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STUDY ON THE COLLECTION CHARACTERISTICS OF ANDERSEN BIOLOGICAL AIR SAMPLERS

--- ESTIMATION OF SIZE DISTRIBUTION OF REAL AEROSOLS---

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Abstract

The collection characteristics of 6 stage type Andersen samplers for biological particles were theoretically analyzed to give the relation of size distribution of original airborne particles and the collected biological particles. For the particles of range of 3 - 6 μm the geometric standard deviations show very uniform relations up to $\sigma_g = 0.7$ which are very popular values for biological particles. For higher σ_g correction is needed. Geometric mean diameters did not show little changes for correction.

Foreword

Clarification of size distribution of airborne microbiological particles, which float on the atomospheric air with intrinsic ones, is an important problem for the research of health effect, engineering measures for contamination control of various subjects.

The Andersen samplers with six stages have generally been used for the collection and measurement of airborne microbiological particles. In order to properly evaluate the result of measurement, their collection and separation characteristics of the apparatus, which might affect the distribution pattern of original aerosols, should be determined. Though many papers have been published on the characteristics of Andersen sampler itself, very few (2,3) on this phase of problems.

This is to report the result of our comparison of the size distribution obtained from particles collected by Andersen samplers and of original aerosols of airborne state through the theoretical analysis of impaction characteristics.

With the postulation that the size distribution of the original aerosols have log-normal ones, quantitative changes of geometric mean value a_g and geometric standard deviation σ_g by the process of collection with Andersen type samplers were determined, and consequently, the method of correction of the obtained distribution characteristics a_g, σ_g are shown.

Collection Mechanism of Andersen Samplers

The impaction characteristics which is the relation of impaction parameter and impaction efficiency was postulated in simulation with May's result (1) as follows.

The collection curves of each stage is expressed by the line drown on the log-normal paper between higher end of impaction character curve of the next stage which is the impaction efficiency 100%-impaction parameter 0.6 of a stage and the lower end of the impaction character curve of the next stage which is the efficiency 0%-parameter 0.2.

When we collect a hypothetical aerosol with uniformly distributed size particles (just like white noise) using Andersen samplers, the state of separation and collection of each stage would be like shown in Fig. 1.

If the separation efficiency is an ideal one, all particles with a certain size range would be collected on the appropriate stage. However, in the actual cases, portion A in Fig. 1 being collected on nth stage, portion B would be collected on "(n-1)"th stage, portion C on "(n+1)"th stage.

Consequently, the collected particles on the nth stage which are equivalent to size range $D_{un} - D_{un}$ consist of the particles with size supposed to have gone to ··· (n+2)th, (n+1)th, nth, (n-1)th, (n-2)th stage and total particles are shown by

$$F_n = \int_{D_{nd}}^{D_{nu}} f(x) \cdot dx = f_n \cdot \Delta x \qquad (1)$$

where $\Delta x = D_{nu} - D_{nd}$

If we denote the portion collected on the nth stage being transferred from ··· (n+2)th, (n+1)th, nth, (n-1)th, (n-2)th, ··· stages as $(n-2) \rightarrow n$, $(n-1) \rightarrow n$, $n \rightarrow n$, $(n+1) \rightarrow n$, $(n+2) \rightarrow n$, respectively, those particles to be transferred to nth stage can be expressed by

$$\begin{aligned} &F_{(n-i)} \cdot P_{(n-i)\rightarrow n} \\ &\quad \vdots \\ &F_{(n-1)} \cdot P_{(n-1)\rightarrow n} \\ &F_n \cdot P_{n\rightarrow n} \\ &F_{(n+1)} \cdot P_{(n+1)\rightarrow n} \\ &\quad \vdots \\ &F_{(n+i)} \cdot P_{(n+i)\rightarrow n} \end{aligned}$$

where F is the aerosol to be collected on each stage, P is the transfer rate.

Thus the total collection on the stage become

$$C_n = F_{(n+i)} \cdot P_{(n+i)\rightarrow n} \qquad (2)$$

which shows the importance of quantity existing in adjacent stage range and the rate of transfer from them.

The apparent collection efficiency on the nth stage can be expressed by the next equation.

$$\eta_n = \sum_{i=-\infty}^{+\infty} F_{(n+i)} \cdot P_{(n+i) \rightarrow n} \Big/ F_n \qquad (3)$$

Transport of Particles to Other Stages

From the calculation of impaction efficiency in reference to particle size, the rate of transport to other stage are obtained and shown in Fig. 2 and Table 1.

As can be seen clearly from Fig. 1, considerable amount can be transferred to other stages and in other word a stage collects aerosols to have gone to other stages.

The collection efficiency of a nth stage might not become 100%.

Estimation of Correction Factor

Generally the airborne particles of natural origin is said to show log-normal distribution which we have also ascertained. With this postulation we tested four kind of geometric mean diameter a_g with eight kind of geometric standard deviation σ_g for the changes of these values by the collection using Andersen sampler of actual separation characteristics.

For the hypothetical original aerosol of log-normal distribution, four stage of geometric mean diameter a_gs, 3, 4, 5 and 6μm, and 8 stage of geometric standard deviation σ_g, 0.3, 0.4, 0.5, 0.6, 0.7, 0.8, 0.85, and 0.9 respectively were chosen in the calculation.

The reason we tested these ranges of values was that, from our experiences, major part of airborne fungal particles are within 3 - 6μm in diameter and around 0.6 in σ_g.

Each aerosol was plotted on the log-normal paper and the lower limit of collection of each stage of Andersen Sampler was obtained to give the amount collected on the stage by from the difference of adjoining stages.

The values given in Table 1 are multiplied to the above mentioned values to give the quantity which is collected on the stage.

Here we denote
a_{g1}:geometric mean diameter of original aerosol
a_{g2}:geometric mean diameter of collected aerosol
σ_{g1}:geometric standard deviation of original aerosol
σ_{g2}:geometric standard deviation of collected aerosol

As for the distribution curves the collected aerosol show the less steep characteristics (smaller standard deviation) than the original one. The geometric mean values show very little changes.

Fig. 3 distribution curves of three kind of σ_{g1} and σ_{g2} for aerosol of $a_{g1} = 3\,\mu m$ with σ_{g1}, 0.4, 0.6, 0.85, are superimposed.

In case σ_{g1} is equal to 0.4, the curves of σ_{g1} and σ_{g2} almost coincide. If σ_{g1} is equal to 0.6, some amount of the peak portion of aerosol is transferred to adjacent stages. In case $\sigma_{g1} = 0.85$ the major part of peak portion of original aerosols is lost. Generally speaking, the larger σ_g and steeper the peaks the more part of peaks is lost.

These would lead to conclusion that when σ_g is small, the correction of the distribution characteristics parameter is not necessary and if σ_g is more than 0.8 the correction would be needed.

The Relation of Characteristic Parameters

For all particle sizes tested, though small amount of changes of the geometric mean diameter a_g occur by the difference of distribution types, the ratio a_{g2}/a_{g1} is nearly equal to 0.97. Correction coefficient of a_{g1} and a_{g2} is $r = 0.991$.

The relation of standard deviation of original aerosol σ_{g1} and of collected aerosol σ_{g2} is shown in Fig. 4, and they can be expressed by the regression curve and give $r = 0.986$ up to $\sigma_g = 0.7$. If σ_{g1} is more than 0.8, σ_{g2} decrease abruptly and the peak would be lost in the distribution curves.

As a conclusion, though we can use geometric mean a_g as obtained, we would have to correct the σ_g according to the relation shown in Fig. 4. However, since biological particles have σ_g value around 0.6, in most cases, the results of measurements need no corrections.

Reference

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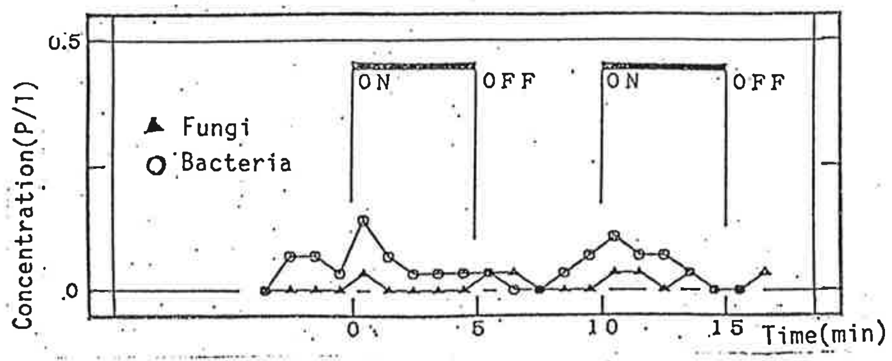

Fig 1. Efffect of Starting Air Conditioning System

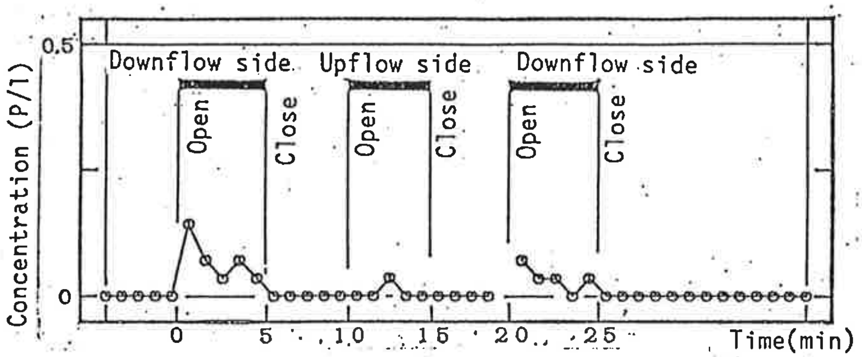

Fig 2. Effect of Opening Service Door (Bacteria)

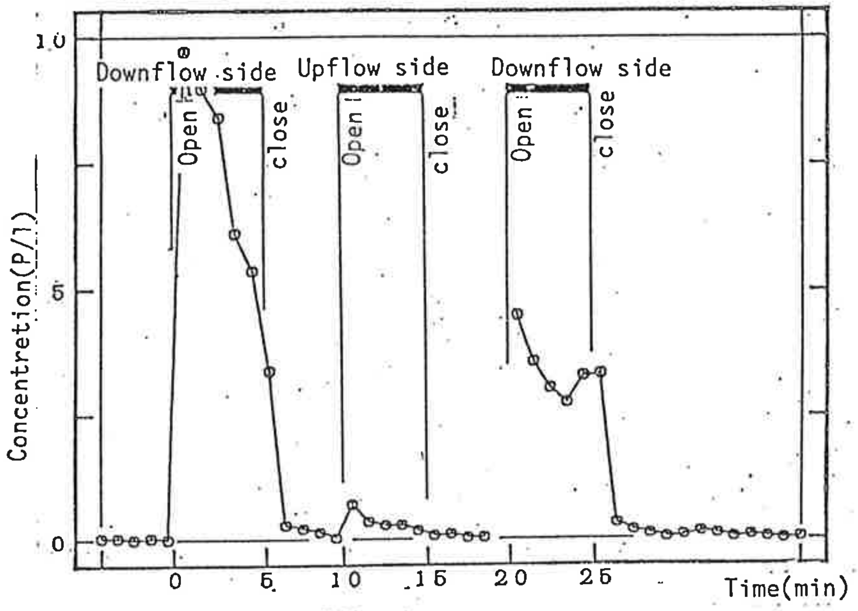

Fig 3. Effect Opening Service Door (Fungi)

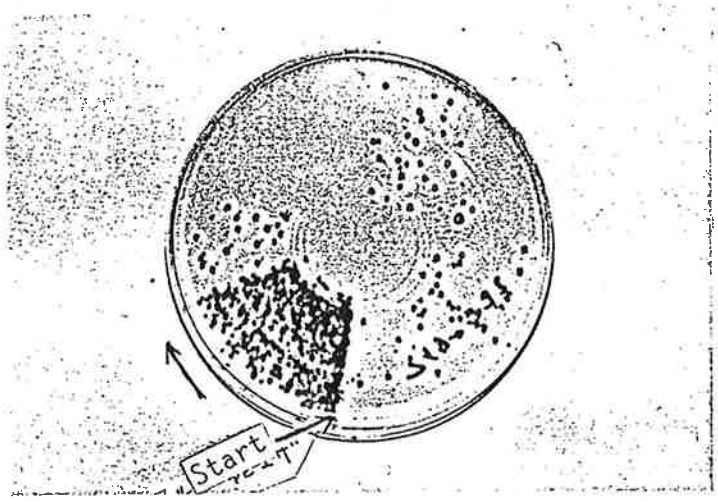

Photo1.Release by Movement of Air Filter