MVOC out of new materials

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ABSTRACT

Especially in new buildings we could find striking concentrations of MVOCs and we could not localize mould damage. We first supposed that some MVOC components are not specific for microorganisms but 'normal' VOC from new materials. But very often the mould dog marked walls and floors spacious in new buildings where we detected MVOC in the indoor air.

To obtain information if new materials contain microorganisms, we analysed gypsum board, Styrofoam and mineralic insulation material for fungi and bacteria that we purchased in three different hardware stores. In some samples microorganisms could be detected. We also found in field cases microorganisms in new materials.

The detection of MVOC in the air of new buildings or as an emission from new materials is not evidence that MVOCs are unspecific for microorganisms. At least in some cases fungi and bacteria in new materials are the source for MVOC.

INDEX TERMS

MVOCs; New buildings; New materials; Toxins; Microorganisms

INTRODUCTION

In the past, detecting microbially produced volatile organic substances has proven itself as a reliable indicator for microbial damage in indoors when performed in a professional manner (Lorenz, 2001a).

When interpreting the results one must take into account indoor-caused sources for disturbances, such as cigarette smoke (Laußmann *et al*., 2002). Other influences, e.g. cooking fumes and baking smells, must also be taken into consideration (Lorenz, 2001b).

During practical investigations in newly built houses we have often found increased concentrations of MVOC in the indoor air, without any localizable water damage. At the same time there were health problems, similar to those that typically occur through fungus infestation. In order to locate the area/s damaged by microorganisms, a dog, which was specially trained in finding microbial odours, was used. In these cases the dog repeatedly marked large floor and wall areas (Lorenz and Diederich, 2001; Lorenz, 2002).

As several emission analyses showed, these materials emitted increased amounts of MVOC in various cases. In one case an unfinished wooden floor emitted noticeable amounts of MVOC, including dimethyldisulphide—a main indicator for MVOC.

The question arose, why newly built houses often show noticeable concentrations of MVOC and if this effect is caused by microorganisms or if there are other explanations.

In this context, it should also be discussed whether a mould dog is also capable of marking volatile organic compounds (VOCs) that do not derive from microbes. In the case of some VOCs (e.g. terpenes, alcohols and ketones) this is possible, as they are also produced by microorganisms.

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METHODS

In order to conduct experiments on new building materials the following materials were obtained from three randomly chosen home improvement stores: gypsum boards, mineral wool and Styrofoam. These materials were tested for cultivable fungi and bacteria. Four samples were tested on the emission of MVOC. Additionally, toxicity tests were done. The results from tests performed on indoor air in the past years were also incorporated.

Analyses on Cultivable Fungi and Bacteria

The samples were suspended in a buffer solution (peptone with 0.05% tween 80) and diluted to a factor of 10, 100, 1000, etc. consecutively. This was followed by the cultivation of differently diluted solutions on three different agars/media at a temperature of 24°C, in some cases at a temperature of 37°C. The CASO-agar (containing cycloheximid) serves as a selective medium for bacteria; for cultivating fungi DG-18-agar (containing chloramphenicol) and malt-extract-agar (containing chloramphenicol) were used.

Determination of the Total Number of Microbial Particles

Since some of the microorganisms are not registered when cultivating microorganisms, because they have already died or are not cultivable on the chosen agar, the total number of microbial particles was determined on some of the samples before cultivation. In order to accomplish this, the samples were coloured with a fluorescent dye and particles were counted under a microscope.

Toxicity Analyses

Additional toxicity analyses were performed. In order to accomplish this four toxins, resp., toxin groups were chosen, namely the mycotoxins aflatoxin, T2-toxin and ochratoxin A, as well as the endotoxins produced by gram negative bacteria.

The toxicity analyses were performed with LALT (Limulus-Amoebozyten-Lysat-Test) for endotoxins and ELISA (Enzyme-linked Immunosorbent Assay) for aflatoxin, ochratoxin A and T2-toxin.

Measurement of MVOC in Indoor Air

In order to measure MVOC in the indoor air, 100 l of air was drawn over active carbon tubes (Anasorb-tubes from SKC) with 0.5 l/min. This was followed by a GC-MS analysis using the ion-trap GC/MS-method (Merten *et al.*, 1996).

MVOC Emission Analyses

The MVOC emission data were acquired using defined test chambers with a volume of 4.5 l. Samples were taken at regular intervals over a period of 25 h. In each case 50 l of air were drawn (1 l/min) over active carbon tubes and analysed the same way as the indoor air samples.

RESULTS

Investigating New Materials for Cultivating Microorganisms

During random sampling of the new building materials from a randomly chosen hardware store a noticeable number of bacteria was found using microscopy (Table 1), although no noticeable amounts of cultivable microorganisms were found.

Table 1 Total number of fungi and bacteria in new materials from one hardware store

Material	Microorganisms (total)
Mineral wool	Increased amounts of bacteria
Styrofoam	Increased amounts of bacteria
Gypsum board	Slightly increased amounts of bacteria

Hereupon three typical building materials, each from three randomly chosen hardware stores, were analysed by the CFU method. The results showed that six of nine new materials also contained substantial populations of microbes at the time they were sold (Table 2). Apart from one exception the bacteria concentrations were especially noticeable.

Table 2 Cultivable fungi and bacteria in new materials from hardware stores

	Material	Cultivable microorganisms (CFU)
Store A	Mineral wool	Normal
	Styrofoam	Normal
	Gypsum board	Slightly increased amounts of bacteria
Store B	Mineral wool	Normal
	Styrofoam	Greatly increased amounts of bacteria
	Gypsum board	Slightly increased amounts of bacteria
Store C	Mineral wool	Increased amounts of fungi
	Styrofoam	Greatly increased amounts of bacteria
	Gypsum board	Greatly increased amounts of bacteria

MVOC in the Test Chamber

The inspected samples all emitted more or less high amounts of MVOC (Table 3). In all three cases detection of the main indicators for microorganisms, 1-octen-3-ol and dimethylsulphide, showed that these high amounts must be ascribed to microorganisms. In the case of a technical source the detected amounts would have to be specific to each material and would not be similar in different materials.

The analysed gypsum boards invariably emitted higher amounts of MVOC than the mineral wool. This coincides with observations from our practical experience, where certain organic materials, such as textiles or gypsum boards, absorb MVOC more readily because of their surface structure are secondary sources and therefore emit more MVOC than inorganic materials such as mineral wool.

Yet, the results do not correlate recognizably with the cultivation results. The mineral wool from store A contains only inconspicuous amounts of cultivable microorganisms but emits noticeable concentrations of MVOC.

A possible reason for this could be that the analysed materials were not populated by microorganisms but emitted MVOC due to contamination (e.g. through storage in buildings with fungus infestation).

Since the CFU analysis only registers the cultivable portion of the microorganisms it is not definitive if the samples contain dead or uncultivable microorganisms.

Table 3 MVOC (total amounts and main indicators) from new building materials compared to evidence of cultivable fungi and bacteria

Material	Cultivable microorganisms (CFU)	MVOC
Mineral wool, store A	Normal	Sum: 1.72 µg/m³; two main indicators[a,b]
Gypsum board, store B	Slightly increased amounts of bacteria	Sum: 11.94 µg/m³; two main indicators[a,b]
Mineral wool, store C	Increased amounts of fungi	Sum: 1.92 µg/m³; two main indicators[a,b]
Gypsum board, store C	Greatly increased amounts of bacteria	Sum: 8.55 µg/m³; two main indicators[a,b]

[a]Dimethyldisulphide.
[b]1-Octen-3-ol.

Toxicity Analyses

In one of the analysed samples the test results showed noticeable amounts of endotoxins that are produced by gram negative bacteria. Comparative measurements with materials without microbial sources showed less than 2000 EU/g. Surprisingly, the sample containing noticeable amounts of endotoxins contained only unremarkable amounts of cultivable microorganisms, according to the cultivation tests (Table 4).

Table 4 Toxins compared to cultivable fungi and bacteria as well as the determined MVOC

Material	CFU	MVOC	Toxins
Mineral wool, store A	Normal	Noticeable	Endotoxins: 126/430[a]; aflatoxin: 0.6/1.3[a]; **T2-toxin: 17.5/49.0**[a]; ochratoxin: u.N./1.7[a]
Gypsum board, store B	Slightly increased amounts of *bacteria*	Noticeable	Endotoxins: 64; aflatoxin: 1.0; T2-toxin: 4.9; ochratoxin: u.N.
Mineral wool, store C	Increased amounts of *fungi*	Noticeable	**Endotoxins: 25 134**; aflatoxin: 0.6; **T2-toxin: 20.6**; ochratoxin: u.N.
Gypsum board, store C	Greatly increased amounts of *bacteria*	Noticeable	Endotoxins: 107; aflatoxin: 0.4; T2-toxin: 0.9; ochratoxin: u.N.

Toxins with noticeable amounts are marked in bold letters.
[a]Verifying measurements performed.

Noticeable amounts of T2-toxin were found in two samples. This toxin is produced by some types of fungi. Concentrations >20 µg/kg are interpreted as a positive finding. Again the results did not correlate to the results from the cultivation tests. The mineral wool from store A, for instance, showed large amounts of T2-toxin, even though the amount of cultivable microorganisms was not found to be ostensibly high (CFU).

This shows that measuring the amount of cultivable microorganisms does not yield the total amount of microbial infestation.

Moreover, the results from the toxicity analyses do not correlate with the results from the MVOC emissions analyses. The gypsum board samples, showing no substantial results during the toxicity analysis, emitted noticeable amounts of MVOC. Noticeable amounts of toxins were only found in the mineral wool samples.

Even though the results from the toxicity analyses may not be reproducible and require more testing, one should consider the fact that toxins were found at all. This shows that new

materials may contain toxins which must have been produced by microorganisms. Furthermore, it is apparent that cultivable microorganisms only yield partial information to the degree of infestation. Non-cultivable microorganisms and toxins are not taken into account when only using the CFU method.

DISCUSSION

Often increased concentrations of MVOC are found during practical investigations of the indoor air in newly built houses. In the course of this investigation it was proved that new materials often emit MVOC. The MVOC contamination in newly built houses is therefore explicable as emissions from new materials.

Due to the results obtained, sources for MVOC emissions out of new materials could be infestation with fungi and bacteria, as well as contamination with MVOC. Microbial infestation is not necessarily always recognized as such, since dead or not cultivable microorganisms do not yield a positive CFU result.

Therefore, the MVOC out of new materials can be ascribed to microbial colonization through fungi and bacteria, e.g. as a result of improper storage.

Materials without cultivable microorganisms showed indications of microbial infestation by certain toxins, even though tests did not show increased CFU values. Surely other toxins should also be taken into account when judging the amount of microbial infestation; however these could not be surveyed with the instruments at our disposal.

Furthermore, some of the investigated materials contained large amounts of fungi and bacteria without noticeable amounts of cultivable organisms. In these cases there was probably a high amount of dead or non-cultivable microorganisms present, caused by improper storage or polluted raw materials.

In one case it was proven that MVOC was being emitted from freshly applied wall plaster, even though the material did not contain cultivable microorganisms. Research showed that celluloid had been mixed to the plaster; the celluloid had been stored in infested silos. The microorganisms, mostly bacteria, found in the celluloid were not cultivable in the end product (Sigrist, 2001).

In an already disclosed case from our practice employees in an office building suffered from health problems when occupying a certain part of the building. These ailments correlated with an odour which occurred in the affected rooms and was difficult to describe and was also intensified when the sun shined directly into these rooms. Our investigations showed that the ambient air contained increased amounts of MVOC. The source of the MVOC was found to be some built-in closets. This was ascertained through emissions analyses as well as employing a specially trained mould dog, capable of smelling odours produced by microbes. Material analyses of the individual closet components did not show noticeable amounts of cultivable fungi and bacteria, although minor amounts of *Stachybotrys chartarum* and other species were found as well as a noticeable amount of fragmented mycel pieces in the wood shavings. The conclusion was that the wood used during the manufacture of the chipboard was populated by microbes (Lorenz and Diederich, 2001).

CONCLUSIONS AND IMPLICATIONS

Since it is almost impossible to trace the path of raw materials up to finished building materials it will never be possible to rule out the existence of microorganisms in these materials. This must be considered during measurements in newly built houses. Therefore it is not recommended to perform MVOC measurements for 1–2 years after the date the house was built.

Furthermore, one must take great care in newly built houses to make sure that they do not become too moist, so as to prevent rapid growth of microbial germs often already present in

new building materials. That is, the residing moisture from floor pavements and cement, etc., should be kept at a minimum.

The acquired results also show that the event of MVOC in newly built houses can be ascribed to microbial infestation. The reasoning of some critics that evidence of MVOC in newly built houses shows that this is not specific to microorganisms can consequently not be maintained.

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