Evaluation of Respiratory Protection of Contagion Masks

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There are several types of contagion or surgical masks commonly used by physicians, nurses, and biological laboratory personnel to minimize the hazard of the transmission of airborne pathogenic microorganisms. As part of a study in which the respiratory protection afforded by various commercially available masks and respirators was evaluated, three representative types of contagion masks were included. Since contagion masks are so widely used, the results of the evaluation of these masks should be of interest to personnel in the medical and biological fields.

Materials and Methods

The three types of masks tested are shown in figure 1. Type A consists of a flexible aluminum frame to which is clipped a replaceable filter pad composed of a thin layer of absorbent cotton backed by a single thickness of gauze. It is held in place on the head by elastic straps attached to the frame. Type B is a typical tie-on surgical mask with 4 thicknesses of gauze serving as the filter medium. The third mask, Type C, consists of a single sheet of wax-impregnanted paper which is held on the head by elastic loops which are placed around the ears.

The efficiency of the filter material used in each of the three types of masks was determined by exposing it to an aerosol of *Bacillus subtilis* var. *niger* (often called *Bacillus globigii*) spores. This bacterium is nonpathogenic and its spores are oval in shape with a particle size of about 0.8 x 1.2 μ. The efficiency tests reported here were conducted by placing a sample of the material in a specially designed holder which allows an area of 13 cm^2 to be exposed to the test aerosol. The holder with the mask material *in situ* was placed inside an aerosol chamber consisting of a plastic sphere with a volume of 120 L. The aerosol was generated from an aqueous suspension of *B. subtilis* var. *niger* spores by means of a Vaponefrin[2] nebulizer and was introduced into the sphere through a glass tube. A relative humidity of approximately 50 per cent was maintained in the chamber. The filter material was then challenged by drawing the aerosol through it by means of a vacuum source. Any spores penetrating it were collected by a cotton collector which served as a tandem sampler. This sampler consists of a glass tube containing absorbent cotton as the collecting medium (figure 2). After a 5-min sampling period, the cotton was aseptically removed from the sampler and placed in a bottle containing a known volume of sterile water. The contents were agitated by means of a mechanical shaker for 10 min in order to resuspend the spores. The number of spores collected was then determined by standard bacteriological procedures. For control purposes, the challenge aerosol was sampled simultaneously by means of another cotton collector. Since both the total penetration and the average concentration of the challenge aerosol were known, the per cent efficiency of the filter material could be determined.

Since this test does not take into account peripheral leakage which may occur when the masks are worn, other tests employing human subjects were conducted in order to determine the over-all mask efficiency. In these tests, the challenge aerosol of *B. subtilis* var. *niger* spores was contained in a room where the temperature and relative humidity could be controlled. The mass median diameter (as defined by Sonkin, 1950) of this aerosol was determined to be 2.1 μ by using a 4-stage cascade impactor. Moreover, 99.15 per cent of the particulates were between 1.0 and 5.0 μ in diameter.

Four subjects were used to wear the test masks at a sedentary work rate. A specially designed mouth collector was used to collect the spores penetrating the masks (figure 3). It consists of a rubber mouthpiece which contains a metal cartridge packed with absorbent cotton to a known resistance and over which the masks are placed. Each subject was instructed to inhale through his mouth and exhale through his nose so that the inspiratory air could be sampled by the mouth collector. The masks and collectors were fitted on the subjects in a room supplied with filtered air which was located near the room containing the challenge aerosol. Negative pressure was maintained in the latter room. The test was designed so that each subject wore each of the thee types of masks two different times in the aerosol room. Each exposure period was for 10 min. At the end of each period, the cotton was aseptically removed from the cartridge and placed in a sterile water blank. The number of spores retained by the cotton was determined by the procedure described previously in this paper. A continous sample of the challenge aerosol was taken during the test period. The

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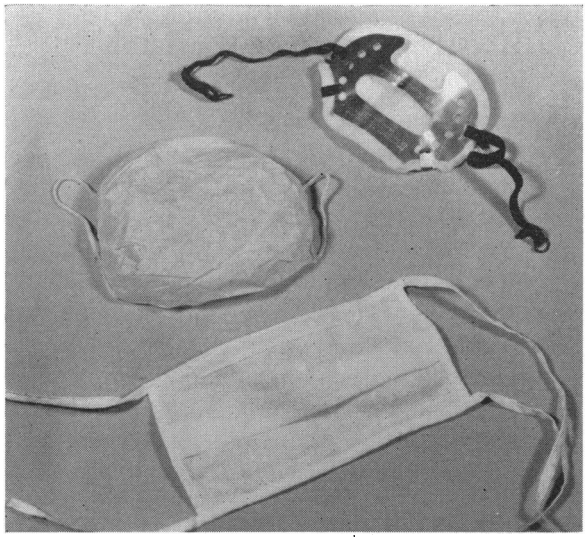

FIG. 1. Three types of commercial contagion masks evaluated

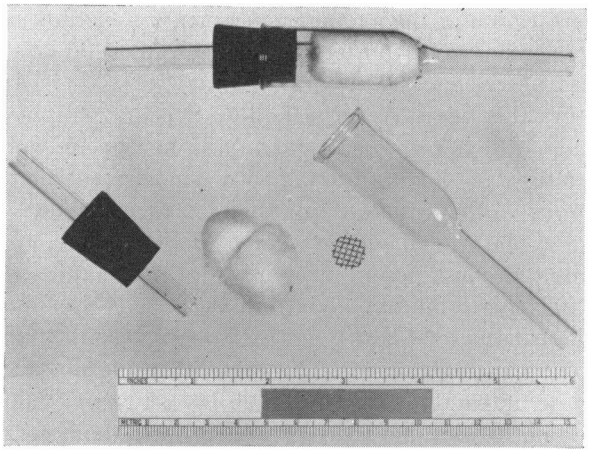

FIG. 2. Cotton collector, assembled and disassembled

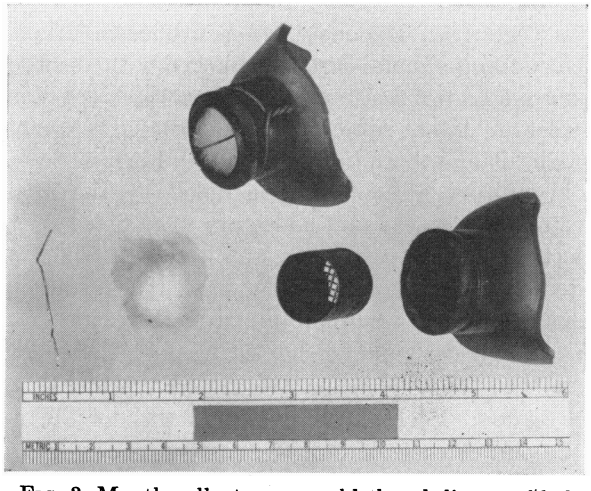

FIG. 3. Mouth collector, assembled and disassembled

per cent efficiency of the masks tested was calculated on the basis of an assumed breathing rate of 10 L. per min.

RESULTS AND DISCUSSION

The results of the tests on the filter material used in each of the three types of masks are given in table 1. They show that each medium is relatively inefficient. Table 2 shows that somewhat erratic results were obtained when these contagion masks were worn by the subjects. This was due mainly to the very poor peripheral fit around the nose and chin. The average efficiency of one of the types of masks was only 17.6 per cent, while the efficiencies of the other two types averaged 38.0 and 39.6 per cent. Although the test conditions were not identical, the difference between the results of the two tests indicates that maximum mask efficiency is dependent upon an adequate peripheral fit as well as efficient filter material.

A comparison of the efficiencies of these three types of contagion masks with those of three representative types of commercially available dust respirators and industrial special-purpose masks, respectively (Guyton and Lense, 1955) is given in table 3. This latter group of masks are full-face masks designed for use in heavy

TABLE 1. *Aerosol filtration tests on filter material in contagion masks*

Trial	Per Cent Efficiency of Filter Material for Masks*		
	Type A	Type B	Type C
1	55.8	50.0	55.5
2	41.9	43.5	58.3
3	47.6	34.6	59.1
Average.....	48.4	42.7	57.6

* Flow rate: 16 L air per min; area of exposure: 13 cm^2.

TABLE 2. *Subject tests on contagion masks*

Subject	Trial	Per Cent Efficiency of Mask*		
		Type A	Type B	Type C
I	1	35.0	1.0	39.3
	2	16.2	19.4	30.4
II	1	41.9	5.7	59.8
	2	14.3	5.8	57.3
III	1	62.5	42.0	41.9
	2	54.3	59.0	20.1
IV	1	37.5	6.8	41.9
	2	42.5	1.2	25.9
Average.....		38.0	17.6	39.6

* Assumed breathing rate: 10 L air per min.

TABLE 3. *Efficiencies of typical commercial protective masks*

Type	Per Cent Efficiency for Three Types*		
	Contagion masks	Dust respirators	Industrial masks
A	38.0	97.35	99.902
B	17.6	99.97	99.9998
C	39.6	99.92	99.9993

* Assumed breathing rate: 10 L air per min.

industries. Dust respirators are normally employed wherever abnormal concentrations of dusts are encountered, such as in coal mines. These respirators have a very low resistance to breathing and could be readily used in hospitals and medical or biological laboratories.

ACKNOWLEDGMENTS

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SUMMARY

The method used in evaluating the respiratory protection provided by representative types of contagion masks against an aerosol of *Bacillus subtilis* var. *niger* spores has been described.

It can be concluded that the contagion masks evaluated offer poor respiratory protection against airborne microorganisms in the particle size range of 1.0 to 5.0 μ in diameter.

Commercially available dust respirators and related masks are approximately 2.5 to 5 times more efficient than contagion masks. An even higher degree of protection can be obtained by the use of full-face masks.

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Relative Resistances of Microorganisms to Cathode Rays

I. Nonsporeforming Bacteria

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Doses of cathode rays required to inhibit microorganisms, under various conditions of test, have been reported by others. Dunn *et al.* (1948) irradiated *Micrococcus pyogenes* var. *aureus* (*Staphylococcus aureus*), *Escherichia coli*, *Serratia marcescens*, a sporeforming bacillus, yeasts and a fungus. Dunn (1952) reported doses required to kill 30 species including bacteria, yeasts and fungi. Katznelson and his associates (1952) studied the quantitative relationship between number of organisms and dose required for sterilization of honey. Studies with a common contaminant, *Micrococcus pyogenes* var. *aureus* (*S. aureus*), were reported by Bellamy and Lawton (1954). The relative resistances of yeasts and molds (Bridges *et al.*, 1956) and bacterial spores (Pepper *et al.*, 1956) to cathode rays have been reported from our laboratories.

In view of the few data available, it was deemed advisable to establish relative resistances for a broad spectrum of nonsporeforming organisms to cathode radiation. Differences in resistances between 24-hr and 5- to 7-day cultures of several species were also determined.

It is well known that following ionizing radiation the survival of a mass population is exponential (Lea, 1946; Bacq and Alexander, 1955). This fact suggested that the sterilizing[1] dose may be dependent upon the concentration of cells. Therefore the relationships between sterilizing dose and cell concentration as well as sterilizing dose and volume of the suspension were investigated. Since it had been observed that more concentrated suspensions required higher sterilizing doses, it was also of interest to determine the limits of this correlation.

MATERIALS AND METHODS

The test organisms were various species of nonsporeforming bacteria which have been maintained in our laboratory for several years. For these experiments, organisms were grown in 10 ml of their optimum liquid media. The majority of the cultures were incubated at 37 C (*Leuconostoc* at 25 C) for 18 to 24 hr. Pneumococci, streptococci, micrococci and sarcina required 48-hour incubation for maximum growth. A 10-day culture of *Mycobacterium tuberculosis* was employed. After incubation, cells were washed twice by centrifugation and resuspended in distilled water to the original volume. Prestandardization of numbers of viable cells per a unit volume of suspension proved extremely difficult and was not attempted. When possible, the number of viable

[1] The term "sterility" here denotes inability of the microorganisms to reproduce under these conditions of test.