

# DETECTION OF MOULD IN INDOOR ENVIRONMENTS USING A MINI ION-MOBILITY SPECTROMETER SYSTEM

Thomas Hübert<sup>1,\*</sup>, Carlo Tiebe<sup>1</sup>, Ina Stephan<sup>1</sup>, Hans Miessner<sup>2</sup>, Bernhard Koch<sup>2</sup>,  
Federal Institute for Materials Research and Testing, Berlin/Germany  
I.U.T. Institute for Environmental Technologies Ltd., Berlin/Germany

\*Corresponding author: Thomas Hübert, +49 30 8104 1824, ~3255, thomas.huebert@bam.de

## Abstract:

Microbial volatile organic compounds (MVOC) as an indicator of the presence of moulds in the indoor environment were detected in-situ using ion-mobility spectrometry. A portable sensor system with a tritium source and 5 cm drift cell was used. MVOC in a range of 1 to 100  $\mu\text{g}/\text{m}^3$  can be detected. The amount and composition of the MVOC mixtures in air were characteristic of mould species, its age and growing conditions.

**Keywords:** mould detection, fungus, indoor air quality, MVOC, biochemical sensor system, ion-mobility spectrometry

## INTRODUCTION

Mould growth in indoor environments cause not only destructive effects on building materials, but also give rise to human diseases such as allergies, pulmonary impairment and infections.

Fungi often grow behind wallpaper, carpeting or shelves and they are not easily detectable.

Detection can be performed by collecting and enumerating spores. The extent of infection can be estimated according to the number of Colony Forming Units (CFU) per  $\text{m}^3$  air after an incubation time of about two to three weeks [1]. After this interval, the species present can also be identified.

As a result of the metabolism of moulds and other microorganisms, microbial volatile organic compounds (MVOC) are produced. These substances can be indicators of the presence of moulds in indoor environments. Using MVOC as an indicator it may be possible to locate this problem, especially hidden mould growth. However, the in-situ measurement of MVOC in a very low concentration range of 1 to 100  $\mu\text{g}/\text{m}^3$  is rather ambitious. These compounds belong to classes of substances such as alcohols, ketones, esters, and furans. They can be detected using gas chromatography and a mass spectrometer detector [2, 3] but, because of the low MVOC concentration, an enrichment process using adsorption tubes is required. Prognoses of mould growth according MVOC detection can be given after an analysis in a laboratory.

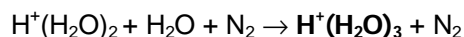
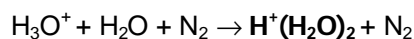
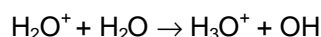
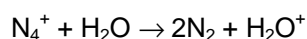
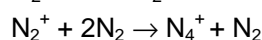
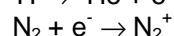
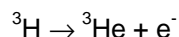
An in-situ analysis employing a short measuring time would be desirable. This would require a portable measuring device.

The aim of this paper is to demonstrate that both single and mixtures of MVOC can be detected in-situ using ion mobility spectrometry.

## EXPERIMENTAL

Ion mobility spectrometry is based on velocity measurements of gas-phase ion clusters in an electric field at ambient pressure. Vapour samples are introduced into an ionisation zone (or reaction zone) by air. The introduced air is ionised by  $\beta$ -radiation from a tritium source. The reaction ions are formed due to the interaction of electrons with the components of air.

For gaseous species the detection of the formation of the following positively charged reactive ions are relevant [4]:



The water containing species react with gaseous molecules M, to form ion clusters:



The resultant ion clusters move through a homogeneous electric field towards a FARADAY-plate (detector). The medium diffusion velocity  $v_d$  is given by:

$$v_d = K \cdot E$$

$E$ - electric field strength in  $\text{V}\cdot\text{cm}^{-1}$

$K$ - mobility constant in  $\text{cm}^2 \text{V}^{-1} \cdot \text{s}^{-1}$ .

Due to the reduced mobility constant  $K_0$ , the experimentally measured  $K$ -values are normalised for standard temperature (273 K) and standard pressure (1013 hPa). This step allows comparisons between different measurements to be made. The following equation explains the normalisation:

$$K_0 = K \cdot \left( \frac{273 \text{ K}}{T} \right) \cdot \left( \frac{p}{1013 \text{ hPa}} \right)$$

A characteristic parameter is the drift time  $t$  needed for an ion cluster to pass through a certain distance  $d$  from the ion shutter to the detector system, where the current is recognised and amplified to visualise signals:

$$t = \frac{d}{v_d}$$

In order to reduce the influence of temperature, pressure and device parameters, a reduced drift time is defined by relating the measured drift time of the substance  $t$  to the drift time of a reaction ion peak (RIP) - an internal signal of the ionised water molecules:

$$t_{rd} = \frac{t_{d,i}}{t_{d,RIP}}$$

This mathematical step allows the normalisation of the abscissa. The relative drift time of the RIP is then always 1.00.

The detection of MVOC in indoor environments is realised by using a mini ion mobility spectrometer (IMS).

The sensor system consists of a gas inlet system with a sample loop. From there a 0.5 ml gas sample can be introduced into a 5 cm cell, where the gas will first be ionised and then drift through an electric field.

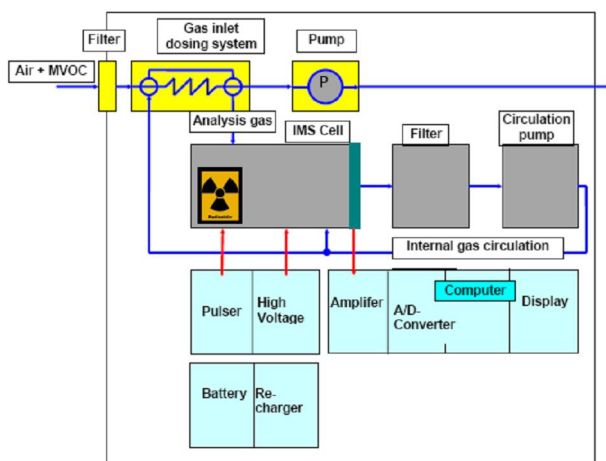


Figure 1. Schema of IMS [6].

The miniaturised detection system is handheld for in-situ measurement and can be combined with pre-accumulation and separation of gaseous substances. Spectra presentation and analysis will be performed by appropriate software on a PC. A schema for the system is given in Figure 1.

The system was calibrated by MVOC generation in trace concentration range using permeation tubes. MVOC mixtures of real systems were detected in the head space in glass containers over growing moulds in order to study different mould species under different growing conditions and ages. In-situ measurements in closed rooms suspected of harbouring mould growth were performed according to VDI guideline 2100 [7] and temperature and relative humidity were measured respectively.

To compare the results, a gas chromatograph with a mass sensitive detector GCMS-QP 5050 A (Shimadzu) was applied as reference.

## RESULTS AND DISCUSSION

For the development of a routine method it was necessary to determine the IMS spectra and detection limits of MVOC which are typical for mould growths in indoor environments.

The positive IMS spectrum of 1-octen-3-ol, what has a characteristic smell, is displayed in Figure 2. According to the analysis procedure, the RIP occurs at a relative drift time of 1 followed by peaks at 1.19 and 1.65. These peaks occur due to the formation of monomer and dimer ion species respectively.

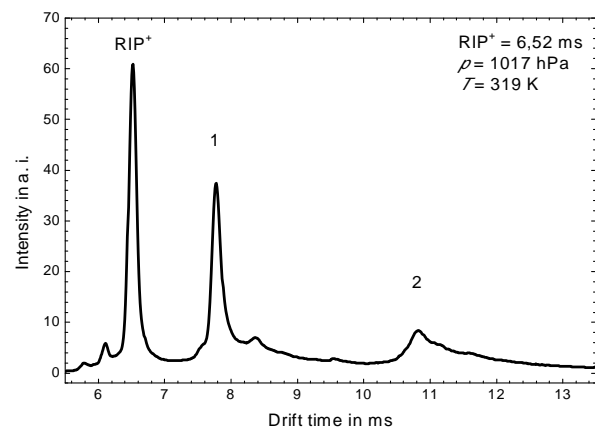


Figure 2. IMS spectra of 1-octen-3-ol.

In a first stage, the IMS system was calibrated with 13 typical MVOC using a permeation device (KINTEK 491M). The minimum detectable concentrations are 20 to 200 ppb (70 to 600  $\mu\text{g}/\text{m}^3$ ) and depend on the proton affinity of each substance (see Table1).

Because of the formation of monomer and dimer ionic species, the shape of spectra varies and a non-linear relation between MVOC concentration and peak intensity occurs.

Table 1.  
Drift times and detection limits of some relevant MVOC.

MVOC	rel. drift time	detection limit in ppb
1-octen-3-ol	1.19	35
3-methyl-1-butanol	1.26	20
2-heptanon	1.29	40
2-methylfuran	1.28	200

Mixtures of up to 5 MVOC components were investigated. Only for up to three-component mixtures was an assignment of peaks of pure substances possible. When more complex mixtures were presented, a completely different spectrum was observed, due to the interference of the peaks and the occurrence of additional peaks as a result of the formation of heterogeneous or complex ion species.

The second stage was achieved by the analysis of different MVOC patterns obtained in-vivo from moulds of different ages (see Figure 3). Several mould species (e.g. *Aspergillus niger* - DSM 1957) were grown in emission chambers at 25 °C and at a relative humidity of 75 %. In order to interpret the complex IMS spectra, different chemometric methods are applied and a comparison with GC/MS measurement was performed. A typical GC/MS-diagram of *Aspergillus niger* (DSM 1957) is given in Figure 4.

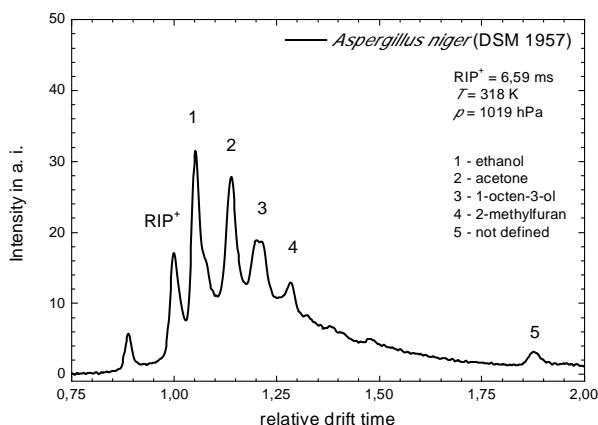


Figure 3. IMS spectra of *Aspergillus niger*. (7 days after inoculation).

The main peaks at 1.5, 5.9, 10.65 and 10.8 min coincide with acetone, dimethyl disulfide, 1-octen-3-ol and 3-octanol. The three MVOC were produced by fungi. Especially 1-octen-3-ol can be regarded as characteristic lead substance of some types of moulds [8]. Further main peaks in the GC-spectrum of figure 4 are produced by the solvent (2.2 min) and the internal standard chlorobenzene (8.4 min). The analysed total MVOC concentration is 120 mg·m<sup>-3</sup>.

It was observed that MVOC formation depended on the species and the stage of growth with a maximum of MVOC formation occurring in the first 10 days.

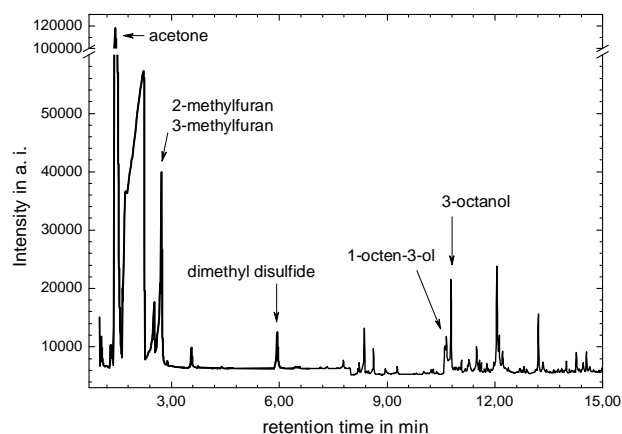


Figure 4. GC spectra of *Aspergillus niger*.

The third stage involved the investigation of air in rooms suspected of harbouring mould growth. In most cases a diffuse increase of background of the spectra was observed.

The de-convolution of the peaks and a comparison with outer air gives clear hints to the presence of increased concentrations of volatile organic compounds and mould growth (compare Figure 5).

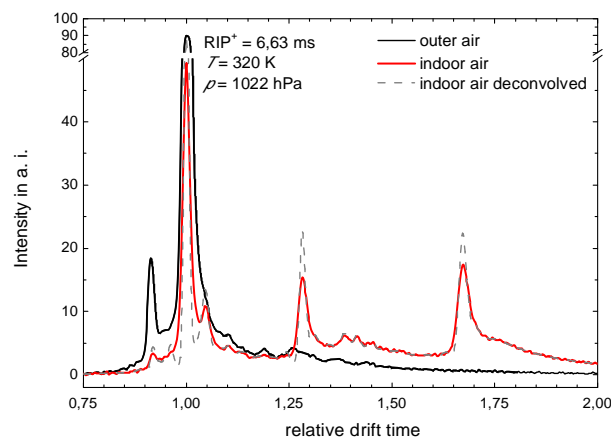


Figure 5. IMS spectra of air indoor from a mould infested room.

## CONCLUSIONS

Typical microbial volatile organic compounds (MVOC) were generated and the characteristic IMS spectra were recorded using a portable, mini-IMS sensor system. The detection limits were in the range of 20 to 200 ppb (70 to 600 µg/m<sup>3</sup>), which covers the upper range of typical MVOC emission caused by mould growth in indoor air. Mixtures of MVOC gave complex spectra due to the interference and interaction of ionic species, which demanded the application of chemometric methods for analysis.

Moulds were cultivated in the laboratory and the MVOC produced were detected by IMS and by GC/MS as a reference method. The formation of

different MVOC was recorded in a range of times from 1 to 45 days. The results show that MVOC of low concentration, produced by moulds, can be detected by mini ion-mobility spectrometer system continuously. It was observed that the formation of MVOC depended significantly on the type of mould present, its life cycle and growing conditions (e.g. temperature, humidity and substrate).

The detection of mould in the indoor environment can be performed if the interference from other sources of similar VOC can be excluded or at least minimised.

These results show that IMS is a very sensitive detection system that can be used to indicate in-situ hidden active mould growth. An analysis of indoor air and gas concentrations generated in the laboratory can be realised by the use of the IMS-system in less than five minutes.

## Acknowledgements

We are grateful to AiF (Arbeitsgemeinschaft industrieller Forschungsvereinigungen - KF 0133712DA6) for financial support. We would also like to thank Christel Teuber, Katrin Oleszak and Simon Bockisch for technical support.

## REFERENCES

1. M. Blei, *Atemwegs- und Lungenkrankheiten*, 31 (2005) 9.
2. W. Lorenz, *Zeitschrift für Umweltmedizin*, 9 (2001), pp. 33.
3. J. Leonhardt et al.; DE 10 2008 003 190.9, Verfahren zum Nachweis von Schimmelpilzbefall in Gebäuden.
4. G. A. Eiceman, Z. Karpas, *Ion Mobility Spectrometry*, Taylor & Francis 2005, ISBN 0-8493-2247-2.
5. Guideline VDI 2100 - part 5, 2007-02.
6. Manual IMS-MINI, IUT Ltd., 2008.
7. A. Good, D.A. Durden, P. Kebarle, *Journal of Chemical Physics*, 52 (1970) 212.
8. B. Seifert, *Leitfaden zur Vorbeugung, Untersuchung, Bewertung und Sanierung von Schimmelpilzwachstum in Innenräumen*, Umweltbundesamt, Berlin (2002) pp. 36.