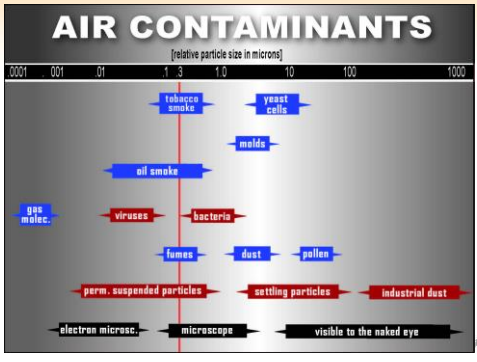
EVE 402/502
Air Pollution Generation and Control

Chapter #5
Particulate Control

Airborne Particulate Terminology

Particulate Matter	Any solid or liquid material that exists in the atmosphere or gas stream at standard conditions
Aerosol	A dispersion of microscopic solid or liquid particles in gaseous media
Dust	Solid particles larger than colloidal size capable of temporary suspension in air
Fly ash	Finely divided particles of ash entrained in flue gas; particles may contain unburned fuel
Fog	Visible aerosol
Fume	Particles formed by condensation, sublimation, or chemical reaction; mostly smaller than 1 mm
Mist	Dispersion of small liquid droplets of sufficient size to fall from the air
Particle	Discrete mass of solid or liquid matter
Smoke	Small particles resulting from combustion
Soot	An agglomeration of carbon particles
PM_{10}	Particles with aerodynamic diameter ≤ 10 mm
$PM_{2.5}$	Particles with aerodynamic diameter ≤ 2.5 mm
$PM_{2.5-10}$	Particles with aerodynamic diameter between 10 and 2.5 mm

Sizes of Various Particulate



Types of Particulate Aerosols: Dust

- Solid aerosols generated by the handling, grinding, abrasion, or cutting of a bulk material
- Dust particle size is related to the amount of energy involved in creation: the higher the energy, the smaller the particle created; the lower the energy, the larger the particle created
- Examples: Saw dust, coal dust

Types of Particulate Aerosols: Mists

- Liquid aerosols generated by condensation from a gaseous state or by the breaking up of a bulk liquid into a dispersed state
- Droplet size related to energy input as in dusts
- Examples: Metal working fluid from lathe, paint spray, liquid mixing operations

Types of Particulate Aerosols: Smoke

- Solid aerosols resulting from the incomplete combustion of carbonaceous materials
- Wide range of particle sizes
- Size related to combustion efficiency
  - High efficiency = smaller particles
  - Low efficiency = larger particles
- Examples: Wood smoke, diesel exhaust

Types of Particulate Aerosols: Fumes

- Solid aerosols generated by the condensation of vapors or gases from combustion or other high temperature processes
- Usually very small and spherical
  - Sources: Welding, foundry and smelting operations, hot cutting or burning operations

Types of Particulate Aerosols: Bioaerosols

- Solid or liquid aerosols from biological sources
- May be infectious, allergenic, and/or irritating
- Wide range of particle sizes
  - Virus (0.002 – 0.03 µm)
  - Tree pollen (10 – 100 µm)
- Examples: Mold spores, animal allergens, anthrax

Types of Particulate Aerosols: Fibers

- A special kind of dust, based on toxicological properties, that is fibrous in nature (i.e., longer than it is wide)
- Aspect ratio (L:W) defined as 3:1 or higher
- Toxicity a function of composition, size, and number of fibers
- Examples: Asbestos, fiberglass, refractory ceramic fibers

Particles and Disease

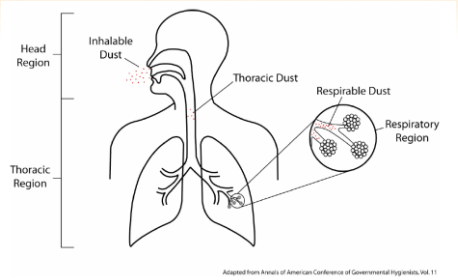
Cytotoxic Dusts

- Direct effect on the lungs
- Examples of lung diseases caused by the inhalation of dust (these are pneumoconioses)
  - Silica—Silicosis
  - Asbestos—Asbestosis (increased mesothelioma risk)
  - Coal Dust—Black lung disease
  - Beryllium—Berylliosis (chronic beryllium disease)
- Knowing how much and where a dust will deposit in the lungs is important for risk determination

Aerosols and Disease

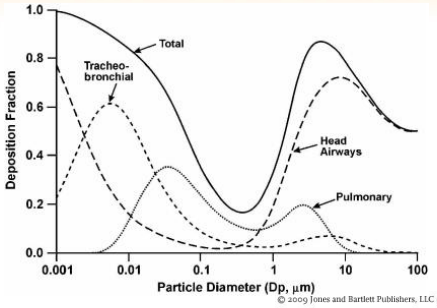
- Disease potential is a function of:
  - Chemical properties of particle
  - Site of particle deposition in respiratory system
    - Head region
    - Thoracic region
    - Respiratory region

Regional Particle Deposition



Adapted from Annals of American Conference of Governmental Hygienists, Vol. 11

Maximal Pulmonary Deposition
(NCRP 1997; ICRP 1995)



Old Particle-Size Conventions

- Non-respirable fraction (>10 µm)
  - Can be breathed into nose or mouth, penetrate head airways, and enter lung airways
- Respirable fraction (<10 µm)
  - Can penetrate beyond terminal bronchioles to gas exchange region

New Particle-Size Conventions

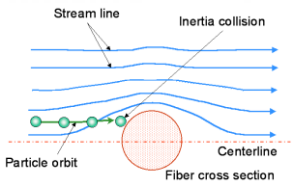
- Inhalable fraction (<100 µm)
  - Can be breathed into nose or mouth
- Thoracic fraction (<25 µm)
  - Can penetrate head airways and enter lung airways
- Respirable fraction (<10 µm)
  - Can penetrate beyond terminal bronchioles to gas exchange region

Mechanisms of Particle Deposition

Mechanisms of Particle Deposition in the Lung

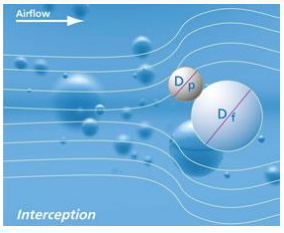
- Inertial impactions
  - Function of particle velocity and mass
- Interception
  - Function of particle diameter
- Sedimentation (gravitational settling)
  - Function of particle velocity (residence time) and mass
- Diffusion (Brownian motion)
  - Function of particle diameter, concentration, velocity (time), and distance

Inertial impaction



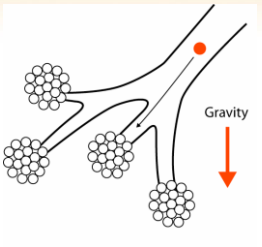
- The process whereby a particle moving in a gas stream is unable to remain in the streamline when the gas changes direction (turns). As a result, the particle strikes a stationary obstacle (e.g., surface in respiratory system) directly in its path and is removed from the air.

Interception



- The process whereby a particle moving in a gas stream remains in that airstream but, because of its dimensions, strikes a stationary obstacle (e.g., surface in respiratory system) and is removed from the air.

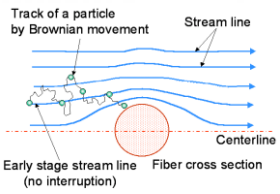
Sedimentation (gravitational settling)



Adapted from http://www.mfg.mtu.edu/cyberman/environment/air/depos.html

- The process by which a particle in an airstream is pulled downward by gravity until it strikes a stationary obstacle (e.g. surface in respiratory system) and is removed from the air.

Diffusion (Brownian motion)



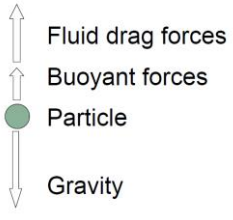
- Random movement of small particles caused by bombardment of gas molecules that eventually causes the particle to strike a stationary obstacle or surface, which leads to the removal of the particle from the gas.

Particle Size

Behavior of Aerosols

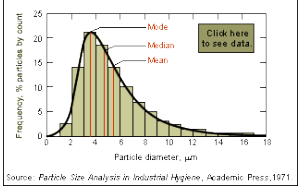
Airborne behavior, such as settling velocity, is a function of:

- Size
- Specific gravity
- Shape
- Surface properties



Particle sizes of an aerosol are typically log-normally distributed

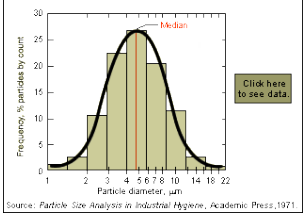
Figure 2. Histogram of a Particle Size Distribution



Source: *Particle Size Analysis in Industrial Hygiene*, Academic Press,1971

Log transformation of particle size distribution is normally distributed

Figure 3. Histogram of a Lognormal Particle Size Distribution



Source: *Particle Size Analysis in Industrial Hygiene*, Academic Press,1971

Coal Fly Ash Distribution