Comparison of air samplers for fungal exposure assessment

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ABSTRACT
Air sampling is the most widely used sampling technique in the fungal exposure assessment. Various air samplers have differing performance. Therefore, the results measured by different samplers cannot be compared directly. When air samplers are chosen for monitoring, the reliability and the usability should be considered.

In this study three air samplers, two kinds of centrifugal sampler (RCS standard and RCS high-flow) and a sieve sampler (BIO sampler) were compared. Three series of experiment were conducted to examine the reliability and the influence of sampling volume and airflow on the sampling efficiency. Sampling volume of more than 320 L for RCS standard, less than 400 L for RCS high-flow and less than 800 L for BIO sampler should be avoided. The reduction of collected CFU caused by airflow for each sampler was identified and the equations for conversion between samplers were determined.

INDEX TERMS
Fungi, Sampling, Measurement Technique

INTRODUCTION
Air sampling is the most widely used sampling technique in the fungal exposure assessment. Various air samplers have differing performance. The results measured by different samplers cannot be compared directly, although in the previous studies a lot of comparison data has been shown on the performance of different samplers (Pasanen, 2001). Lee et al. who evaluated the comparative field performance of three widely used samplers, concluded that apparent concentration of airborne mould was highly dependent on the sampling and analytic method utilized by the investigator (Lee, Black and Brauer, 2002). However, a rough conversion ratio is necessary to evaluate the concentration of airborne fungi measured.

EC Concerted Action 613 guidelines for levels of viable fungi in indoor air were determined using either Andersen six-stage sampler in combination with malt extract agar, or N6 Andersen one-stage sampler with either malt extract agar or DG- 18 agar (Maroni, Seifert and Lindvall 1995). It is difficult to decide what is “high” concentration, because no concrete guidelines for fungi exposure are shown in Japan.

In this study three kinds of air samplers were used to identify the reproducibility, the effects of sampling volume and airflow on collected CFU and conversion ratio between them. Then, the magnitude of these effects was examined by comparison with EC Concerted Action 613 guidelines.

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REPRODUCIBILITY

Methods

Three kinds of airborne fungi samplers, RCS standard (Biotest), RCS high-flow (Biotest) and BIO sampler (MIDORI-ANZEN)(Yamazaki, 2002), were tested. Figure 1 shows the samplers. YM (Rose Bengal Agar)•strip for RCS sampler, DG-18 (Dichloran Glycel 18 Agar) and Potato Dextrose Agar (PDA) are used as culture media.

The experiment was carried out in an experiment room (264.5 m^2) in Tokai University in Tokyo. The samplers were placed centrally within the room and were raised to sampling height of approximately 1.2 meters. The sampling time of RCS standard was 4 minutes (40 L/min.), while that of RCS high-flow and BIO sampler was 2 minutes (100 L/min.). Consequently the sampling volumes are 160 L, 200 L and 200 L respectively. For each sampler, sampling was repeated 7 times. The samples were then put in an incubator at 25°C for 96 hours and CFU was counted. Temperature and relative humidity were measured continuously during the experiment.

Results

Two-way analysis of variance (samplers * sampling repeated) showed that significant difference was shown in samplers but not shown in sampling repeated (1% of level of significance). The average and coefficient of variance (SD/AVE.) for each sampler was compared. Figure 2 shows the average and standard deviation. The coefficients of variance were shown in Table 1.

THE EFFECTS OF SAMPLING VOLUME

Methods

The samplers and culture media were similar to the experiment for reliability. Sampling volumes and sampling times are shown in Table 2. Each condition was repeated two times.

Results

Figures 3 shows the relationship between sampling volume and collected CFU. Aside from RCS standard, they seem to have linear relationships. RCS standard, which has 8 min. maximum sampling

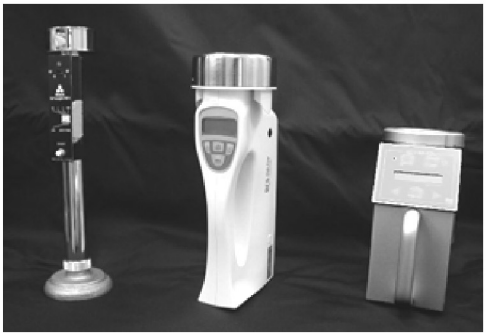
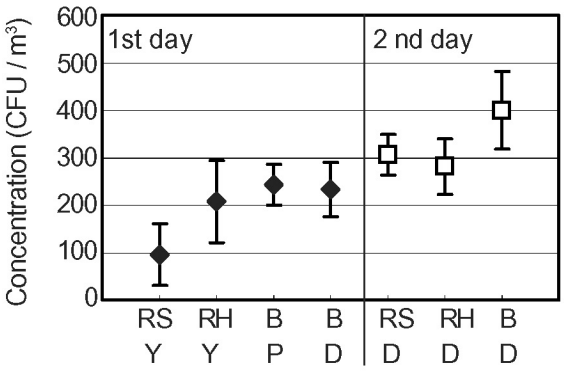


Figure 1. Air Samplers



RS: RCS standard RH:RCS high-flow
B: BIO sampler
Y:YM D:DG-18 P:PDA

Figure 2. Reliability

Table 1. Coefficient of variance

Sampler	culture media	coefficient variance	Sampler	culture media	coefficient variance
RCS -S	YM agar	0.41	RCS -S	DG-18	0.14
RCS -H	YM agar	0.29	RCS -H	DG-18	0.21
BIO	PDA	0.15	BIO	DG-18	0.20

Table 2. Sampling volume tested

	Sampling volume[L](Sampling time[min])						
RCS standard	40(1)	80(2)	160(4)	320(8)	400(10)	480(12)	640(16)
RCS high-flow	100(1)	200(2)	400(4)	800(8)	1000(10)	1200(12)	1600(16)
Bio sampler	100(1)	200(2)	400(4)	800(8)	1000(10)	1200(12)	1600(16)

time, showed a poor correlation after sampling was restarted. Therefore, for RCS standard a sampling volume of more than 320 L cannot be recommended while RCS high-flow and BIO sampler allow 1600 L of sampling.

Figure 4 shows the relationship between the sampling volume and the measured concentration. Sampling volume of less than 400 L and less than 800 L should be avoided for RCS high-flow and BIO sampler, because smaller sampling volume causes unstable higher concentration for both samplers. Environment with low concentration of airborne fungi, where large sampling volume is necessary, RCS high-flow or BIO sampler are more suitable.

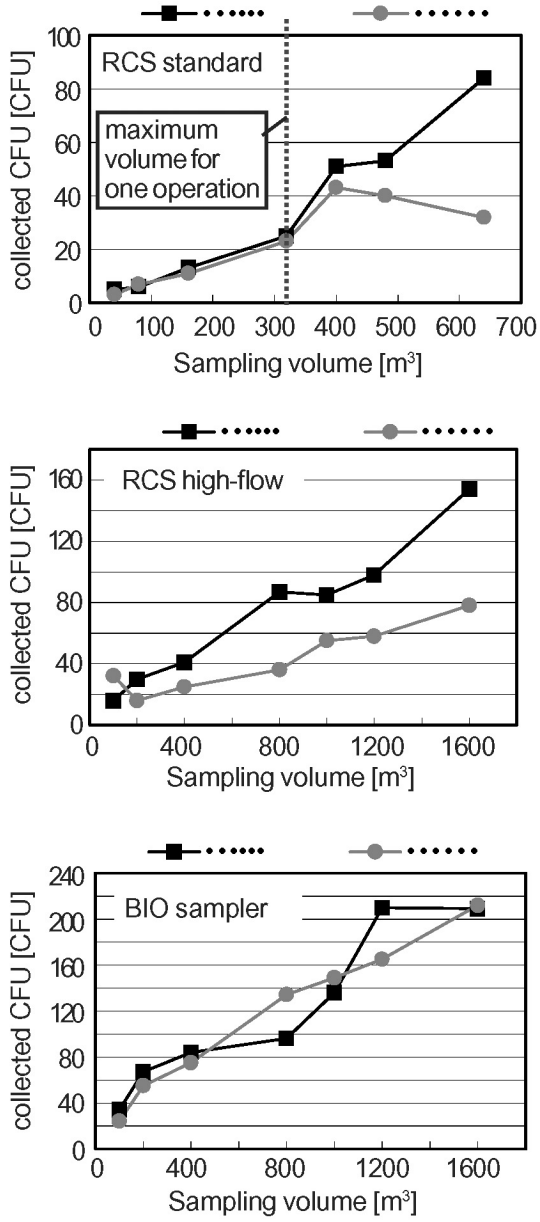


Figure 3. Sampling volume vs CFU collected

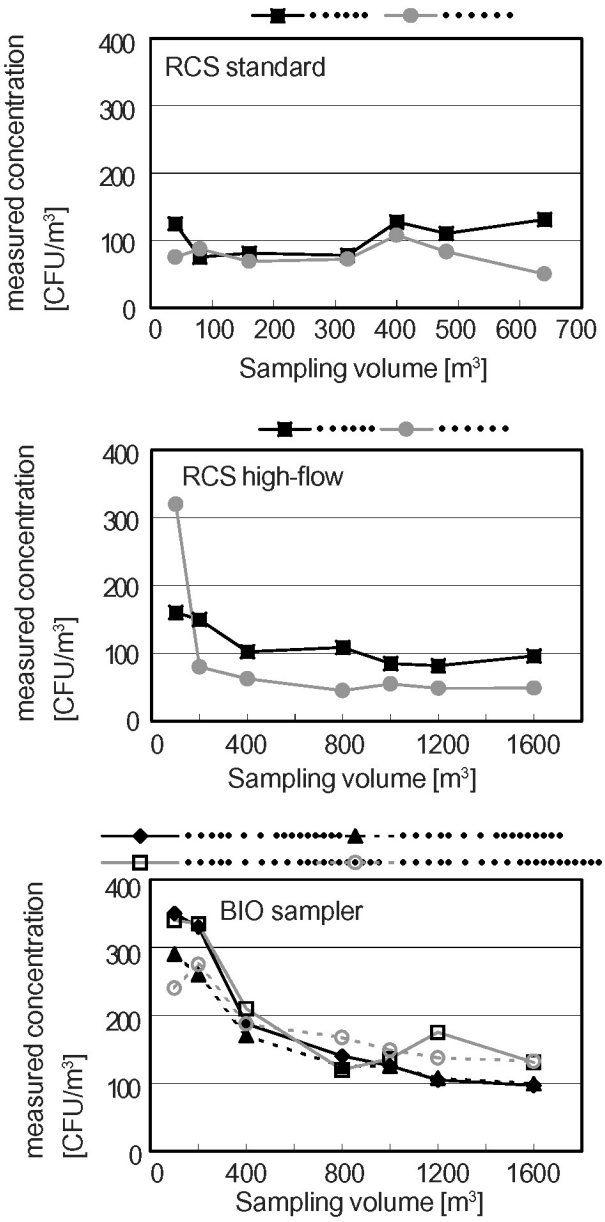


Figure 4. Sampling volume vs concentration measured

EFFECTS OF AIR FLOW ON MEASUREMENT

The effects of air flow on the measured concentration was also examined.

Methods

The three samplers were used. For each samplers 11 levels of air velocity ranging from 0.2 to 2.8 m/s were tested. Figure 5 shows the experimental apparatus. Three electric fans which have different power were used to make different air velocity. Air velocity was measured by thermal anemometer (SHIBATA) just before and after sampling. For RCS standard, two directions of air flow, a following and an adverse wind, were tested

Results

Figure 6 shows the relationships between the air velocity and the percentage of reduction of CFU collected. The percentage of reduction was defined as follows,

$$PR = (Cv{=}i - Cv{=}0)/ Cv{=}0 * 100 \qquad (1)$$

PR: percentage of reduction
Cv=i: concentration under air velocity of *i* [m/s]
Cv=0: concentration without air flow

For RCS standard under an adverse wind, the percentage of reduction increased with increment of air velocity, while constant measurement was achieved under a following wind. For BIO sampler, air velocity of less than 0.5 m/s provided constant measurement, however, with higher air velocity, the effects of the airflow on sampling efficiency was significant. For RCS high-flow no obvious tendency could be found, because of the large variance. Table 3 shows formulae for modification considering air

Figure 5. Experimental appratus

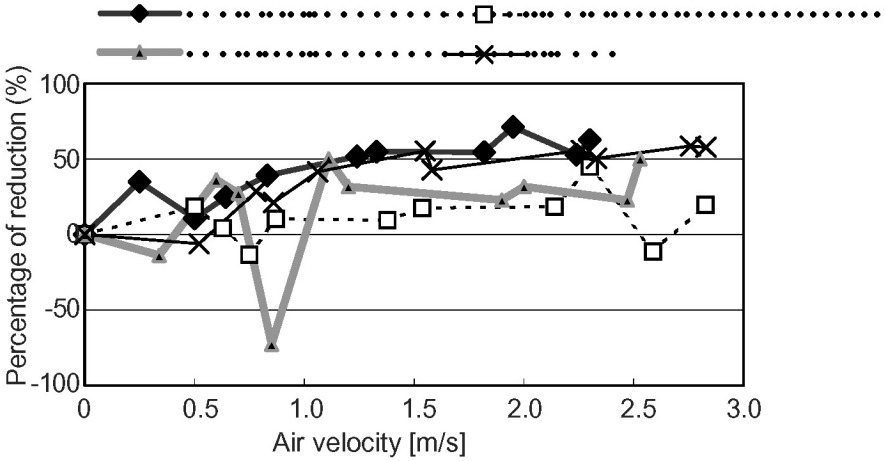


Figure 6. Air velocity vs. Percentage of reduction

Table 3. Percentage of reduction caused by airflow

Sampler	applicable range	Percentage of redunction
RCS standard following wind	$0<v<=0.5$	$PR=0$
	$0.5<v<=2.3$	$PR(v)=10.51 * \mathrm{Ln}(v - 0.5) + 54.2$
RCS standard adverse wind	$0<v<=0.33$	$PR=0$
	$0.33<v<=2.5$	$PR(v)=8.31 * \mathrm{Ln}(v - 0.33) + 33.2$
BIO sampler	$0<v<=0.5$	$PR=0$
	$0.5<v<=2.8$	$PR(v)=12.14 * \mathrm{Ln}(v - 0.5) + 46.2$

v: air velocity [m/s]

velocity. When the concentration of airborne fungi is measured by these samplers, the air velocity should be measured.

RELATIONSHIP BETWEEN SAMPLERS

Methods

In three lecture rooms and nine apartment houses, concentration measured by the three samplers were compared. The sampling time was 8 minutes. The measurement in apartment houses were conducted in July and August, 2002.

Results

Figures 7 to 9 showed the relationships between concentrations measured by the three different samplers. A high correlation coefficient (R=0.93) was found between RCS standard and RCS high-flow. Correlation coefficient of RCS standard and BIO and that between RCS high flow and BIO sampler are 0.76 and 0.83 respectively.

Lee et al. (Lee, Black and Brauer, 2002) showed regression equations indicating the relationship between concentrations measured by different samplers; N6 Andersen one-stage, RCS standard, SAS and Air-o-Cell sampler. The regression equation indicating the relationship between concentrations measured by RCS standard and N6 Andersen is as follows.

$$\text{Ln N6} = 0.909 * \text{Ln RCS} + 0.887(\text{I/O}) \qquad (2)$$

where I/O=indoor/outdoor(indoor=0,outdoor=1)

The correlation coefficient of this regression equation R was 0.78 (Lee, Black and Brauer, 2002)

The concentration in the study by Lee ranged from 8 to 3000 CFU/m^3 which was similar to our measurement. Following to the study by Lee et al. (Lee, Black and Brauer, 2002), the concentrations measured by RCS high-flow and that by BIO sampler used in this study were converted to the concentration measured by Aandersen N6 sampler. Then data obtained by the three samplers can be compared to the guidelines proposed by Working group of the EC Concerted Action 613 (Maroni , Seifert and Lindvall 1995). As shown in Figure 7, 2% of the concentration measured in the apartment houses was "very low", while 49% was" low". "Intermediate" was 44% , "high" was 5% and "very high" level could not be found.

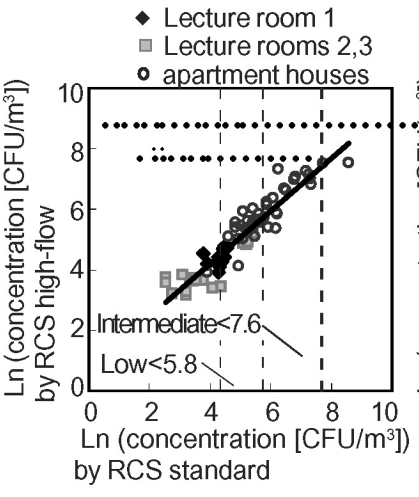


Figure 7. RCS standard vs RCS high-flow

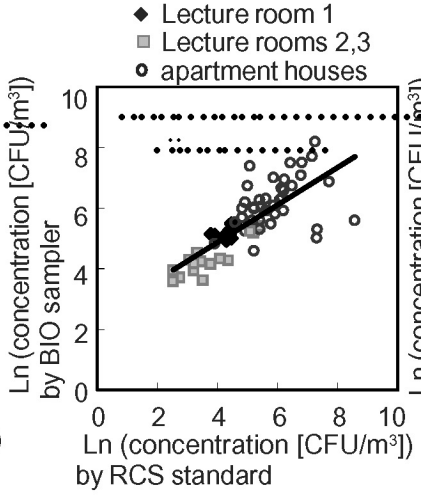


Figure 8. RCS standard vs BIO sampler

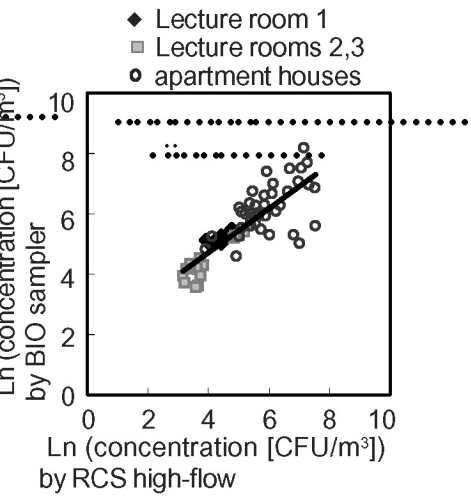


Figure 9. RCS high-flow vs BIO sampler

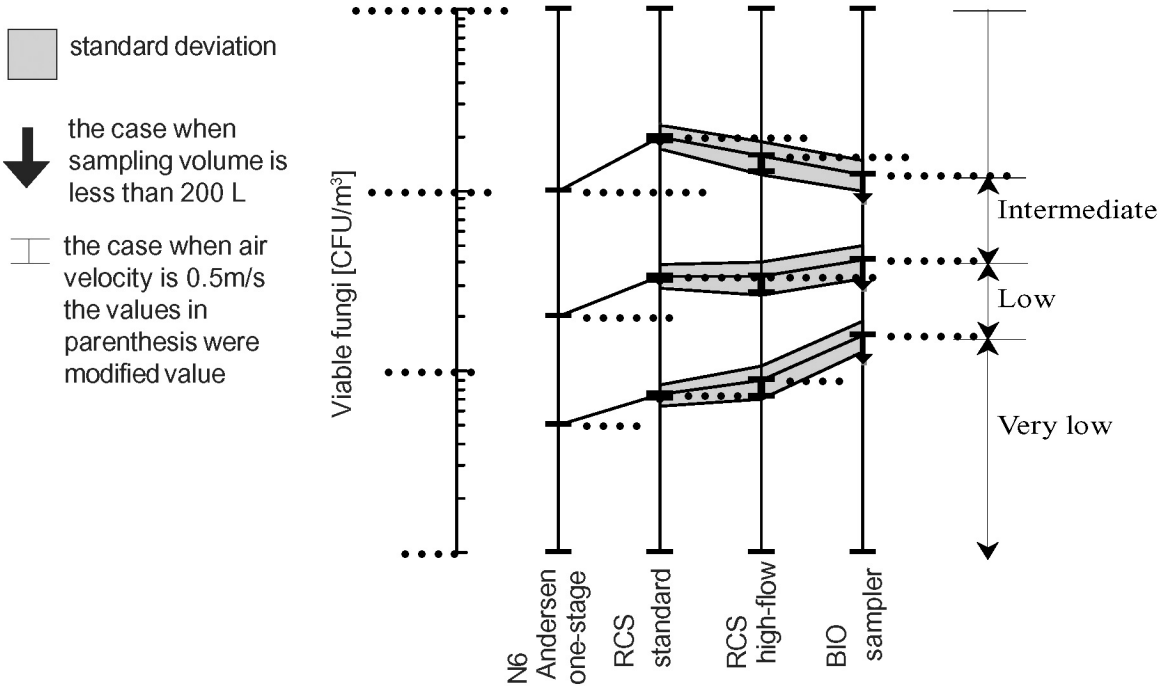


Figure 10. Guidelines for each sampler and results of this study

DISCUSSION

In this study, the reproducibility, the effects of sampling volume and airflow on the sampling efficiency were examined and the relationships between the samplers were identified. Figure 10 summarizes the results from this study with the guidelines proposed by Working group of the EC Concerted Action 613 (Maroni , Seifert and Lindvall 1995). The effects of sampling error, samppling volume and airflow on sampling efficiency were rather small.

CONCLUSIONS

Three air samplers, two kinds of centrifugal sampler (RCS standard and RCS high-flow) and a sieve sampler (BIO sampler) were compared. Three series of experiment were conducted to examine the reliability and the influence of sampling volume and airflow on the sampling efficiency.

1.Sampling volume of more than 320 L for RCS standard, less than 400 L for RCS high-flow and less than 800 L for BIO sampler should be avoided.

2.The reduction of collected CFU caused by airflow for each sampler was identified

3. A diagram showing guidelines for the three samplers was presented.

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