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, allergens, and pathogenic organisms. Recent news stories have illustrated the widespread use of face masks for protection against Swine flu (H1N1), Severe Acute Respiratory Distress Syndrome (SARS), Highly Pathogenic Avian Influenza (HPAI) virus outbreaks in Asia, and dust from the collapse of the World Trade Center. 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 potentially harmful aerosols. Three types of commonly available face masks were tested: a surgical mask, a pre-shaped dust mask, and a bandana. An N95 respirator was tested as the positive control. Masks were fit onto a Styrofoam™ mannequin head modified with a 5/8-inch diameter sample probe that was placed inside a 147.5 liter test plenum; a 5/8-inch diameter reference probe was positioned next to the mannequin head. Saline aerosols were generated in the test plenum using an IV HEART™ (Westmed, Inc., Tucson, AZ) nebulizer. Each face mask was challenged for 30 minutes. 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 sample probe concentration. The protective efficiencies were 33.3%, 11.3%, and 6.1% for the surgical, bandana, and dust masks, respectively. The N95 mask protective efficiency was 89.6%. 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, and wearing these face masks may produce a false sense of protection.

Method

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 (Chan, 2002; Selinus, 2005). Therefore, the test plenum target aerosol concentration was 0.40 mg/L and the target particle size was 1.0 to 2.5 µm. Although this particle size range is larger than the actual geometric diameter of viral particles (approximately 0.02 to 0.2 µm), it should be noted that droplet nuclei generated during a sneeze range in size from 0.5 to 12 µm and contain many viral particles (3M Technical Data Bulletin #174, 2004).

Adults breathe at a rate of approximately 7.5 L/min while resting and 13 to 25 L/min during light exercise (Adams, 1993). The mannequin filter sampler volumetric flow rate was set at 8.75 L/min to simulate a near resting state respiratory ventilation rate. Efficiency data collected under these conditions represented a best-case scenario for protection; that is, protection would presumably be less and inhaled dose greater at light exercise ventilatory flow rates. The reference sampler volumetric flow rate was set at 1.72 L/min. Mannequin and reference filter sampler flow rates were metered with custom-designed critical orifi.

A rectangular plenum with a volume of 147.5 L was used to test the masks. Aerosols were generated using an IV HEART™ nebulizer operated at 40 psig and 12.7 L/min. At this volumetric flow rate, the theoretical time to fill the test plenum with aerosol was 11.6 minutes. Therefore, the nebulizer was run for 12 minutes prior to filter samples being collected. All volumetric flow rates were calibrated using a DryCal DC-Lite (BIOS International, Butler, NJ) primary flow calibration device. A schematic of the face mask test system is presented in Figure 1.

Procedure

A Styrofoam™ mannequin head was fitted with a sample probe. Face masks and a N95 respirator were placed on the mannequin head and positioned in the test plenum. 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, and filter samplers were connected to the mannequin head and reference sample probes. The nebulizer was filled with approximately 20 mL of 0.045% saline, connected to the compressed air source and placed in the test plenum.

The nebulizer was actuated and allowed to run for 12 minutes. Mannequin and reference filter samplers were actuated simultaneously, and 30-minute aerosol samples were collected. Initial and final filter pressure differentials were recorded from magnehelic pressure gages. Pres-

Figure 1
Face Mask Test System

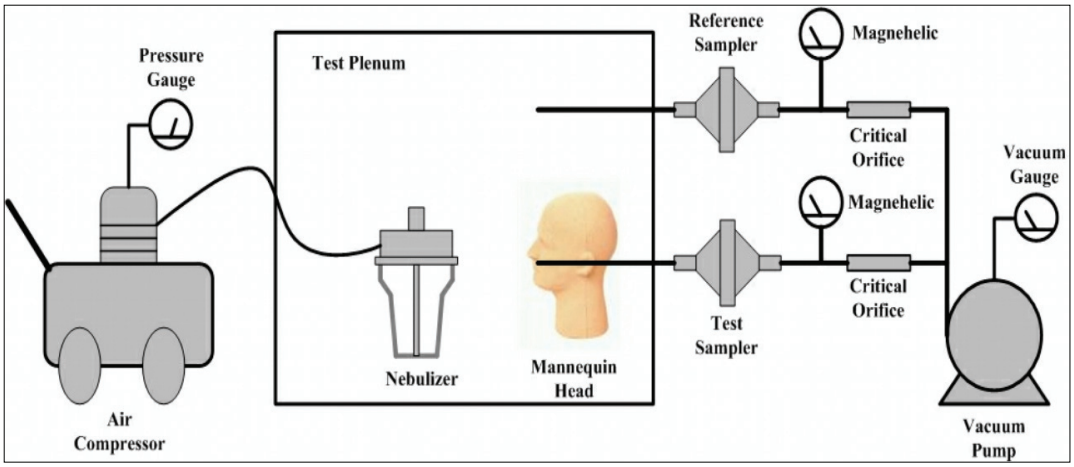


Figure 2
Surgical Face Mask

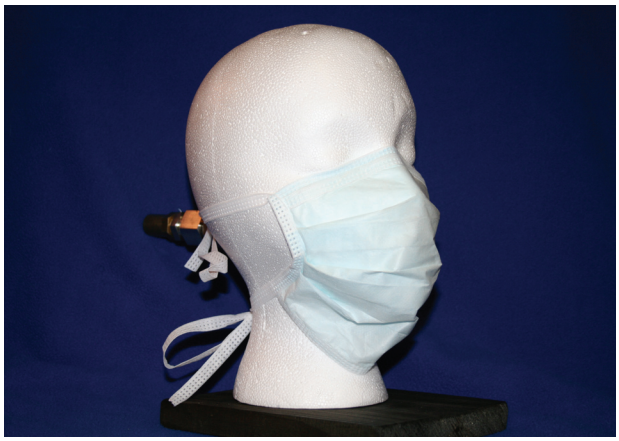
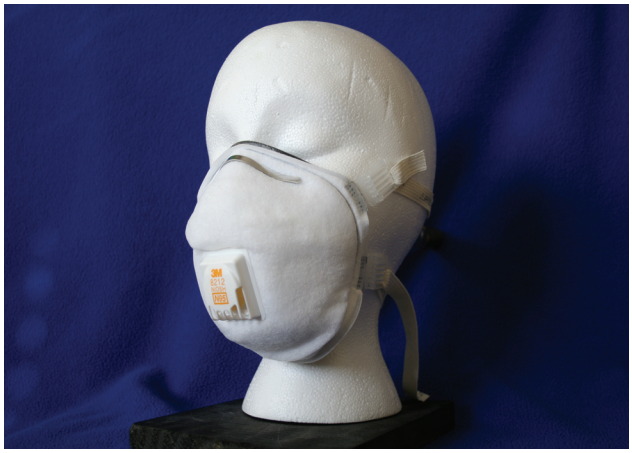


Figure 3
Pre-Shaped Face Mask

Figure 4
Bandana Face Mask

Figure 5
N95 Face Mask



sure-corrected filter sampler volumetric flow rates were determined using Equation 1 (McClellan, 1989; Miller, 1983). Mannequin and reference filter sample volumes were calculated as the product of the pressure-corrected flow rate and sample time. Mass per unit volume aerosol concentration (reference and passing through the mask) was determined using Equation 2 (Hinds, 1982). Face mask protective efficiency was determined using Equation 3 (Elimelech, 1998). The particle size distribution of the saline test aerosol was determined by the collection of a cascade impactor (In-Tox Products, Albuquerque, NM) sample from the reference sample probe after a 12-minute nebulization period. Each mask type was tested three times and a new mask was used for each test.

Results

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 0.004 ± 0.001 mg/L for the surgical mask, dust mask, bandana, and N95, respectively. 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 0.042 ± 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%. The efficiency of the bandana was 11.3%, while

Equation 1
Flow Rate Pressure Correction

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

where:
Qc = pressure corrected flow rate
Qm = measured flow rate
ΔP = mean pressure differential
P = ambient pressure

Equation 2
Aerosol Concentration

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

where:
mg = filter net weight

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

min = sample collection time

Equation 3
Face Mask Protective Efficiency

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

where:
C = sample concentration
Co = reference sample concentration

Table 1
Surgical Face Mask Data

Test I.D.	Mask Sample Concentration (mg/L)	Reference Sample Concentration (mg/L)	Efficiency (%)
1	0.017	0.031	45.2
2	0.032	0.043	25.6
3	0.017	0.024	29.2
MEAN	0.022	0.033	33.3
STDEV	0.009	0.010	10.4
% CV	40.9	30.3	31.2

Table 2
Pre-Shaped Face Mask Data

Test I.D.	Mask Sample Concentration (mg/L)	Reference Sample Concentration (mg/L)	Efficiency (%)
1	0.047	0.051	7.8
2	0.051	0.057	10.5
3	0.041	0.041	0.0
MEAN	0.046	0.050	6.1
STDEV	0.005	0.008	5.5
% CV	10.9	16.0	90.2

the dust mask had the worst efficiency at 6.1%. The reference N95 mask efficiency was 89.6%. Mannequin filter sample concentrations, reference sample concentrations, and mask efficiency data are presented in Tables 1-4 for surgical, pre-shaped dust mask, bandana, and N95 face masks, respectively.

Saline aerosol particle size distribution was measured with a cascade impactor. The mass median aerodynamic diameter particle size was 1.6 µm, and the geometric standard deviation was 2.0. The particle size distribution is presented in Figure 6.

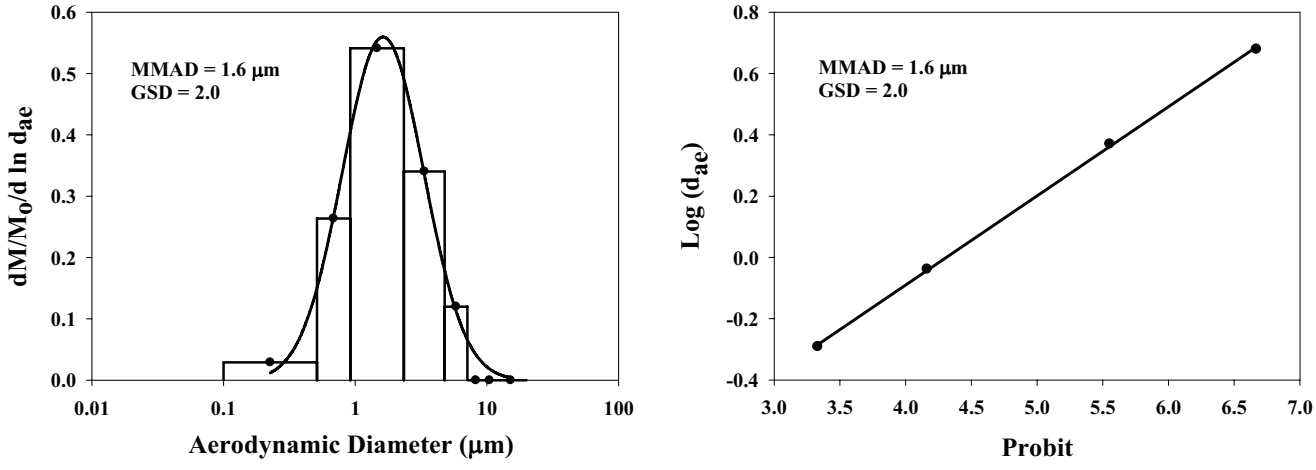
Table 3
Bandana Face Mask Data

Test I.D.	Mask Sample Concentration (mg/L)	Reference Sample Concentration (mg/L)	Efficiency (%)
1	0.035	0.044	20.5
2	0.048	0.053	9.4
3	0.048	0.050	4.0
MEAN	0.044	0.049	11.3
STDEV	0.008	0.005	8.4
% CV	18.2	10.2	74.3

Table 4
N95 Face Mask Data

Test I.D.	Mask Sample Concentration (mg/L)	Reference Sample Concentration (mg/L)	Efficiency (%)
1	0.005	0.038	86.8
2	0.004	0.042	90.5
3	0.004	0.047	91.5
MEAN	0.004	0.042	89.6
STDEV	0.001	0.005	2.4
% CV	25.0	11.9	2.8

Figure 6
A) Left—Saline Aerosol Mass Histogram Particle Size Distribution
B) Right—Saline Aerosol Mass Linear 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 the positive control and challenged under the same conditions. All three masks performed poorly, with protective efficiencies less than 34% as compared to the N95 respirator that had a protective efficiency of nearly 90%. Possible factors related to the protective efficiencies observed with face masks and the N95 respirator includes the penetration efficiency and particle load characteristics of the fabrication materials. Equally important is the fit of the face mask and respirator. This may account for the less than 95% efficiency observed for the N95.

Protection from dust, allergens, and infectious aerosols with face masks and respirators is dependent on the aerosol concentration of the compound and the infectious or inhaled dose. The results demonstrate that use of these types of face masks may not provide as much protection as desired against inhaled aerosols.

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Survival of Bacteriophage MS2 on Filtering Facepiece Respirator Coupons

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Abstract

The reuse of filtering facepiece respirators (FFRs) after decontamination has been suggested as a strategy to conserve supplies during an influenza pandemic. The feasibility of decontaminating FFRs has been investigated under laboratory conditions; however, the need for decontamination of FFRs is not well characterized. In this study the potential for FFRs to act as fomites was examined using bacteriophage MS2. Virus was applied to FFR coupons as an aerosol or liquid drops and stored at 22°C and 30% relative humidity. Viability of the virus was monitored every 24 hours from 1 to 5 days with a final sampling occurring on day 10. At least 10% of the initial MS2 load was able to survive for 4 days on the FFR coupons regardless of the deposition method. All coupons contained detectable levels of MS2 on the tenth day. MS2 viability did not appear to be affected by the location of deposition within the layers of the coupon under the test conditions. The results indicate that FFRs have the potential to serve as a fomite.

Introduction

The transmission of influenza and many other infectious diseases occurs primarily through contact exposure to fomites (virus-contaminated objects) and inhalation of infectious particles (Bean et al., 1982; Boone & Gerba, 2005; Mubareka et al., 2009; Tellier, 2006; Weiss et al., 2007; World Health Organization Writing Group, 2006). Nonpharmacological interventions, such as the use of personal protective equipment (PPE) (e.g., respiratory protection) and standard hygiene (e.g., hand washing) may help limit the spread and transmission of influenza (World Health Organization Writing Group, 2006). For example, current recommendations call for healthcare workers to use disposable National Institute