

Infections by Bio-aerosols

Objectives

The objectives of this activity are to enable the learner to:

- Understand prevention at the sources of aerosols and droplets
- Describe environmental factors contributing to dispersion of droplet/aerosols
- Select appropriate preventive measures against inhalation of infectious agents
- Implement a comprehensive infection control plan adapted to the conditions

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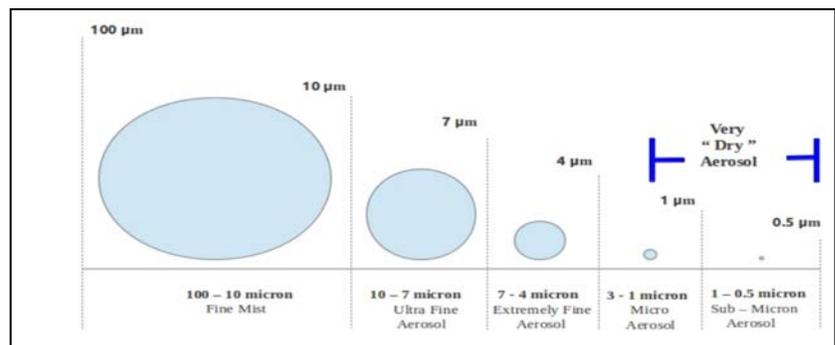
Aero-Biology & Bio-aerosols

Aerobiology is the study of the processes involved in the movement of microorganisms in the atmosphere from one geographical location to another, including the aerosolized transmission of disease

Bio-aerosol Properties

Physical attributes

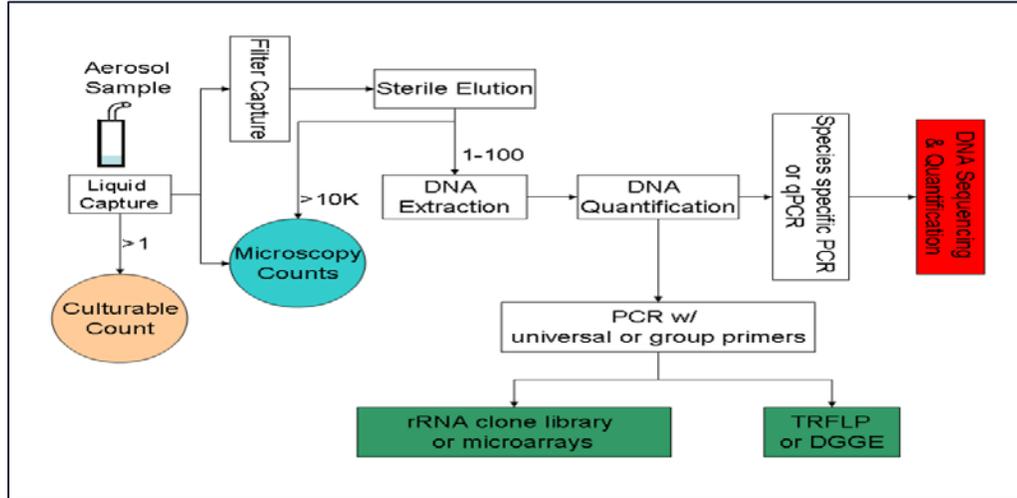
- Physical shape
- Diffusion
- Gravitation (Density)
- Temperature
- Electrostatic forces
- Relative humidity
- Air currents, ventilation



Biological attributes

- Biological materials hygroscopy
- Morphology of micro-organism
- Shape changes due to dehydration/rehydration cycles

Bio-aerosol Analysis Procedure



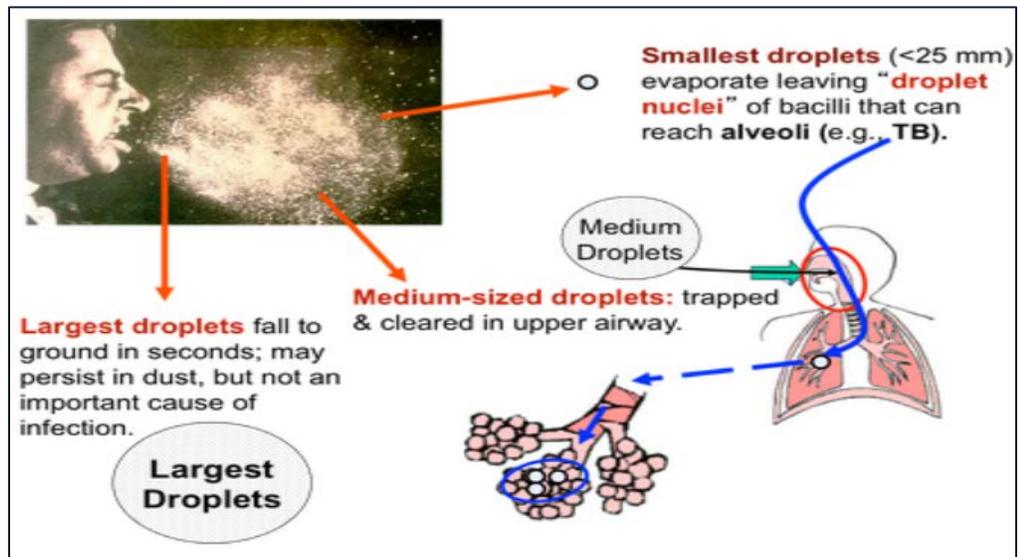
Bio-aerosol Size

Bio-aerosols size and reach into the Respiratory Tract:

- $>10 \mu\text{m}$ in aerodynamic diameter blocked by nasal region
- Between 5 and $10 \mu\text{m}$ deposit in the upper respiratory system
- $\leq 5 \mu\text{m}$ can reach the alveoli and cause lower respiratory tract infection

Based on size and persistence as an aerosol, the World Health Organization uses a particle diameter of $5 \mu\text{m}$ to delineate between

- Airborne ($\leq 5 \mu\text{m}$)
- Droplet ($> 5 \mu\text{m}$) transmission



Droplet / Airborne

Droplet transmission

- Bio-aerosol likely to settle quickly, typically within 3 feet of source
- Large particles $> 5 \mu\text{m}$
- For droplet transmission: target (susceptible individual) must be close enough to source (infected individual) for the droplet (containing infectious microorganism) to make contact with the susceptible individual's respiratory tract, eyes, mouth, nasal passages

Airborne transmission

- Bio-aerosol remain suspended in air for long periods of time
- Transported by air currents
- Small particles $\leq 5 \mu\text{m}$
- Target may be far away: different rooms

Bio-aerosol Size and Persistence in the Air

A droplet of	will fall in
100 μm	10 seconds
40 μm	1 minute
20 μm	4 minutes
10 μm	20 minutes
5-10 μm	30-45 minutes
$\leq 5 \mu\text{m}$ Droplet nuclei	May be inhaled to alveoli

The Five Parts of Bio-aerosol Transmission

- Emission of contaminated aerosol
- Transport of droplets through air
- Heat and mass interaction between bio-aerosol and air;
- Microorganism presence and viability
- Inhalation and deposition of droplets on the respiratory tract

Emission of Bio-aerosols

Sources of Bio-aerosols

- Infectious persons
- Health Care sources
 - Nebulizers,
 - Sputum induction
 - Bronchoscopy
- Indoor sources:
 - Humidifiers,
 - Heating, ventilation, and air conditioning (HVAC) systems
 - Washing, flushing toilet, showering, sweeping floor
 - Dusts in air conditioners, ceiling tile, carpet

- Laboratory activities
- Outdoor sources:
 - Cooling tower water
 - Dusts: construction, roads...

Activity	Bio-aerosol Count	Droplet Nuclei after 30 mn	Units
Sneezing	40,000		Per sneeze
Bowel Evacuation	20,000		Per event
Vomiting	1,000		Per event
Coughing	500-800	200	Per cough
Talking	1,800	100	Per 100 words

Cough Mechanical Events

Rapid successions of:

- Deep initial inspiration;
- Tight closure of the glottis, reinforced by supraglottic structures;
- Forceful contraction of the expiratory muscles;
- Sudden opening of the glottis while the contraction of the expiratory muscles continues.
- High intrapulmonary pressure → very rapid airflow from the lungs once glottis opens.
- Combination of high airflow and airway narrowing results → expulsion of airstream with linear velocity sometimes nearing the speed of sound.
- Explosive sound of coughing results from vocal cords vibrations , mucosal folds above and below the glottis, and accumulated secretions

Cough Produces Good Droplet Nuclei

- 1 good cough → 465 DN
- after 30 minutes → 228 DN (49%)

Infectious & Non Infectious Bio-aerosols

Two classes of biological hazards exist, based on the characteristics of bio-aerosol microorganisms:

1. Infectious hazards (viruses, pathogenic bacteria);
2. Non-infectious hazards (non-pathogenic bacteria and molds).

Infectious bio-aerosols

- Must be living to cause infections
- Must penetrate and develop in host
- Cause lesions by multiplying /secreting toxins /spreading through the bloodstream

Non-infectious bio-aerosol:

- Microorganisms found in the environment
- Even when dead, can produce immunological or toxic reactions when inhaled (Example Molds)

Bacterial survival:

- Airborne Gram-negative bacteria do not survive well at high RH
- Some airborne Gram-positive bacteria survive poorly at intermediate RH

Fungal survival:

Higher concentrations in summer and fall reflect higher temperatures & humidities and resulting increases in microbiological

Temperature

Viral survival:

- Higher temperature → lower virus survival
- Low temperatures (i.e., 7°C- 8°C) ideal for airborne influenza survival
- Survival decreasing at 20°C - 24°C
- Very low at high temperatures >25°C
- Bacteria are more resistant to temperature than viruses

Duration of viral shedding:

- Peak duration of viral shedding longer at 5°C than at 20°C comparing last day of nasal wash titer 10⁶ PFU/ml
- Duration likely cause of increased transmission in cold conditions.

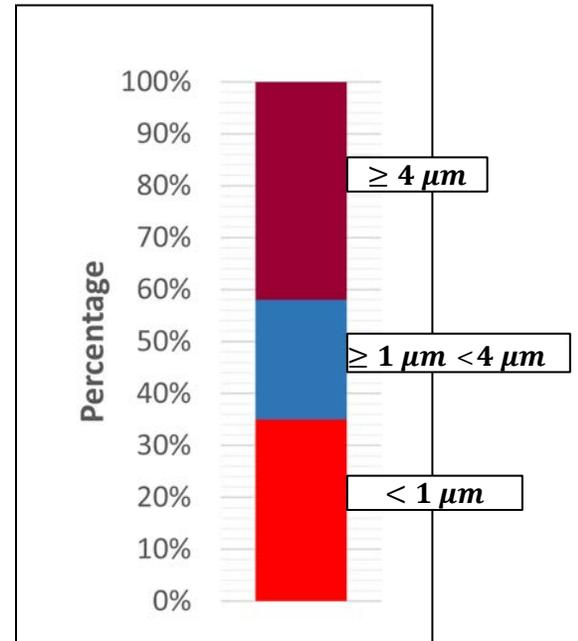
Microorganisms Presence & Viability

Infectious Dose

Infectious Doses of Microorganisms or Diseases and Inoculation Routes			
Microorganisms or Diseases	Infectious Dose	Route	Note
<i>Mycobacterium tuberculosis, M. bovis</i>	10	Inhalation	
<i>Bacillus anthracis</i>	8,000-50,000	Inhalation	
Tularemia (<i>Francisella tularensis</i>)	5-10	Inhalation	
	10,000,000	Ingestion	
Q fever (<i>Coxiella burnetii</i>)	10	Inhalation	
Influenza	800+	Inhalation	
Coxsackie A21 virus (<i>Enterovirus</i>)	18	Inhalation	
Adenovirus	150+	Intranasal	
Respiratory syncytial virus	100-600	Intranasal	
<i>Histoplasma capsulatum</i>	10	Inhalation	Mice

Influenza RNA in Aerosols

- Measurements of amount and size of aerosol particles containing influenza virus produced by coughing done to understand transmission
- Student with ILI
- Collection of nasopharyngeal swabs then 3 coughs into a spirometer
- Cough-generated aerosol collected using a NIOSH two-stage bio-aerosol cyclone sampler or an SKC BioSampler
- Amount of influenza viral RNA in samplers analyzed using quantitative RT Reverse-Transcription PCR targeting gene M1
- Tested 58, positive flu qPCR 47, flu viral RNA detected in coughs from 38 subjects (81%)
- Coughing by influenza patients emits aerosol particles containing influenza virus
- Much of the viral RNA is contained within particles in the respirable size range
- Airborne route may be a pathway for influenza transmission, especially in the immediate vicinity of an influenza patient.
- Aerosol particles exhaled by influenza patients collected
- Patients shed about
 - 33 viral copies/minute in aerosol particles $\geq 5 \mu\text{m}$
 - 187 viral copies/minute in particles $< 5 \mu\text{m}$.
- Surgical masks substantially reduced particle release (especially for large particles), and found culturable virus in the breath from two subjects.



Inhalation and Deposition of Bio-aerosols on the Respiratory Tract

The 5-10 scheme

- $> 10 \mu\text{m}$ in aerodynamic diameter blocked by nasal region
- Between 5 and $10 \mu\text{m}$ deposit in the upper respiratory system
- $\leq 5 \mu\text{m}$ can reach the alveoli and cause lower respiratory tract infection

The 2-6 scheme

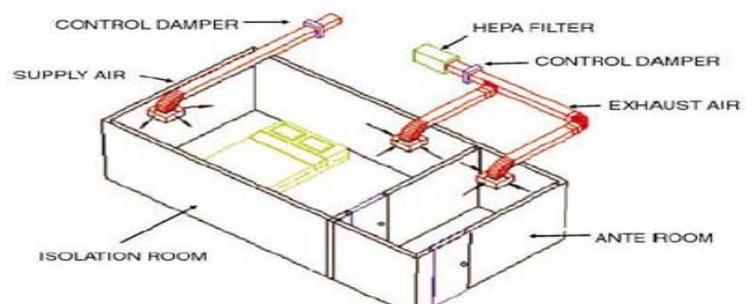
- Particles $> 6 \mu\text{m}$ mainly deposit in the upper airway
- Particles $< 2 \mu\text{m}$ mainly deposit in the alveolar region

Prevention: Isolation . Precautions

Airborne Precautions

1-ROOM WITH VENTILATION CONTROL

- Negative air pressure
- > 6 air exchange /hour
- HEPA filtered or exhaust out



2-PERSONAL RESPIRATOR

3-PATIENT wears surgical mask if coughing & when transported

Airborne Precautions: Personal Respirator

For Personnel

- In AIRBORNE ISOLATION ONLY
- To prevent inhalation of droplet nuclei
- Main leak comes from poor fit around face

Diseases requiring Airborne Precautions

- Tuberculosis (Infectious)
- Suspects of TB: request sputum smear
- Measles
- Varicella
- Smallpox (hemorrhagic)

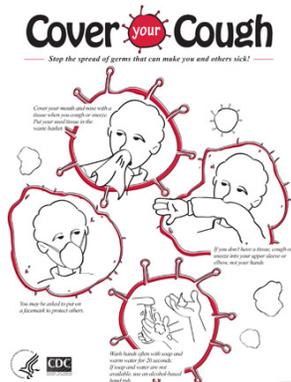
Droplet Precautions

- Private room
- Mask when entering room

Diseases Requiring Droplet Precautions

- *Hemophilus influenzae*
- Meningococci
- Pneumococcal infections (invasive, resistant)
- BACTERIAL RESPIRATORY Infections
- Diphtheria, Pertussis, pneumonic plague, *Mycoplasma pneumoniae*
- Strepto-pharyngitis, pneumonia, scarlet fever
- VIRAL RESPIRATORY Infections
- Adenovirus, Influenza, Mumps, Parvovirus, Rubella
- ANY PAROXYSMAL COUGH (Pertussis?)

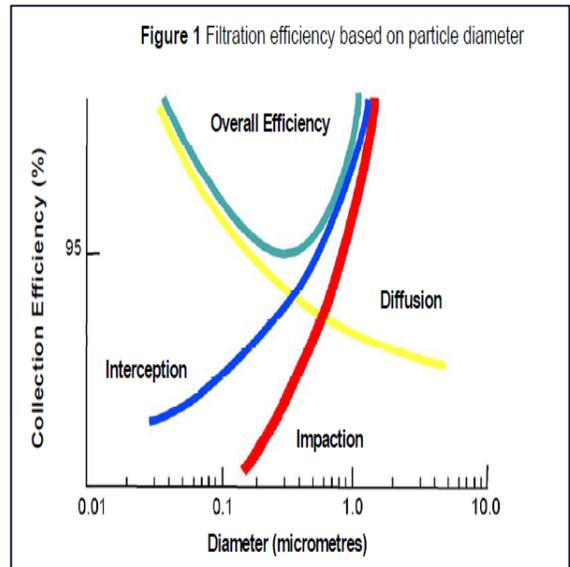
Respiratory Etiquette



Prevention: Personal Protective Equipment Collection Efficiency

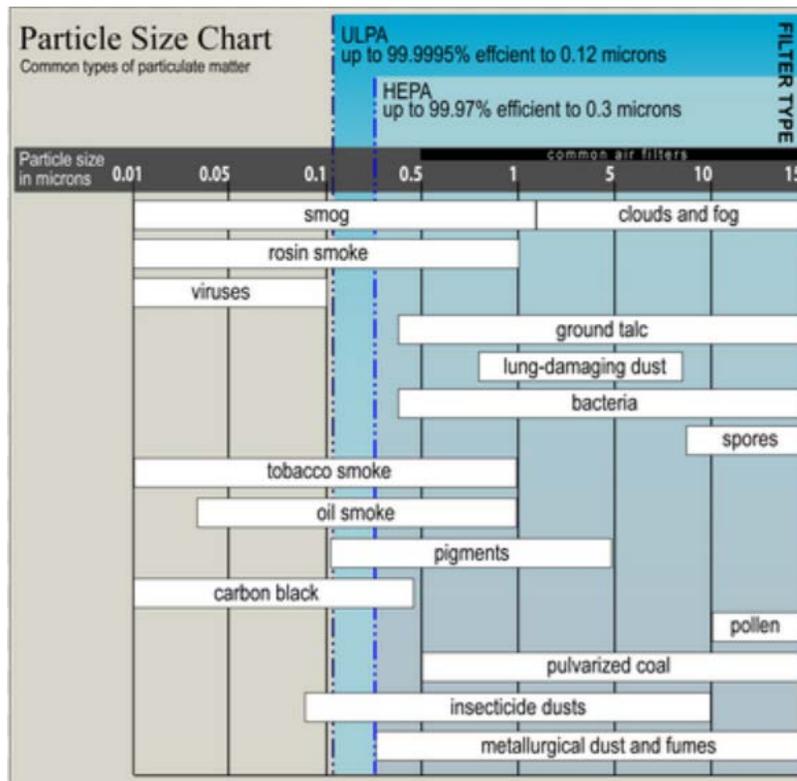
Several mechanisms affect behavior of particles in the air:

- Diffusion, by Brownian motion
- Sedimentation
- Impaction
- Interception and
- Electrostatic force..
- For each type of filter, there is a particle diameter that minimizes the collection efficiency.
- Several well-known institutions consider the 0.3-micrometre (μm) particle as being the one that penetrates the deepest based on tests on respirator filters
- It is the basic parameter for certification tests carried out on respirators in European standard EN149: 2001, NIOSH 42 CFR Part 84, and Australian Standard AS1716
- N95 filter respirator retains 95% of the most penetrating particles, meaning 0.3-micrometre (μm) particles, while the N99 retains 99%, and the N100, close to 100%.



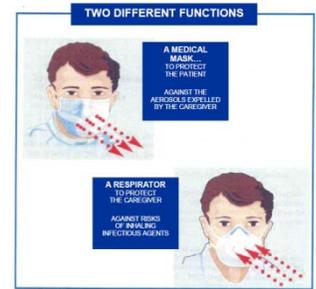
- The respirators must fit well. Seal must be checked before each use, except for some loose-fitting models (e.g., powered air-purifying respirator with loose-fitting facepiece/visor or supplied-air)

HEPA Filters



Simple Mask or Respirator

- Surgical masks designed to protect sterile field from respiratory secretions of wearer
- Respirators designed to protect the wearer from inhalation of air borne aerosols
- Protection depends on
 - Efficiency of filter
 - Fit (seal between facepiece and face)
- Surgical masks are not respiratory protection devices for wearer



Surgical Masks

STANDARD PRECAUTIONS

For personnel to protect from splashes /sprays of BBF/ S E

DROPLET PRECAUTIONS

to prevent large droplets (>5µm) on/from patient

For patients: to prevent emission of droplet (large and droplet nuclei)



N95 Respirator

- N95 respirator most commonly used in industrial /health care
- N95 respirators have higher filtration efficiencies than Dust/Mist (DM) and Dust/Fume/Mist (FM)
- N95 respirators made by different companies have different filtration efficiencies for the most penetrating particle (0.1 to 0.3 µm), but at least 95% efficient at that size for NaCl particles
- Filtration efficiency increases with size; it reaches approximately 99.5% or higher at 0.75 µm
- Tests with bacteria of size and shape similar to *Mycobacterium tuberculosis* showed filtration efficiencies of 99.5% or higher
- Aerosol mass concentrations inside respirator without face leakage: 0.02% for large particle to 1.8% for sub-micrometer-size welding fumes → N95 respirators provide excellent protection against airborne particles when there is a good face seal.



Fit Test

- Respirators of N95 Type must be properly adjusted to the user. They must be put on in such a way that they form a tight seal with the face to prevent contaminated air from entering the filtering facepiece around its periphery
- Qualitative evaluation by assessing the subjective perception of the odor or taste of a product (saccharine, bitrex or other) in a test chamber
- Electronic instruments will fulfill the same objectives, quantitatively.
- The equipment must also be chosen, fit, used and cared for according to CSA standard Z94.4-93
- Selection, Use, and Care of Respirators. In addition, a respiratory protection program must be developed and applied by complying with this standard.



Seal Check

Check seal of filtering facepieces before each use.

Negative pressure test:

- Put on respirator and tighten straps (if adjustable)
- Block filter or the filtering surface with your hands without deforming it, for a short period of time
- Disconnect the hose or shut off the air supply if it is a powered or supplied-air respirator
- Inhale to create a vacuum and check whether the respirator flattens somewhat; if not, there is a leak in the face seal or in a component.



Positive pressure test:

- Must be carried after the negative pressure seal checks
- Lightly cover the filter or the filtering surface with hands without crushing it or deforming it
- Exhale into the facepiece
- If the seal is good, the facepiece will bulge slightly. If not, the respirator must be re-adjusted.

Powered air-purifying respirators – PAPR

- The purpose of this type of respirator is to take exterior air (suspected of being contaminated) with one or more types of pollutants (bio-aerosols for example), filter out those pollutants and then supply the air to the user
- Different units for different environments
- Units consist of a powered fan which forces incoming air through filters for delivery to the user for breathing. Fan and filters are carried by the user
- The type of filtering must be matched to the contaminants: fine particulates (dust, bio-aerosol), volatile organic compounds (spray paints)



Prevention: Environment

HVAC

Seven actionable items to reduce airborne particle risk

1. Minimize filter bypass by sealing, caulking, and gasket filter cartridges, retainer banks, and tracking
2. Commission buildings during design and construction, and recommission routinely to ensure ventilation systems operating as intended
3. Increase air filtration to the maximum economically justifiable Minimum Efficiency Reporting Value (MERV) level or properly supplement with engineered UVPCO oxidative technology
4. Maintain filter systems by regular inspections
5. Ensure proficiency of HVAC maintenance staff
6. Tighten building envelope to reduce infiltration rate
7. Pressurize building to reduce the infiltration rate.

MREV Rating Chart

Standard 52.5 Minimum Efficiency Reporting Value	Dust Spot Efficiency	Arrestance	Typical Controlled Contaminant	Typical Applications and Limitations	Typical Air Filter/Cleaner Type
20	n/a	n/a	< 0.30 µm particle size	Cleanrooms	≥99.999% eff. On .10-.20 µm Particles
19	n/a	n/a	Virus (unattached)	Radioactive Materials	Particulates
18	n/a	n/a	Carbon Dust	Pharmaceutical Man.	Particulates
17	n/a	n/a	All Combustion smoke	Carcinogenic Materials	>99.97% eff. On .30 µm Particles
16	n/a	n/a	.30-1.0 µm Particle Size	General Surgery	Bag Filter- Nonsupported
15	>95%	n/a	All Bacteria	Hospital Inpatient Care	microfine fiberglass or synthetic media, 12-36 in. deep, 6-12 pockets
14	90-95%	>98%	Most Tobacco Smoke	Smoking Lunges	Box Filter- Rigid Style Cartridge Filters 6 to 12" deep may use lofted or paper media.
13	89-90%	>98%	Propel Nuclei (Sneeze)	Superior Commercial Buildings	
12	70-75%	>95%	1.0-3.0 µm Particle Size Legionella	Superior Residential	Bag Filter- Nonsupported microfine fiberglass or synthetic media, 12-36 in. deep, 6-12 pockets
11	60-65%	>95%	Humidifier Dust Lead Dust	Better Commercial Buildings	Box Filter- Rigid Style Cartridge Filters 6 to 12" deep may use lofted or paper media.
10	50-55%	>95%	Milled Flour Auto Emissions	Hospital Laboratories	
9	40-45%	>90%	Welding Fumes		
8	30-35%	>90%	3.0-10.0 µm Particle Size	Commercial Buildings	Pleated Filters- Disposable, extended surface area, thick with cotton-polyester blend media, cardboard frame
7	25-30%	>90%	Mold Spores Hair Spray	Better Residential	Cartridge Filters- Graded density viscous coated cube or pocket filters, synthetic media
6	<20%	85-90%	Fabric Protector Dusting Aids	Industrial Workplace	Throwaway- Disposable synthetic panel filter.
5	<20%	80-85%	Cement Dust Pudding Mix	Paint Booth Inlet	
4	<20%	75-80%	>10.0 µm Particle Size	Minimal Filtration	Throwaway- Disposable fiberglass or synthetic panel filter.
3	<20%	70-75%	Pollen Dust Miles	Residential	Washable- Aluminum Mesh
2	<20%	65-70%	Sanding Dust Spray Paint Dust		Electrostatic- Self charging woven panel filter.
1	<20%	<65%	Textile Fibers Carpet Fibers	Window A/C Units	

Bio-aerosols as Biological Weapons

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