

Enumeration and identification of airborne viable mould propagules in houses

A field comparison of selected techniques

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A number of techniques for the enumeration and identification of viable mould propagules in the indoor air of houses were evaluated in order to document to what extent different results are obtained when different methods are used. A comparison was made between the results obtained with five commercially available air sampling devices (Slit-to agar sampler, N6-Andersen sampler, Surface Air System sampler, Reuter Centrifugal Air sampler, Gelatine Filter sampler) and a non-volumetric sampler (the Open Petri Dish), in combination with four culture media (malt extract agar, dichloran glycerol-18 agar, oxytetracycline glucose yeast extract agar and dichloran rose bengal chloramphenicol agar). The coefficients of variation were high (generally > 20 %) for all combinations. Statistical analysis showed that the Slit sampler and the N6-Andersen sampler in combination with DG18 and MEA gave the best precision and the highest yield in terms of colony forming units per square cubic meter of air (CFU/m³) and number of species isolated.

Key words: air sampling techniques; culture media; fungi; indoor air; moulds.

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Damp houses are common in The Netherlands: about 15 % of the homes may be affected to some degree. Several epidemiological studies have suggested a relation between living in damp houses and an elevated prevalence of respiratory symptoms for the residents (2, 21, 27, 28). Case histories indicate that moulds, which encounter favourable conditions in damp houses, can induce adverse health effects (3, 15, 25). For an inhalation-allergic population, prevalences of fungal allergy ranging from 2-30 % are reported (11). To get more clarity on the possible health effects, it is necessary to be able to measure the concentrations of moulds in indoor environments and to assess the relationship between home dampness and the presence of moulds. The presence of viable moulds in

indoor environments has been studied by a number of authors. However, in most studies different (air) sampling devices and media were used for the enumeration and identification of viable mould propagules (e.g. 3, 8, 10, 15, 28). Until now, there is no standardized method for the sampling of airborne moulds, although a proposal was recently published by the American Conference of Industrial Hygienists (ACGIH) (7). However, the ACGIH recommends several air sampling devices for the sampling of viable mould propagules.

In this study, carried out before the ACGIH recommendation was published, several available methods for the enumeration and identification of viable mould propagules in the indoor air of houses were compared. A number of

parallel measurements were performed under normal living conditions in order to document to what extent different results are obtained when different methods are used.

MATERIAL AND METHODS

Sampling devices

The following air sampling devices were used:

1. *Slit-to-agar sampler* (Slit)

The Slit sampler used was a Slit-to-agar sampler (Apparaten fabriek van Doorn, de Bilt, The Netherlands). The sampler draws air at 30 l/min by a vacuum pump (Charles Austin F65), through a slit orifice and the mould propagules are impacted onto a rotating medium. The sampling time per rotation is limited to 2, 6 or 8 min. The impaction efficiency of the Slit-to-agar sampler seems to be high (3). According to Gregory (12) it is best used indoors for occasional or routine sampling of short periods.

2. *N6-Andersen sampler* (N6)

The standard six-stage Andersen cascade sampler is widely used in aerobiological studies (3). This sampler collects air at 28.3 l/min through six stages with decreasing diameter holes in each succeeding plate (1). In this study the N6 modification of the Andersen sampler (16) was used. The results obtained with the Andersen six-stage sampler and the N6-Andersen sampler are highly comparable (16). The N6-Andersen sampler, however, is more efficient regarding time and cost of sampling and is recommended by the National Institute of Occupational Safety and Health (22). The N6-Andersen sampler draws air by a vacuum pump (Charles Austin, F65), through a sieve plate containing 400 holes over a medium. The air volume sampled was recorded by a gasmeter (G1.6 Meterfabriek, Dordrecht, The Netherlands).

3. *Surface air system sampler* (SAS)

The SAS sampler (Pool Bioanalyse Italiana, Milan, Italy) collects air at 180 l/min through a single-stage sampling head with 220 holes (diameter 2 mm) (19). The mould propagules are impacted on an agar contain-

ing 50 mm special petri dish (contact plates). The SAS sampler is portable, operates on a 12 V rechargeable battery and can be set to sample from 20 s to 6 min.

4. *Reuter centrifugal air sampler* (RCS)

The RCS (Biotest - Frankfurt, FRG) is a battery operated portable air sampler which collects mould propagules by drawing air through a fan and impacting the propagules on a medium coated strip, inserted into a drum surrounding the fan. The rated flow is 40 l/min.

5. *Gelatine filter sampler* (GF)

The GF has been shown to be suitable for the enumeration of airborne fungi in highly contaminated environments (4). Using gelatine filters, the possibility of overloading culture plates can be avoided, because after sampling the filters are dissolved and then diluted stepwise prior to culturing. Gelatine filters (Satørius) with a pore size of 3.0 µm and a diameter of 50 mm were placed in plastic filter cassettes (Schleiger and Schull filterholder). The filterholder was connected by rubber tubing to a Charles Austin F65 pump. The sampling flow was set to 15 l/min and the volume recorded using a gasmeter (G1.6 Meterfabriek, Dordrecht, The Netherlands).

6. *Open petri dish* (OPD)

For illustrative purposes, the OPD was also included in this study. This method relies on the gravitational deposition of mould propagules. This method has been and is still widely used, especially in clinical studies (3). An advantage of this method is the possibility of a long period of sampling (up to several hours). Further, sampling with the OPD may be performed by untrained persons after simple instructions. However, the quantitative estimation of propagules in a given amount of air is not possible. In addition, the influence of wind and air turbulence is great, especially around the edge of the plate and larger particles might be overrepresented (12).

Collection media

The following media were used for sampling viable airborne fungal propagules in combina-

tion with the sampling devices mentioned above:

1. *Malt extract agar* (MEA)

MEA, as described by Galloway & Burgess (9), is widely used as collection medium in aerobiological studies (4, 5, 22). It was recently recommended by the ACGIH (7). It is a general purpose medium and most fungi can be isolated. However, if a high concentration of moulds is expected, the colonies of fast growing fungi easily overgrow the slow growing moulds.

2. *Dichloran 18% glycerol agar* (DG18).

DG18, developed by Hocking & Pitt (13), is supposed to be a selective medium with a low water activity ($a_w = 0.995$), intended for isolation of xerophilic fungi. Dichloran restricts the growth of fast growing genera like *Rhizopus* and *Mucor*, facilitating the counting of colonies and the isolation of all species present.

3. *Oxytetracycline glucose yeast extract agar* (OGYA)

OGYA, as developed by Mossel et al. (24), is a general purpose medium for detecting moulds in food and is widely used in The Netherlands.

4. *Dichloran Rose Bengal chloramphenicol agar* (DRBC)

DRBC, as developed by King et al. (17) and modified by Hocking (14) in replacing chlorotetracycline with chloramphenicol, is recommended by NIOSH (22). It is a general purpose medium for detecting moulds in food. However, Rose Bengal-containing media have also proved to be good for aerobiological studies (23). The growth of the mould colonies is restricted by Rose Bengal. This allows the isolation of the various species without overgrowing of *Mucor* and similar moulds. Further, some xerophilic moulds can also be isolated.

Incubation isolation and identification

The Slit, the N6, the SAS and the RCS were used in direct combination with all of the selected media. The OPD was not used in combination with DRBC. After sampling, the plates

were directly incubated at 25°C for 4 days. Then the number of colony forming units (CFU) was counted.

The gelatine filters were first dissolved in 5 ml peptone solution (8.5 g peptone + 1 g NaCl/1 l distilled deionized water). After shaking for 15 min, the solution was diluted stepwise and 0.2 ml of each sample was applied in duplicate on the four different media. After 4 days of incubation at 25°C the colonies were counted. The number of CFU/m³ was calculated as the ratio of the number of CFU counted and the collected air volume. With the N6 and the SAS, a so-called positive hole conversion table is necessary to derive a more accurate number of CFU/m³.

After colony counting, fungal spores and/or mycelium were transferred onto appropriate media for identification up to species level, as described by Samson & van Reenen-Hoekstra (26).

Sampling procedures

The study was conducted in 11 different houses during the winter of 1987 (November 1986-March 1987). The samples were taken under usual living conditions in living-room or bedroom, when visible mould growth was present. Sampling was performed at a central point in the room approximately 1.5 m above the floor. During airsampling, no other activities were carried out on the sampling locations. The sampling periods of all methods used depend on the expected number of CFU/m³. Especially when the sampling period is too long and/or the concentration of the mould propagules is high, the number of CFU will be too high to be counted properly. The following sampling periods were chosen: Slit sampler 2 min, N6 Andersen sampler 2 min, SAS 20 s, RCS 1 min and 30 s, GF 30 min and OPD 60 min. With these sampling periods similar amounts of air were sampled by the first four sampling devices.

Sequential duplicate samples were taken with the first four sampling devices. Parallel duplicate samples were taken with the GF and the

Table 1

Geometric mean number of CFU/m³ obtained with the different combinations of air sampling device and culture medium

Medium	Sampler				GM per medium
	Slit	SAS	N6	RCS	
MEA	545	164	508	721	424
DG18	713	478	518	327	493
DRBC	455	147	361	193	260
GM/sampler	561	226	455	358	

GM: geometric mean.

OPD samplers, and also with the SAS and N6 samplers. No parallel samples were taken with the Slit and RCS samplers, because only one of these samplers was available for the study. The air sampling devices were run parallel for each medium. The samplers were cleaned between each run with 70 % ethanol.

In nine houses sufficient data were obtained to make a complete comparison in terms of CFU/m³, whereas in 10 houses sufficient data were obtained for a comparison in terms of number of species isolated.

Data analysis: comparison of the results

The following quantities were used to compare the results obtained with the different measurement techniques:

- a) yield in terms of CFU/m³, in order to compare the volumetric results;
- b) yield in terms of number of species isolated;
- c) reproducibility of parallel and sequential duplicate samples;
- d) correlations between the results obtained with the different techniques.

RESULTS

During the fieldwork at the first five locations, it appeared that about 20 % of the samples taken on OGYA were overgrown by fast growing mould genera such as *Rhizopus* and *Mucor*. Further, counting the number of CFU on OGYA was difficult, because the colonies spread widely. Therefore, OGYA was excluded

Table 2

Analysis of variance of the yield in terms of CFU/m³

Source	DF	SS	MS	F	P
Model	59	140.09	2.37	6.49	< 0.001
Residual	48	17.55	0.37		
location	8	94.69		32.37	< 0.001
sampler	3	12.51		11.41	< 0.001
medium	2	7.91		10.82	< 0.001
Medium × sampler	6	9.39		4.28	0.002
Location × sampler	24	7.70		0.88	0.627
Location × medium	16	7.89		1.35	0.209

DF: degrees of freedom; SS: sum of squares; MS: mean square; F: F-value.

from the further sampling program and the analysis of the results.

Yield in terms of CFU/m³

On nine locations sufficient data were obtained to make a complete comparison between the yields in terms of CFU/m³. The results obtained with the OPD were compared separately.

The average yields (geometric mean, GM) on these locations varied from 71 CFU/m³ (geometric standard deviation, GSD 3.54) to 1266 CFU/m³ (GSD 2.25). The numbers of CFU/m³ obtained varied widely from 0 to 17750 CFU/m³. The values were right skewed, but became normally distributed after logn-transformation. Therefore, the statistical analysis (apart from the analysis of reproducibility) was performed with the logn-transformed data. Before logn-transformation, any zero counts were given the value one. Further, the results obtained with the GF could only be compared with the results obtained with the SAS.

The geometric mean numbers of CFU/m³, obtained with the Slit, N6, SAS and RCS in combination with MEA, DG18 and DRBC, are presented in Table 1. High yields were more consistently obtained with the Slit and the N6, in combination with DG18 and MEA. However, the RCS in combination with MEA gave the highest yield of all.

An analysis of variance was performed for the Slit, N6, SAS, and RCS in combination

with MEA, DG18 and DRBC, in order to assess the effects caused by sampling location, type of sampling device and type of medium. This analysis was based on 108 means of sequential duplicates. They refer to nine different locations with complete data sets (9 locations × 4 samplers × 3 media).

The results are presented in Table 2 and indicate that the location, type of air sampling device and the type of medium all significantly contributed to the variance of the results. Furthermore, there was a significant interaction between air sampling device and medium, which was caused by the relatively much higher yield of the RCS in combination with MEA than in combination with DG18 and DRBC.

The results obtained with the GF were compared with the results obtained with the SAS, because a sufficient number of parallel duplicate samples were taken on the same locations with these samplers ($n = 8$). The average yields in terms of CFU/m³ were compared by medium (t-test). No significant differences were found between the yields obtained with the GF and the SAS.

With the OPD in combination with MEA, the geometric mean number of CFU was 18 (GSD 1.42). Also in combination with DG18, the geometric mean number of CFU was 18 (GSD 1.50). For illustrative purposes a comparison was made between the yield obtained with the OPD and the yields obtained with the

volumetric air sampling devices by calculating Pearson correlation coefficients. Rather high correlations were found between the yields obtained with the OPD and the Slit in combination with MEA and DG18 (0.92 and 0.79 respectively, $n = 11$) and between the yields obtained with the OPD and the N6 in combination with MEA and DG18 (0.95 and 0.83 respectively, $n = 11$).

Yield in terms of number of species isolated

The yield in terms of number of species isolated varied between the 10 different locations from 14 to 39. The number of isolated mould genera varied from 6 to 18. In total, 76 mould species belonging to 28 genera were found. Species belonging to the genera *Cladosporium*, *Eurotium*, and *Penicillium* were found in all the investigated houses. Table 3 presents the most frequently identified mould species. The numbers of isolated mould species were normally distributed.

The mean numbers of species isolated, obtained with the Slit, N6, SAS and RCS in combination with MEA, DG18 and DRBC are presented in Table 4. The highest number of species isolated was obtained with the Slit, followed by the N6, in combination with DG18. The yields obtained with MEA and DRBC were similar.

To assess the effects caused by sampling location, type of air sampling device, and type of medium, an analysis of variance was performed, based on 72 observations referring to six different locations with complete qualitative results (6 locations × 4 samplers × 3 media). Table 5 presents the results.

Table 3
Mould species identified in the indoor air of more than seven houses

Species	No. of houses
<i>Cladosporium herbarum</i>	10
<i>Eurotium herbariorum</i>	10
<i>Penicillium chrysogenum</i>	10
<i>Penicillium glabrum</i>	10
<i>Penicillium verrucosum</i>	10
<i>Aspergillus versicolor</i>	9
<i>Cladosporium cladosporioides</i>	9
<i>Cladosporium</i> spp.	9
<i>Penicillium brevicompactum</i>	9
<i>Cladosporium sphaerospermum</i>	8
<i>Penicillium olsonii</i>	8
<i>Wallemia sebi</i>	8

Table 4
Mean number of species isolated, obtained with the different combinations of air sampling device and culture medium

Medium	Sampler				Mean/ medium
	Slit	SAS	N6	RCS	
MEA	4.5	3.8	5.2	4.3	4.5
DG18	6.8	5.8	6.7	4.2	5.9
DRBC	4.8	4.7	4.2	4.3	4.5
Mean/sampler	5.4	4.8	5.3	4.3	

Table 5
Analysis of variance of the yield in terms of number of species isolated

Source	DF	SS	MS	F	P
Model	41	279.58	6.82	4.85	< 0.001
Residual	30	42.19	1.41		
location	5	133.11		18.93	< 0.001
sampler	3	14.78		3.50	0.027
medium	2	31.19		11.09	< 0.001
Medium × sampler	6	19.14		2.27	0.064
Location × sampler	15	63.89		3.03	0.005
Location × medium	10	17.47		1.24	0.306

Abbreviations: see Table 2.

This analysis of variance indicates that the location, type of air sampling device and the type of medium all significantly contributed to the variance of the results. Furthermore, there was a significant interaction between air sampling device and location, which was caused by the relatively much lower yield of the RCS on location 1 and the relatively much higher yield of the RCS on location 5. When the results obtained with the RCS were excluded from this analysis, the influence of the type of air sampling device as well as the interaction between air sampler and location became insignificant.

The results obtained with the GF could not be compared with the results of the remaining air sampling devices, because the number of GF-samples analysed qualitatively was too small.

The yield in terms of number of species isolated obtained with the OPD in combination with MEA and DG18 could be compared

(Mann-Whitney test) with the yield obtained with the volumetric air sampling devices, except the GF. In combination with MEA, no significant differences were found. With DG18, the number of species isolated on the OPD was lower than the yield obtained with the Slit and the N6 ($P < 0.05$).

Reproducibility

The reproducibility in terms of CFU/m³ was assessed by calculating the mean coefficients of variation (CV) of parallel and sequential duplicate samples. The results are presented in Table 6. The mean CV values of parallel duplicate samples varied from 7.6% (N6/MEA) to 43.6% (GF/DRBC), whereas the CV value of the sequential duplicate samples varied from 11.1% (SAS/DG18) to 38.7% (RCS/DRBC).

The reproducibility of the results in terms of number of species isolated from sequential duplicate samples was calculated as the fraction of the number of identical species isolated in both samples and the total number of species isolated from both samples (agreement rate). With the Slit the mean percentages were respectively 22% (MEA, $n = 3$), 63% (DG18, $n = 4$) and 34% (DRBC, $n = 4$). With the SAS the mean percentages were 10% ($n = 3$), 36% ($n = 6$) and 21% ($n = 6$) respectively and with the N6 33% ($n = 3$), 38% ($n = 4$) and 40% ($n = 3$). The agreement rate could not be calculated for the RCS, GF and OPD, nor for the parallel duplicate samples, because the number of samples was too small.

Table 6
Coefficients of variation (CFU/m³, %) of sequential and parallel duplicates

Sampler	Sequential ($n = 10$)			Parallel ^a		
	MEA	DG18	DRBC	MEA	DG18	DRBC
Slit	12.2	17.6	17.8	–	–	–
SAS	23.0	11.1	19.8	26.6	19.3	30.6
N6	14.0	17.0	16.1	7.6	23.5	8.3
RCS	21.4	18.3	38.7	–	–	–
GF	–	–	–	27.6	40.3	43.6
OPD	–	–	–	16.5	16.7	–

^anumber of parallel duplicates: SAS: 22; N6: 6; GF: 13; OPD: 14.

Correlations

Pearson correlation coefficients were calculated between the yields in terms of CFU/m³ obtained with the different air sampling devices by medium. The correlations varied from 0.30 (N6/RCS in combination with DRBC) to 0.97 (Slit/SAS in combination with DG18). In general, the correlations were weaker between the yields obtained with the different air sampling devices in combination with DRBC. Correlations were also calculated between the yields obtained with the different media by air sampling device. These correlations varied from 0.19 (DG18/DRBC in combination with the RCS) to 0.93 (DG18/MEA in combination with the Slit). In general, the correlations of the yields obtained with the different culture media were (much) better in combination with the Slit and the N6 than those in combination with the SAS and the RCS. Regarding the GF, only a sufficient number ($n = 8$) of parallel samples was obtained in combination with the SAS. The correlations between the yields were 0.57 (MEA), 0.69 (DG18) and 0.67 (DRBC).

DISCUSSION

Because the "accuracy" – i.e., agreement between the measured results and the "true" number of CFU/m³ and mould species – can not be determined, the different measurement techniques could not be compared by this criterion. However, the validity of the measurements was partly assessed with the yields in terms of CFU/m³ and number of species isolated, and the precision of the results.

The results of this study indicate that high yields in terms of CFU/m³ were more consistently obtained with the Slit and the N6 samplers, in combination with DG18 and MEA. However, the highest yield of all was obtained with the combination RCS/MEA. A comparison with data reported in the literature is hardly possible, because in most studies different types of air samplers and media were used. Lach (18) reported that the collection efficiency of the SAS was 70–85% of the collection efficiency of

the Slit sampler. The RCS has a single opening for air intake and discharge, making it difficult to quantify the flow rates.

Macher & First (20) indicated that the total sampling rate of the RCS was somewhat lower than the calculated total sampling rate of the manufacturer (210 ± 27 l/min versus 280 l/min). Further, they reported that the effective sampling rate depended on the particle size. The manufacturer advises to assume that the effective sampling rate is 40 l/min, irrespective of the particle size. Macher & First concluded that it would be more convenient to calculate the number of CFU/m³ obtained with the RCS using the total sampling rate. This would imply that the yield obtained with the RCS will be about five times lower than as reported in this study. In this study, the flow rate of the RCS was not determined. The GF was shown to be suitable for the enumeration of airborne mould propagules in highly contaminated environments (4). With low concentrations the yield obtained with this device may be unreliable due to the heterogeneous distribution of spores in the solution. Burge et al. (6) stated that the yields on media containing Rose Bengal were lower than the yield on MEA. Apart from a lower yield, Rose Bengal has the disadvantage that it decomposes in light and might then become toxic to some mould species, which restricts the applicability in field studies.

The highest yields in terms of number of species isolated were obtained with the Slit and N6 samplers in combination with DG18. The yields on MEA and DRBC were comparable. Species belonging to the genera *Aspergillus*, *Cladosporium*, *Eurotium* and *Penicillium* were found in most of the investigated houses, which is – apart from *Eurotium* – in good agreement with the results presented in the literature (3, 8). Apart from the presence of *Wallemia sebi* on DG18 only, no striking differences were found in the occurrence of the isolated species on specific samplers, media or combinations. Regarding the isolation of often cited pathogenic mould species, e.g. species belonging to the genera *Alternaria*, *Aspergillus*, *Cladosporium* and *Penicillium* (3, 11), no systematic differences were found between samplers and media.

The *reproducibility* of the parallel duplicate samples was only assessed for the SAS, N6, GF and OPD; The best reproducibility was obtained with the N6, in combination with MEA and DRBC. However, in combination with DG18, the best reproducibility was obtained with the OPD.

The reproducibility of the sequential duplicate samples was better with the Slit and the N6 with CV values between 10% and 20%, than with the remaining devices. With those devices, CV values above 20% and even 30% were found. For the culture media, the lowest CV values were found for DG18, followed by MEA and DRBC. However, the value of the lowest CV found (11.1%) indicates that even samples taken within 2 min after each other at the same location show only a moderate reproducibility. This is in agreement with Hunter et al. (15), who indicated that the numbers of CFU/m³ in the indoor air varied widely within dwellings over short periods.

The reproducibility in terms of number of species isolated in sequential samples was moderate. In general, the agreement rates were less than 50%. With the SAS and the Slit, the reproducibility was better in combination with DG18 than in combination with the other media. With the N6, no clear differences between media were found. It is concluded that the presence of moulds in indoor environments in terms of CFU/m³ and in terms of number of species, can not be determined reliably with single samples.

The calculated *correlation coefficients* between the yields obtained with the different combinations of air sampling device and medium, demonstrated that, in general, the relations between the different air samplers were stronger with DG18 and MEA as culture medium than with DRBC. The relations between the media were stronger in combination with the Slit and the N6 than with the SAS and the RCS. The results obtained with the GF correlated moderately with those obtained with the SAS, while the results of the OPD correlated strongly with the results obtained with the Slit and the N6.

The results of this study indicate that from the selected volumetric sampling methods, the

SAS gave consistently lower results than the others. The RCS gave high results on MEA, but not on DG18 and DRBC. High yields were more consistently obtained with the Slit and the N6. Of the selected culture media, OGYA was not suitable and DRBC gave consistently lower values than MEA and DG18. The yield on DG18 was somewhat higher than on MEA, and colony counting was easier, because the colonies did not grow as fast on DG18 as on MEA. Further, xerophilic mould species as well were isolated on DG18.

From the available non-volumetric methods, only the OPD was included in this study. Strong correlations were found between the OPD and the Slit and N6 (the most suitable volumetric samplers) in combination with DG18 and MEA (the most suitable culture media). However, with the OPD no information is obtained of the concentration of viable mould propagules. On the other hand, the OPD has the advantage of (much) longer sampling periods, which provides a more time-integrated picture of the presence of viable mould propagules. This aspect may be important when the indicators of exposure to mould propagules are needed as part of studies in which the possible health effects of moulds are investigated. However, it should be noted that an interpretation of the health significance of the results of studies like this is impeded by several difficulties: not only viable mould propagules are potentially able to induce adverse health effects, but also non-viable moulds or mould products; different mould species do not have the same potency to induce health effects; and the immunological sensitivity differs widely between individuals. Furthermore, the type of exposure that may be relevant is not known. Short periods of increased concentrations of moulds in the air may induce allergic reactions, but also long-term mean exposures may cause adverse health effects.

The ACGIH recently published guidelines for the assessment of bio-aerosols in the indoor environment (7). According to the ACGIH, the highest yield in terms of CFU/m³ will be obtained using Slit-to-agar samplers and impingers. In most cases, however, this degree of

accuracy is not considered essential by the ACGIH and more portable samplers may be used. Therefore, the ACGIH recommends several air sampling devices for viable microbiological aerosols (slit-to-agar samplers, sieve plate impactors, filter cassettes, glass impingers and centrifugal samplers). Malt Extract Agar is recommended by the ACGIH as collection medium. Methods relying on gravitational deposition of particles are not recommended by the ACGIH, because they do not provide representative quantitative and qualitative results.

To be able to make proper comparisons between different studies, standardization is needed. In view of the results of this study, the Slit and the N6-Andersen air sampling devices can be recommended. With regard to the use of a medium, the results of this study are somewhat contrary to the recommendations of the ACGIH. This may be because DG18 has not been widely used in aerobiological studies and was therefore probably not evaluated by the ACGIH. However, given the favourable results obtained with DG18, further research to investigate the utility of this culture medium in comparison with MEA is recommended.

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