

Labor Dr. Rabe
HygieneConsult

Labor Dr. Rabe HygieneConsult
Postfach 13 01 01, D-45291 Essen
Am Technologiepark 1
Gebäude A 6
D-45307 Essen
Tel.: 0201/201 87-0
Fax: 0201/201 87-11
e-mail: labor@hygieneconsult.de
www.hygieneconsult.de

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- Test Report -

on the
Comparative Test of the
Integrated Physical and
Biological Sampling Efficiency
of Bioaerosol Samplers

Comparative Test of the
Remote-Slit-Impactor R2S
manufactured by EMTechnologies
Longmont CO 80504, USA

Study carried out on behalf of EMTechnologies
Longmont CO 80504, USA

Contact: Erik Swenson

Expert report prepared by Dr. Rudolf Rabe

Checked by: Michael Mehring

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Introduction

As yet there has been no norm established for validating bioaerosol samplers except in the case of clean room measurements (DIN EN ISO 14698-1). As a result, back-to-back measurements are frequently taken using a range of devices with different procedures, and even with samplers not optimally suited to specific task in hand. In the USA, the International Aerobiology Symposium and the American Conference of Governmental Industrial Hygienists have recommended the six-stage Andersen impactor and the ACE Glass AGI- 30 all-glass impinger as the reference methods for the sampling of microbial aerosols. However, these samplers do not cover all and every area of measurement needed in industry, health, in buildings, and for emissions and immissions; moreover, both of these samplers have particular weaknesses. Furthermore, neither of these procedures for measuring microbial aerosols are widespread in Europe. There have been numerous comparative studies carried out previously but they have always been limited to only comparing a few devices or have solely compared samplers using one particular sampling method (e.g. impaction). In many cases, the test conditions were not sufficiently standardized. For this reason, this test is intended to provide, for the first time, standardised test conditions for a comprehensive comparison between as many devices as possible using all the commonly accepted methods of sampling (filtration, impaction, impingement and virtual impaction).

The test design represents a further development of the guidelines established under ISO 14698-1. In particular, this test allows for measurements of higher bioaerosol concentrations and longer sampling times and, by using an EN 799 standardised testing tunnel, creates better comparative conditions for the individual test devices. In addition, the test design takes into account the guidelines detailed in EN 14583 (2004).

This assessment of bioaerosol samplers, carried out by the Dr. Rabe HygieneConsult Laboratory, investigates the overall effect of the devices' physical and biological sampling efficiency. In addition, test volume accuracy is also incorporated into the results for each individual device.

Criteria for reference methods are derived from the comparative test results. The sampling devices involved in the comparative test are then evaluated in terms of how well they fulfil these criteria. It is hardly to be expected that any single device can be used for all measurement tasks in all situations (e.g., high / low bioaerosol concentrations, short / long sampling periods). Consequently, on the basis of the comparative test findings, the devices will be categorized as suitable for taking measurements under specific conditions.

Test principles

The sampling device to be tested takes samples from a monodisperse test aerosol generated in a bioaerosol testing tunnel. Two AGI-30 impingers are set up parallel as reference samplers. The tests use aerosols with bacteria or spores of different concentrations and, in addition, micro-organisms with differing degrees of sensitivity. A culturing process is used to analyse the tests. Each test sample is repeated ten times. The findings from the bioaerosol sampler devices in the test are then compared to the reference devices and with each other.

The bioaerosol testing tunnel

The testing tunnel used has a total length of 13.1 meters, a rectangular cross-section of 0.372 m² and an end edge of 610 mm. The air-stream is created by a radial fan. The tunnel has an air pressure of 1 – 2 mbar negative pressure, monitored in the measuring section area. The airflow volume is given by the measured airflow speed and the tunnel cross-section and can be regulated by a butterfly valve. Airflow speed in the tunnel is 0.8 -1.0 ± 0.1 m/s at a given airflow of 17.9 – 22.3 m³/min.

The testing tunnel was operated by the DMT-Prüfstelle für Lufthygiene (*Inspection Office for Air Hygienics*). Since the testing tunnel was no longer available for us from 02/01/2004 on, we then constructed and validated an identical testing tunnel on our own testing premises. All of the measurements contained in this report and dated prior to the 01/31/2004 were carried out in the DMT testing tunnel; the measurements dated after 03/24/2004 took place in our own identical testing tunnel.

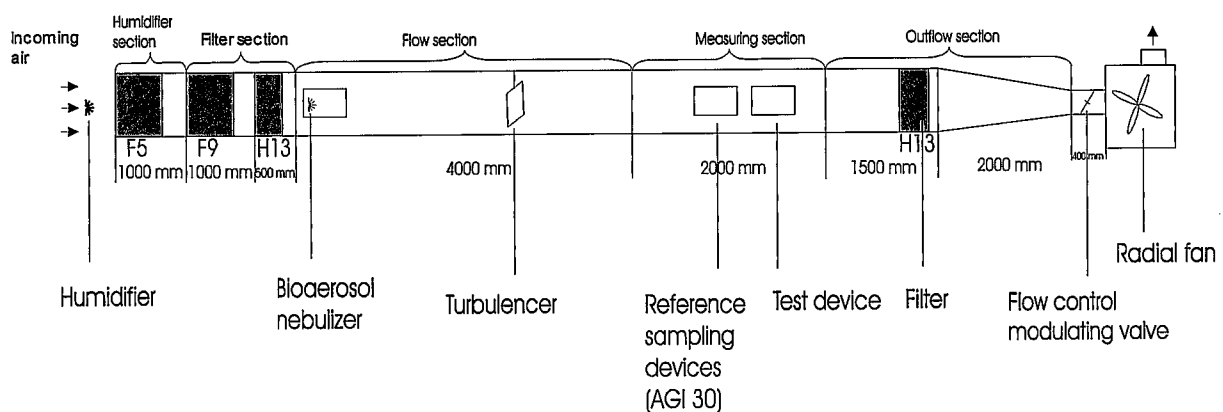


Fig. 1: Scheme of the bioaerosol testing tunnel

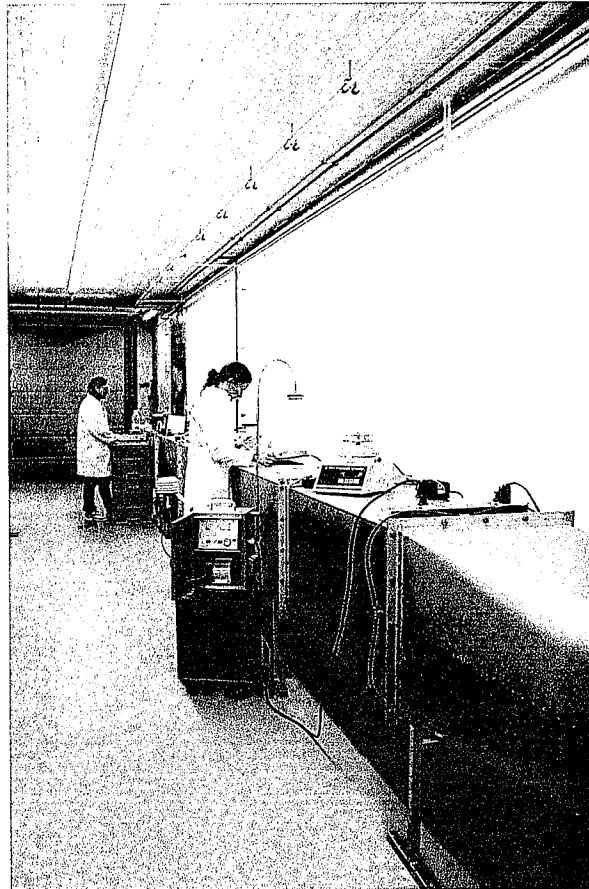


Fig. 2: Bioaerosol testing tunnel at the Labor Dr. Rabe HygieneConsult testing hall

After conditioning (moisture and temperature regulation), the air passes over a pre-filter (filter class F5) and through an intake filter (filter class F9) and a high efficiency submicron particulate air filter HEPA 13 placed in the entrance to the testing tunnel. This latter filter retains more than 99.97% of all particles of the same size as those micro-organisms used in the test and hence ensures the air is practically germ-free before it reaches the bioaerosol release stage. A jet of the micro-organism suspension is then released behind the HEPA 13 filter into the airstream. The HEPA 13 filter and measurement section are separated by a 4.5 m lead section. To ensure homogeneous aerosol distribution and a turbulent airflow, the air passes over a turbulence inducing plate, half the size of the tunnel cross-section. The lead section takes the air directly to the measurement section. In each test, the two reference devices are set up in this section (ACE Glass AGI-30 impingers, as recommended by the American Conference of Governmental Industrial Hygienists – ACGIH). Airflow speed, temperature, humidity and partial negative pressure are measured in the section where the devices are tested, and regulated if necessary. Since humidity can be a factor in particle sampling efficiency in the tests, it is monitored on-line during the measurements in the testing tunnel's measurement section and manually regulated.

Airflow distribution

EN 779 (2003) was taken as the standard of constant airflow speed. The speed of the airflow was measured at nine measuring points in the cross section of the measurement section using anemometers (Testo, Anemometer 271 TG 016 / Testo 445). Each individual measurement lasted two minutes. The average was taken of three individual measurements for each of the nine measuring stations. From these nine values, an average, a standard deviation and a coefficient of variation (CV) were calculated.

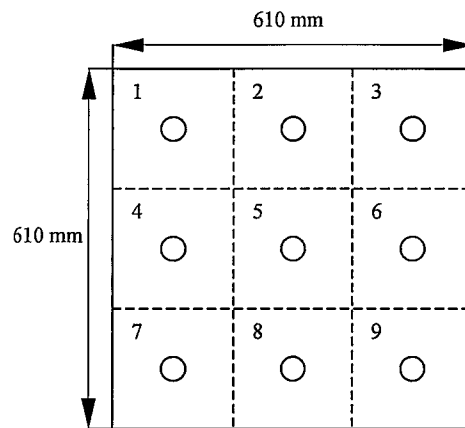


Fig. 3: Measuring points to determine the evenness of air velocity in the tunnel cross section

Table 1: Single measures of air velocity

Measuring point	air velocity [m/s]			air velocity [m/s]			air velocity [m/s]		
	03/17/2003			12/02/2003			03/19/2004		
	I	II	III	I	II	III	I	II	III
1	1,01	1,02	1,04	1,05	1,08	1,03	1,11	1,10	1,10
2	1,00	1,04	1,04	1,05	1,06	1,03	1,09	1,08	1,08
3	1,11	1,13	1,10	1,09	1,09	1,06	1,06	1,03	1,05
4	0,95	0,94	0,94	0,97	0,98	0,98	1,07	1,09	1,07
5	1,02	0,93	1,03	1,05	1,05	1,02	1,09	1,05	1,07
6	1,10	1,16	1,10	1,04	1,00	1,06	1,01	1,02	1,02
7	0,84	0,84	0,83	0,97	0,96	0,98	1,00	1,02	1,03
8	0,83	0,86	0,91	0,97	0,97	0,99	1,04	1,03	1,01
9	1,00	1,02	0,98	1,04	1,02	1,03	0,98	0,98	0,97
mean	0,99			1,02			1,05		
CV	9,8 %			3,8 %			3,9 %		

CV must be less than 10%. In 03/17/2003, for the airflow distribution measurements in the DMT testing tunnel, the CV was 9.8 %; on 12/02/2003, it was 3.8 %. In the identical testing tunnel constructed at the Dr. Rabe HygieneConsult Laboratory, the CV was only 3.9% on 03/19/2004 so that one can assume the evenness of airflow at all nine measuring points in both the "old" and the "new" testing tunnel.

Test organisms

The test organisms were bacteria and mould fungi (see table 2). In the case of the latter, the aerosol used conidia of the *Penicillium citrinum*. The bacteria tests employed not only spores of *Bacillus subtilis* var. *niger* but also the more sensitive vegetative states of a gram positive *Staphylococcus* strain (i.e., *Staphylococcus epidermidis* as recommended in ISO 14698 B1.1 [2003]).

Table 2: List of the selected test microorganisms

Group	Representative	Ident.-No.	Incubation temperature [°C]	Life stadium	Length of cells or spores [µm]	Aerosol
Gram-positive cocces	<i>Staphylococcus epidermidis</i>	DSMZ ¹ 20040	36	vegetative	0.5 – 1.5	Cell suspension
Spore bearing bacteria	<i>Bacillus subtilis</i> var. <i>niger</i>	ATCC ² 9372	36	spores	0.8	Spores suspension
Filamentous fungi	<i>Penicillium citrinum</i>	CBS ³ Culture	25	spores	2 – 3	Spores suspension

Test aerosol

The test micro-organisms described above were multiplied in a pure culture and this was then diluted to produce the testing suspension.

The mould fungus cultures were prepared by introducing infected smears with spores of *Penicillium citrinum* onto a culture medium (DG 18 Agar) and leaving the culture medium to incubate for a period of at least 14 days at 25° C. The colonies develop conidiospores, removed by covering the culture with 10 ml of dist. H₂O with an added 0.01 % Tween 80[®] (Poly(oxyethylene)(20)-sorbitan monooleate) and carefully and repeatedly turning the culture dish. The *Bacillus subtilis* spore suspension production followed DIN EN 14347, Appendix A (Draft 2002). The base suspension had a concentration of approx. 10⁸ spores/ml and can be kept for several years in alcohol at a temperature of 4-8 ° C. To produce the *Staphylococcus*

¹ DSMZ: Deutsche Sammlung von Mikroorganismen und Zellkulturen

² ATCC: American Type Culture Sampling

³ CBS: Centraalbureau voor Schimmelcultures

epidermidis suspension, a culture in nutrient broth (peptone water) was inoculated and left overnight at 36 °C.

The micro-organism suspension thus produced was ultrasound treated for 2 minutes and finally whorled by a vibration mixer for a further 2 minutes to divorce agglomerates. A Neubauer counting chamber was used to establish the number of cells or spores per ml in the stock suspension and simultaneously check for the absence of agglomerates. The stock suspension was diluted with sterile distilled water to obtain the testing suspensions for aerosolising in the bioaerosol testing tunnel.

The testing suspension was kept in a storage vessel with a magnetic stirrer used to ensure constant movement, guaranteeing suspension homogeneity over the entire testing period. The micro-organism suspension was transported to a two-substance atomising nozzle (Schlick, 970 S8) via a hose pump (Heidolph, PD 5201 with Pump Head Standard SP). A balance (Kern, 880-22 or 572-49), attached to a laptop for data transfer, was used to determine the flow rate. The micro-organism suspension was aerosolised using a hydro-pneumatic two-substance atomising nozzle. The nozzle bore was 0.5 mm. Adjusting the atomisation air pressure and flow rate of liquid regulates the number and size of the droplets. The compressed air was set at 1.0 bar and liquid flow rate set at 12 - 14 ml/min. The compressed air was provided in-house and was oil and germ free filtered in a compressed air filter (TSI, HEPA glass fibre capsule filter # 1602344) with a retaining power of 99.98% for particles of $\geq 0.3 \mu\text{m}$.

During the entire period of testing, the microorganism suspension flow rate was controlled and recorded on-line and, if necessary, was regulated. The influence on the findings of minimal flow rate variations was mathematically compensated for by all individual results in each of the ten repeated measurements being normed with individual correction values to the average flow rate. The correction value for the individual measurement was the relationship of the suspension flow rate recorded in each measurement to the average flow rate during the 10 repeated measurements.

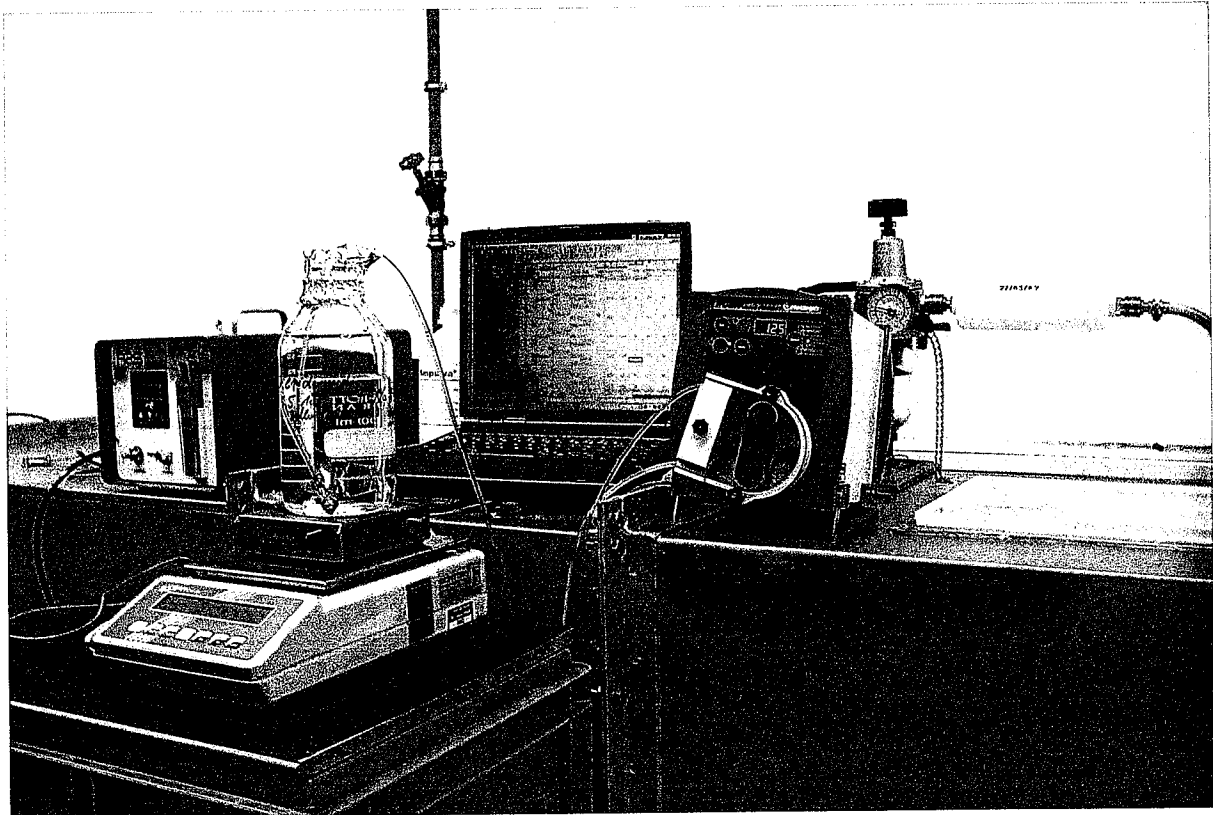
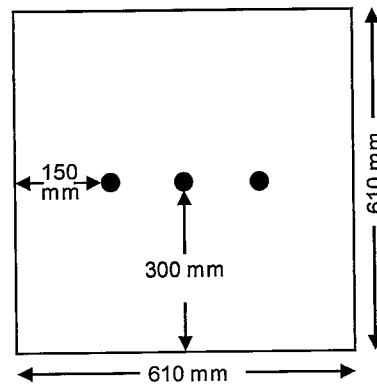


Fig. 4: Aerosol feeding

Aerosol distribution

To ensure even aerosol distribution in the testing tunnel, bioaerosol measurements were taken simultaneously at three points 300 mm above the tunnel floor. The three impingers used to monitor aerosol distribution were set up 150 mm apart and from the tunnel walls. The suction inlets were aligned to be parallel to the airflow. Each impinger took 10 measurements lasting 10 minutes each at an airflow of 12.5 l/min.



**Fig. 5: Position of impingers
in tunnel cross section**

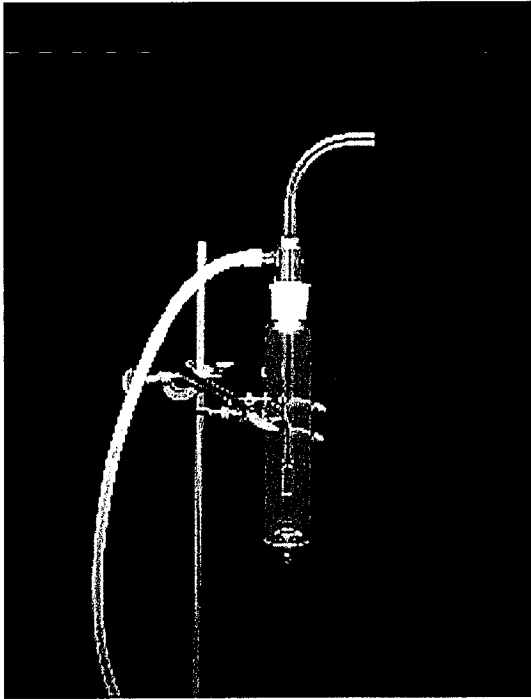
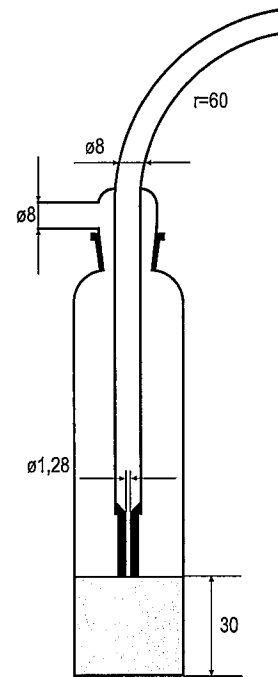


Fig. 6: Impinger – set up and



scheme

The test organisms used to determine aerosol distribution were *Penicillium citrinum* and *Bacillus subtilis* spores and vegetative cells of *Staphylococcus epidermidis*. The spore or cell concentration in the tunnel lay within 10^2 or 10^6 CFU/m³ of air. The airflow speed was set at 1.0 m/s (flow rate: 22.3 m³/min). The suspension feed flow rate was within the range of 10 – 15 ml/min. The flow rate was recorded for each measurement and factored into the calculation for the spore or cell concentration.

The impinger test sampling and analysis is described in below in the sections "The Test" and "Sample Analysis".

In line with EN 779 (2003), the average of the 10 measurements was calculated for each of the three measuring points. These three values were then used to calculate the average and the standard deviation. The CV coefficient of variation (relative standard deviation) is supposed to be less than 15 %.

Table 3: Spatial variation of concentration of *Penicillium citrinum*, *Staphylococcus epidermidis* and *Bacillus subtilis* in tunnel cross section

Date	No. of samples taken	Concentration range [CFU/m ³]	CV	Species of microorganism
04/30/03	10	5·10 ⁵	9,9	<i>Penicillium citrinum</i>
05/09/03	5	1·10 ⁶	8,1	<i>Penicillium citrinum</i>
05/15/03	10	1·10 ⁶	13,0	<i>Penicillium citrinum</i>
05/21/03	10	5·10 ⁵	11,6	<i>Penicillium citrinum</i>
05/27/03	10	5·10 ⁵	12,9	<i>Penicillium citrinum</i>
05/30/03	10	2·10 ²	11,8	<i>Penicillium citrinum</i>
07/17/03	10	2·10 ²	14,7	<i>Staphylococcus epidermidis</i>
07/29/03	10	5·10 ²	13,1	<i>Staphylococcus epidermidis</i>
08/07/03	10	5·10 ²	14,8	<i>Bacillus subtilis</i>

The Test

The airflow for the tests was set to ensure an airflow speed of 0.8 -1.0 ± 0.1 m/s in the bioaerosol testing section. As far as micro-organism uptake in the test device samplers are concerned, there is no difference, in principle, between this airflow speed and standing air.

The devices to be tested were positioned in the measurement section of the tunnel. As recommended by the ACGIH, two ACE Glass all-glass impingers also took reference samples parallel to the test device's sample sampling. Preliminary tests ensured that the positioning of test equipment or sampler intakes in the measuring section did not affect the results. The sampling medium in the impingers was 20 ml of a 0.9 % NaCl solution (with an additional 0.01 % Tween 80® for the mould and *Bacillus subtilis* spores).

Sample sampling for each individual impinger was carried out using an Ilmvac MP 601 Ep diaphragm pump set so that the impinger was operated as a critical orifice with an airflow of 12.5 l/min. A condensate trap and an absorption tower were arranged in-line to protect the suction system. All of the parts and linkage elements that the airflow passed through, including the condensate trap, are made of soft soda glass. The link between the absorption tower and the suction appliance is via a fabric tube.

To determine the conditions in the bioaerosol testing tunnel and the airflow in the tunnel, appropriate devices were used to record tunnel temperature, airflow speed, humidity and static pressure and temperature, humidity and air pressure in the bioaerosol chamber.

Blank values were also taken on every test day. In this case, the impingers and test device were prepared as described above and set for measurement, but no micro-organisms were suctioned through. Subsequently, the sampling liquid or culture medium dishes were processed as in all other tests. Blank values were not proven in any of the test series.

The entire test comprised 3 (test organisms) x 2 (bioaerosol concentrations) test elements repeated 10 times.

In testing the **EMTechnologies "R2S" Bioaerosol Sampler**, the suspensions in the two bioaerosol concentrations were adjusted so that the detectable aerosol concentration lay within a range of 10^2 CFU/m³ and 10^3 CFU/m³, respectively. These are the pertinent concentrations for Bioaerosol Samplers used to take samples in interior and clean rooms. The concentrations were selected together with the device-specific test times so that, when evaluating the samples, the colony numbers lay within the optimal range.

In taking the samples, the device was used in line with the manufacturer's guidelines (instruction booklet).

Before the device was made available for testing, the manufacturer had calibrated it to the airflow.

Table 4: Parameters of the tests

Tested microorganisms	<i>Staphylococcus epidermidis</i> , <i>Bacillus subtilis</i> , <i>Penicillium citrinum</i>
Test concentration [CFU/m ³]	10 ² , 10 ³
Testing time [min.]	5 / 10 / 20
Air flow [l/min.]	28,3
Test volume [l]	141,5 / 283 / 566

Sample analysis

After sample taking was completed, the impingers were sealed with aluminium foil and placed in an ice bath for interim storage. Sample processing occurred within 6 hours of completing the sample collection phase. In line with the anticipated concentration, 1 – 20 ml suspension from the samples was membrane filtered and the filters set on culture medium. The culture medium trays from the tested devices were kept for a maximum of 6 hours at room temperature before incubation.

The micro-organism cultures were incubated at the appropriate temperature and the number of colonies counted several times in the respective time periods (see Table 5 for details). These findings, taken together with the final volumes in the impinger bottle and the airflow results, were used to calculate the number of colony forming units (CFU) per air volume unit (m³ of air).

Table 5: Culture conditions for the used microorganisms

Test microorganism	Culture medium	Incubation temperature [°C]	Incubation period
<i>Bacillus subtilis</i>	CASO (TSA)	36	2 days
<i>Staphylococcus epidermidis</i>	CASO (TSA)	36	2 days
<i>Penicillium citrinum</i>	Sabouraud	25	5 days

Data evaluation

For each device tested and for each test component the normed mean of the individual cell numbers of the test series was calculated. A coefficient of variation was calculated for each mean. The results were presented in tabular form for each individual test. In addition, there was also a tabular comparison with the reference device. The findings on relative sampling efficiency (in relation to the reference device) from all of the devices involved in this comparative test were ordered both as a graph and a table.

All the tests always involved reference measurements with two AGI 30 devices. The reference measurement variances are given in Table 6. In general, they show very good reproducibility of the measurement results. In principle, the higher the bioaerosol's micro-organism concentration, the lower the repeat standard deviation.

Table 6: Device data (as given by the manufacturer)

Participant-No.	10
Manufacturer	EMTechnologies
Country	US
Contact partner	Mr. Erik Swenson
Device name	Remote-Slit-Sampler
Model	R2S-C.001 & R2S.001
Serial No.	1117
Year of manufacture	
Voltage / frequency	220-230V / 50 Hz
Power W	
Nominal capacity mA	
Power supply	Power socket
Dimension (l / w / h) mm	R2S-C.001: 381/228,6/177,8 R2S.001: 127/139,7
Weight kg	R2S-C.001: 9,53 R2S.001: 1,134
Equipment pieces	3
Operational area	Clean room, LAF hoods, Isolator environments
Remote control	no
HEPA-Filter (exhaust)	0,2-0,3 µm; 99,97%
Timer	
Sampling principle	Slit-Impaction
Sampling orifice separat yes / no	yes
Particle size µm	
Agar plate Ø mm (Agar height or -volume)	100 (distance Slit/agar surface 2-3 mm)
Flow rate	
Variable yes / no	no
l / min	28,3
Tolerance (+/- %)	8,33
Sampling efficiency ($d_{ae}50$) µm	
Impaction velocity m/s	76 +/- 7
Sampling volume	
Variable yes / no	yes, with sampling period
Sampling period	
Variable yes / no	1" to 59' 59"

Results

Table 7: Remote-Slit-Impactor R2S

Date	Test microorganism	Concentration range [CFU/m ³]	Sampling period [min]	Sampling volume [l]	Sampled test microorganism concentration Mean (10 replicates) ± CV [CFU/m ³]		Relation R2S / Impinger [%]
					Impinger AGI 30	R2S	
12/04/03	<i>Bacillus subtilis</i>	10 ² - 10 ³	5	141,5	420 ± 18 %	696 ± 9 %	166
12/11/03	<i>Bacillus subtilis</i>	10 ¹ - 10 ²	20	566,0	32 ± 16 %	58 ± 19 %	181
01/13/04	<i>Penicillium citrinum</i>	10 ² - 10 ³	5	141,5	341 ± 27%	604 ± 16 %	177
05/06/04	<i>Penicillium citrinum</i>	10 ¹ - 10 ²	20	566,0	33 ± 24 %	61 ± 15 %	185
10/06/03	<i>Staphylococcus epidermidis</i>	10 ¹ - 10 ²	10	283,0	83 ± 23 %	146 ± 14 %	176
09/01/04	<i>Staphylococcus epidermidis</i>	10 ² - 10 ³	5	141,5	1.521 ± 25 %	2.296 ± 8 %	151

Table 8: Sampling efficiency of all tested bioaerosol samplers

Test device	Sampling type	Air flow l/min	Sampling efficiency in percent of reference impinger AGI 30 (= 100 %)								
			Staphylococcus epidermidis			Penicillium citrinum			Bacillus subtilis		
			A	B	C	A	B	C	A	B	C
2	Filter	30		17	38		167	174		101	99
11		33 - 57		6	16		84	92		108	87
1	Slit impactor	100	114	96		220	201		110	110	
R2S		28,3	176	151		185	177		181	166	
8		30	259	200		266	239		171	141	
9		146,8	121	107		198	275		53	66	
12 a	sieve impactor	100	71	13		149	190		16	35	
12 b		100	41	12		188	187		14	30	
13		100	318	341		187	282		42	77	
6		125	339	294		286	361		164	215	
5		30 / 100	34	71		7	11		17	17	
4	Multi-stage sieve impactor	28,3	113	145		163	121		135	191	
7		125	249	214		189	240		146	168	
14	Centrifugal sampler	50	63	69		189	195		28	29	
10	Virtual impactor + filter	3		43	11		166	158		106	96

A= Concentration range 10² CFU/m³, B= Concentration range 10³ CFU/m³, C= Concentration range 10⁴ CFU/m³

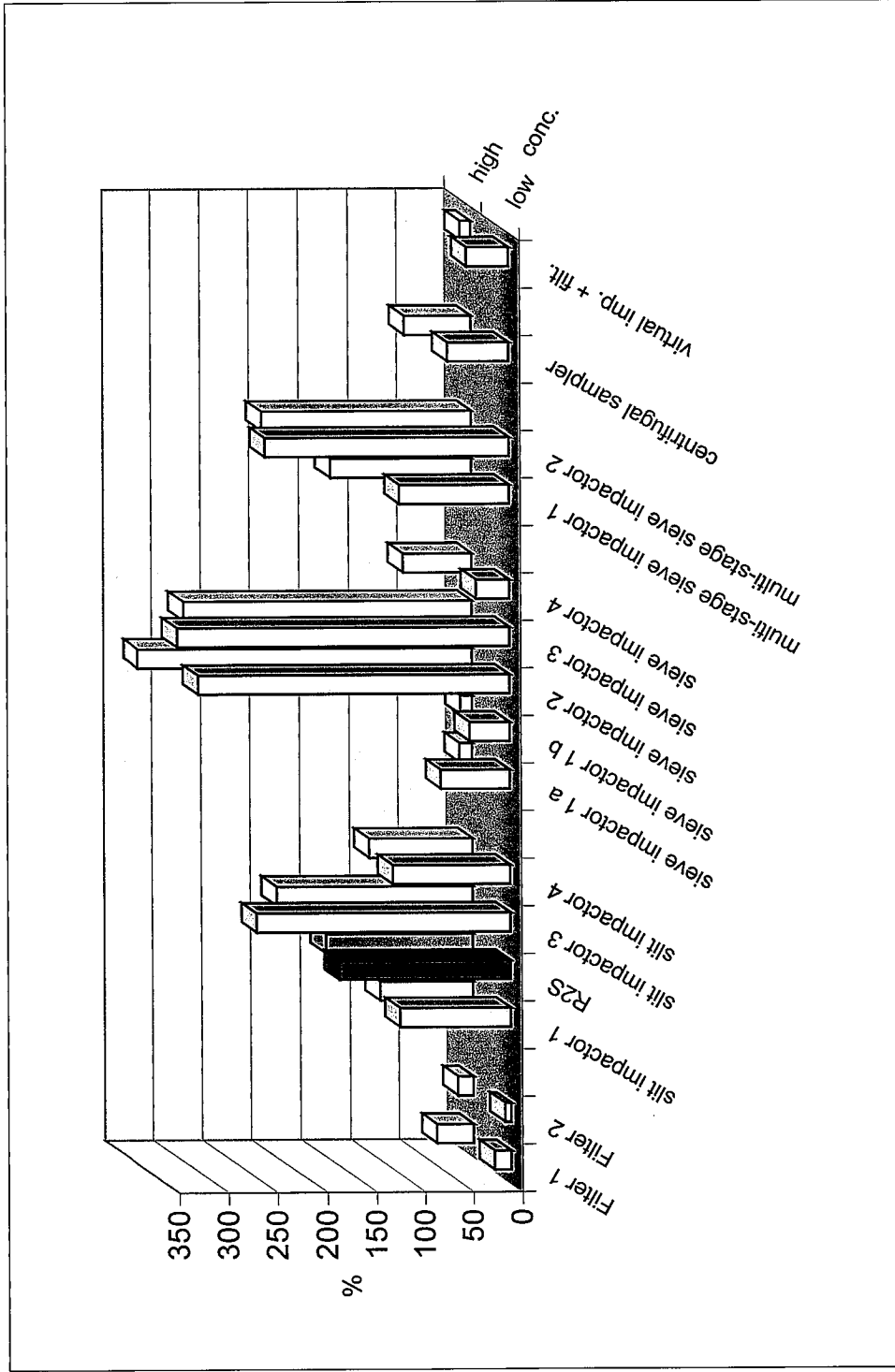


Fig. 7: Sampling efficiency of all tested bioaerosol samplers with respect to *Staphylococcus epidermidis* in relation to reference impinger AGI 30 (≅ 100 %)

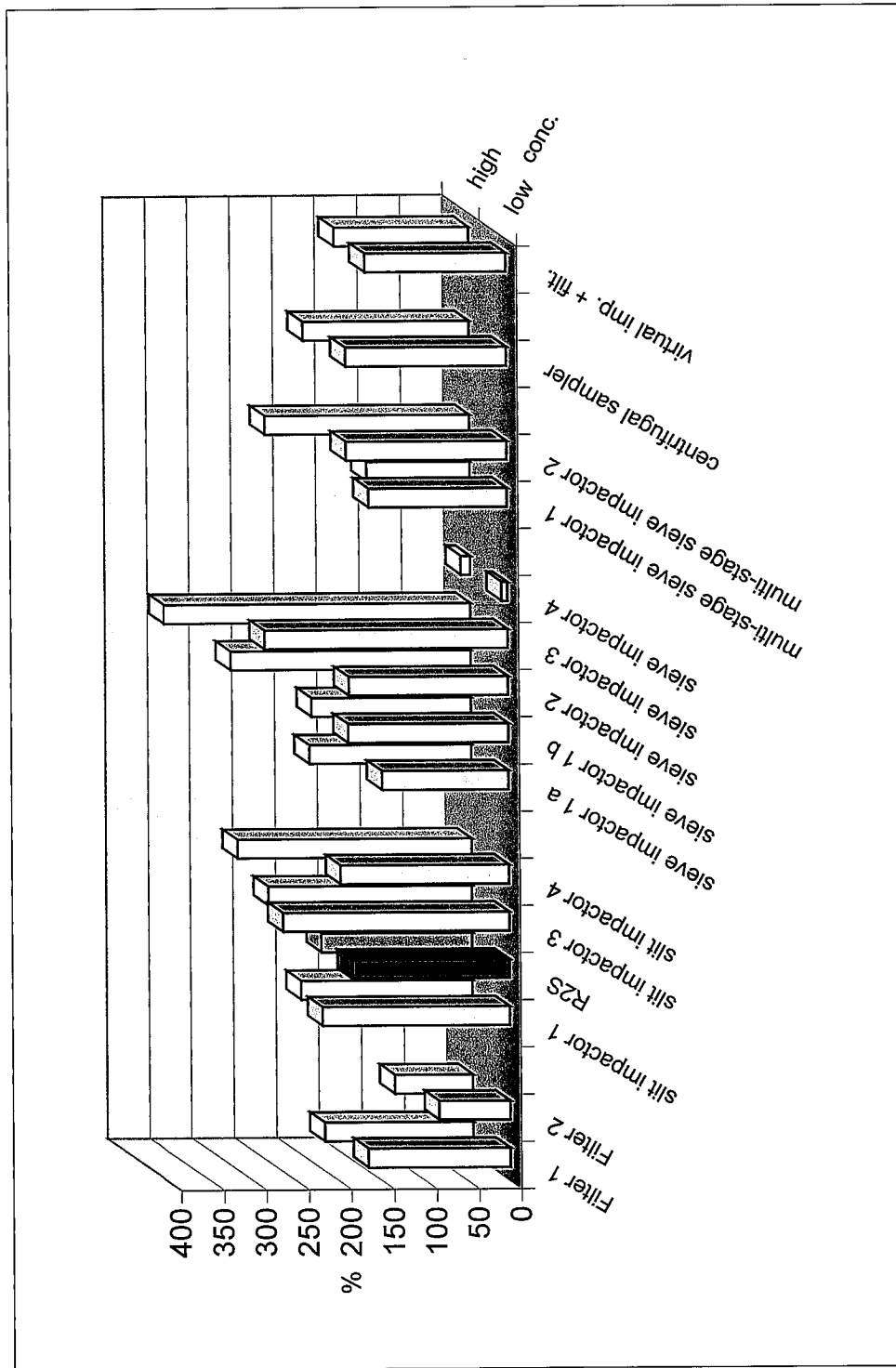


Fig. 8: Sampling efficiency of all tested bioaerosol samplers with respect to *Penicillium citrinum* in relation to reference impinger AGI 30 (= 100 %)

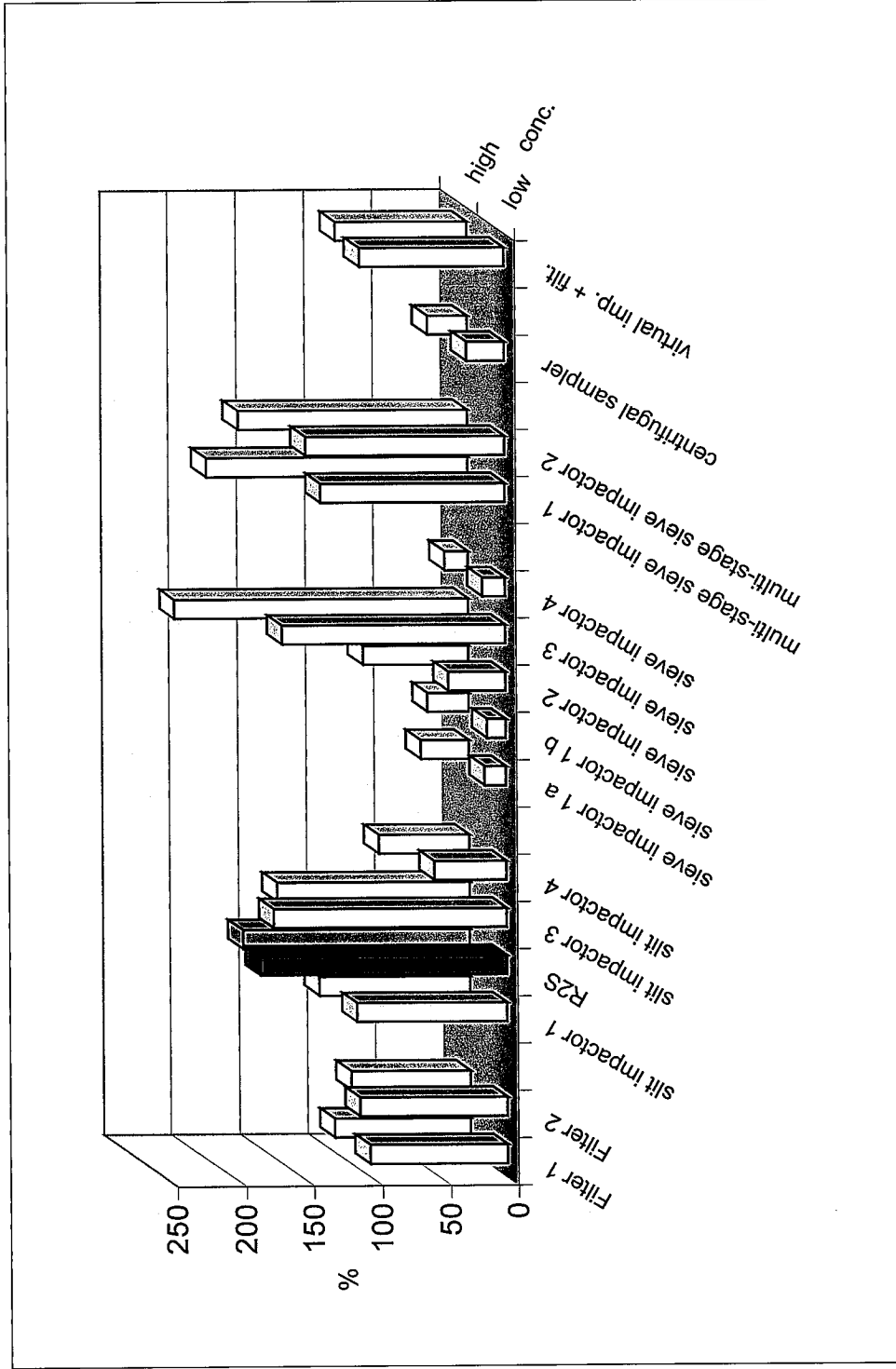


Fig. 9: Sampling efficiency of all tested bioaerosol samplers with respect to *Bacillus subtilis* in relation to reference impinger AGI 30 (= 100 %)

Summary of findings, evaluation and comments; comparison with the other bioaerosol samplers in the test

In comparison to the other test devices, the R2S showed a very low level of sample measurement distribution. The repetition standard deviation ($n = 10$) was between 8 % and 19 %, with an average of 14% (Table 7 and individual results in the Appendix). The majority of the other bioaerosol samplers in the test showed higher coefficients of variation.

The sampling efficiency of the R2S differed significantly from that of the reference device, depending on the test organisms used. The efficiency was as follows:

- with *Staphylococcus epidermidis* as a vegetative bacteria 176 % or 151 % respectively of the reference device's sampling efficiency
- with mould spores from *Penicillium citrinum* 177 % or 185 % respectively of the reference device's sampling efficiency.
- with *Bacillus subtilis* (very small bacteria spores) 166 % or 181 % respectively of the reference device's sampling efficiency

The test organisms all have different aerodynamic diameters:

- *Bacillus subtilis*: 0.7 – 1.0 μm
- *Staphylococcus epidermidis*: 1.2 – 2.0 μm
- *Penicillium citrinum* : 2.0 – 3.5 μm

Bioaerosol samplers can only quantitatively sample very small bacteria, such as the spores of *Bacillus subtilis*, if the device's cut-off is sufficiently small. This is apparently the case in the R2S sampler. As with the other test organisms, sampling efficiency with *Bacillus subtilis* was more than one-and-a-half-times higher than in the reference AGI 30 impinger.

In the group of slot impactors, the sampling efficiency of the R2S with mould spores was exceeded by the other test devices, although the differences between the individual devices was not that great. Of the other ten devices, only two recorded a higher sampling efficiency than the R2S, with five at the same level, and three recording lower efficiency.

There were notable differences between the individual devices for sampling efficiency of *Staphylococcus epidermidis*. The filtration devices and the virtual impactor with final filtration show only little sampling efficiency. The reason for this is that, while taking the samples, the sensitive vegetative bacterias on the filter are exposed to a significant stress from dehydration and oxygen toxicity, which leads to a number of them dying off. The sampling efficiency in all the other ten devices impacting bioaerosol particles onto culture mediums was greater in four cases, while the other six devices had a lower sampling efficiency than the R2S. For publication of the final results in the overall comparison, statistical tests are being used to check how far the observed differences between the various devices are significant.

The size of the cut-off value is noticeable in the tests using the extremely small bacteria spores of *Bacillus subtilis*, and here the device shows its efficiency. In the tests with *Bacillus subtilis*, only one device with a comparatively low cut-off value had a slightly higher sampling efficiency than the R2S and three devices recorded similar results. The other nine devices showed a lower sampling efficiency.

On the basis of these excellent test results, the bioaerosol sampler R2S can be recommended for use in taking validation measurements in clean rooms, in operating rooms and all areas where there are high demands on having reliable and precise measuring results and where individual bacteria also occur in the bioaerosol. The device is very well suited for all other interior and workplace measurements too.

For the content:

(Dr. Rudolf Rabe)

Appendix

Individual measurement data

Test with *Bacillus subtilis* on 12/04/03

R2S	Impaction CFU/m ³
Sample 1	692
Sample 2	742
Sample 3	611
Sample 4	733
Sample 5	810
Sample 6	620
Sample 7	n.a.*
Sample 8	676
Sample 9	742
Sample 10	641
Mean 1-10	696
Std dev 1-10	66
CV (%) 1-10	9,5

* n.a. = not analysed

Impinger	Position 1	Position 2	
	CFU/m ³		
Sample 1	420	282	
Sample 2	603	308	
Sample 3	539	376	
Sample 4	606	350	
Sample 5	541	444	
Sample 6	644	556	
Sample 7	614	436	
Sample 8	520	419	
Sample 9	564	376	
Sample 10	542	376	
Mean	447	392	420
Std dev	51	77	74
CV (%)	11,4	18,7 19,6	17,4

Test with *Bacillus subtilis* on 12/11/03

R2S	Impaction CFU/m ³
Sample 1	n.a.*
Sample 2	71
Sample 3	41
Sample 4	76
Sample 5	62
Sample 6	52
Sample 7	47
Sample 8	58
Sample 9	55
Sample 10	60
Mean 1-10	58
Std dev 1-10	11
CV (%) 1-10	18,8

* n.a. = not analysed

Impinger	Position 1	Position 2	CFU/m ³
	CFU/m ³		
Sample 1	29	31	
Sample 2	29	31	
Sample 3	32	34	
Sample 4	32	34	
Sample 5	31	31	
Sample 6	34	33	
Sample 7	37	20	
Sample 8	37	20	
Sample 9	38	37	
Sample 10	39	38	
Mean	34	31	32
Std dev	4	6	5
CV (%)	10,8	20,5	16,3

Test with *Penicillium citrinum* on 01/13/04

R2S	Impaction CFU/m ³
Sample 1	463
Sample 2	n.a.*
Sample 3	528
Sample 4	525
Sample 5	736
Sample 6	594
Sample 7	600
Sample 8	688
Sample 9	587
Sample 10	718
Mean 1-10	604
Std dev 1-10	93
CV (%) 1-10	15,5

* n.a. = not analysed

Impinger	Position 1	Position 2	CFU/m ³
	CFU/m ³		
Sample 1	319	314	
Sample 2	278	361	
Sample 3	174	234	
Sample 4	280	269	
Sample 5	386	382	
Sample 6	468	316	
Sample 7	431	346	
Sample 8	302	199	
Sample 9	525	393	
Sample 10	484	359	
Mean	365	317	341
Std dev	112	65	92
CV (%)	30,7	20,4	27,1

Test with *Penicillium citrinum* on 05/06/04

R2S	Impaction CFU/m³
Sample 1	48
Sample 2	50
Sample 3	54
Sample 4	70
Sample 5	61
Sample 6	68
Sample 7	70
Sample 8	69
Mean 1-10	61
Std dev 1-10	9
CV (%) 1-10	15,3

Impinger	Position 1	Position 2	
	CFU/m³		
Sample 1	19	28	
Sample 2	19	27	
Sample 3	29	39	
Sample 4	29	40	
Sample 5	32	35	
Sample 6	32	34	
Sample 7	34	45	
Sample 8	35	46	
Mean	29	37	33
Std dev	6	7	8
CV (%)	22,3	19,1	23,6

Test with *Staphylococcus epidermidis* on 10/06/03

R2S	Impaction CFU/m ³
Sample 1	n.a.*
Sample 2	153
Sample 3	155
Sample 4	191
Sample 5	132
Sample 6	129
Sample 7	126
Sample 8	156
Sample 9	134
Sample 10	138
Mean 1-10	146
Std dev 1-10	21
CV (%) 1-10	14,1

* n.a. = not analysed

Impinger	Position 1	Position 2	CFU/m ³
	CFU/m ³		
Sample 1	116	n.a.*	
Sample 2	68	83	
Sample 3	55	59	
Sample 4	98	81	
Sample 5	104	56	
Sample 6	95	61	
Sample 7	92	81	
Sample 8	93	112	
Sample 9	104	65	
Sample 10	71	90	
Mean	90	76	83
Std dev	19	18	19
CV (%)	21,4	23,8	23,3

* n.a. = not analysed

Test with *Staphylococcus epidermidis* on 09/01/04

R2S	Impaction CFU/m ³
Sample 1	2.649
Sample 2	2.194
Sample 3	2.283
Sample 4	2.061
Sample 5	2.216
Sample 6	2.125
Sample 7	2.451
Sample 8	2.231
Sample 9	2.347
Sample 10	2.400
Mean 1-10	2.296
Std dev 1-10	172
CV (%) 1-10	7,51

Impinger	Position 1	Position 2	CFU/m ³
	CFU/m ³		
Sample 1	n.a.*	996	
Sample 2	1.253	975	
Sample 3	1.475	1.362	
Sample 4	1.331	1.303	
Sample 5	1.396	993	
Sample 6	1.356	2.026	
Sample 7	1.139	2.682	
Sample 8	1.702	2.532	
Sample 9	1.256	2.286	
Sample 10	934	1.908	
Mean	1316	1.706	1.521
Std dev	215	411	381
CV (%)	16,3	24,1	25,0

* n.a. = not analysed