

The Gazette

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TRIO.BAS MONO 100: The Device That “Sniffs Out” Microbes in the Air



Did you know that the air we breathe—especially in sensitive environments like hospitals and laboratories—can contain bacteria, fungi, and other invisible particles that pose a health risk?

That’s why special instruments exist, called microbiological air samplers, specifically designed to detect and measure these microorganisms.

One such device is the **TRIO.BAS MONO 100**. Designed in Italy by **ORUM INTERNATIONAL**, it has been tested by researchers from the **UNIVERSITY OF MILAN** and the **ACCREDITED LABORATORY STATIM LAB**.

What did they discover?

That the TRIO.BAS MONO 100 is **precise, effective, and reliable**, capable of capturing **nearly 100% of airborne microbes**—even outperforming other instruments already considered industry standards.



 The study showed that it is **ideal for air quality monitoring in cleanrooms, operating theatres, and pharmaceutical facilities**, where every single microbe matters.

 With the TRIO.BAS MONO 100, air is monitored **safely, quickly, and in compliance with European regulations**, ensuring a cleaner and more protected environment for everyone.

Biological Efficiency of the Active Microbial TRIO.BAS MONO-100 Air Sampler

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Abstract

The novel simplified laboratory method for the qualification of microbial air samplers has been previously described in the EN17141:2020 Cleanroom and associated controlled environment-Biocontamination Control document. This paper is to demonstrate the practical application of this method to validate the TRIO.BAS MONO-100 active air sampler, constructed to detect bioaerosols, to be applied to different environments with unknown or normal microbial concentrations. Airborne microbial particles, that include bacteria, viruses, fungi, spores, and pollen grains with different size range, may compromise human health, and should be removed from clean rooms and hospital surgical sterile environments. The performance of TRIO.BAS MONO-100 air sampler was compared to the one of the previously qualified and calibrated air sampler MAS100 from Millipore (Bedford, MA, USA). The first series of tests was conducted at the qualified ISO/IEC 17025:2017 Statim laboratory in Milan, whereas the second one was performed in a laboratory at the University of Milan (UNIMI). Our results show a good biological efficiency of the TRIO.BAS MONO-100 air sampler in aspirating the airborne microorganisms. The average efficiency determined for the TRIO.BAS MONO-100 sampler in the two environments was 99% at Statim and 109% at UNIMI compare to MAS100 air sampler, used as a control device.

Keywords: Air Sampler; Bioaerosol; Biological Collection Efficiency; CFU; Microorganisms; Moulds

Abbreviations

TSA: Trypticase Soy Agar; CFU: Colony Forming Units; o/n: Overnight

Introduction

Human health may be compromised by airborne microorganisms and the consciousness of the importance of bioaerosol detection is well established [1]. To this aim, laboratory clean rooms and hospital surgical sterile environments as well as pharmaceutical manufacturing areas must be constantly monitored. The most relevant source of biological contamination is represented by microorganisms as bacteria, viruses, fungi and spores [2]. These can remain suspended in the air for longtime [3], contaminate the air of these areas and thus compromise the successful outcome of the work performed in these premises [4-6].

Different bioaerosol samplers are available at present that include impactors, cyclones, impingers, and filters [2], but impaction-based samplers are the most used ones because of the simplicity and low cost of this sampling method.

Most microbes arise from aerosols, as fragments of skin or cells released by human beings [5,7], and microbial air samplers can monitor the amount of the viable population of airborne microorganisms.

Active air samplers harvest and accelerate the airflow through an array of nozzles on the sampler head and impact the microorganisms onto the surface of a nutrient agar-medium culture plate, laid underneath the sampler head (Figure 1). The petri dish is used for the direct collection of the microorganisms and then incubated overnight (o/n) at the established temperature. After incubation, the microbial colonies are counted and expressed on the basis of the aspired air volume.

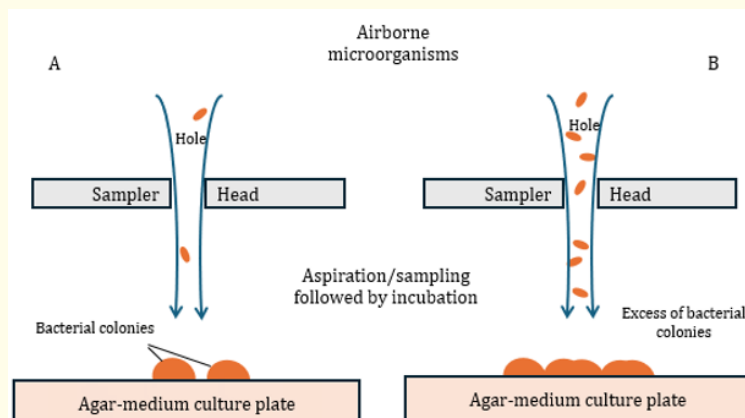


Figure 1: Scheme of the air operating sampler. The TRIO.BAS MONO-100 sampler is provided with a head of 300 holes, each hole having a diameter of 0,6 mm. Aspiration of a low (A) to high (B) number of bacteria through one hole is shown. Bacteria passing through the holes impact on the agar medium of the petri dish and, after incubation, they form colonies. The number of colonies may depend on the sampling time.

The occurrence of colony overlapping is taken into consideration to avoid an excess of harvested microorganisms as well as the incubation time and a temperature that can inhibit mould growing and hamper CFU counting [5].

The MAS100 system, which was developed by Meier and Zingre (2000) [8], is a very efficient one to monitor the number of live microorganisms in the air. It is a simplified laboratory method, described in the EN 17141:2020 standard document [9,10], as an alternative to the aerosol chamber method. According to the European Standard Guidelines [11], this procedure was demonstrated to be the most suitable for microbial collection, where the requested volume of aspirated air in a low contamination environment should be of 1m³ for 10-minutes sampling time.

Two different environments were used for all of the tests to ensure that the microbial concentration was in the range between 80 and 150 CFU/m³. After the preliminary aspirations/samplings at the constant time of 10 minutes, different aspiration times were tested to increase the capture of most microorganisms. As extended sampling times result in the loss of agar moisture in the petri dishes, the dehydration of the petri dishes after aspiration was also calculated. The reduced weight of the Petri dish before and after each sampling and after incubation was controlled for its possible correlation with the colony number/counting. Different sampling times were also tested that might affect not only the number of the colonies, but the regular growing of the colonies (i.e. the number of CFU/m³).

Methods

Air samplers

The active microbial air samplers TRIO.BAS MONO-100 (TRIO.BAS MONO-100A, and the TRIO.BAS MONO-100B, ORUM International, Milan, Italy) were used, that aspire microbial particles directly and impact them onto the agar surface. When the experiments were performed in double, the MAS100 reference instrument was set in the central position between TRIO.BAS MONO-100A and TRIO.BAS MONO-100B (Figure 2). The TRIO.BAS MONO-100 sampler is provided with a head with 300 holes, each hole having a diameter of 0.6 mm (with an area of 0.2826 mm²). The holes cover a total area of 0.8478 cm² and aspire 1965.87 cm/sec with a sampling rate of 100 L/min. They are arranged symmetrically (Figure 3A) and, after sampling, imprints are left on the agar surface (Figure 3B), that reflect the arrangement of the bacterial colonies grown after incubation (Figure 3C).

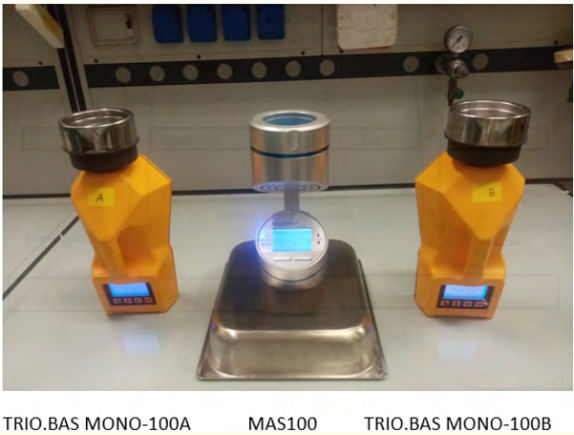


Figure 2: Three samplers were used in this study: 2 TRIO.BAS MONO-100 (A and B) and the reference sampler MAS100, in the middle. During the test all of the samplers were set up at a distance of at least 1m from one another, and around 80 cm from the ground.

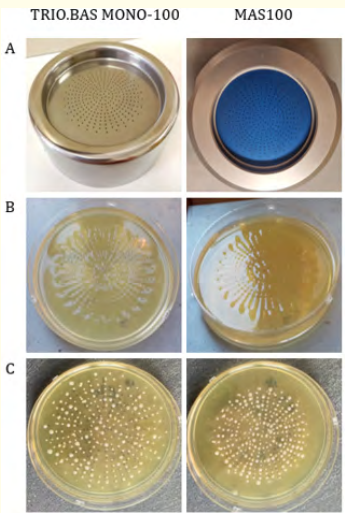


Figure 3: A: Heads of TRIO.BAS MONO-100 and MAS100 samplers, showing the symmetrical arrangement of the holes. B: After sampling, imprints are left on the agar surface due to the impact of the air. C: After 24h incubation at 37°C, the symmetrical arrangement of the bacterial colonies on the surface of the agar medium reflects the arrangement of the holes of the sampler head.

Petri dishes

Ready-to-use 90-mm sterile Petri dishes (BD, San José, CA) with 30-ml Trypticase™ soy agar with lecithin and polysorbate 80 (TSA + LP, BD GmbH, Heidelberg, Germany) were used to capture and grow airborne microorganisms.

Sampling

The dishes were opened just before switching on the air samplers and they were set over the heads of the instrument for 10 minutes at Statim laboratories or for different experimental times (10, 20, 40 minutes) at UNIMI at room temperature. The air samplers were positioned on a flat surface at the distance of 1m from each other and around 80 cm from the floor before starting the tests simultaneously. Samplings were repeated in different days and in two different locations and performed in closed rooms. The Petri dishes were then incubated upside-down at 32°C or 37°C in an incubator, with identification number.

Colony counting

The total number of the colonies was performed after o/n growing. Only colony counts higher than 80 - 150 CFU/culture plate were taken into consideration, and expressed as colony forming units (CFU)/m³. Although some tests were initially performed at 48h, the incubation time was then reduced to avoid mould growing, that prevented bacterial counting (Figure 4). When the experiment was performed in double, the average CFU number of the TRIO.BAS MONO-100A and TRIO.BAS MONO-100B devices was considered.

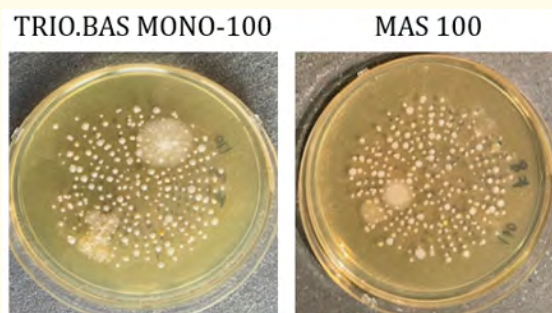


Figure 4: After 48-h incubation at 32°C, mould colonies were present that prevented the counting of the bacterial colonies. Shorter 24-h incubations at 37°C overcame this problem.

Calibration of the instruments

Before starting the tests, the airflow rate through the air samplers was calibrated for all of the samplers to validate the efficiency of the devices, as requested by the EN 17141:2020 regulations. The qualified, calibrated gold-standard MAS100 (Merck Millipore, Bedford, MA) air sampler, that also aspires 100 L/min was used as the reference device.

The instruments were calibrated to capture the same air volume and, when in double, their position was inverted after each experiment.

Active microbiological air samplers are based on two operational principles: the physical and the biological collection efficiency. The physical collection efficiency is based on the cut-off diameter size (d₅₀, Stokes number) of the holes of the instrument. It defines the diameter size at which the air sampler harvests 50% of the air particles. The Stokes number equals the quotient between the constant factor/hole diameter (mm) and the impact speed (m/s). The pre-determined 40.725 constant factor takes into consideration the air viscosity, the particle density, and the correction factor. As the particles carrying viable microorganisms are generally larger than 1μm, a cut-

off size (d_{50}) $\leq 2\mu$ is considered appropriate. The physical calculations of the TRIO.BAS MONO microbial air samplers were performed at the LIUC University (Libero Istituto Universitario Cattaneo, Castellanza, Varese). The impact speed (m/s) equals the quotient between the sampling rate (cm^3/s) and the total area of the holes (cm^2) and should not exceed 40 m/s. The biological collection efficiency indicates the effectiveness of the tested air sampler compared to a qualified air sampler.

Experimental plan

The study was set up in two different environments and all of the experiments were repeated in different days using the MAS100 calibrated gold-standard reference air sampler for comparison. The air sampler heads were disinfected with 70% EtOH before loading the TSA-containing plates. The air was aspirated directly onto a standard 9-cm diameter Petri dish plate by the air sampler [12]. When the sampling cycle was completed, the Petri dish was aseptically removed, and incubated for one or more days before counting the airborne viable microorganisms (CFU), that formed visible colonies at 32°C or 37°C. The experiments were performed so that the airborne bacteria harvested by the air samplers could result in a microbial colony concentration of 80 - 150 CFU/ m^3 with an acceptable limit of (100 $\pm$ 50%), as requested by the EN 17141:2020 specifications. When the CFUs were outside of this range, the experimental data were not considered for the efficiency calculations. When two instruments were used, the average CFU number was calculated. The drying of the agar medium during samplings was also determined and considered on the basis of the aspiration times. A significant number of tests was performed to reduce variations due to environmental conditions.

Results

The ORUM sampler shows an adequate physical efficiency

The d_{50} value for active microbial air samplers is based on the impact of aspired airborne microorganisms on the agar. The d_{50} size is used to describe the impact physical efficiency of a sampler, i.e. the size that consents 50% of the particles to be harvested, whereas 50% of them pass through the sampler, as they are too small to impact.

The d_{50} value (Stokes number) for the TRIO.BAS MONO air samplers with multiple holes equals 1.11μ (Figure 5), as calculated with the formula:

$$d_{50} = \sqrt{[(40.725 \times 0.6 \text{ mm})/19.66 \text{ m/s}]} = 1.11\mu$$

Where the 40.725 constant factor is pre-determined on the basis of air viscosity, particle density and correction factor, whereas 0.6 mm is the hole diameter and the 19.66 m/s impact speed is thus determined:

$$1666.67 \text{ cm}^3/\text{s}$$

$$\text{Impact speed} = \frac{\text{-----}}{\text{-----}} = 19.66 \text{ m/s}$$

$$0.8478 \text{ cm}^2$$

Where 1666.67 cm^3/s indicates the 100-L/min sampling rate and 0.8478 cm^2 indicates the total area of the holes.

These data indicate that the ORUM TRIO.BAS MONO-100 air samplers, that have an impact speed below 40 m/s as requested by the EN 17141:2020 guidelines have a stoke number below 2.0μ .

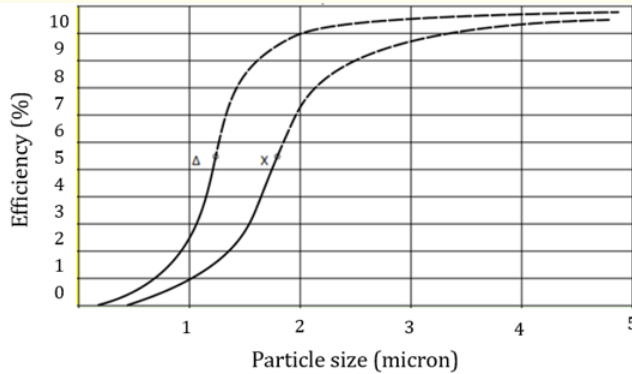


Figure 5: Air samplers physical efficiency. The stokes number of TRIO.BAS MONO at two different airflow rates of 100 and 200 L/min is shown. This number indicates the physical sampling efficiency, i.e. the ability to collect particles carrying viable microorganisms. The stokes number must be lower than 2 microns.

X = airflow rate of 100 L/min at 50% = 1.75
Δ = airflow rate of 200 L/min at 50% = 1.24.

The biological efficiency was very high

According to the EN 17141:2020 guideline document, the biological efficiency of the microbial air samplers is calculated in percentage as follows:

$$\begin{aligned} &\text{CFU/m}^3 \text{ of TRIO.BAS MONO-100} \\ \text{\% of biological efficiency} &= \frac{\text{CFU/m}^3 \text{ of TRIO.BAS MONO-100}}{\text{CFU/m}^3 \text{ of MAS100}} \times 100 \end{aligned}$$

The results of the experiments performed at the Statim laboratory are shown in figure 6, whereas those performed at UNIMI are in figure 7. The biological efficiency was calculated only when the CFU values were inside the range of 80 - 150 CFU/m³ with the acceptable limits of (100 +/- 50%). The average efficiency of TRIO.BAS MONO-100, as calculated at the Statim laboratory, was 99% (Figure 6, Panel A). A graph comparison between the average of CFU/m³ of TRIO.BAS MONO-100 (A and B) vs MAS100 is also shown in figure 6 (Figure 6, Panel B). At UNIMI laboratory, where different sampling times were taken into consideration, the average efficiency was 109.7% when sampling for 10 minutes, 112% after sampling for 20 minutes and 105.2% when aspirating for 40 minutes, with an average efficiency of 110.9% (Figure 7, Panel A). A graph comparison between the TRIO.BAS MONO-100 values and the MAS100 CFU/m³ is also shown (Figure 7, Panel B).

The aspiration time affects the thickness of the agar layer, but does not affect the number of CFU/m³

The aspiration time, which was increased to enhance the total number of CFU, was also performed for different times to verify which was the decrease in the agar layer. Petri dishes were weighed before and after each sampling, and showed an increased reduction in the agar layer with the increase of the sampling time. The mean agar reduction was around 1.5 times from 10 to 20 minutes aspiration

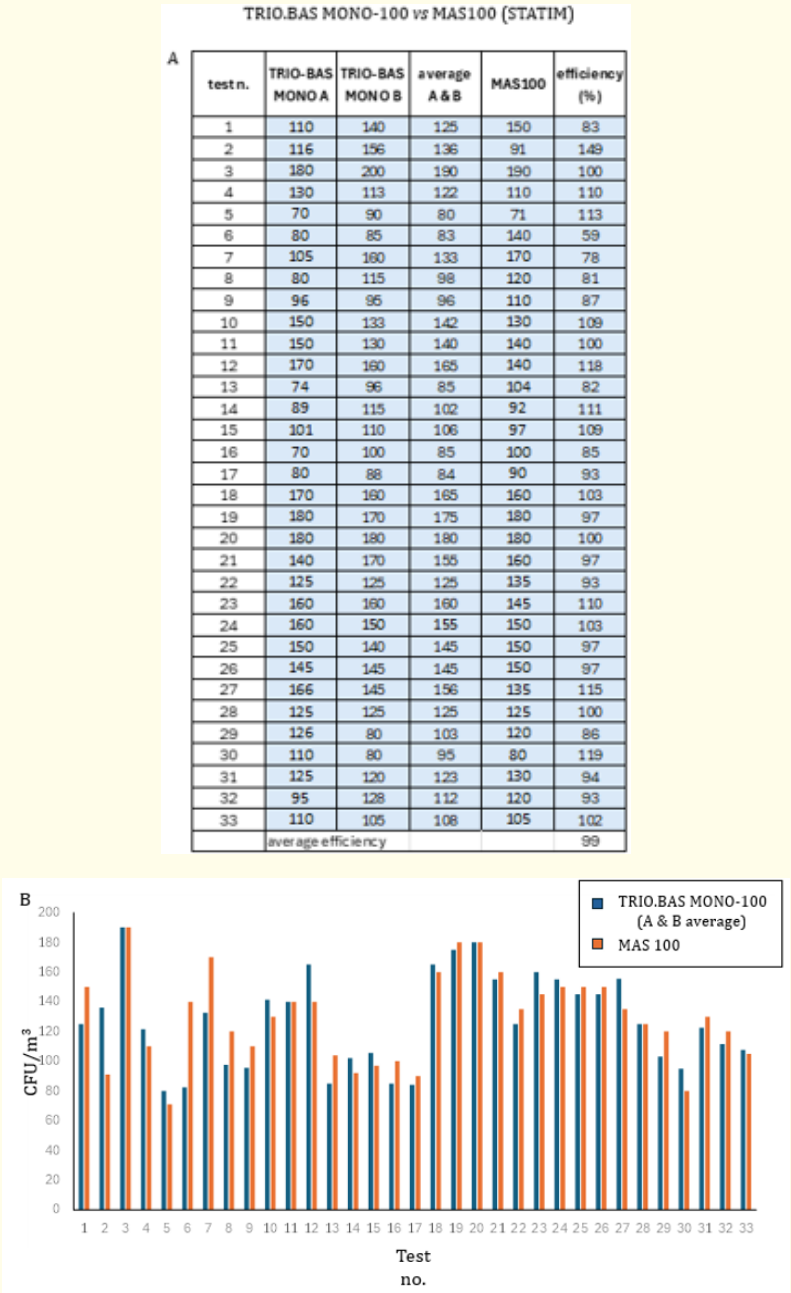
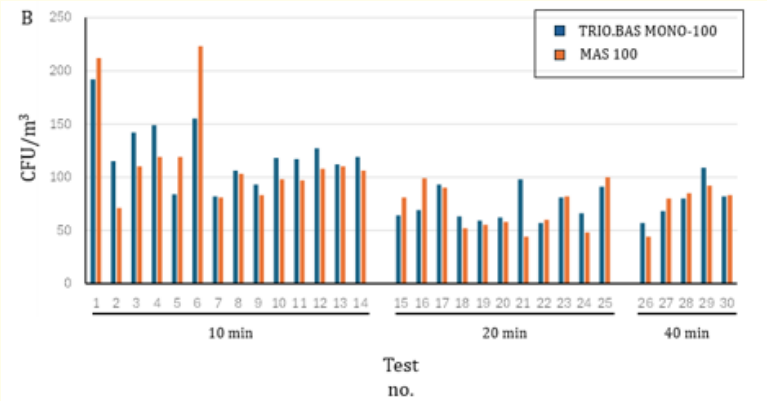


Figure 6: A: Biological efficiency of TRIO.BAS MONO-100, as determined at Statim laboratory. The average of the number of the colonies between A and B samplers was made. Only tests with a range of 80-150 CFU/m3, with a limit of acceptability of +/- 50%, were considered. B: Graph comparison between the CFU/m3 collected by TRIO.BAS MONO-100 and MAS100 reference sampler.

TRIO.BAS MONO-100 vs MAS100 (UNIMI)

A

test no.	sampling time (min)	TRIO.BAS MONO-100 CFU/m ³	MAS100 CFU/m ³	efficiency (%)
1	10	192	212	91
2	10	115	71	162
3	10	142	110	129
4	10	149	119	125
5	10	84	119	71
6	10	155	223	70
7	10	82	81	101
8	10	106	103	103
9	10	93	83	112
10	10	118	98	120
11	10	117	97	121
12	10	127	108	118
13	10	112	110	102
14	10	119	106	112
average efficiency				110
15	20	64	81	79
16	20	69	99	70
17	20	93	90	103
18	20	63	52	121
19	20	59	55	107
20	20	62	58	107
21	20	98	44	223
22	20	57	60	95
23	20	81	82	99
24	20	66	48	138
25	20	91	100	91
average efficiency				112
26	40	57	44	130
27	40	68	80	85
28	40	80	85	94
29	40	106	92	118
30	40	82	83	99
average efficiency				105



C

test no.	sampling time (min)	TRIO.BAS MONO-100					MAS100				
		Petri weighth (g)					Petri weighth (g)				
		before sampling	after sampling	after incubation	sampling reduction	incubation reduction	before sampling	after sampling	after incubation	sampling reduction	incubation reduction
1	10	46	42	nd	4	nd	46	41	nd	5	nd
2	10	46	44	nd	2	nd	46	44	nd	2	nd
3	10	45	42.7	40.8	2.3	4.2	45	42.8	40.8	2.2	4.2
4	10	44.8	42.4	41.3	2.4	3.5	44.8	42.5	41.4	2.3	3.4
5	10	45.2	43	42.2	2.2	3	45	42.6	41.7	2.4	3.3
6	10	44.5	42.3	41.4	2.2	3.1	44.7	42.4	41.5	2.3	3.2
7	10	45.3	42.2	41.1	3.1	4.2	45	42	40.8	3	4.2
8	10	45.4	42.2	41	3.2	4.4	44.8	41.7	40.4	3.1	4.4
9	10	45.1	42	40.8	3.1	4.3	45.2	41.9	40.8	3.3	4.4
10	10	45.3	42.4	41.3	2.9	4	45.1	43.1	41.1	2	4
11	10	44.8	42.2	40.8	2.6	4	44.9	42.1	40.7	2.8	4.2
12	10	44.9	42.4	41	2.5	3.9	44.8	42.2	40.8	2.6	4
13	10	45.4	42.9	41.6	2.5	3.8	44.5	42	40.8	2.5	3.7
14	10	44.7	42.2	41	2.5	3.7	44.6	42	40.9	2.6	3.7
15	20	46	41	nd	5	nd	46	42	nd	4	nd
16	20	46	44	nd	2	nd	46	44	nd	2	nd
17	20	44.8	41	39.7	3.8	5.1	45.1	41.5	40	3.6	5.1
18	20	45.9	41.6	40.4	4.3	5.5	44.9	40.9	39.7	4	5.2
19	20	45.1	41.1	40.2	4	4.9	45.1	40.7	39.9	4.4	5.2
20	20	44.7	40.9	40	3.8	4.7	45.1	41	40.1	4.1	5
21	20	45.4	41	39.8	4.4	5.6	44.4	39.8	38.7	4.6	5.7
22	20	44.3	39.8	38.7	4.5	5.6	44.3	39.8	38.7	4.5	5.6
23	20	45.3	40.4	39.3	4.9	6	44.9	40.1	38.8	4.8	6.1
24	20	44.7	40.1	38.8	4.6	5.9	44.8	40.1	38.8	4.7	6
25	20	45	41.6	40.8	3.4	4.2	45	42.6	41.7	2.4	3.3
27	40	46	37	nd	9	nd	46	37	nd	9	nd
28	40	46	40	nd	6	nd	46	39	nd	7	nd
29	40	46	37	nd	9	nd	46	38	nd	8	nd
30	40	44.9	37	36.2	7.9	8.7	45	36.8	36	8.2	9
31	40	45	37.2	36.4	7.8	8.6	45	37.2	36.4	7.8	8.6

D

Sampling time (min)	TRIO.BAS MONO-100 Petri weighth reduction (g)		MAS100 Petri weighth reduction (g)	
	After sampling	After incubation	After sampling	After incubation
10	2.7	3.8	2.7	3.9
20	4.1	5.3	3.9	5.2
40	7.9	8.7	8.0	8.8

Figure 7: A: Biological efficiency of TRIO.BAS MONO-100, as determined at UNIMI laboratory. B: Graph comparison between the CFU/m3 collected by the TRIO.BAS MONO-100 and the MAS100 reference sampler. C: Weight reduction of the agar medium layer after different sampling times and overnight incubation. D: Average weight reduction of the agar medium layer of petri dishes due to dehydration after different sampling times and overnight incubation.

time and around twice from 20 to 40 minutes both when using the TRIO.BAS MONO-100 device or the MAS100 (Figure 7, Panel C and D). Conversely, a very similar average of 1-g reduction was observed after incubating all of the Petri dishes (Figure 7, Panel D). With the decrease in the agar layer, the number of CFU also seemed to be reduced by around 50% from 10 to 20 minutes aspiration time, but not by the further increase of the sampling time to 40 min. However, when a few experiments were performed in parallel by aspiring for 10 and 20 minutes, the number of CFU/m³ was very similar (data not shown).

The incubation temperature can be affected by mould growing

Human pathogens are generally grown at temperatures similar to those of the human host (35 - 37°C), but environmental bacteria harvested by the air samplers should grow at lower temperature. According to the FDA Aseptic Guide [13], the plates used to determine

the total aerobic bacterial counts should thus be incubated at 30 - 35°C for 48 - 72h, whereas the temperature for the total yeast/mould counts should be 20 - 25°C for 5 - 7 days. In some of the tests performed in parallel using 10 minutes aspiration time, but incubating at either 32°C for 2 days or 37°C o/n the number of CFU/m³ seemed to increase (data not shown). However, the easier mould growing after 2 days at 37°C prevented bacterial counting and suggested the o/n incubation at 37°C.

Discussion and Conclusion

The microbial air samplers produced in 1940-50 [12] could efficiently impact single microbial cells with a size of about 1-5 μ . Since then, different air samplers were constructed to face the problem of contamination in hospitals or industrial environments that should be sterile or with a few microorganisms. However, some of these devices showed a low biological efficiency in collecting viable microorganisms [12].

Impaction-based samplers are the most used ones because of their simplicity and low cost.

This method is not applied to artificial bioaerosol, but to naturally occurring microorganisms and can be carried out in environments with different levels of airborne contamination.

The collection efficiency of these samplers may depend on the particle and nozzle diameters, and on the airflow. Smaller particles carried by the airflow, also known as streamline [2], can escape capture, and do not impact on the agar plate. Therefore, calibrating the airflow passing through the device is very important to make impactors suitable to capture higher-size particles, while the smaller ones will remain in the air.

In spite of some discrepancies among the single tests performed during various days, a good biological efficiency was found in all of the tests by comparing TRIO.BAS MONO-100 vs MAS100.

As the tests performed at Statim (Figure 6) showed a very high biological efficiency after 10-minutes aspiration time, the tests were repeated at UNIMI using different sampling times and by weighing petri dishes before and after each sampling, and after overnight incubation.

Here, we have demonstrated that: (i) the TRIO.BAS MONO-100 air sampler can harvest bioaerosol particles carrying viable microorganisms with a value of acceptability below the limits of 2 μ , as foreseen by the EN 17141:2020 guidelines [9]; (ii) the agar-medium dehydration using the TRIO.BAS MONO-100 air sampler mainly depends on the aspiration time, and not on the incubation time, and the weight loss is very similar when using the TRIO.BAS MONO-100 device and the reference MAS100 sampler; (iii) no correlation was found between dehydration, due to different aspiration times, and the number of CFU/m³.

As the agar layer diminishes during the aspiration time, and the number of colonies also decreased, we also tested in parallel whether the CFU/m³ were reduced by the loss of weight of the Petri dish during aspiration. The different reduction in the agar layer after 10 or 20 minutes sampling times did not affect the number of CFU/m³ both when using the TRIO.BAS MONO or the MAS100.

By reducing the aspiration time, the number of colonies on petri dishes is reduced, but the average number of CFU/m³ increases, which suggests that this increase is not directly correlated with the aspiration time.

Overall, as far as the physical efficiency is concerned, the TRIO.BAS MONO-100 air sampler shows a good ability in collecting particles carrying viable microorganisms and its acceptability is included in the foreseen limit of 2 μ . The biological efficiency of the ORUM devices is also very similar to the one of the MAS100 reference sampler. Thus, if a reliable number of colonies is present, increasing the aspiration time is not mandatory, as the number of CFU/m³ is even higher when aspiration is performed for shorter times [14].

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