5 key things to know about real-time aerosol measurement instruments

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UNDERSTANDING, ACCELERATED

Goal – to appreciate the value of real-time aerosol measurement instruments.

What are aerosols

How are aerosols measured

Types of real time aerosol instruments

1. How light scattering photometric instruments work
2. Strengths and limitations of photometric aerosol instruments
3. The value of real-time, logged data
4. Case Studies and application examples
5. Demonstrated return on investment

Wrap up / Q&A

What are Aerosols

- **Dust**

What are Aerosols

+ Dust
+ **Fume**

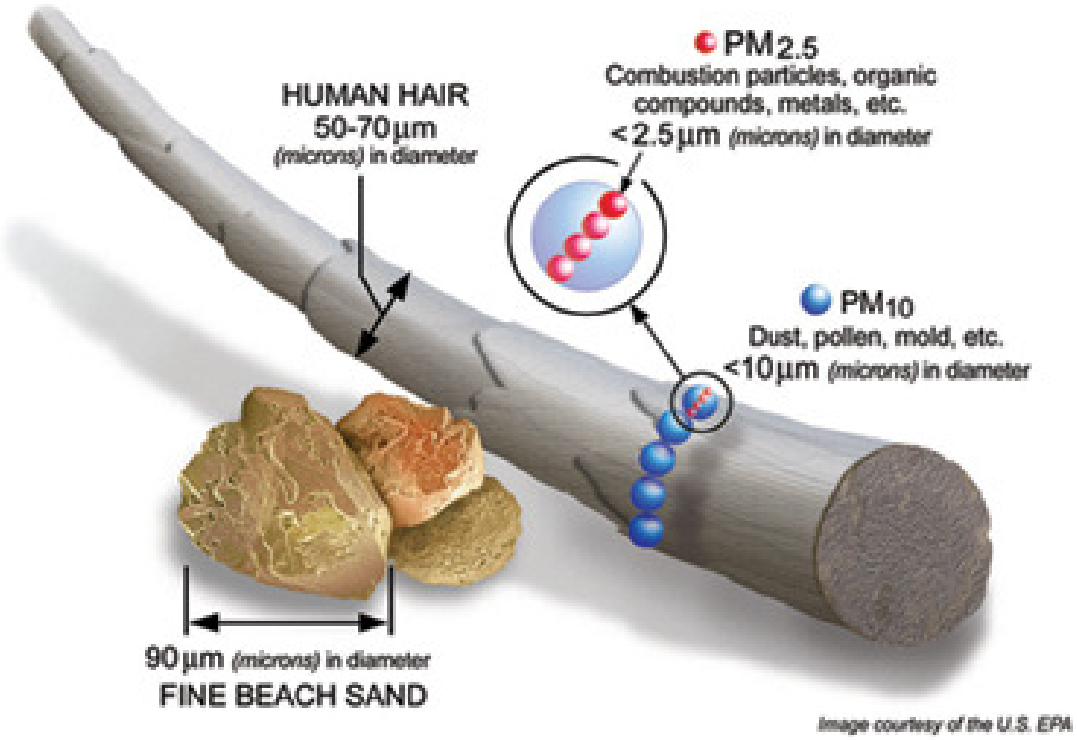
What are Aerosols

+ Dust
+ Fume
+ **Mist**

What are Aerosols

+ Dust
+ Fume
+ Mist
+ **Smoke**

Aerosol Size Matters

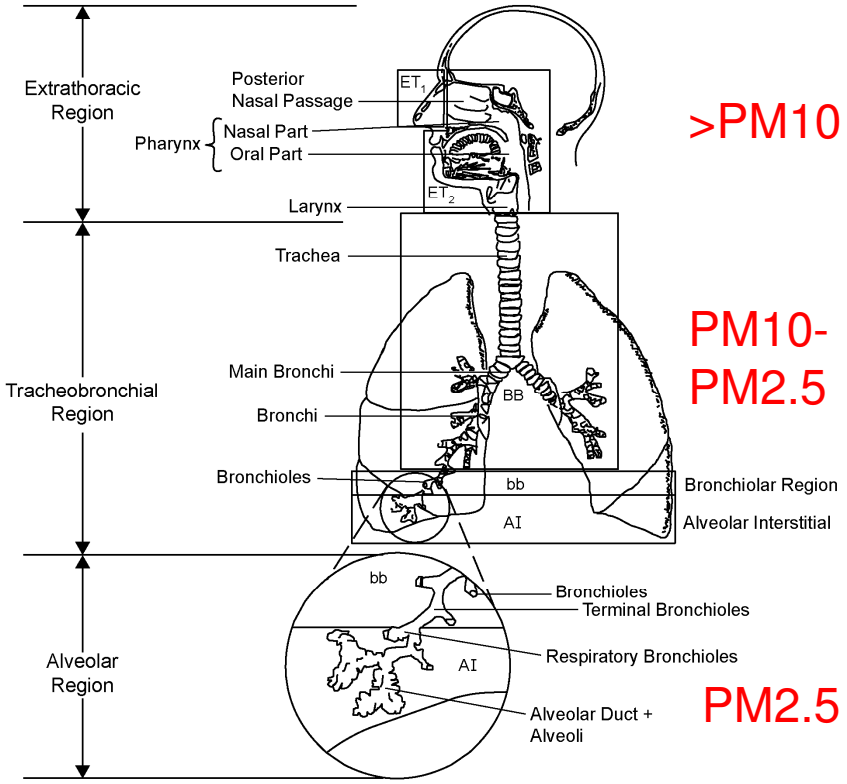


Respiratory Tract

Extrathoracic region

Tracheobronchial (TB) region

Alveolar (A) region



Based on International Commission of Radiological Protection (1994) and U.S. Environmental Protection Agency (1996a). Air Quality Criteria for Particulate matter, 2004, p 6-5.

How are aerosols measured

Gravimetric Sampling

- Sampling Pump
- Sample media
- Sampling train
- Flow calibrator
- Laboratory analysis or microbalance

How fast do you need the data?

Aerial photograph of Manhattan, NY. Sept 12, 2001
Wikipedia, source NASA

Do we evacuate or shelter?

U.S. Air Force photo/Master Sgt. Wally Bacio
https://www.flickr.com/photos/chucksimmins/2857833739

Measurement of Aerosols

Gravimetric Sampling

- Sampling Pump
- Sample media
- Sampling train
- Flow calibrator
- Laboratory analysis or microbalance

Real time measurement instruments

+ Speedometer
+ Altimeter
+ Thermometer
+ scale
+ Noise meter
+ Data logging dosimeter
+ RF Survey meter
+ PID / FID
+ Geiger counter
+ Confined Space 4-gas monitor

http://www.flickr.com/photos/oregondot/3698915292/
Oregon Department of Transportation

"Do you know how fast you were going?"

Types of real time aerosol monitoring instruments

+ Beta Attenuation Monitor (BAM)
+ Tapered Element Oscillating Microbalance (TEOM)
+ Piezoelectric microbalance
+ Aerodynamic Particle Sizer (APS)
+ Differential Mobility Analyzer Spectrometer (DMS)
+ **Integrating Nephelometer (Photometer)**
+ **Condensation Particle Counter (CPC)**
+ **Optical Particle Counter (OPC)**

"IH-based" field instruments

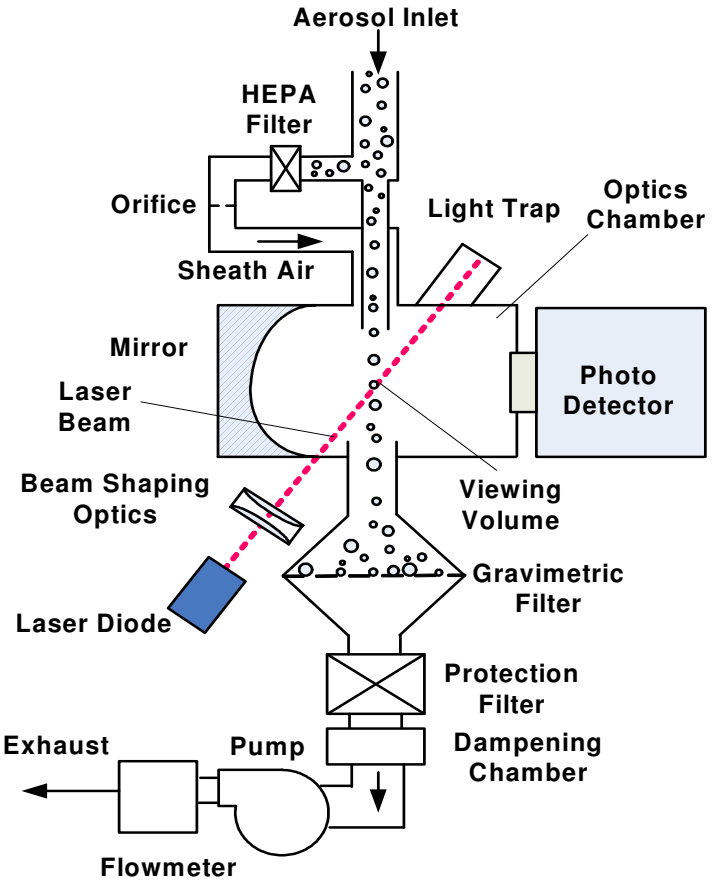
+ Photometers
+ Optical Particle Counters
+ Condensation Particle Counters

DustTrak™ DRX 8533
Photometer

AeroTrak® 9306 OPC

P-Trak® 8525
CPC

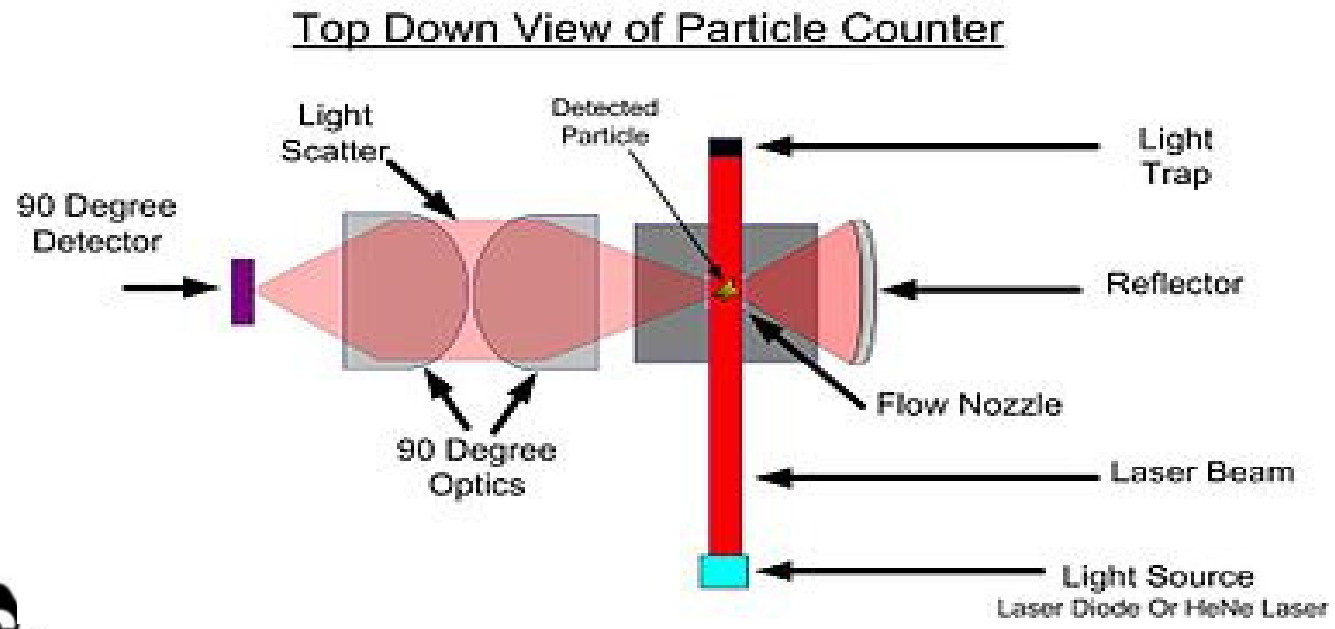
Light Scattering Photometer Technology



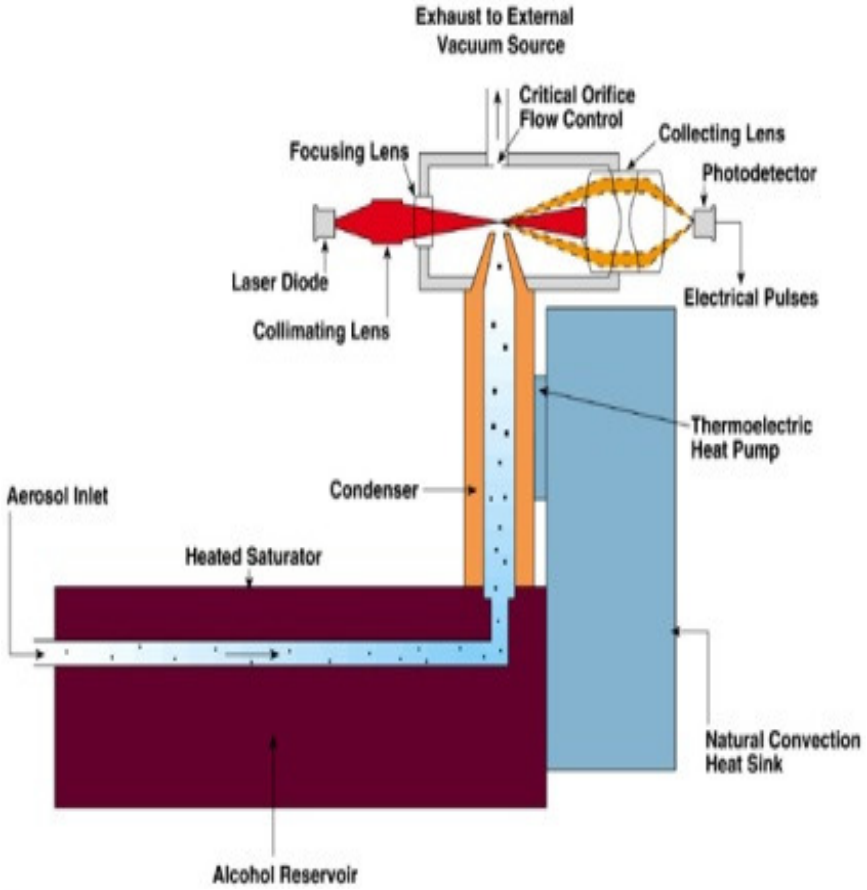
8533 DustTrak™ DRX

Optical Particle Counter (OPC)

Optical Particle Counter (OPC) – light scattered by individual particles traversing a light beam is detected at various angle. These signals are interpreted in terms of particle size via calibrations. *The TSI Aerotrak Handheld Particle Counter 9303 and 9306 use this technology.*

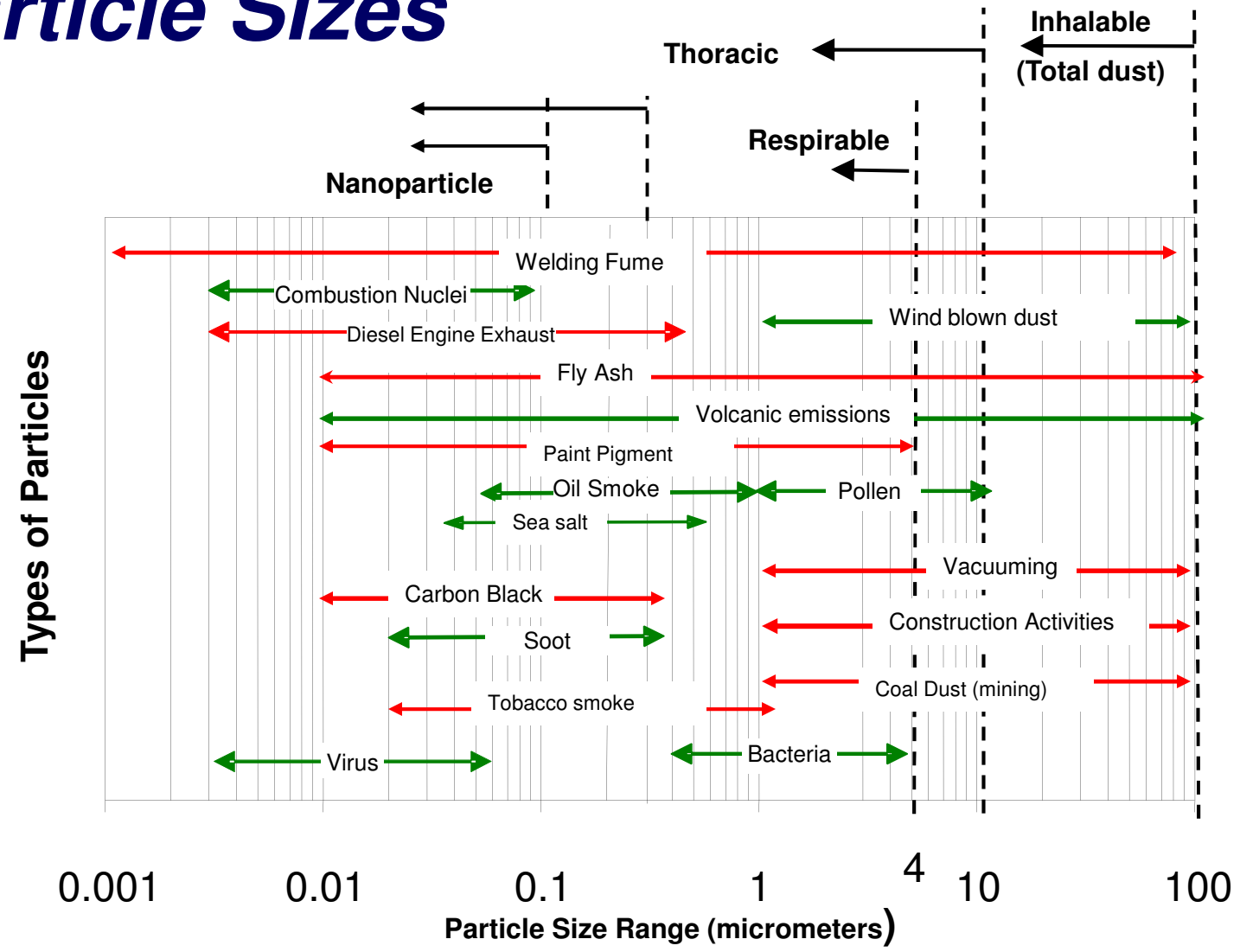


Condensation Particle Counter (CPC)



Condensation Nuclei Counter (aka Condensation Particle Counter) – This methodology uses a condensing liquid (alcohol or water) to grow the particle size large enough to be counted optically. These instrument s count numbers of particles, not mass concentration. *The TSI PortaCount and P-Trak use this technology.*

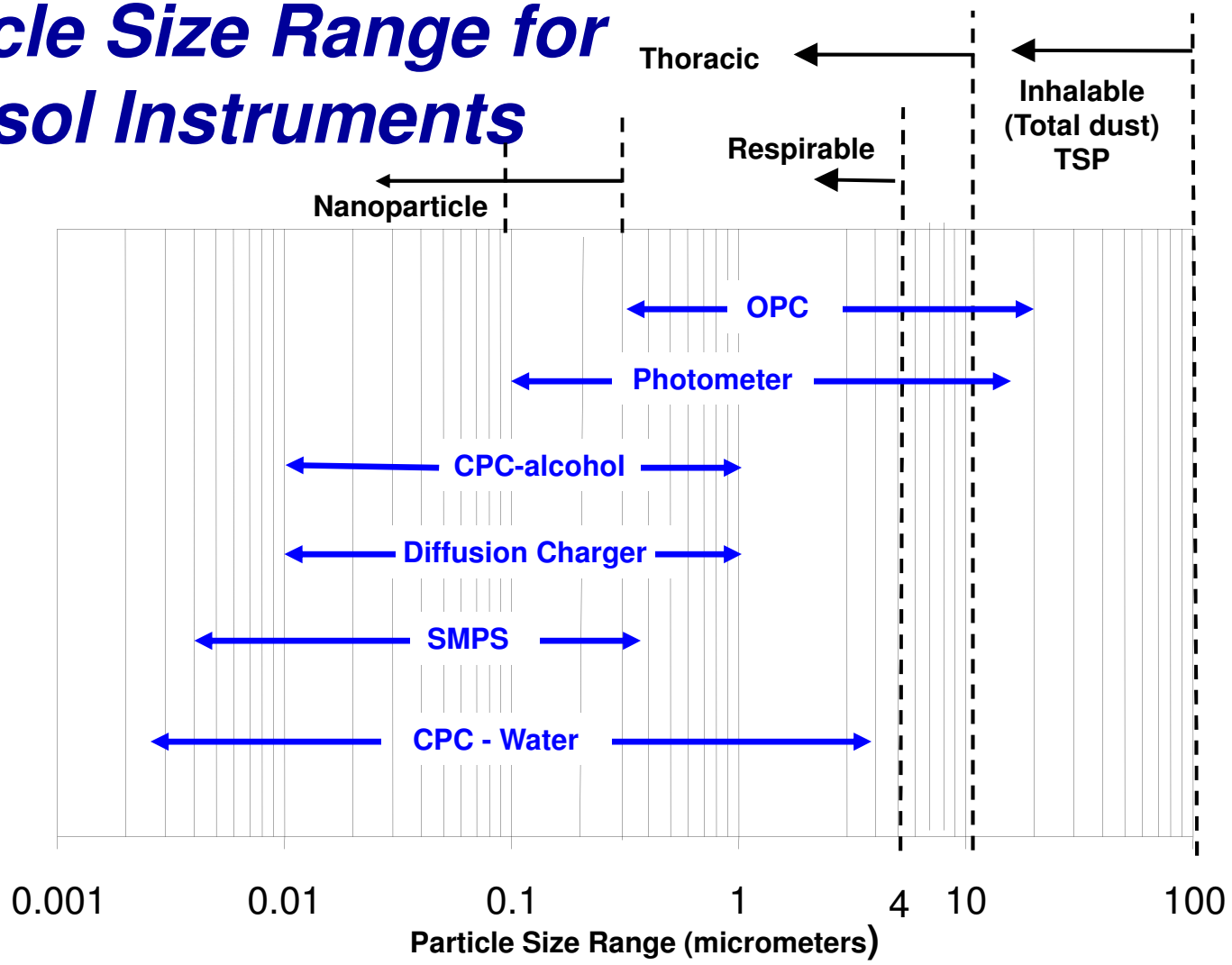
Particle Sizes



Environmental / Naturally Occurring Particles

Workplace / man-made Particles

Particle Size Range for Aerosol Instruments



Optical Particle Counter 0.3 to 25 µm

Condensation Particle Counter 0.02 to 1 µm

Photometer: 0.1 to 15 µm

Aerosol concentration measurement range

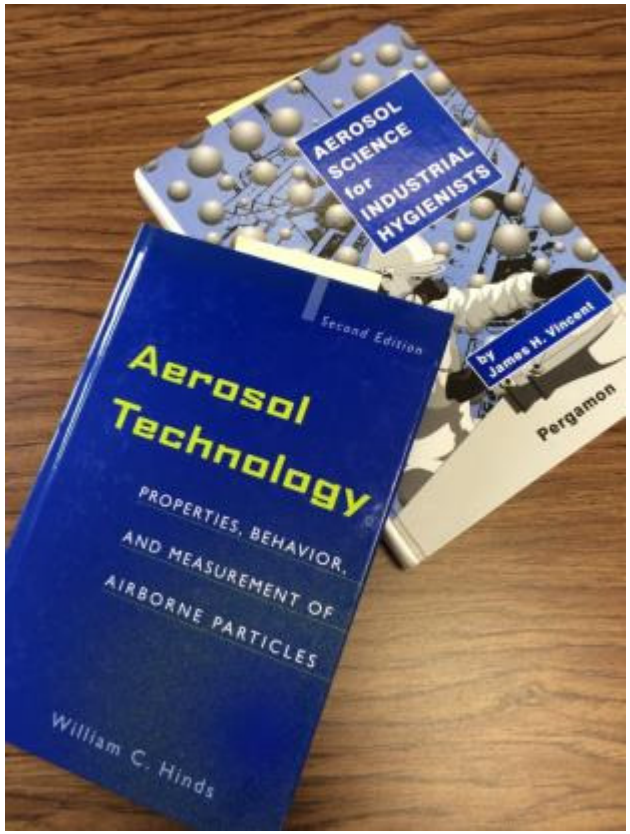
+ Photometers	0.001 – 150 mg/m3
+ Optical Particle Counters	0 – 200,000 particles/cc
+ Condensation Particle Counters	0 - 500,000 particles/cc

1. How light scattering photometric instruments work

Aerosol Basics

Physics of aerosols

- Properties
- Behavior
- Measurements



Aerosol Characteristics

Size

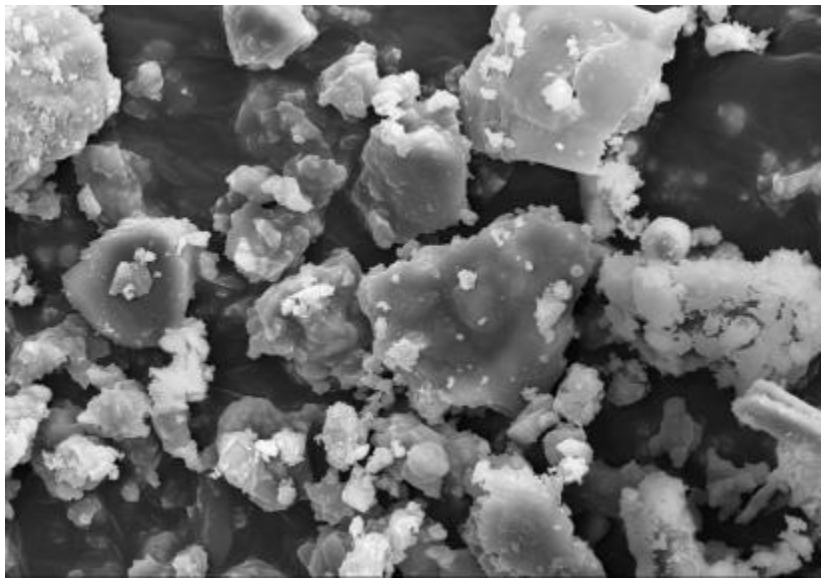
Shape

Density

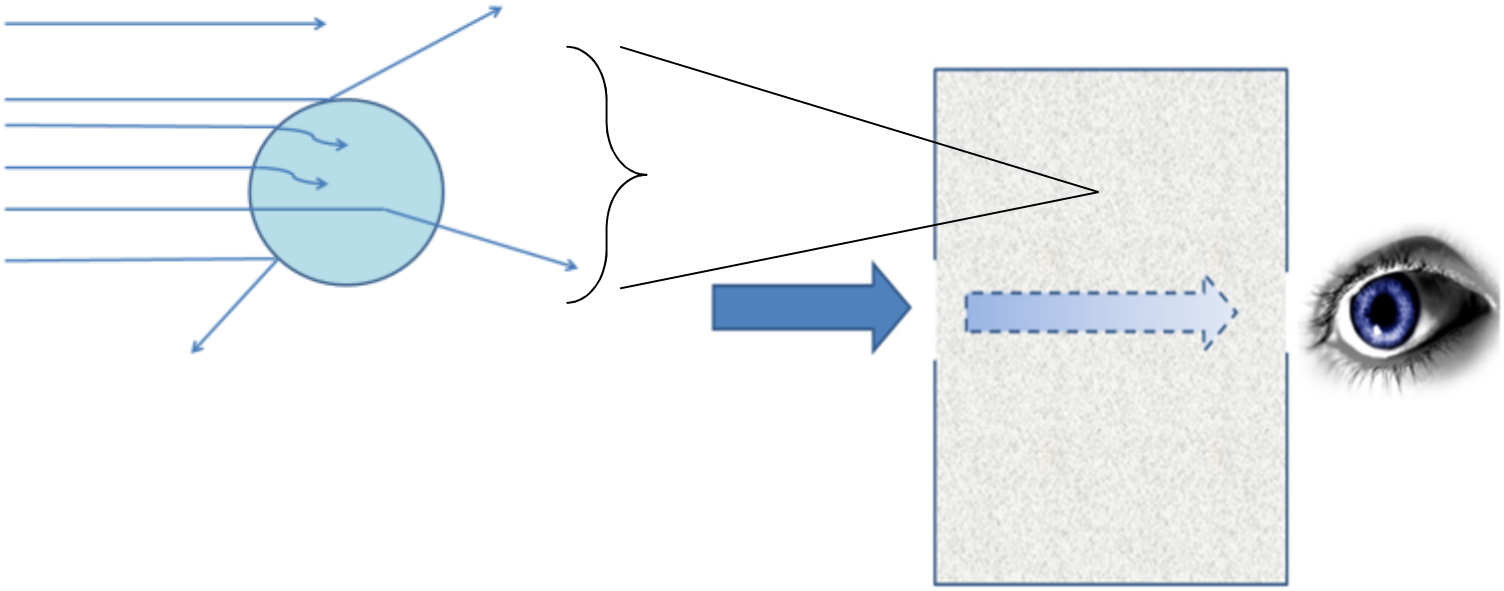
Aerodynamic diameter

Not all particles are spheres

Mass concentration is calculated from known density

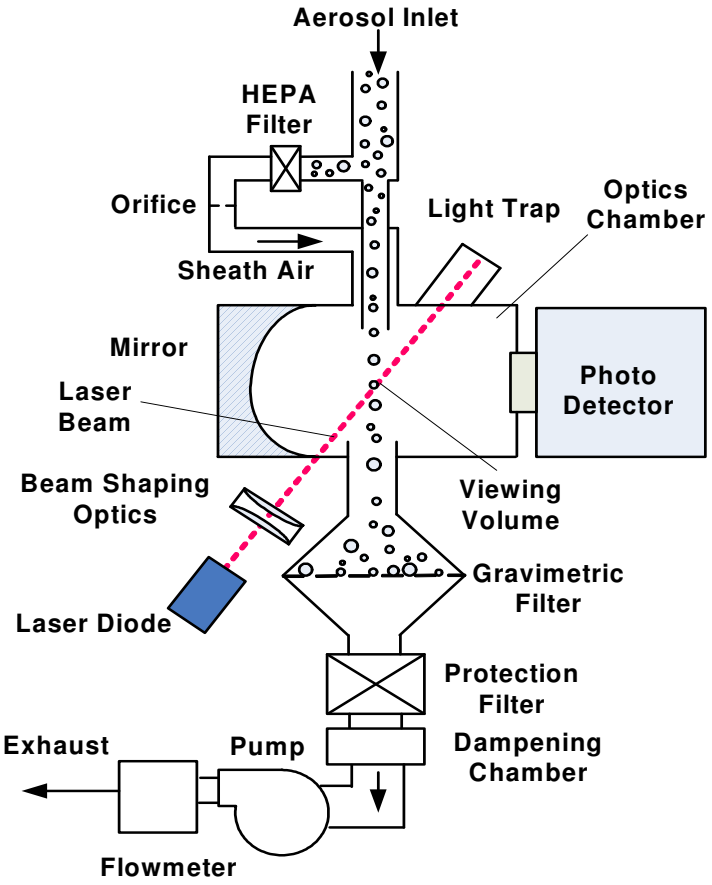


Aerosol properties



- **Aerosols absorb, reflect, refract and diffract light**
- **Light passing through an aerosol concentration is affected by the properties of the aerosol.**

Light Scattering Photometer Technology



8533 DustTrak DRX

Particle counting vs. light scattering

Particle counting is like counting the number of rain drops or snow flakes that hits the window

OPCs count the number of raindrops (or snow flakes) hitting the windshield.

- Works for certain size drops at low concentration levels

CPCs count the number of ultrafine particles

Photometric light scattering

Photometers measure the amount of light scattered by the fog.

Think of how bright the fog is in the headlights.

“thicker fog” is brighter.

A photometer would calculate more mass based on a brighter response from thicker fog based on the calibration aerosol.

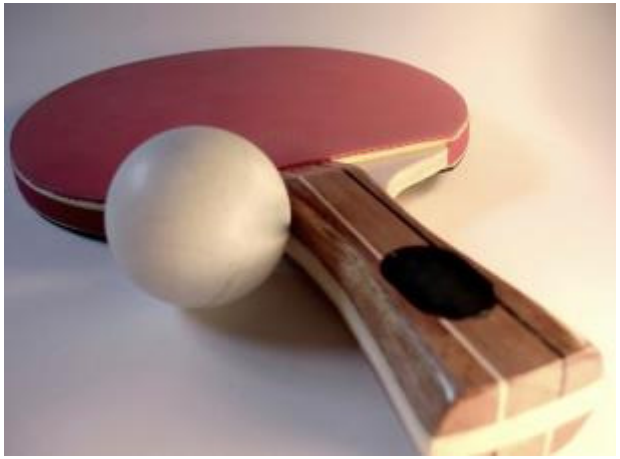
Calibration aerosol

Photometers are calibrated to a known test aerosol.

- known density
- known refractive index
- known size distribution

A bucket of golf balls will not weigh the same as a bucket of ping pong balls.

The photometer sees Ping Pong balls, but calculates mass concentration based on the calibration aerosol (golf balls)



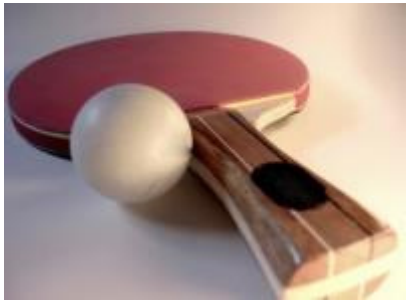
Calibration factor

Calibration factors are developed to 'inform' the instrument that the sampled aerosol is different than the test aerosol. Thus the mass measurement needs correction.

Density

Size

Refractive index

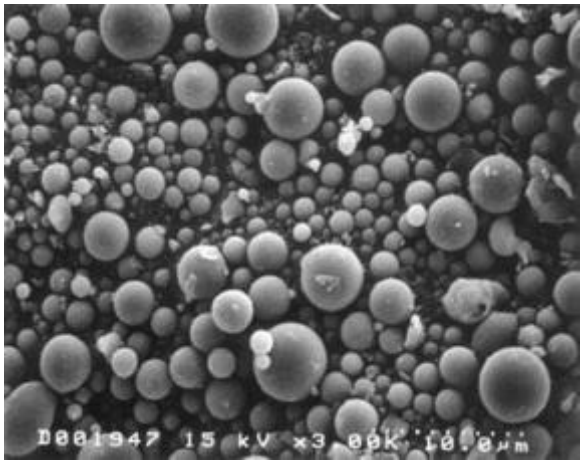


Aerosol distribution

A photometer sees aerosols of all shapes and sizes

The photometer measures the light scattering of these particles as a group.

Mass is calculated based on the properties of the calibration aerosol.



Fly ash – FHWA.dot.gov

2. Strengths and limitations of photometric aerosol instruments

limitations

Calibrated to test aerosol

Humidity effects

Contaminated optics

Calibrated to test aerosol

+ Precise instrument response to all aerosol

+ Response to aerosol similar to calibration aerosol will more closely match actual gravimetric result

+ Use side-by-side gravimetric results to develop custom calibration factors (K factors)

Humidity effect

+ Hygroscopic aerosols swell as humidity levels increase

+ Photometric instrument readings will be elevated in humid conditions

+ Inlet conditioners to reduce the effects of humidity are added to photometric instruments for long term environmental monitoring

Optic contamination

+ High aerosol levels can result in contaminated optics and measurement drift

+ Zeroing the instrument regularly helps correct

+ Use size selective inlet conditioners to sample only small size fractions

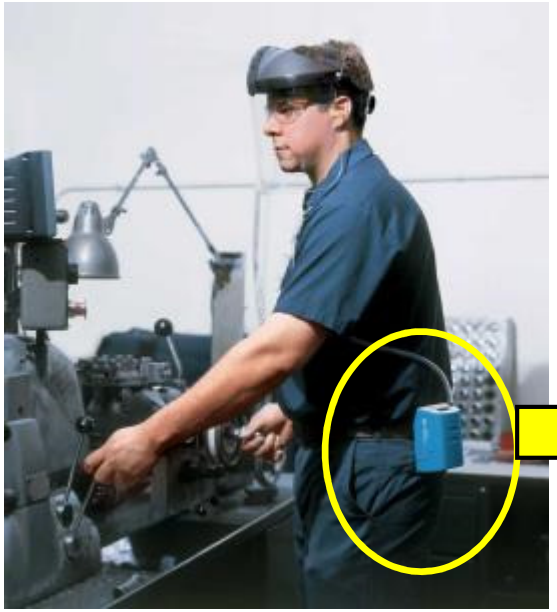
Strengths

Real-time
Data logging
Alarms

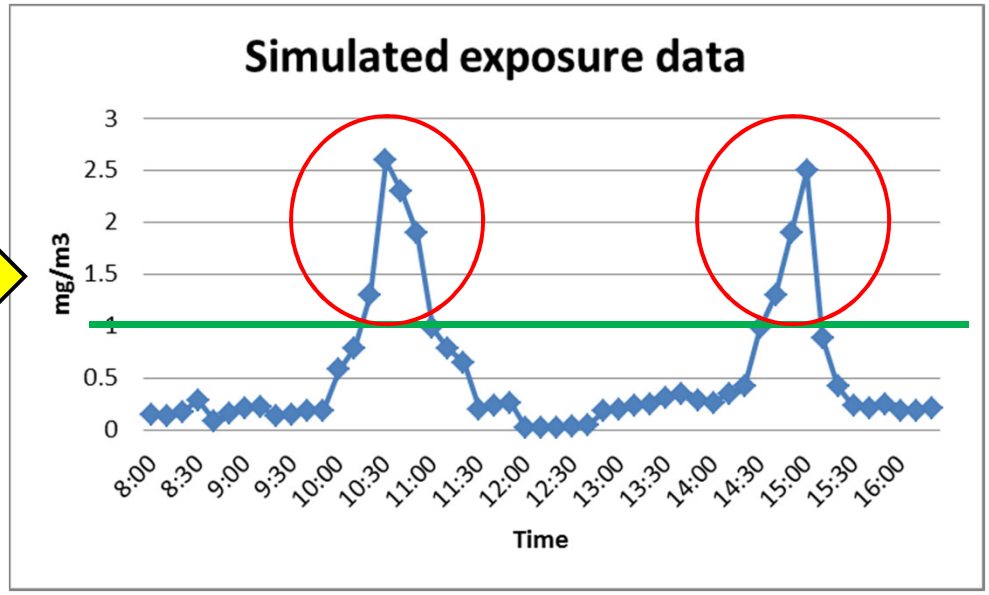
3. The value of real-time data

"How far down wind do we need to evacuate people?"

Data logging



Average = 0.527 mg/m3



Alarms

+ Audible or visual notification at selected levels.

+ Stop the work and adjust engineering controls

+ Prevents exposure, prevents complaints

4. Case studies and application examples

Optical Particle Counter
Clean Room Certification

FED-STD 209E

ISO 14644-1 Cleanroom Classification

Number of particles of various size per unit volume

NASA
https://commons.wikimedia.org/wiki/File:MSL_Rover_Environmental_Monitoring_Station.jpg

P-Trak Ultrafine Particle Counter
Construction below nurses station

+ Construction on 1st floor of hospital.
+ Nurses on 2nd floor above construction complaining of odors and headaches.

UFPs Tracked to the Source...	
• Background (outdoors)	9,440
• Second-floor supply air	562
• Second-floor adjacent offices	550
• Second-floor nurses' area	14,200
• Second-floor expansion joint	158,000
• Nurses' area after repair	562

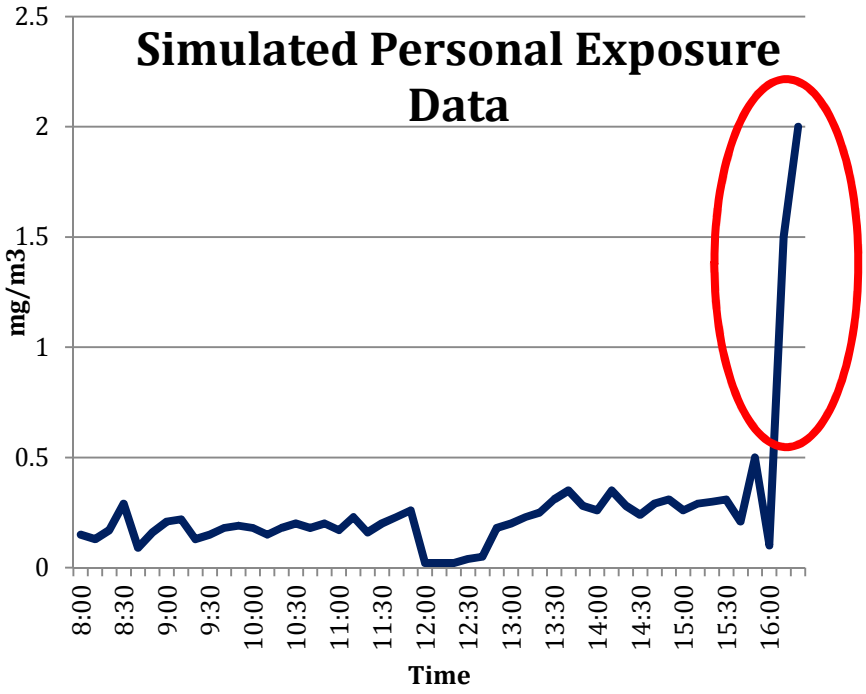
+ High concentration of ultrafine particles found coming through expansion joint.
+ Duct Tape applied to joint, complaints ceased.

Perimeter monitoring

+ Track wind, weather and aerosol concentration
+ Logging data for community awareness
+ Action level for dust suppression activities

5. Return on investment

Foundry ventilation project



+ Recent large engineering control investment (ventilation)
+ One person sampled high for silica on follow up

Future considerations

Nanoparticles / ultrafine particles

+ high number concentration
+ very low mass

Future metrics

Swiss Regulation 941.242

+ *Solid particle number concentration downstream of the Diesel Particulate Filter must be below 250,000 particles/cc*

Summary

+ How photometric instruments work
+ Strengths and limitations
+ Value of real-time, logged data
+ Case studies
+ Demonstrated return on investment

Q & A

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