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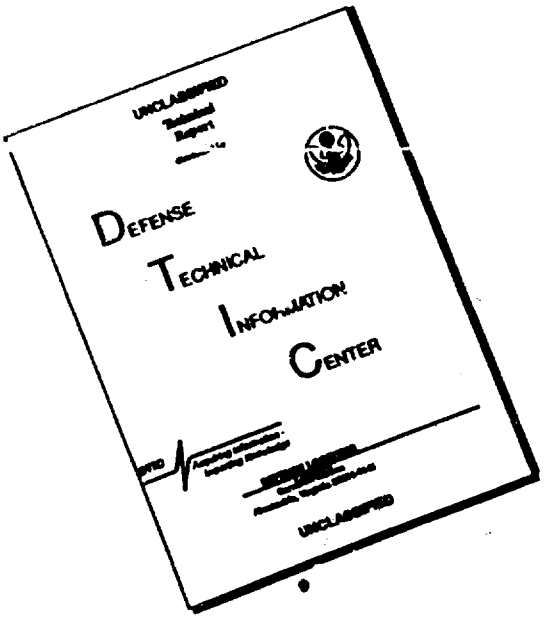

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Novel Multi-Slit Large-Volume Air Sampler

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Scientific investigators who are interested in the various facets of airborne transmission of disease in research laboratories and hospitals need a simple, continuous, high-volume sampling device that will recover a high percentage of viable microorganisms from the atmosphere. Such a device must sample a large quantity of air. It should effect direct transfer of the air into an all-purpose liquid medium in order to collect bacteria, viruses, rickettsia, and fungi, and it should be easy to use. A simple multi-slit impinger sampler that fulfills these requirements has been developed. It operates at an air-sampling rate of 500 liters/min, has a high collection efficiency, functions at a low pressure drop, and, in contrast to some earlier instruments, does not depend upon electrostatic precipitation at high voltages. When compared to the all-glass impinger, the multi-slit impinger sampler collected microbial aerosols of *Serratia marcescens* at 82% efficiency, and aerosols of *Bacillus subtilis* var. *niger* at 78% efficiency.

Wolf et al. (2) reviewed in monograph form the sampling characteristics of 37 different aerosol samplers; yet none of those described would collect sensitive microorganisms while continuously sampling large volumes of air. Searching with these samplers for small numbers of microorganisms in large volumes of air was as difficult as looking for a needle in a haystack. There is an obvious need for devices that will recover a high percentage of viable ambient microorganisms from a large volume of air, and concentrate them in a small volume of liquid medium. This requirement is faced often by scientific investigators interested in the various facets of airborne transmission of disease in research laboratories and hospitals.

Since publication of the monograph by Wolf et al., large-volume air samplers that will sample up to 15,000 liters/min have become available commercially. These samplers, which electrostatically precipitate organisms into a collection liquid, are valuable research tools for isolating airborne microorganisms (1). So far, only a few such instruments have been constructed, and some investigators have found their operation rather complex. For example, (i) the sampler must operate at the correct voltage, (ii) the surface of the rotating disc must be wet continuously, and (iii) the proper distance must be maintained between the sampling head and the rotating disc. Considerable engineering and developmental work must be accomplished before existing large-volume samplers can be considered practical devices suitable for daily use as monitoring tools without frequent servicing.

Because of the need for a large-volume air sampler that is both reliable and simple, the Fort Detrick laboratory has explored the possibility of developing improved devices. Areas of investigation include samplers operating on the principles of (i) electrostatic precipitation in a field produced by a space charge, (ii) electrostatic precipitation in a field produced by charged parallel plates, (iii) electrostatic precipitation of particles onto oppositely charged liquid droplets, (iv) air washing, (v) inertial impaction by a rapidly moving surface, and (vi) inertial impingement onto a wet surface.

Of particular interest to investigators at Fort Detrick and to their contractor, Environmental Research Corp., St. Paul, Minn., is the principle of inertial impingement onto a wet disc by use of a multi-slit impinger. A. R. McFarland, of Environmental Research Corp., has applied for a patent. This paper describes a prototype of the sampler developed at Fort Detrick.

Sampler Design

The multi-slit impinger sampler (Fig. 1) operates on the principle of inertial impingement of airborne particles into a liquid film maintained on the surface of a rotating disc. Air is drawn into the sampler through small rectangular slits located very near the surface of the liquid film. The collection liquid is pumped to the center of the disc through a thin stainless-steel tube that is sus-

pended above and across the diameter of the disc. This tube serves also as a spreader to distribute the liquid uniformly over the surface of the disc. High-velocity air jets directed against the film cause the airborne particles to impinge into the liquid. The particle-laden liquid then flows across the surface of the disc and is removed by a hollow plastic scraper that touches the rim of the disc and allows the liquid to pass into a collection tube from which it is removed by vacuum into the effluent container. The principal components of the sampler are (i) a cylindrical Lucite body, (ii) an adjustable Lucite top containing eight equally spaced rectangular slits, (iii) a rotating aluminum disc, (iv), a variable-speed motor for the disc, (v) a liquid reservoir, (vi) a variable-speed peristaltic pump, (vii) a liquid feed tube, (viii) a hollow scraper, and (ix) an effluent container.

SAMPLER EVALUATION

The multi-slit impinger sampler was evaluated with separate aerosols of *Bacillus subtilis* var. *niger* spores and *Serratia marcescens*, which were measured and found to consist mainly of single cells with an average number median diameter (NMD) of 1 μ. In all tests, Normal Growth Tissue Culture Medium containing 0.2% Methocel (Dow Chemical Co., Midland, Mich.), a methylcellulose product with a viscosity of 15 centipoises, was used as the collection liquid in the multi-slit sampler. Separate experiments showed that the addition of 0.2% Methocel increased the viscosity and lowered the surface tension of Normal Growth Tissue Culture Medium and resulted in higher recoveries for both *S. marcescens* and *B. subtilis* var. *niger* aerosols.

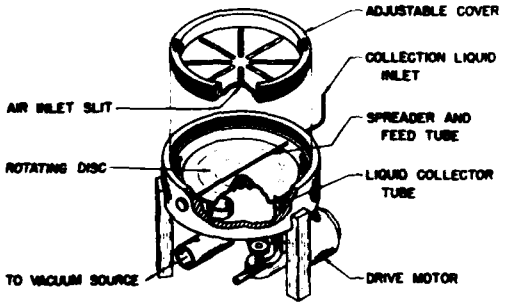

FIG. 1. *Schematic of the multi-split impinger sampler.*

The test apparatus for evaluation of the multi-slit sampler is shown in Fig. 2. The test aerosols were produced by continuously spraying suspensions of 10^7 cells/ml of *B. subtilis* var. *niger* and *S. marcescens* from a Vaponefrin nebulizer (Vaponefrin Co., Metuchen, N.J.) operated at 10 psig, which produced an airflow through the nebulizer of 6 liters/min, and a fluid atomization rate of 0.18 ml/min. The aerosol then passed into a duct 7.6 cm in diameter and 0.91 m long, where it was mixed thoroughly with incoming filtered air to produce an aerosol concentration of approximately 7,300 organisms/liter of air. The pressure in this duct was maintained at 0.05 inch of water below atmospheric pressure to prevent possible escape of the organisms into the room.

The test aerosol was then drawn through the sampler and an air flow meter by a vacuum pump at a rate of 500 liters/min, and was discharged after passing through a high-efficiency particulate arrestor filter. Four all-glass impingers (AGI-30) were operated at 12.5 liters/min for each 5-min test period: two were placed upstream of the multi-slit sampler to determine the challenge aerosol concentration, and two were placed downstream to determine the effluent concentration.

The collection liquids for the AGI-30 samplers were distilled water (20 ml) for sampling *B. subtilis* var. *niger* aerosols and Normal Growth

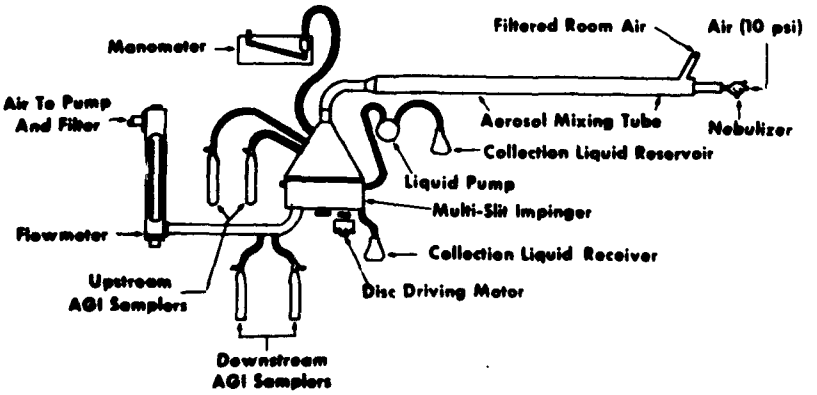

FIG. 2. *Test apparatus for evaluation of the multi-slit impinger sampler.*

Tissue Culture Medium (20 ml), containing 0.03% Dow Corning Antifoam A, for sampling *S. marcescens* aerosols. Separate collection fluids were selected on the bases of maximum collection efficiency, physiological compatibility with the organism, and physical compatibility with the sampler.

Immediately after each test and after making the appropriate serial dilutions in distilled water for *B. subtilis* var. *niger* and in Normal Growth Tissue Culture Medium for *S. marcescens*, the collection liquids from the multi-slit and AGI-30 samplers were assayed on streak plates of Tryptose Agar (Difco). Colonies were counted after incubation for 16 to 20 hr at 37 C.

The variables shown below were investigated to establish an optimum viable collection efficiency for the multi-slit sampler. The values selected were as follows: (i) slit width, 0.01 inch (0.25 cm); (ii) liquid input rate, 4 to 6 ml/min; (iii) disc speed, 180 rev/min; (iv) air flow rate, 500 liters/min; (v) air impaction velocity, 180 ft (55 m)/sec; (vi) slit-to-disc distance, 3 mm; and (vii) pressure drop across sampler, 10 inches (25 cm) of water.

RESULTS OF SAMPLER EVALUATION

The viable collection efficiency of the multi-slit sampler was computed on the basis of the viable organisms recovered from the multi-slit sampler compared to the total number of organisms entering the device as measured by the upstream AGI-30 samplers.

The AGI-30 samplers positioned downstream from the multi-slit sampler determined the quantity of viable organisms that passed through the sampler. This information was useful in establishing whether reduced collection efficiency was the result of slippage through the sampler or loss within the sampler.

Studies with S. marcescens. Forty 5-min tests were performed during a 3-day period. Results showed that the collection efficiency of the multi-slit sampler averaged 82% of that of the AGI-30 sampler (Table 1). Although a relatively wide range of collection efficiencies was experienced, only 3 of the 40 tests were in the 60 to 69% range, and the remainder fell in the 70 to 106% range.

Studies with B. subtilis var. niger spores. Forty 5-min tests were performed during a 3-day period. The results from three tests were discarded because of obvious malfunction of the peristaltic pump. Results showed that the collection efficiency of the multi-slit sampler averaged 78% of that of the AGI-30 sampler (Table 1). Although the multi-slit sampler again showed a relatively wide range of collection efficiencies (60 to 98%), only 8 of the 37 tests were in the 60 to 69% range, while the remainder of the tests were in the 70 to 98% range.

DISCUSSION

A large-volume multi-slit impinger sampler has been developed and evaluated. It has an average collection efficiency, compared to the AGI-30, of 82% for *S. marcescens* and 78% for *B. subtilis* var. *niger* spores. It has potential application in studies related to the airborne transmission of disease, and for the continuous monitoring of air to detect viable airborne microorganisms. Among the valuable features of the multi-slit sampler are its ease of fabrication and use, its large air flow rate (500 liters/min) at a relatively low pressure drop, its low collection-liquid flow rate, and its ability to concentrate organisms from large volumes of air into small quantities of liquids at about 100,000:1.

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TABLE 1. *Collection efficiency of multi-slit impinger compared to the standard all-glass impinger (AGI-30) for the recovery of bacterial aerosols*[a]

No. of tests performed	Test aerosol	Collection liquid		Relative viable collection efficiency		Viable slippage	
		AGI-30	Multi-slit impinger	Avg %	Range %	Avg %	Range %
40	*S. marcescens*	NGTCM[b]	NGTCM + 0.2% Methocel − 15	82	60 to 106	11	7 to 17
37	*B. subtilis* var. *niger*	Water	NGTCM + 0.2% Methocel − 15	78	60 to 98	13	9 to 20

[a] Test conditions: temperature, 21.1 to 23.8 C; relative humidity, 30 to 40%.
[b] Normal Growth Tissue Culture Medium.

enthusiastic interest in the fabrication of the prototype sampler.

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