A Monitor for Airborne Bacteria[1]

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Abstract

Andersen, A. A., (Andersen Samplers and Consulting Service, Provo, Utah), and M. R. Andersen. A monitor for airborne bacteria. Appl. Microbiol. **10**:181–184. 1962.—A unique agar drum sampler is described which indicates, continuously, the number of viable, bacterial particles per unit volume of air at the time and point of sampling. By selection of the timer and the sampling rate the sampler is suitable for quite a wide range of concentration and time. An impaction line of 484 in. greatly increases the capacity of this device over slit samplers and other instruments designed to give time-concentration data for viable airborne particles. This sampler should prove useful for: (i) monitoring airborne bacteria in hospitals, public places, and food and industrial plants; (ii) decay rate studies of bacterial aerosols; (iii) evaluation of aerial germicides; (iv) determination of effectiveness of air conditioning systems in removing airborne bacteria; and (v) many other studies in aerobiology.

The usual air sampler does not indicate the concentration of particles or cells of a moving bacterial cloud. The reason for this is that the sampling device is usually set in operation before the cloud reaches it and operates for some time after the cloud passes. This timing is necessary because it is not known precisely when the cloud is present. Therefore the actual volume of the cloud sampled is not known and consequently the concentration is likewise not known. Furthermore, the concentration of particles in a moving cloud increases laterally from the edge of the cloud to the center, and from front to back the concentration increases rapidly, then decreases more slowly. This kind of information is not obtained with ordinary sampling devices such as the all-glass impinger (Greenberg and Smith, 1922), the sieve sampler (DuBuy and Crisp, 1944), or the Andersen Sampler (Andersen, 1958). The slit sampler (Bourdillon, Lidwell, and Schuster, 1948; Decker and Wilson, 1954) yields concentration data but is of such limited capacity that it is of little value. Decker et al. (1958) extended the slit sampler to give an impaction line of about 18 in. but this too is quite inadequate to fill the requirements for many kinds of sampling. This inadequacy or limited capacity of present sampling devices prompted the development of a sampler with far greater capacity. It is, therefore, the purpose of this paper to describe the product of this development, a time-concentration sampler with an impaction line of 484 in., hereafter designated Monitor.

Materials and Methods

Description. The particle concentration-time sampler described in this paper is shown in Fig. 1. It consists of an agar-coated drum, $5\frac{1}{2}$ in. in diameter by $3\frac{5}{8}$ in. high (Fig. 2 and 3), mounted on a threaded shaft in a $3\frac{1}{2}$-quart stainless steel beaker. The edges of the drum extend $\frac{3}{16}$ in. for the purpose of holding the agar. The drum is rotated by a Cramer timer which is mounted on the $\frac{3}{16}$-in. thick aluminum plate cover. A jet for impacting the airborne particles on the drum is mounted in the side of the beaker. The air outlet, to which a vacuum pump is connected, is also mounted in the cover. A small vacuum pump may be mounted on the cover to make the unit more complete, and a thermostatically controlled heating element may be installed which would convert the unit to an incubator for

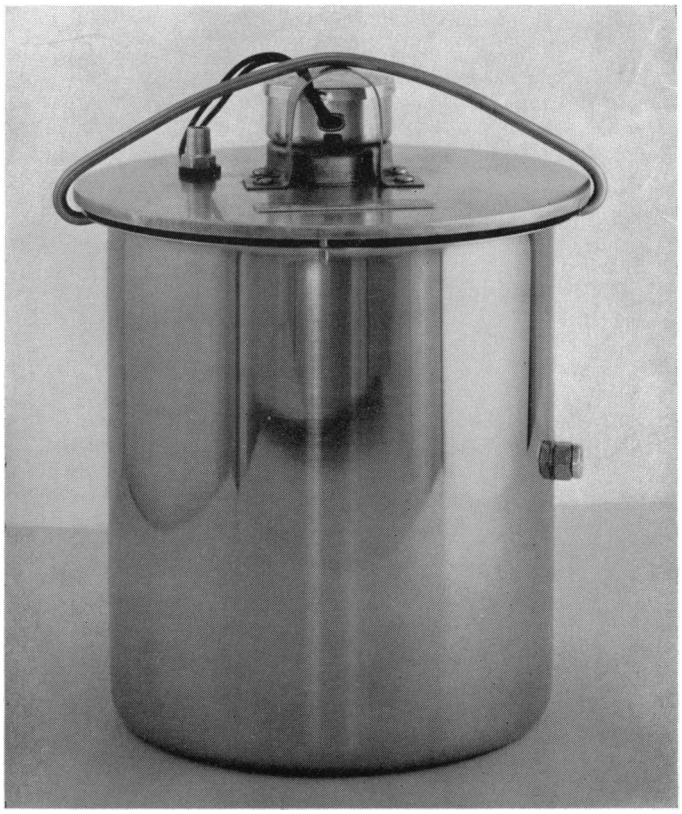

FIG. 1. *Agar drum sampler for monitoring airborne bacteria*

[1] Patent has been applied for.

its own sample; or the sampler could be placed in a box with a thermostatically controlled heating element to serve as an incubator or a cold weather sampler.

Operation. The agar medium is placed on the drum by tightening a sheet metal band around the drum and injecting melted agar into the cavity thus formed. The metal band has a $\frac{1}{16}$ in. neoprene gasket to make it leakproof. After the agar solidifies, the band is removed and the drum is placed in the top of the unit.

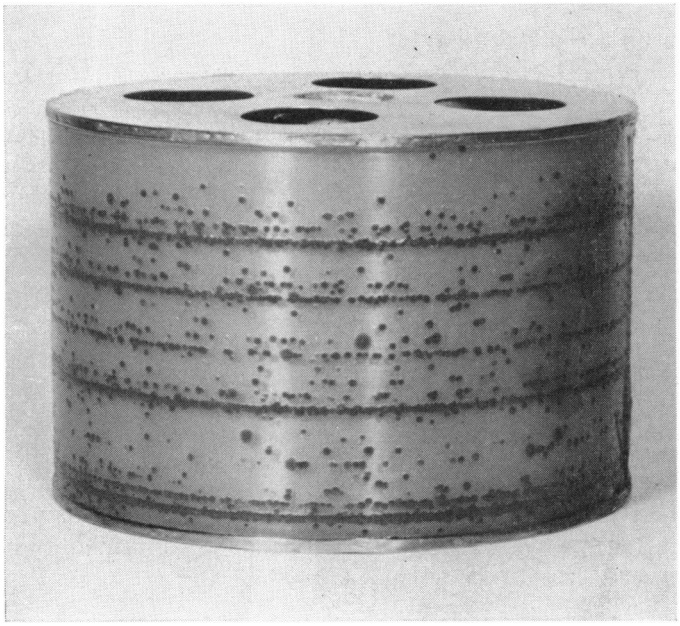

FIG. 2. *Agar drum sample showing the results of 26 min of continuous sampling in a ventilated room in which short bursts of an aerosol of Serratia marcescens were shot into the room at 1, 8, 12, 16, and 20 min after sampling began.*

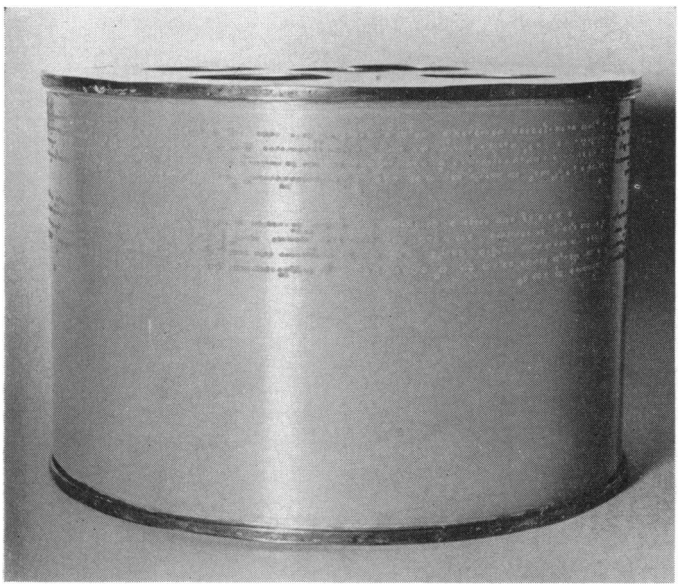

FIG. 3. *Two 4-min samples of an aerosol of Bacillus subtilis, withdrawn from a chamber, are shown on the agar drum of the Monitor.*

When the sampler is operated, the drum moves downward $\frac{1}{8}$ in. each revolution while a jet of air impinges onto the drum any airborne particles in the sample of air. The particle impaction line extends 28 times around the drum, for a total of 484 in. When the drum reaches the bottom of the container, it disengages from the drive shaft. Inexpensive Cramer timing motors are available in many speeds ranging from 1 revolution per sec (rev/sec) to 1 revolution per 48 hr ($\frac{1}{48}$ rev/hr). Timers from 1 rev/min to 1 rev/hr would perhaps satisfy most requirements. These would give total sampling periods ranging from 28 min to 28 hr. A timer of the desired speed can be quickly installed on the sampler. To reduce agar dehydration during long sampling periods, a moistened sponge may be placed in the drum.

The sampler can be operated at different flow rates by simply changing the jet and adjusting the pumping rate. The whole range of flow rate has not been investigated. However, flow rates of 0.5 to 3 liters per min are considered practical in this sampler. The flow rate to be selected for any specific study usually may be anticipated and the proper jet selected. The flow rate to be selected is also somewhat dependent upon the speed of rotation selected. If a long sampling period is required in a light aerosol, then slow speed and high flow rate should be selected. If a concentrated aerosol is to be sampled for a short time, then a fast speed and a low flow rate are used.

By noting the exact time when the sampler is started, the precise time of cloud passage can be determined from the position of the impacted particles.

Counting method. The length of the jet path on the agar drum represents a definite period of time. The number of colonies per unit length represents the number of viable particles in a certain volume of air. When dense aerosols are sampled and the developing colonies are too numerous to be counted visually, they can be counted microscopically while very small. To facilitate counting microcolonies, the drum could be rotated, on a threaded shaft, under a stereoscopic microscope. One microscope field along the jet path would represent a definite time period and in turn a definite volume of air. For example, if the flow rate were 1 liter per min and the rotation was 1 rev/min, then the particles in 1 liter would be distributed along a line 17.7 in. long. If 10 microcolonies were found in one microscope field (with a 2-mm field width), this would represent a concentration of 2,210 particles per liter at that sampling time. With this same flow rate and timing, 20 colonies per inch could be counted visually, and would represent a concentration of 354 viable particles per liter of air at the indicated time and point of sampling. If the drum were turned 10 rev/min, then concentrations 10 times higher could be counted.

RESULTS

Figure 2 shows a drum sample from a ventilated room in which a short burst of bacterial aerosol was put into the room at 1, 8, 12, 16, and 20 min. The drum was rotating

1 rev/min and the sampling rate was 1.9 liters per min. The effectiveness of ventilation is shown by the rapid decrease in bacterial colonies along the impaction line.

To demonstrate the collection efficiency of the Monitor it was compared with the particle-sizing Andersen (1958) sampler (commercial model no. 0101). The Andersen sampler was selected for this comparison because it has been shown to be extremely sensitive and, in several laboratories, it has been found to be superior to other bacterial samplers (Andersen, 1958; Hill and Cox, 1959; Dahlgren et al., 1960). The comparison experiments consisted of placing the two samplers close together in a 3,250-liter cubical chamber, generating an aerosol of *Bacillus subtilis* (var. *niger*) spores into the chamber, and drawing samples with each device. Both samplers were started, simultaneously, 4 min after the aerosol was generated in the first experiment and 10 min after in the second experiment. The Andersen sampler samples 1 ft^3 or 28.3 liters of air per min and was run 1 min. Its true sampling volume for the 1 min was reduced by 500 ml, the volume of unsampled air left in the device when it was shut off. The Monitor sampled 1.9 liters per min and was run for 4 min. Each minute of sampling is represented by one revolution of the drum. Figure 3 shows the drum with the two samples after incubation. Because the aerosol consisted of spores in small particles, over 95% under 5 μ the decay rate was low. The same medium, incubation time, and temperature were used for each sampler. The data listed in Table 1 include counts for each minute by the Monitor, and the calculated number of viable particles per liter of chamber air for each instrument.

Discussion

The high efficiency of the Monitor is explained by the fact that a round jet is used to impact the particles on a moving agar surface. The round jet is the most effective type of jet (Ranz and Wong, 1952) and the continual moving of the agar surface under the jet prevents the agar surface from drying and the consequent killing or failure to impact as is the case in the single stage sieve sampler, which was reported by Fort Detrick (1958) to be only 43 to 73% efficient.

TABLE 1. *Comparison of collection efficiency of the Monitor and the Andersen Sampler*

Experiment	Sampler	Volume Sampled	Total no. of particles	No. of particles per liter of air
		liters		
A	Andersen	27.8	4,911	177
	Monitor	1·9	337	177
		1.9	352	185
		1.9	300	158
		1.9	341	179
B	Andersen	27·8	4,683	168
	Monitor	1.9	324	171
		1.9	326	172
		1.9	310	163
		1.9	321	169

The sampler described herein indicates, continuously, the number of particles per unit volume of air at the point of sampling. It also indicates the precise time of passage of bacterial clouds. This information should not only be very valuable in relating the infectivity of exposed animals to the sampler data, but should also be equally important in studying decay rates in field tests or in chamber experiments. These same characteristics make the sampler ideal for studying: (i) residual or secondary aerosols following cloud passage over rough or vegetated terrain, (ii) building penetration by bacterial aerosols and their persistence and removal, (iii) the effect of aerial disinfectants on airborne bacteria, and (iv) the effect of ultraviolet light and solar radiation on aerosols in chamber studies. Likewise, the device should also be useful for detection and surveillance studies in laboratories, animal holding rooms, hospitals, processing plants, etc. Its continuous sampling characteristics, versatility, and rugged simplicity make it a very suitable instrument for monitoring airborne microorganisms.

Another advantage of this instrument is that for some types of work many samples may be collected on one drum just as numerous movie shots may be taken on one reel of film. To illustrate: suppose one needed to take 28 samples at various times or places in a laboratory or hospital; then one sample could be collected on each revolution of the drum.

By using a drum with a sensitive paper or film instead of agar, the sampler may be useful for monitoring airborne radioactive dusts. Similarly, aluminum foil or paper with a sticky surface placed on the drum would make it suitable for collection of fluorescent particles (FP) used as tracers for bacterial clouds. There are also many other possibilities for this sampler, such as pollen surveys, and detection of, and monitoring for, phage in dairy plants.

The significance of the above applications should be emphasized because with this sampling device information that is very much needed can be obtained, information that cannot be secured with sampling devices currently in use.

It should be mentioned that the instrument described here could be made larger and capacity increased if need be.

It is not claimed that this sampler will entirely replace other samplers now in use, but its use would supplement the data now obtained, with additional, valuable information. It will alone, however, in many studies yield adequate information.

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