g. after earthquakes and landslides, and in common graves or those hidden after a crime is nowadays usually done using body-tracking dogs, although geophysical investigation techniques are also available, such as bulk ground resistivity and conductivity, fluxgate gradiometry and high-frequency ground-penetrating radar, soil magnetic susceptibility, electrical resistivity tomography and self-potential [1].

Typically, large areas have to be covered over a longer period of time. Tracking dogs can only work for a limited time span, as their performance suffers under exertion. Thus, more than one dog is needed. Training and keeping body-tracking dogs is expensive and time-consuming [2]. In their search, dogs presumably use typical scent patterns of gaseous decomposition products, as they develop in the putrefaction of dead human bodies, as well as animal and plant tissue [3].

As reported by Statheropoulos et al. [4], volatile organic compounds and determination of expired air, blood and urine can be used for the early location of entrapped people in earthquakes.

The aim of this pilot study was to determine if it would be possible to develop a mobile apparatus to find hidden bodies in analogy to metal detectors and mine-seeking devices, based on the technology of the "electronic nose". An "electronic nose" is an instrument which applies electrochemical sensors of overlapping specificity and an adapted pattern recognition system that recognises simple

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and complex odours [5]. Contrary to human and animal noses, electronic noses can detect minimal quantities of gas or quasi-odourless matter. As an electronic nose does not adapt, any number of measurements over any amount of time are possible, and a classification system allows for scent detection in real time [6].

Currently, sensor technology is based on metal oxide semiconductors, mass-sensitive piezo-electronic sensors, electroconductive polymers and sensor systems coupled to gas chromatographs or mass spectrometers [7, 8].

Electronic noses have been used for some years in commercial quality control, e.g. in the examination of foodstuffs, in environmental testing and in material research [9–12]. Applications in the medical field are increasingly being introduced [13–20]. The potential for applications within legal medicine and criminalistics has hardly been scrutinised [21, 22].

Materials and methods

The sensor system Multigas-SENSORiCCARD® (Jena-sensoric, Jena, Germany), which has been successfully applied in clinical studies before, was used (Fig. 1) [17]. It is an array of three metal oxide semiconductor gas sensors. With normal air, the sensors have a high internal resistance, R_0, as oxygen is absorbed at the sensor surface. As soon as other gas molecules (i.e. of hydrocarbons, alcohols or ketones) touch the sensor surface, electrons are emitted towards the crystalline surface, and the oxygen is spent. This catalytic reaction diminishes the internal resistance, R_i, and the quotient, R_0/R_i, is measured in relation to time.

The sensors are non-selective, and they register not only one but several gases with varying degrees of sensitivity. Sensitivity and selectivity can be changed by variations in temperature. The sensitive layer is warmed by a platinum heating element between the sensor layer and the ceramic substrate. Thereby, complex scent patterns can be detected and classified like a fingerprint.

For the measurements, a miniaturised sensor system was used in which a chamber with the gas sensors was flushed with the gas sample by a membrane pump. The software of the sensor system allowed continuous online measurement with a constant sensor temperature of 400°C as well as cyclic measuring in a range from 200°C to 400°C. From the registered resistance, changes of the sensor S and Q quotients (without dimensions) were calculated with a feedback resistance and with a calibration factor.

$$S_i = R_i/R_k$$
$$Q_i = S_i - k_i S_{i-1}$$

where R_i is the sensor resistance (i=1, 2, 3), R_k the gain control resistance, S_i the relative sensor resistance (i=1, 2, 3) and k_i the calibration factor.

Temperature and humidity of the gas samples were registered in the sensor chamber. In the outdoor experiment, cyclic measuring was used; the laboratory analyses were performed with continuous online measurement with a constant sensor temperature of 400°C as well as cyclic measuring in a range from 200°C to 400°C.

Outdoor experiment

In order to test the sensor system under conditions near the intended use, three measuring points were created in a lawn of the Botanical Garden of Jena University (Fig. 2). For ethical reasons, instead of human tissue, two freshly killed coney carcasses (weight, 5 kg each) were buried at a depth of 30 cm (measuring point 1) and 15 cm (measuring point 2), respectively. A third grave was excavated and refilled as a reference (measuring point 3). Plants that covered the excavated sites were filled in together with earth. Above all

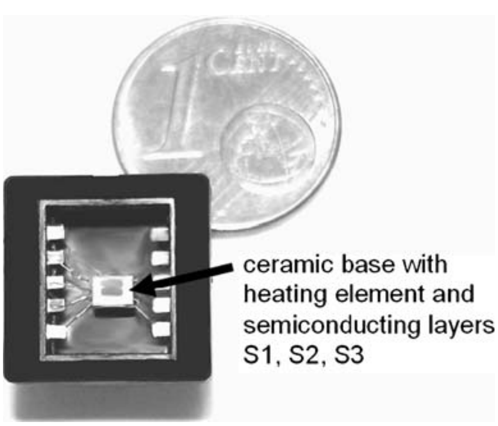

Fig. 1 The miniaturised sensor system with three metal oxide semiconductor sensors as the core of the electronic nose

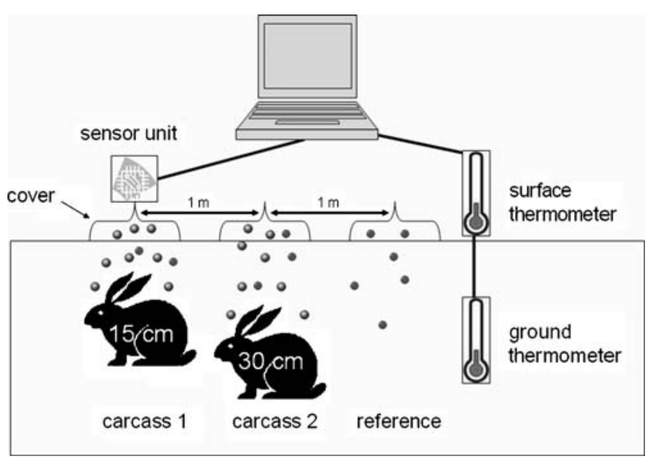

Fig. 2 The outdoor test with two animal carcasses in different depths (15 and 30 cm) and a reference measuring point

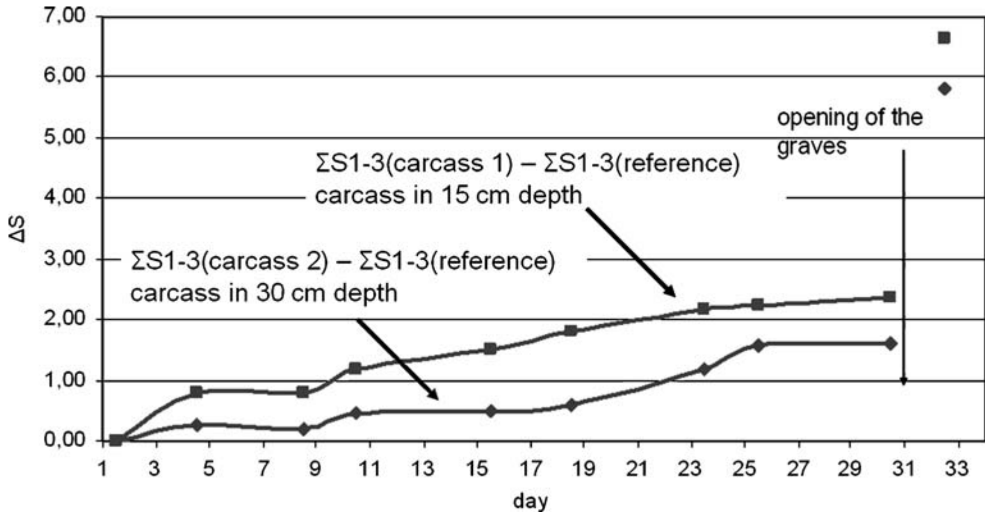

Fig. 3 Result of the scent measurement investigation giving difference of the summed measurements of all three sensors between carcasses and reference measuring point

three sites, plastic covers were erected from which the gas samples were drawn towards the sensors. Scent measuring took place twice a week over 4 weeks in springtime. At the same time, temperature in the ground and at the surface was taken, and temperature and moisture of the gas samples were recorded.

Laboratory experiments

After 4 weeks, the measuring points were re-opened, and tissue samples were taken from the carcasses. The scent pattern of the samples was determined in the laboratory and compared with purified air as a reference. Furthermore, tissue samples were analysed by gas chromatography–mass spectrometry (GC–MS), and the qualitative composition of the gaseous putrefaction products was established. Headspace samples of 1 ml at room temperature were injected into an HP 5890 II gas chromatograph, chromatographically split by a capillary column Poraplot Q (25 m×0.32 mm, *df*= 8 μm) and analysed by MS (MSD HP 5972).

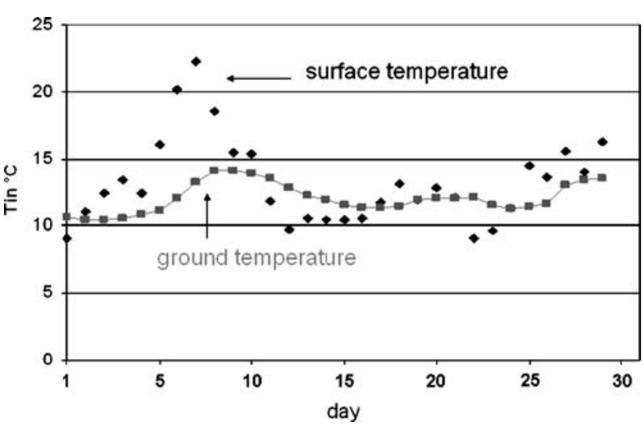

Fig. 4 Temperatures in the ground (between carcasses) and surface

Results

For analysis of the data of the outdoor experiment, the *S* values of the three sensors were combined and documented along the time axis. For specification of the different scent activities, the signal differences between measuring sites 1 and 2 and the reference point were determined (Fig. 3). An increase in signal differences over 4 weeks was found, hesitantly at first then steadily. As expected, odour intensity over the more deeply buried carcass was weaker than over the shallower grave. After opening the measuring point on the 31st day, the signals above the grave sites with carcasses were much more intense than above grave sites with control material. Only from that time on could a distinct odour of putrefaction be detected by the researchers using their noses. The soft parts of the carcasses were softened and discoloured by putrefaction. Plant material that was buried along the carcasses had rotted.

The temperature at the ground surface ranged from 9°C to 22°C, depending on insulation (Fig. 4). According to temperature at the ground surface, temperature and humidity of the analysed gas samples varied (Fig. 5). Below the ground, in 30-cm depth, temperature was between 10°C and 15°C.

Laboratory examination of the tissue samples taken after opening of the sites showed that the sensors reacted a few seconds after exposition. Sensor S3 was the most sensitive with the largest signal difference (Fig. 6). The *Q* values showed a scent pattern clearly different from that of the reference measuring point and from purified air (Fig. 7).

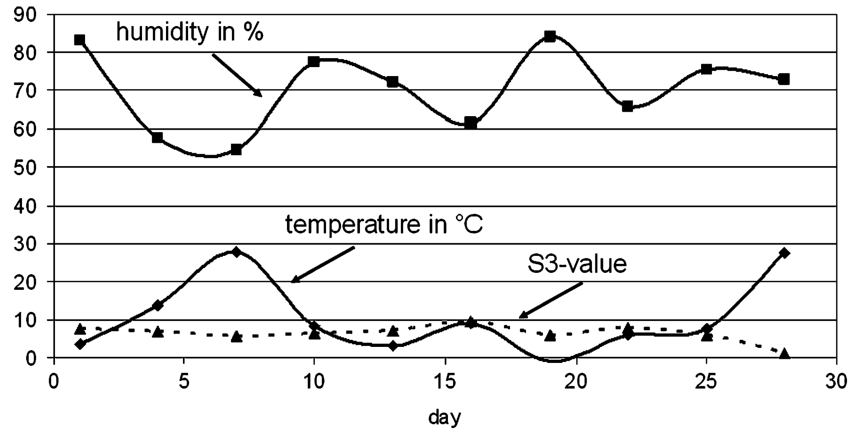

Fig. 5 Air humidity, temperature of gas samples and S3 values during time of measurement

The results of the GC–MS examination of the two carcasses showed a spectrum that was very similar and contained the gaseous putrefaction products, which are also found with human bodies [23, 24] (Table 1).

Discussion

Our findings confirm that an electronic nose can detect typical scent patterns of putrefaction products selectively and specifically. Scent patterns of carcasses are different from those of soil with rotting plant matter [25]. Thus, it can be used in overgrown terrain as well.

With establishing different scent patterns, there are sufficient characteristics for automatic classification of putrefaction odours [24].

The results of the GC–MS examination of the two carcasses showed that the gaseous putrefaction products are those also found with human bodies (Table 1).

External factors such as air temperature and humidity are of no relevant consequence in the sensors in the closed system used in this study (Fig. 5). Semiconductor sensors are well adapted for outdoor use, as they are relatively insensitive to moisture and need only simple circuitry. On the downside, they have high operating temperatures, only limited selectivity, a high energy consumption and limited sensitivity (5–500 ppm) [8]. Optimising the measurement procedure should result in improved sensitivity, specificity and selectivity, thus rendering detection of smaller amounts of decompositional odours possible. Bodies might then be found a shorter period of time after death or in deeper graves.

Conclusions

In principle, an electronic nose based on the sensors applied in this study can be used to find decomposing human bodies in terrain. However, for design and development of a practically applicable device, sampling and measurement procedures have to be optimised. Further fields in which an electronic nose might be useful, such as determination of the time of death or detection of poisons using body odour, should be considered.

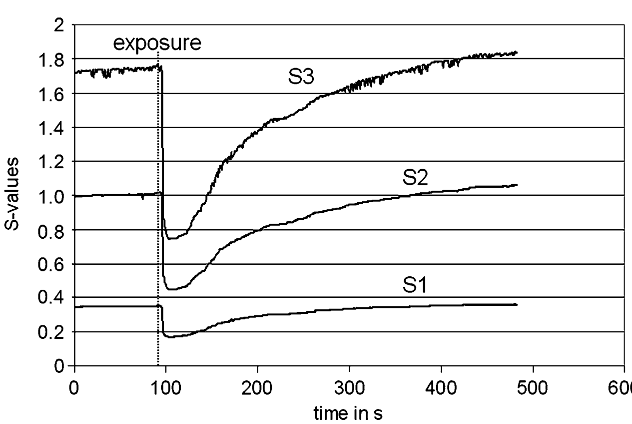

Fig. 6 Changes in measurements S1, S2 and S3 values a few seconds after exposition of a carcass sample to a 400°C sensor

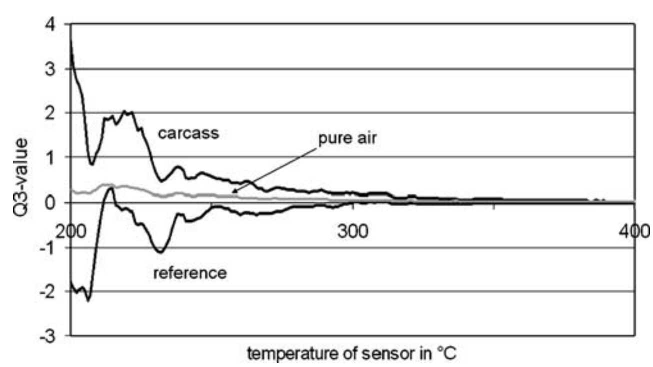

Fig. 7 Scent patterns (Q3 values) of carcasses, reference measuring point and purified air

Table 1 Results of the GC–MS examination of the two carcasses

Acetaldehyde[a]
Acetone[a]
Pentane[a]
Acetic acid butylester[a]
Acetic acid ethyl ester[a]
Butane
Butanoic acid
Butanoic acid butylester
Butanoic acid ethylester[a]
Decanal[b]
Dimethyl disulfide[a]
Heptane[a, b]
Hexane[a]
Nonanal[b]
Octane[a]
Propane
Propionaldehyde
1-Butanol[a]
2-Butanone[a]
2-Methyl butanoic acid[a]
2-Methyl butanoic acid butylester[a]
2-Methyl butanoic acid ethylester[a]
1-Pentanol[a]
1-Propanol
2-Propanol[b]
1,3-Propandiol
Propionic acid

[a] Organic compounds also evolved from decaying human body [24]

[b] Organic compounds also evolved from decaying human body [23]

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