----------mists or droplet nuclei. Hantav
dust that became airborne after rodents shed virus via urine, feces
ct, it is generally thought that airborne viruses are normally
exist as naked organisms.

(1)

Inhalation of these bioaerosols may be reduced by wearing respirators. The Centers for Disease Control and Prevention (CDC), the World Health Organization (WHO) and many National Health Authorities have made numerous recommendations for respirator use where they believed the potential for the spread of disease through the airborne route exists. Considerations for selection and use of respirators for exposure to bioaerosols include filtration, microorganism survival on the filter, potential reaerosolization of the bioaerosol, reuse of the respirator, fit and the assigned protection

smaller than approximately 5 m can enter the deep lung and are considered the "respirable" fraction. [3] Certain diseases can be spread through the airborne route. This means that if the organism that causes the disease is aerosolized the potential exists for illness. Tuberculosis is one disease that is spread through the airborne route. Evidence has been presented that indicates the airborne route is one of the ways that severe acute respiratory syndrome (SARS) and seasonal influenza can be spread. [4-8] When airborne, viruses and bacteria can be filtered by respirators with particulate filters. Because no respirator will prevent the inhalation of all particles, such as viruses and bacteria, respirators cannot eliminate the risk of exposure, infection and illness. With so many respirator use recommendations being made on websites and other sources, it is important to understand respirators and the role they have in helping to reduce exposures to bioaerosols.

Terminology

Bioaerosols are those airborne particles that are living or originate from living organisms. [9] They include microorganisms and fragments, toxins and particulate waste from all varieties of living things.

A **respirator** is a device designed to help provide the wearer with respiratory protection against inhalation of a hazardous atmosphere. [10] For bioaerosols, particulate removing respirators are often recommended to help reduce exposure. Particulate respirators are available as:

1. a filtering half facepiece respirator where the filter is the entire respirator
2. an elastomeric (reusable) half mask with a particulate filter
3. an elastomeric (reusable) full facemask with a particulate filter
4. a powered air purifying respirator (PAPR) that includes a particulate filter

Particulate respirators are classified by their performance against local certification standards. In the US, testing is done by the National Institute for Occupational Safety and Health (NIOSH). In Europe respirators are tested against the relevant European Standard and are approved as category 3 devices under the PPE Directive 89/686/EEC.

Filtration efficiency is one of the performance parameters evaluated for certification. These tests are designed to be very stringent or "worst case." Following are some of the minimum filtration requirements according to US and European standards. However, it is often inappropriate to compare results from the different tests as there are many test variables that affect performance such as type of aerosol, particle size, d5owing are fic7(m5 TD,ld8n41ate to)8n

It should be noted that penetration of particles through the filter is only one of the possible sources of exposure to contaminants. Other potential sources such as face seal leakage, leakage as a result of improper maintenance, or not wearing the respirator when necessary may contribute more to exposure than filter penetration. Each of these factors must be addressed and controlled. For example, all particulate respirators designed to seal to the face (including filtering facepiece respirators) can be fit tested using the saccharin or Bitrex™ qualitative fit test methods. Wearers must be trained how to properly maintain their respirators and the importance of wearing them all of the time during potential exposure.

It is important to recall that respirators help reduce exposure to airborne contaminants but do not prevent the inhalation of all particles. As a result, when properly used and maintained, respirators can lower exposures to concentration considered safe for most non-biological particles. However, they do not eliminate the risk of exposure, infection or illness where biological particles where safe exposure levels have not been established. In many countries, types or classes of respirators are given an "assigned protection factor" or APF. APF is the expected ability of the respirator to reduce exposure when used according to an effective respiratory protection program. For example, an APF of 10 means that a respirator may reduce exposure by a factor of 10 (or 90%) when properly selected, maintained, fitted and worn. Therefore, even if a filter is 100% efficient, the expected amount of exposure reduction would be limited by the APF. Because no respirator will prevent the inhalation of all particles, they cannot eliminate the risk of exposure, infection and illness.

For more information on the proper selection and use of respiratory protection, please see the United States (US) OSHA standard for respirator

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Filtration

A number of questions have been raised regarding the use of respirators against biological agents. The primary question is whether or not particulate respirators can filter small particles such as fungal spores (2 to 5 μm), bacteria (0.3 to 10 μm), or viruses (0.02 to 0.3 μm). [15] The physical size of various organisms is shown in Table 1. As noted previously, biological organisms may be carried on other particles including dust, blood, saliva, etc. Droplets generated from talking, coughing or sneezing will quickly dry in the air to form droplet nuclei. Droplet nuclei generated from coughs, sneezes and speaking have been found to range from submicron to over 20 microns. [15,16] Influenza viruses, and other viruses, have been collected from exhaled breath. [17] It is thought that droplet nuclei that contain *Mycobacterium tuberculosis* may range from less than 1 μm to greater than 5 microns. [18,19] Airborne particles containing influenza viruses have been sampled from the air of hospital rooms containing influenza patients and found to be in the size range from less than 1 m to greater than 4 m. [4]. Understanding filtration mechanisms can help answer whether or not these particles can be filtered by particulate respirators.

Many particulate respirators use a non-woven fibrous filter media to capture particles. Fibers from less than 1 m to 100 m in size crisscross to form a web of many layers which is mostly air due to the large spaces between the fibers. It is the spaces between fibers that allow for breathability. Therefore, a particle does not become trapped because it tries to go through a hole that is too small. Rather, while flowing through the layers of filter media, a particle becomes attached to a fiber due to a number of different mechanisms. The most common of these are gravitational settling, inertial impaction, interception, diffusion, and electrostatic attraction. [1]

To understand how a particle is captured, one must first consider the movement of air through the filter media. The path of the air around a fiber may be described in terms of imaginary streamlines. Any particle carried by the air may or may not stay within the streamlines depending largely upon the particle's size (aerodynamic diameter).

Very large particles (< 100 m), in slow moving airstreams may settle out due to gravity. However, most respirable particles are too small for this mechanism. Respirable particles above 0.6 m in diameter are captured efficiently by interception and inertial impaction. [20] Inertial impaction occurs when a particle cannot follow an air streamline around a fiber because of its inertia and instead impacts into the fiber. In the interception mechanism, the particle holds to the streamline, but that

Filtration efficiencies of six different commercially available US N95 filtering facepiece respirators as tested by 3M are shown in the left side of Figure 1. (Previous research has shown that for 3M

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more studies have been published evaluating the filtration efficiency of respirator filters challenged with nanometer sized particles. These studies have found that NIOSH-approved respirators show filtration efficiencies similar to what would be expected based on their approval category.

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Selection and Use

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Table 1. Size of Various Microorganisms

Microorganism (common name or disease)	Physical Size (µm)
Hepatitis virus (Hepatitis B)	0.042 – 0.047
Adenovirus (respiratory infections)	0.07 – 0.09
Filoviruses (Ebola)	0.08 diameter 0.79-0.97 length
Bunyaviridae (Hantavirus)	0.08-0.12
Orthomyxoviridae (Influenza A, B, & C)	0.08-0.12
Coronaviridae (SARS –CoV)	0.10-0.12
Variola Virus (Smallpox)	0.14-0.26 diameter 0.22-0.45 length
Mycobacterium tuberculosis (TB)	< 1 to > 5 µm diameter
Bacillus anthracis spore (Anthrax infection)	1.0-1.5 diameter

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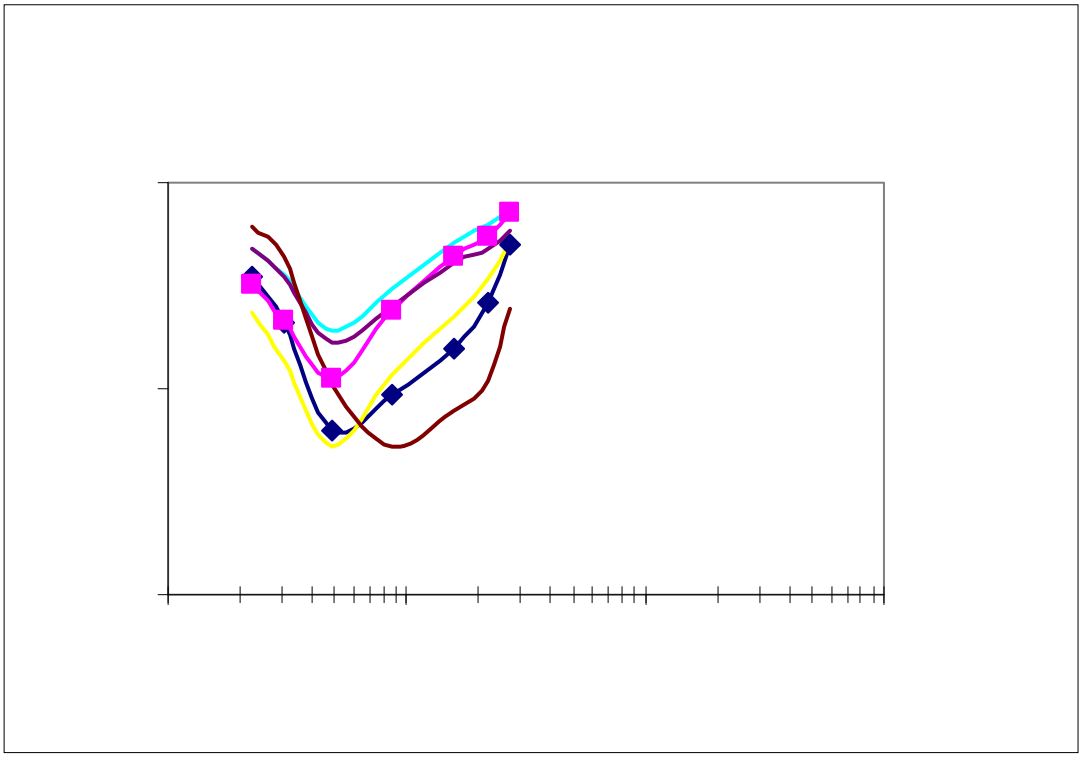
Figure 1. Averaged Filtration Efficiency for Six N95 respirators (on the left), and Size Distribution of Droplet Nuclei from a Sneeze (on the right).



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