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Does That Face Mask Really Protect You?

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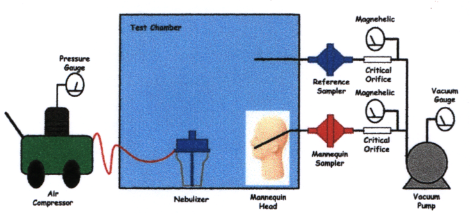
Abstract

Various types of face masks available to the general public are worn for protection against inhalation of dust, pollutants, toxic materials, and pathogenic organisms. Recent news stories have illustrated the widespread use of face masks for protection against Severe Acute Respiratory Distress Syndrome (SARS) and Highly Pathogenic Avian Influenza virus (HPAI) outbreaks in Asia, toxic dusts from the collapse of the World Trade Center, and toxic vapors from volcanic eruptions in the Pacific Rim. However, the level of protection provided by face masks is unknown. The objective of this study was to determine how efficiently face masks prevent respiratory exposure to harmful aerosols. Three types of commonly available face masks were tested, a surgical mask, a pre-shaped dust mask, and a bandana. A N95 respirator was tested as a negative control. Masks were fit onto a Styrofoam mannequin head modified with a 5/8-inch sample probe that was placed inside a 147.5 Liter test chamber. A 5/8-inch reference probe was positioned next to the mannequin head. Saline aerosols were generated in the test chamber using an IV HEART™ nebulizer. Filter samples were collected simultaneously from the mannequin and reference sample probes and used to calculate aerosol concentrations. The mannequin sample probe and the reference sample probe volumetric flow rates were 8.75 L/min. and 1.72 L/min., respectively. The mean challenge aerosol concentration, determined from the reference sample probe, was 0.045 ± 0.008 mg/L with a mass median aerodynamic particle size of 1.6 µm. Face mask protective efficiency was calculated as the ratio of mannequin sample probe concentration to reference probe concentration. Each face mask was challenged for 30 minutes. The protective efficiencies were 33.3%, 10.2%, and 8.0% for the surgical, bandana, and dust masks, respectively. The N95 mask protective efficiency was 89.4%. In conclusion, the surgical mask protected the best of the three face masks tested. However, it is important to note that all three masks offer very little protection when compared to the N95. People who wear these face masks may not be as protected as perceived.

Background

- Dust storm aerosol concentrations and particle size distributions have been measured in many countries. The mean aerosol concentration of a moderate dust storm is 0.040 mg/L and the particle size is less than or equal to 2.5 µm. [1,2]
- Adults breathe at a rate of approximately 7.5 L/min while resting and 13-25 L/min during light exercise [3].
- The mannequin filter sampler flow rate was 8.75 L/min.
- The reference filter sampler flow rate was 1.72 L/min.
- Filter sampler flow rates were controlled by critical orifi.
- A rectangular plenum with a volume of 147.5 L was used as the test chamber.
- An IV Heart™ nebulizer operated at 40 psig and 12.7 L/min. was used to generate saline test aerosols. The time to fill the plenum with aerosol was 11.6 minutes (147.5 L / 12.7 L/min.). Thus, the nebulizer was run for 12 minutes before the filter samplers were started.
- All flow rates were calibrated with a primary flow calibration device, DryCal DC-Lite, (BIOS International, Butler, NJ).
- A schematic of the face mask test system is presented in Figure 1.

Figure 1. Face Mask Test System



Procedure

A Styrofoam™ mannequin head was fitted with a sample probe. Face masks were placed on the mannequin head and positioned in the test chamber. Pictures of the face masks on the mannequin head are presented in Figures 2-5. A reference sample probe was positioned next to the mannequin head. Filter samplers were connected to the mannequin head and reference sample probes. The nebulizer was filled with approximately 20 mLs of 0.045% saline, connected to the compressed air source, and placed in the test chamber.

The nebulizer was actuated and allowed to run for 12 minutes. Filter samplers were actuated simultaneously and 30 minute aerosol samples were collected. Initial and final filter pressure differentials were recorded from magnehelic pressure gages. Pressure corrected filter sampler volumetric flow rates were determined using Equation 1. Mannequin and reference filter sample volumes were determined using Equation 2. Mass per unit volume aerosol concentration was determined using Equation 3. Face mask protective efficiency was determined using Equation 4. Equations 1, 2, 3, and 4 are presented in Figure 6.

The particle size distribution of the saline test aerosol was determined by collection of a cascade impactor sample from the reference sample probe after a 12 minute nebulization period.

Figure 2. Surgical Face Mask

Figure 3. Pre-Shaped Face Mask

Figure 4. Bandana Face Mask

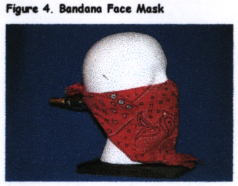


Figure 5. N95 Face Mask

Results

Each mask was tested three times. New masks were used for each test. The mean mannequin filter sample concentrations were 0.022 ± 0.009 mg/L, 0.046 ± 0.005 mg/L, 0.044 ± 0.008 mg/L, and 0.005 ± 0.002 mg/L for the surgical mask, dust mask, bandana, and N95, respectively. The mean reference filter sample concentrations were 0.033 ± 0.010 mg/L, 0.050 ± 0.008 mg/L, 0.049 ± 0.005 mg/L, and 0.047 ± 0.005 mg/L for the surgical mask, dust mask, bandana, and N95, respectively. The overall mean of the reference filter sample concentrations was 0.045 ± 0.008 mg/L which was 112.5% of target. The surgical mask had the best efficiency of the three test masks at 33.3% while the dust mask had the worst efficiency at 8.0%. The efficiency of the bandana was 10.2%. The N95 mask efficiency was 89.4%. Mannequin filter sample concentrations, reference sample concentrations and mask efficiencies are presented in Tables 1-4.

Saline aerosol particle size distribution was measured with a cascade impactor (In-Tox Products, Albuquerque, NM). The mass median aerodynamic diameter particle size was 1.6 µm and the geometric standard deviation was 2.0. The particle size distribution, presented as mass median aerodynamic diameter (MMAD) and geometric standard deviation (GSD) is presented in Figure 7.

Results

Figure 6. Equations [4]

1. $$Qc = Qm\left(1 + \frac{\Delta P}{P}\right)$$

where:

Qc = pressure corrected flow rate, $\frac{L}{\min}$

Qm = measured flow rate, $\frac{L}{\min}$

ΔP = mean pressure drop, psig

P = ambient pressure, psig

2. $$\text{Aerosol concentration}, \left(\frac{mg}{L}\right) = \frac{mg}{(Qc)\min}$$

where:

mg = filter net weight

Qc = pressure corrected flow rate

min = sample collection time

3. $$\text{Sample Volume} = Qc \times \text{SampleTime}$$

4. $$E(\%) = \left(1 - \frac{C}{Co}\right)100$$

where:

C = mannequin sample concentration

Co = reference sample concentration

Table 1. Surgical Mask

Sample ID	Mannequin Filter Concentration (mg/L)	Reference Filter Concentration (mg/L)
Test 1	0.017	0.031
Test 2	0.032	0.043
Test 3	0.017	0.024
MEAN	0.022	0.033
STDEV	0.009	0.010

Efficiency (%) = 33.3

Table 2. Dust Mask

Sample ID	Mannequin Filter Concentration (mg/L)	Reference Filter Concentration (mg/L)
Test 1	0.047	0.051
Test 2	0.051	0.057
Test 3	0.041	0.041
MEAN	0.046	0.050
STDEV	0.005	0.008

Efficiency (%) = 8.0

Table 3. Bandana

Sample ID	Mannequin Filter Concentration (mg/L)	Reference Filter Concentration (mg/L)
Test 1	0.035	0.044
Test 2	0.048	0.053
Test 3	0.048	0.050
MEAN	0.044	0.049
STDEV	0.008	0.005

Efficiency (%) = 10.2

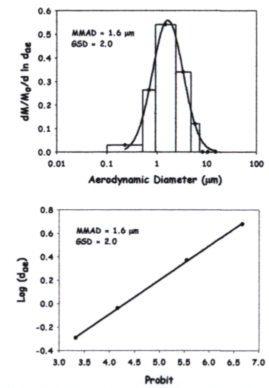
Table 4. N95

Sample ID	Mannequin Filter Concentration (mg/L)	Reference Filter Concentration (mg/L)
Test 1	0.003	0.042
Test 2	0.005	0.048
Test 3	0.006	0.051
MEAN	0.005	0.047
STDEV	0.002	0.005

Efficiency (%) = 89.4

Results, continued

Figure 7. Particle Size Distribution



Conclusions

Three commonly available face masks, a surgical mask, a pre-shaped mask, and a bandana were challenged with saline aerosols in concentrations and particle size distributions representing dust storm conditions to determine their protective efficiencies. A N95 respirator was used as a negative control and challenged in the same conditions. All three masks performed poorly with protective efficiencies less than 34% as compared to the N95 respirator which had a protective efficiency of nearly 90%. The use of these types of face masks may not provide as much protection as desired against inhaled aerosols. However, the type of face mask worn is only one of several factors that should be considered when making a risk assessment of the protective efficiency. Face mask or respirator fit must also be considered. The penetration efficiency of the mask material could also be tested to determine if the poor performance of the masks observed was a result of improper fit or inadequate materials.

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