Welcome
to the

Air Quality Module

Virendra Sethi
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IIT Bombay

2023

NAAQS

National Ambient Air Quality Standards

- CPCB Website :

cpcb.nic.in/air-quality-standard/

Revised National Ambient Air Quality Standards (NAAQS)

[NAAQS Notification dated 18th November, 2009]

S. No.	Pollutants	Time Weighted Average	Concentration in Ambient Air		Methods of Measurement
			Industrial, Residential, Rural and other Areas	Ecologically Sensitive Area (notified by Central Government)	
1	Sulphur Dioxide (SO_2), µg/m^3	Annual*	50	20	1. Improved West and Gaeke 2. Ultraviolet Fluorescence
		24 Hours**	80	80	
2	Nitrogen Dioxide (NO_2), µg/m^3	Annual*	40	30	1. Modified Jacob & Hochheiser 2. Chemiluminescence
		24 Hours**	80	80	
3	Particulate Matter (Size <10µm) or PM_{10} µg/m^3	Annual*	60	60	1. Gravimetric 2. TEOM 3. Beta attenuation
		24 Hours**	100	100	
4	Particulate Matter (Size <2.5 µm) or $PM_{2.5}$ µg/m^3	Annual*	40	40	1. Gravimetric 2. TEOM 3. Beta attenuation
		24 Hours **	60	60	
5	Ozone (O_3), µg/m^3	8 hours**	100	100	1. UV photometric 2. Chemiluminescence 3. Chemical Method
		1 hours **	180	180	
6	Lead (Pb), µg/m^3	Annual *	0.50	0.50	1. AAS/ICP Method after sampling using EPM 2000 or equivalent filter paper 2. ED-XRF using Teflon filter
		24 Hour**	1.0	1.0	
7	Carbon Monoxide (CO), mg/m^3	8 Hours **	02	02	Non dispersive Infra Red (NDIR) Spectroscopy
		1 Hour**	04	04	
8	Ammonia (NH_3), µg/m^3	Annual*	100	100	1. Chemiluminescence 2. Indophernol blue method
		24 Hour**	400	400	

8	Ammonia (NH_3), $\mu g/m^3$	Annual*	100	100	1. Chemiluminescence 2. Indophernol blue method
		24 Hour**	400	400	
9	Benzene (C_6H_6) , $\mu g/m^3$	Annual *	05	05	1. Gas chromatography based continuous analyzer 2. Adsorption and Desorption followed by GC analysis
10	Benzo(a)Pyrene (BaP)-particulate phase only, ng/m^3	Annual*	01	01	Solvent extraction followed by HPLC/GC analysis
11	Arsenic (As), ng/m^3	Annual*	06	06	AAS/ICP method after sampling on EPM 2000 or equivalent filter paper
12	Nickel (Ni), ng/m^3	Annual*	20	20	AAS/ICP method after sampling on EPM 2000 or equivalent filter paper

** Annual Arithmetic mean of minimum 104 measurements in a year at a particular site taken twice a week 24 hourly at uniform interval.** 24 hourly 08 hourly or 01 hourly monitored values, as applicable shall be complied with 98% of the time in a year. 2% of the time, they may exceed the limits but not on two consecutive days of monitoring.*

NOTE: Whenever and wherever monitoring results on two consecutive days of monitoring exceed the limits specified above for the respective category, it shall be considered adequate reason to institute regular or continuous monitoring and further investigation.

Nature of Air Pollutants

1. Gaseous (SOx, NOx, CO…)

2. Particulate Matter (PM)

Gaseous Pollutants

- Similar sized molecules
- Behaviour
  - Physics : Same
  - Chemistry : Different
    - EXAMPLES
      - Solubility
      - Toxicity
      - Ozone Depletion Potential

Particulate Pollutants

- Behaviour
  - Physics : NOT the same
    - Size
    - Morphology
  - Chemistry :
    - Inert (Dust, Sand, No more reactive)
    - Smoke (Toxic, intoxicating)

Air Pollution

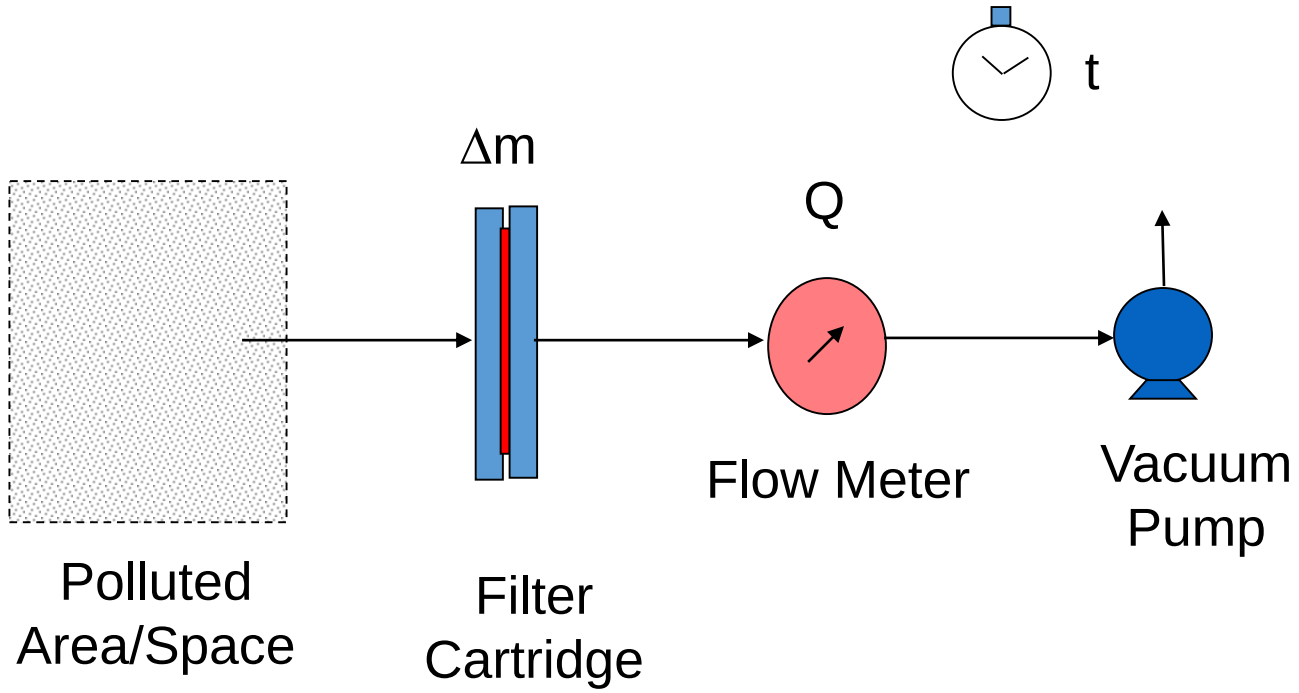
- Concentration
  - mass of pollutant / volume of air
  - number of particles / volume of air
  - opacity

- Duration – hours to days to years

- Criteria Pollutants
  - Primary
    - SOx
    - NOx
    - CO
    - PM-10, PM-2.5
    - …
  - Secondary
    - Ozone

- How do you measure the mass concentration of PM ?

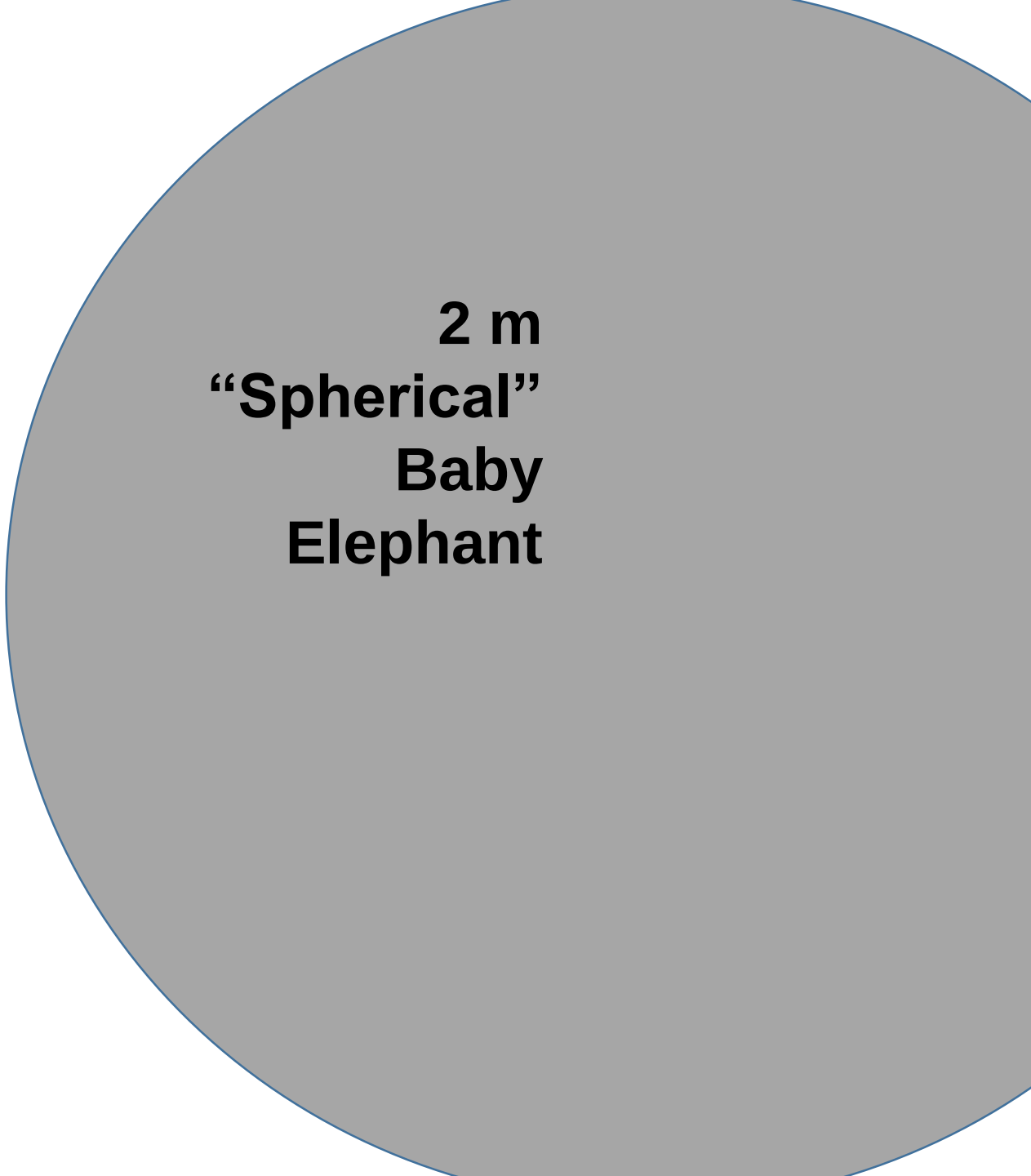
$$C_{TSP} = \Delta m/Qt$$



Perception

(Scales)

2 mm
Ant



3 Orders of Magnitude

Ants and Elephants

- Ant ~2mm
- “Spherical” Baby Elephant ~2 m
    - Order of magnitude 3
- Nitrogen Molecule ~0.3 nm
- Respirable particle ~300 nm
    - Order of magnitude 3

Particles in Air

are like

Elephants

suspended

in an

Ocean

of

Ants

(Gas Molecules)

Ants and Elephants

- All the well established physics of “ants” (IDEAL GAS) is not applicable to the “elephants”
- All the MAGIC of “nano” is in this “new” world of “elephants”
- Ability to understand this range of sizes has become possible due to development of instrumentation
- Last 4-5 decades have been exciting times for Aerosol Science and Engineering
    - Powder Production – Material science
    - Nano-products
    - Atmospheric Pollutants
    - Medical Sciences

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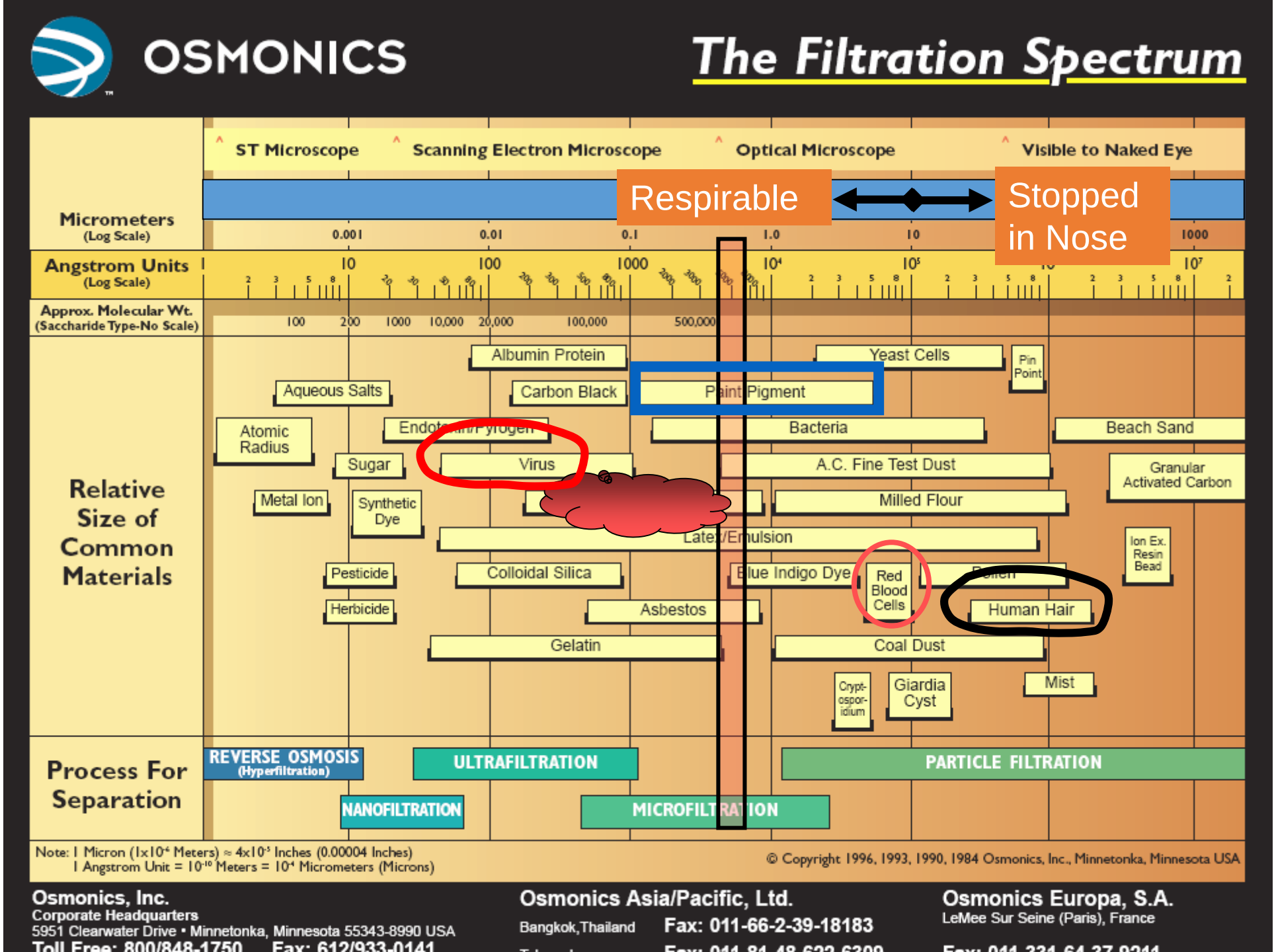
Even within the “Elephants”
There is a range of Sizes

which decide
WHERE
they would deposit in the lungs


OSMONICS
The Filtration Spectrum
ST Microscope
Scanning Electron Microscope
Optical Microscope
Visible to Naked Eye
Respirable
Stopped in Nose
Micrometers (Log Scale)
Angstrom Units (Log Scale)
Approx. Molecular Wt. (Saccharide Type-No Scale)
Relative Size of Common Materials
Albumin Protein
Yeast Cells
Pin Point
Aqueous Salts
Carbon Black
Paint Pigment
Atomic Radius
Bacteria
Beach Sand
Sugar
Virus
A.C. Fine Test Dust
Granular Activated Carbon
Metal Ion
Synthetic Dye
Milled Flour
Ion Ex. Resin Bead
Pesticide
Colloidal Silica
Blue Indigo Dye
Red Blood Cells
Herbicide
Asbestos
Human Hair
Gelatin
Coal Dust
Crypt-ospor-idium
Giardia Cyst
Mist
Process For Separation
REVERSE OSMOSIS (Hyperfiltration)
ULTRAFILTRATION
PARTICLE FILTRATION
NANOFILTRATION
MICROFILTRATION
Note: 1 Micron (1x10⁻⁴ Meters) ≈ 4x10⁻⁵ Inches (0.00004 Inches)
1 Angstrom Unit = 10⁻¹⁰ Meters = 10⁻⁴ Micrometers (Microns)
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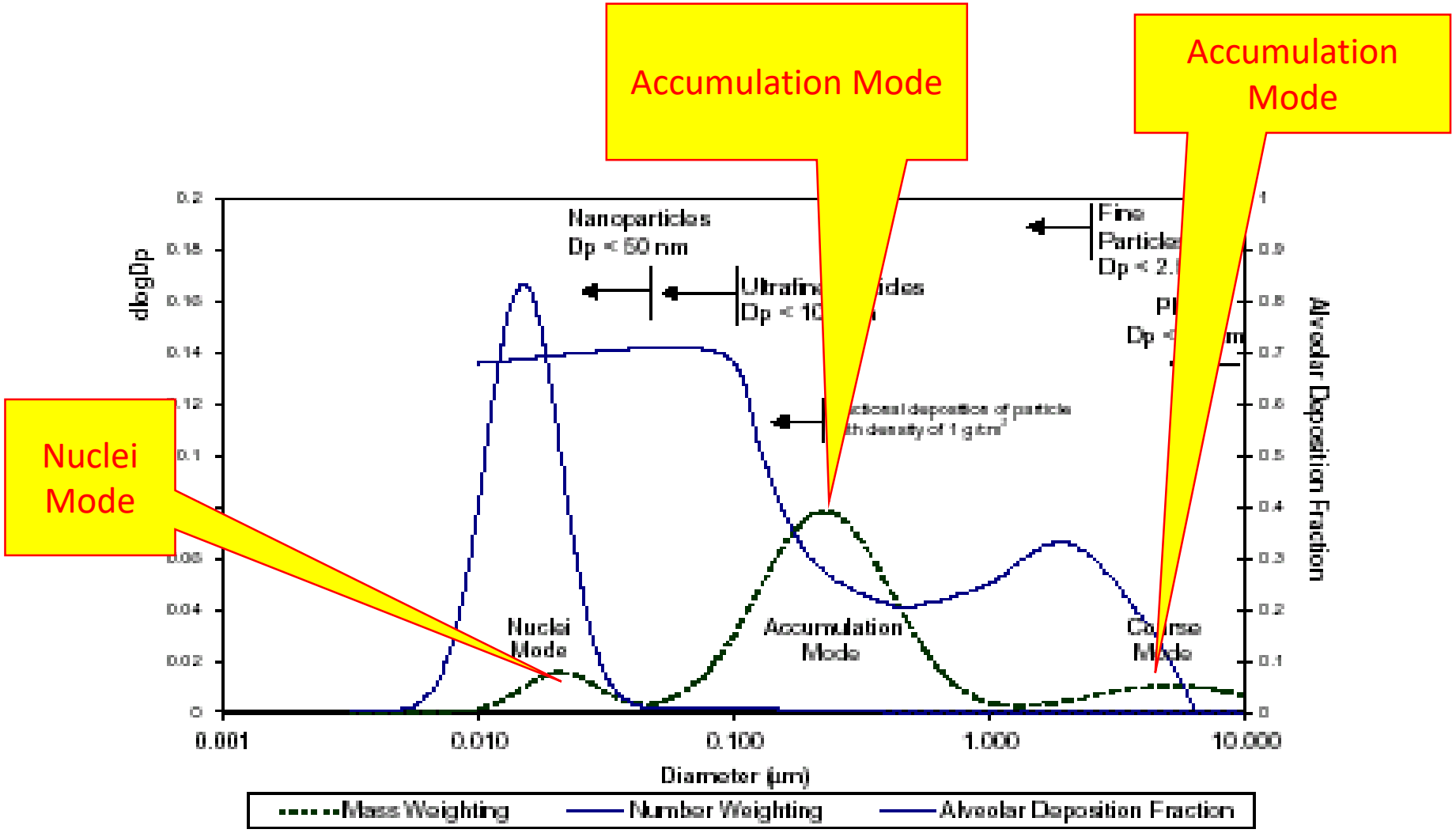


Tri-modal Particle Size Distribution

(Source: Kittelson *et al*. 1999)

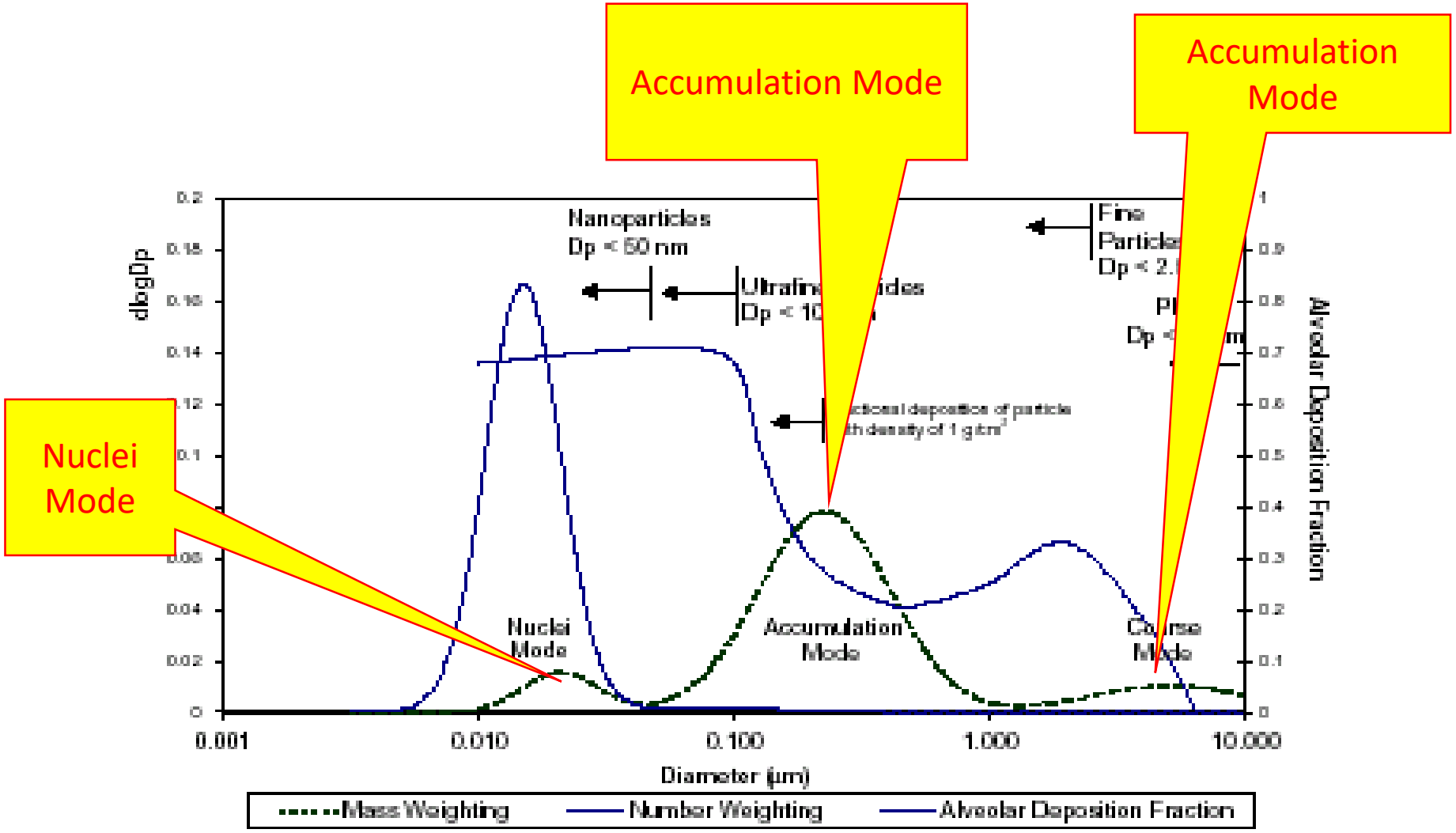
18

Mass - Size

Mass of ONE 1 μm particle

EQUALS

Mass of X 0.1μm particles

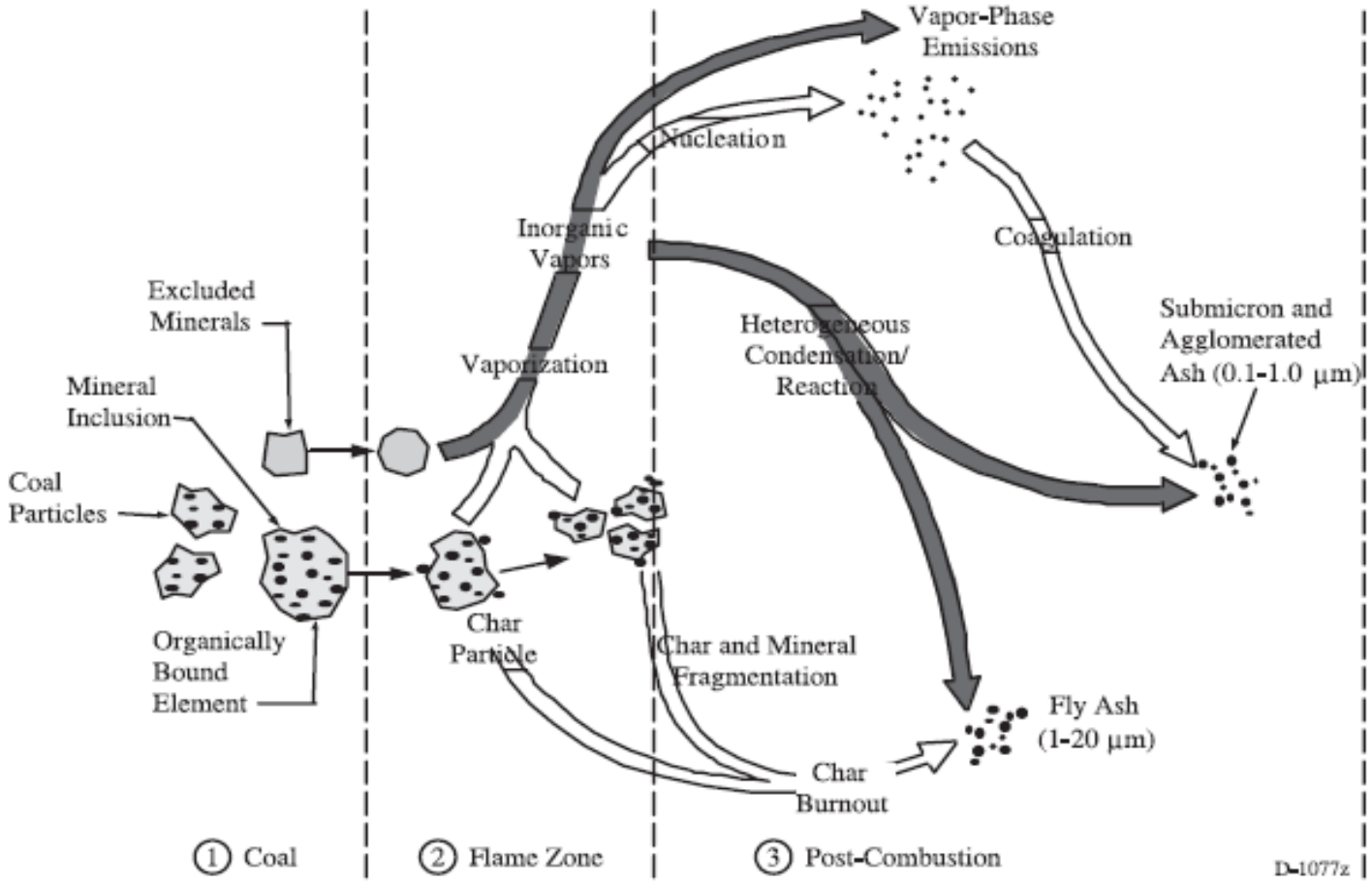


Tri-modal Particle Size Distribution

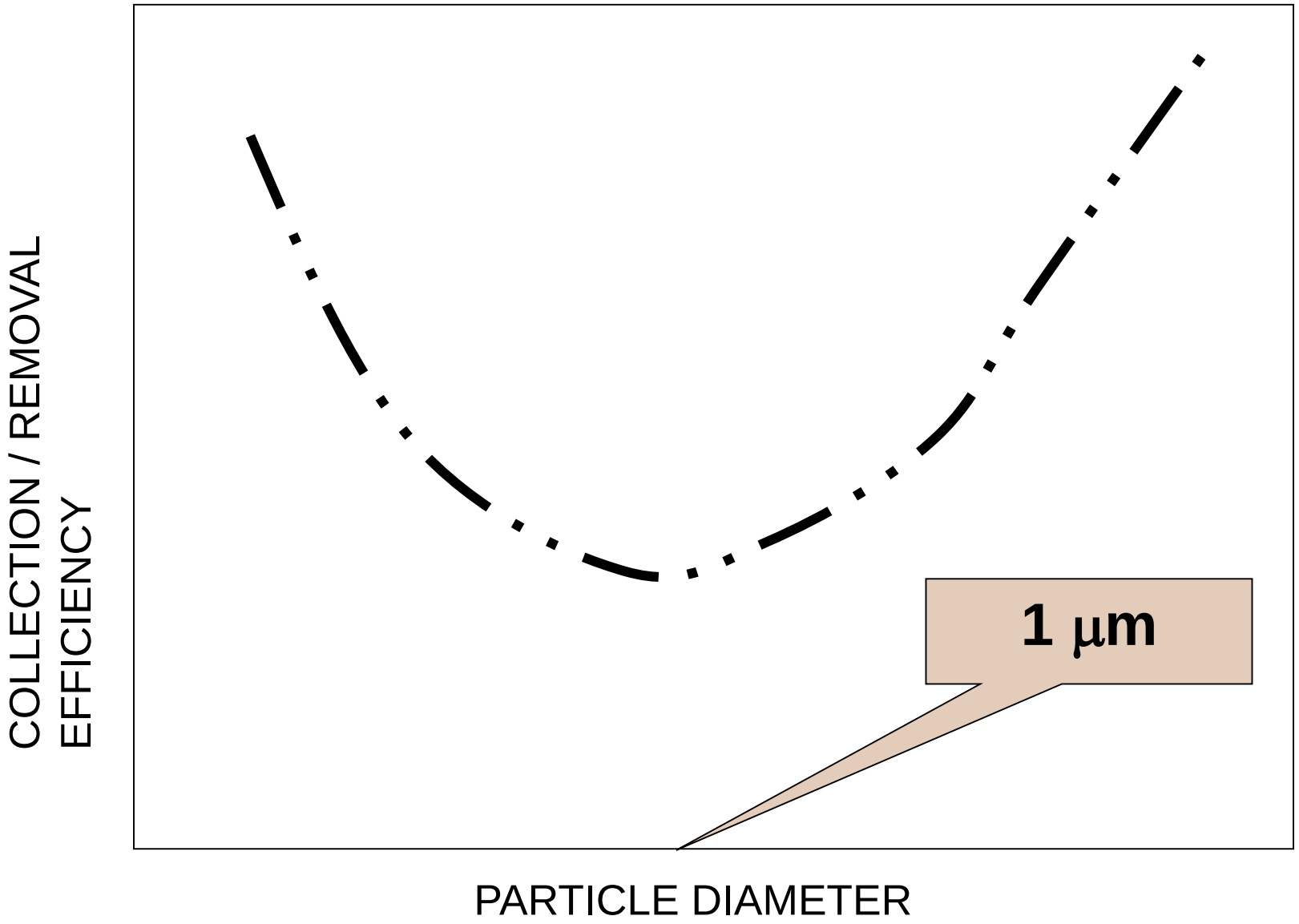
(Source: Kittelson *et al*. 1999)

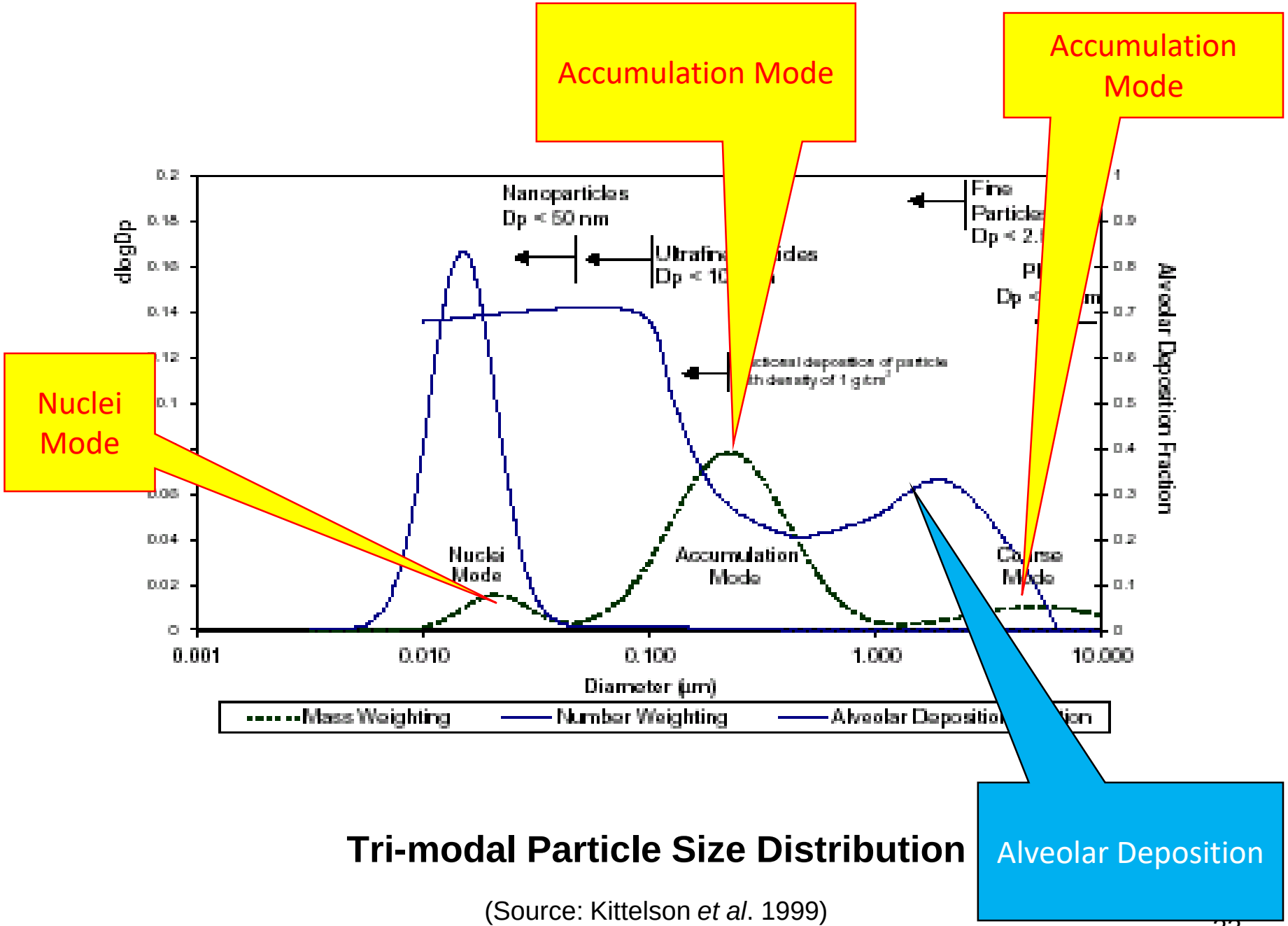
20

Particle Formation in Coal Combustion



Source: Flagan and Seinfeld, 1988

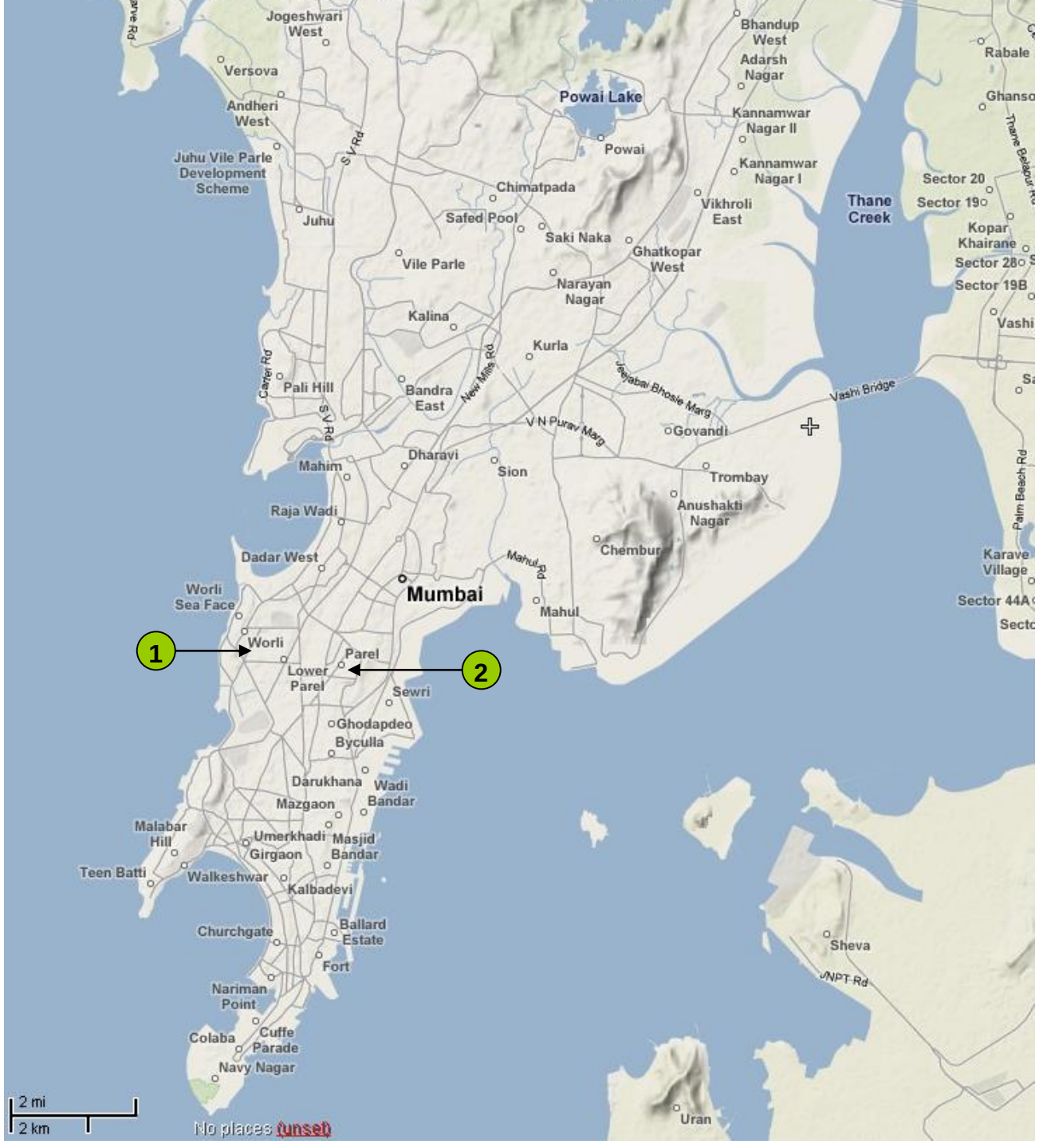

COLLECTION / REMOVAL EFFICIENCY
1 μm
PARTICLE DIAMETER



Tri-modal Particle Size Distribution

(Source: Kittelson *et al*. 1999)

23



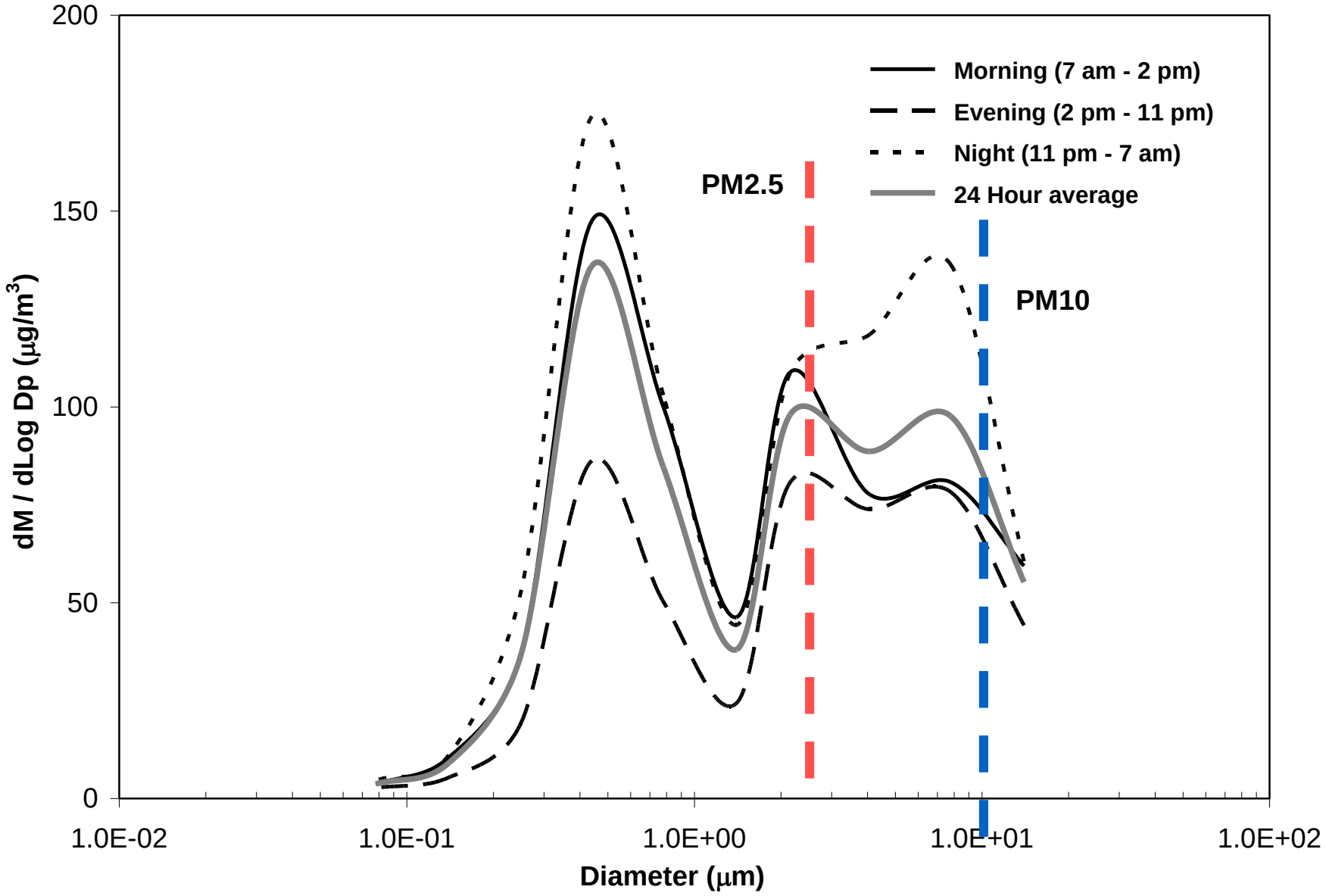
Study Area Mumbai

1. WRL (residential)

2. PAL (industrial)

Map Source:
http://wikimapia.org

Mass Size Distributions Measured for 5 Days in Mumbai (Goyal, 2008)



PM_{10} and $PM_{2.5}$

- PM_{10} is the mass concentration of particulate matter less than **10 μm** expressed as $\mu g/m^3$

- $PM_{2.5}$ is the mass concentration of particulate matter less than **2.5 μm** expressed as $\mu g/m^3$

$PM_{2.5}$ is a subset of PM_{10}

- Plot mass distribution function

- Mode in the <2.5 μm size is sourced by combustion and other anthropogenic activities. More toxic.

- Area under the curve
  - 0 to 10 μm PM_{10}
  - 0 to 2.5 μm $PM_{2.5}$

Ratio of $PM_{2.5}$ to PM_{10}

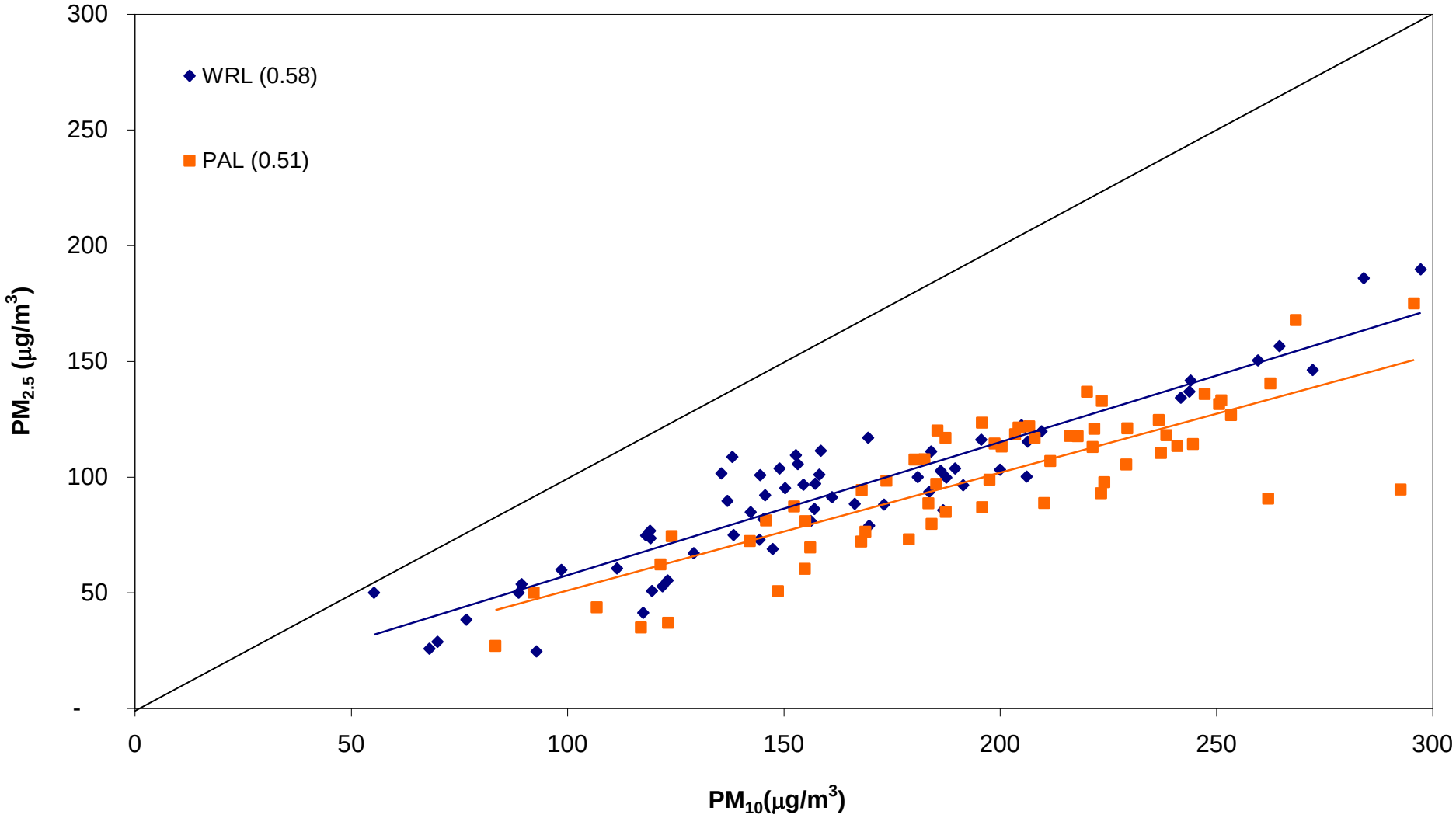
INDICATOR OF

ANTHROPOGENIC / COMBUSTION ACTIVITIES

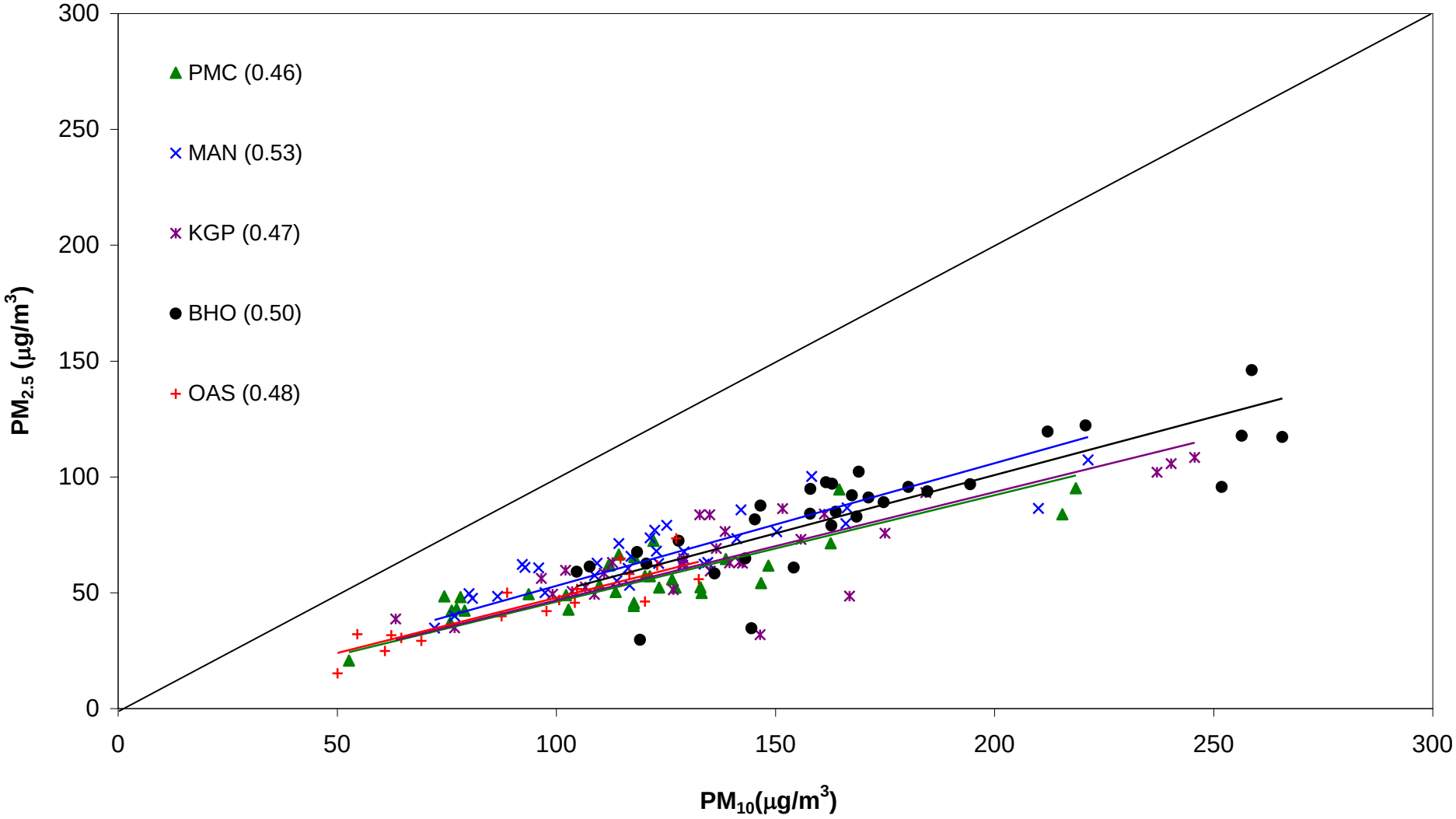
Ratio Small = Benign Particulate

Ratio Large = Most particles will reach lungs and possibly more toxic

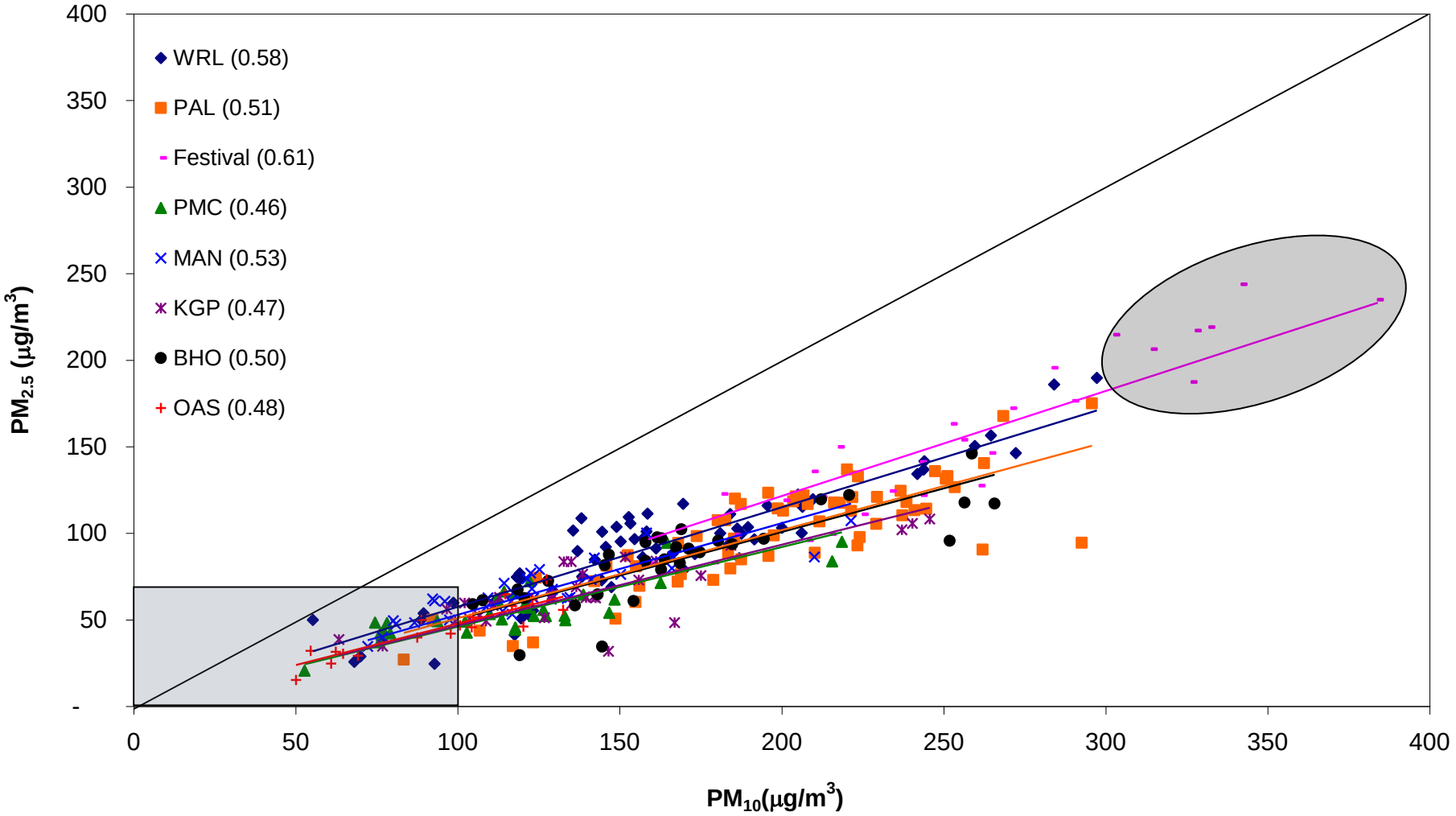
$PM_{2.5}$ and PM_{10} Measurements at Mumbai



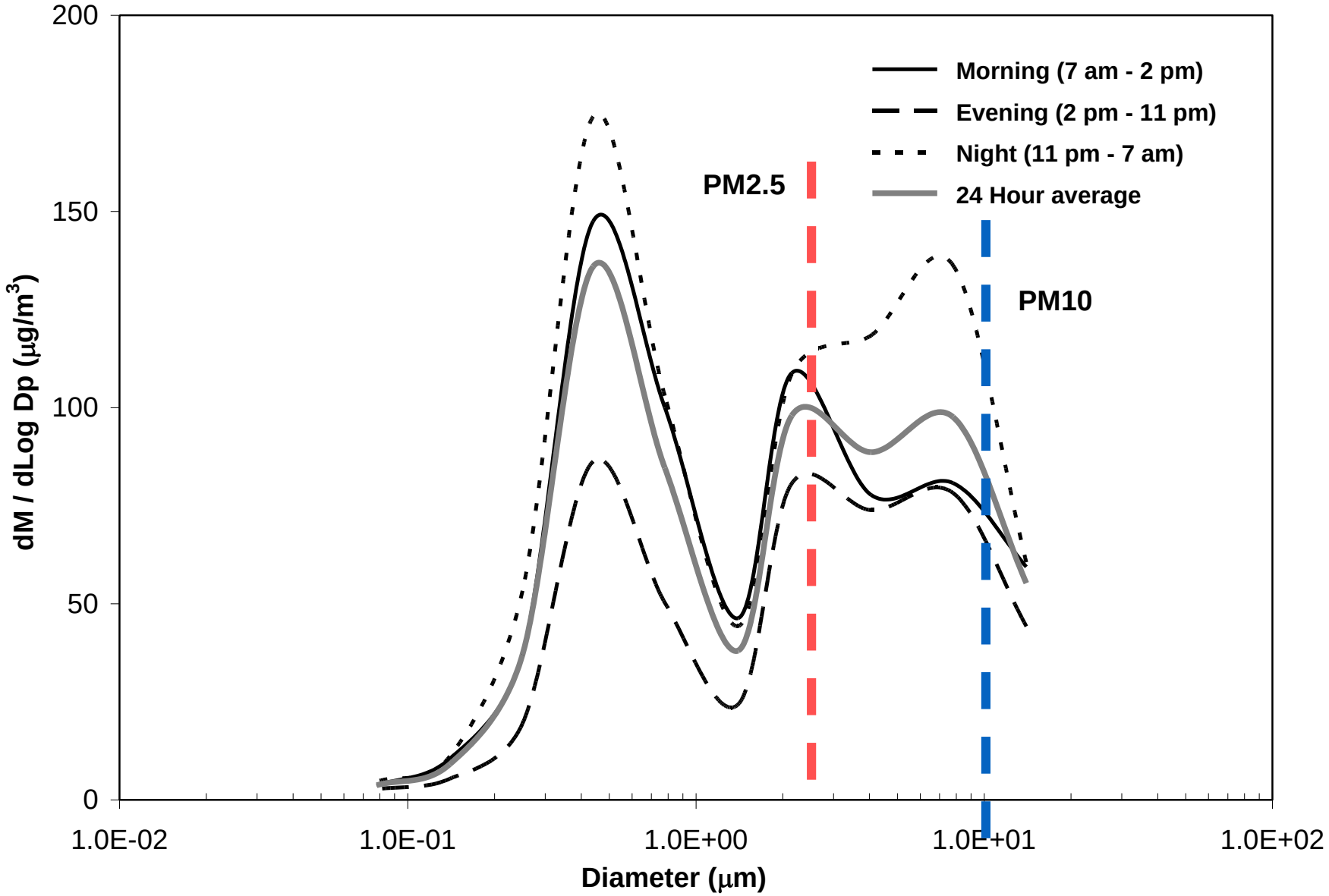
$PM_{2.5}$ and PM_{10} Measurements at Pune



$PM_{2.5}$ and PM_{10} Measurements at Mumbai and Pune



Mass Size Distributions Measured for 5 Days in Mumbai



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Sizing of Particles

Thought Exercise

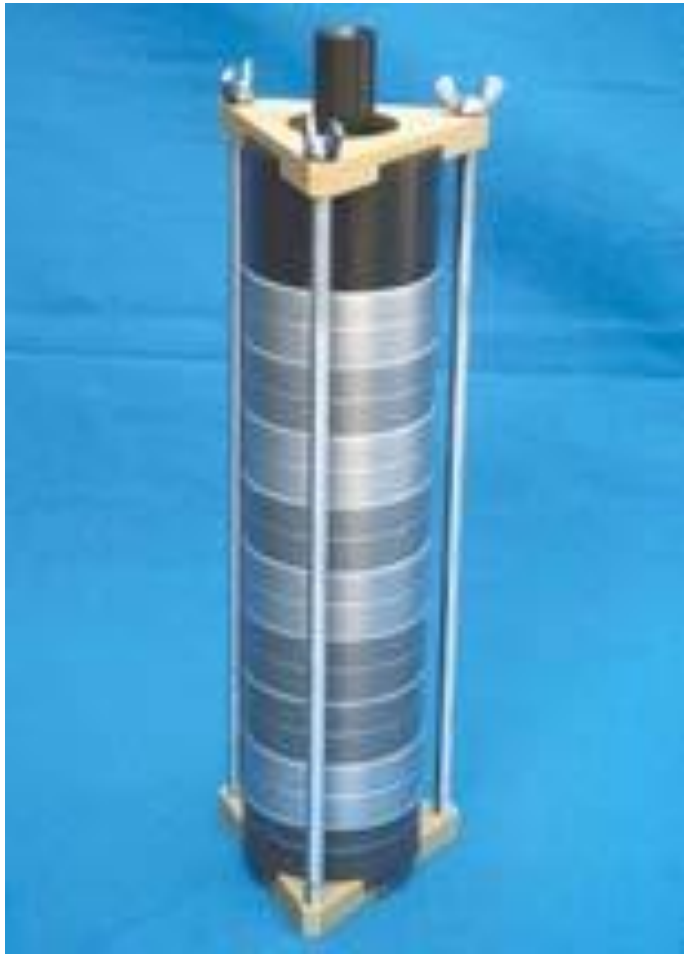
How would you
size and count
particles in air
in the
nanometer size range ?

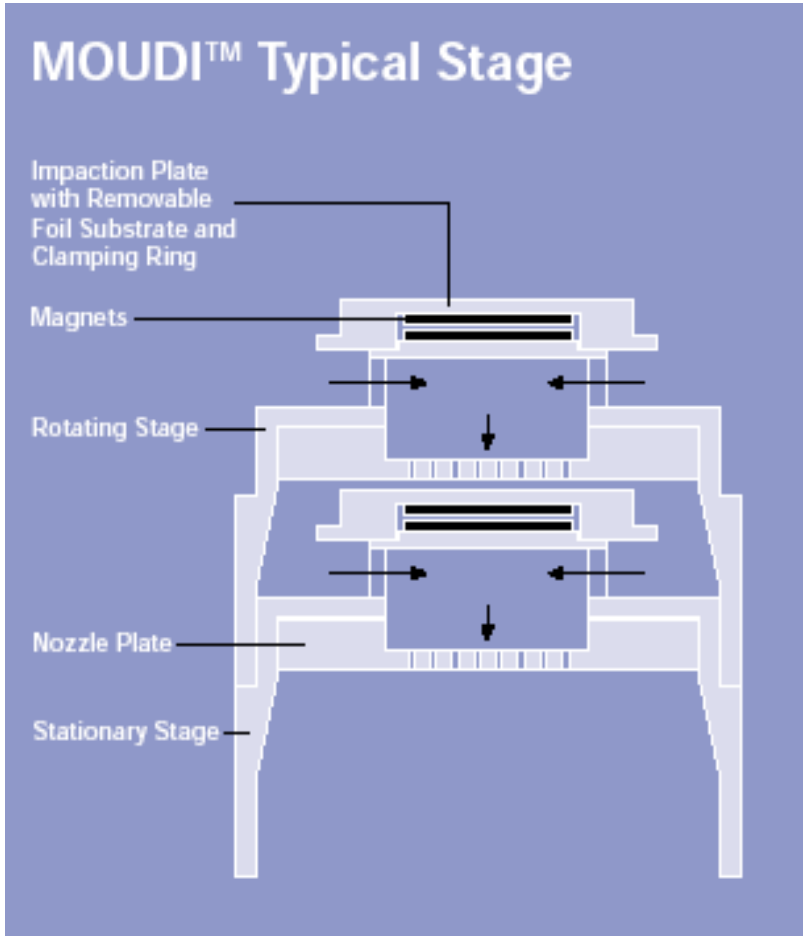
Instrumentation

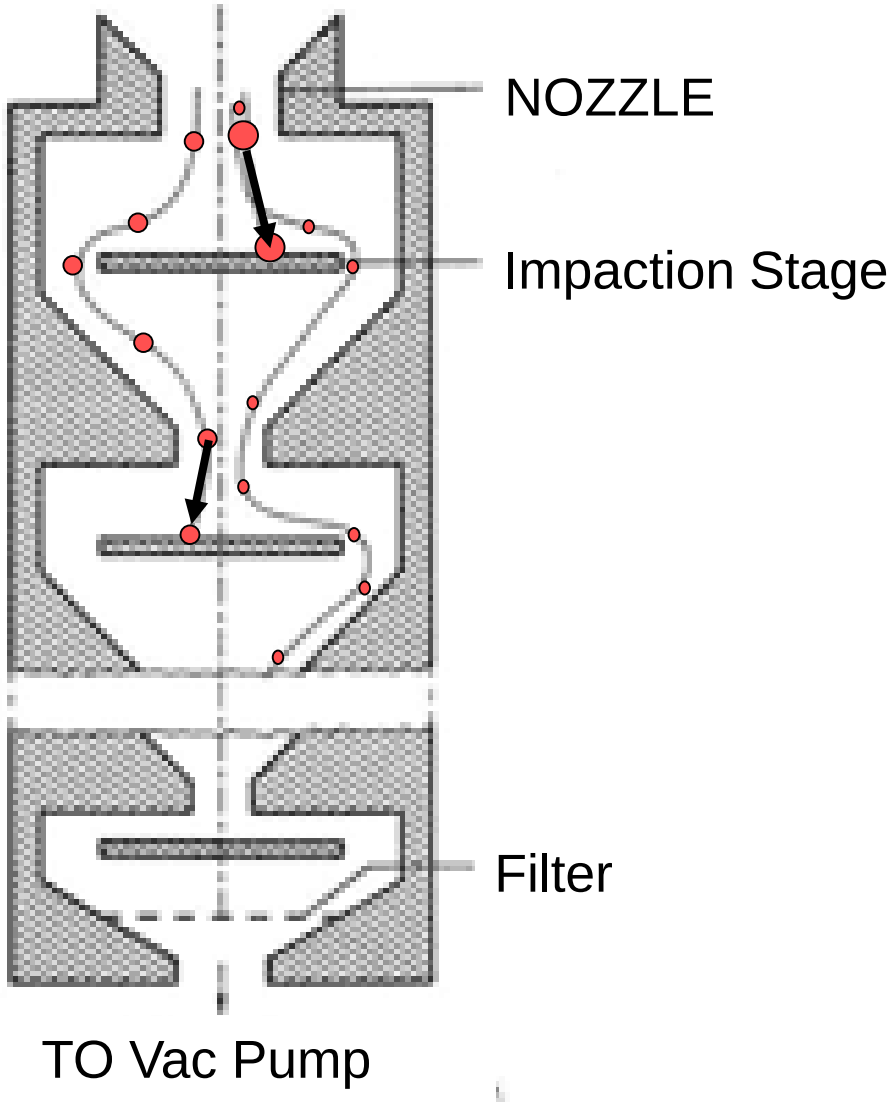
- Inertial Impactors
  - Mass based (> 56 nm)
- Optical Particle Counters
  - Number based (> 100 nm)
- Electrical Mobility
  - Sizing (> 6 nm)
  - Counting (Condensation Nuclei Counters)

MOUDI

Micro-Orifice Uniform Deposit Impactor






NOZZLE
Impaction Stage
Filter
TO Vac Pump

Instrumentation

- Inertial Impactors
  - Mass based (> 56 nm)
- Optical Particle Counters (OPC's)
  - Number based (> 100 nm)
- Electrical Mobility
  - Sizing (> 6 nm)
  - Counting (Condensation Nuclei Counters)

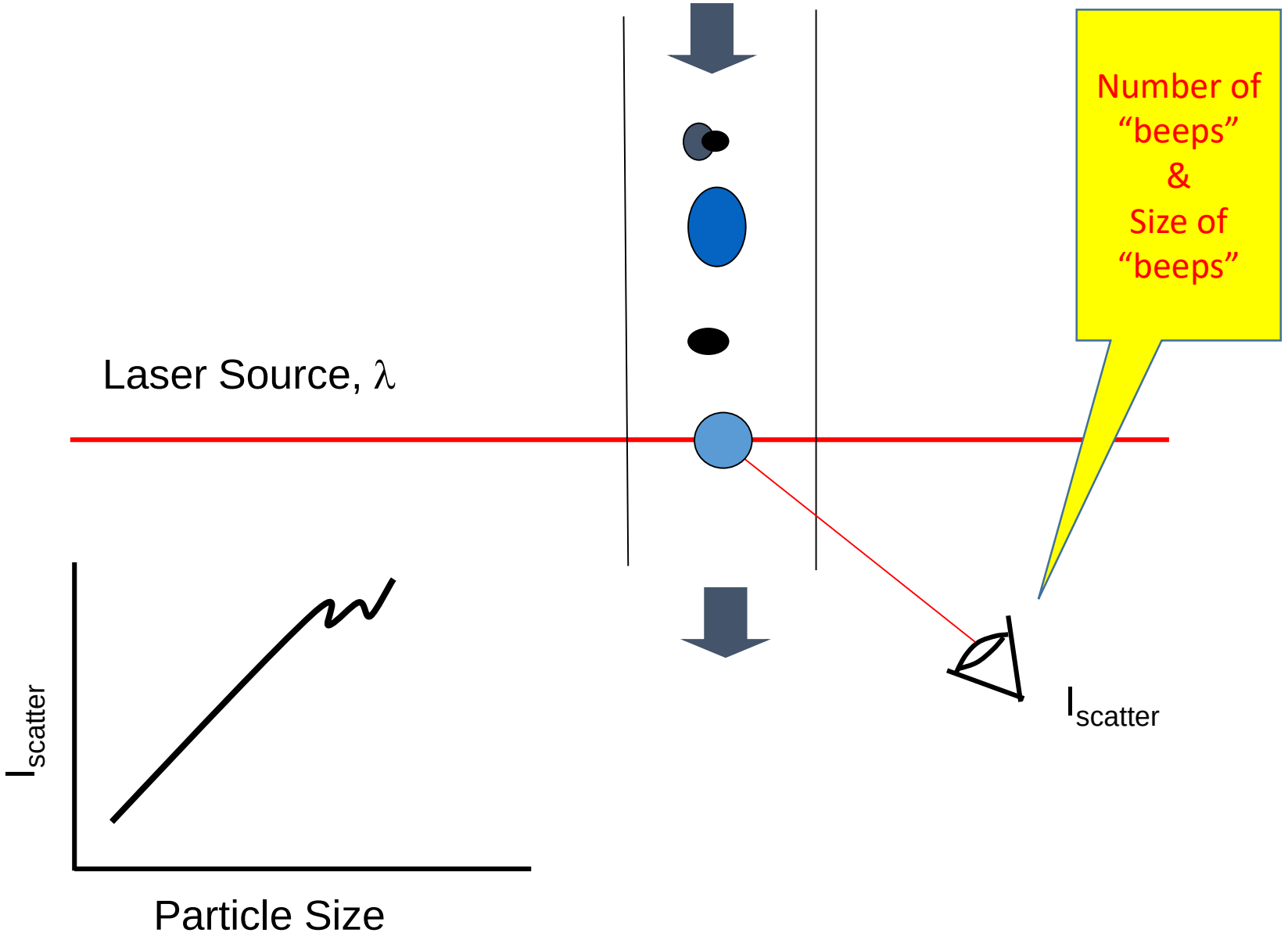
OPC's

- Light Scattering
- Light Extinction

  Limited to 0.09 μm

  $0.4 > \lambda_{opt} > 0.7$ μm

- Single Particle /Cloud of Particles


Number of
“beeps”
&
Size of
“beeps”
Laser Source, λ
$I_{scatter}$
$I_{scatter}$
Particle Size

x

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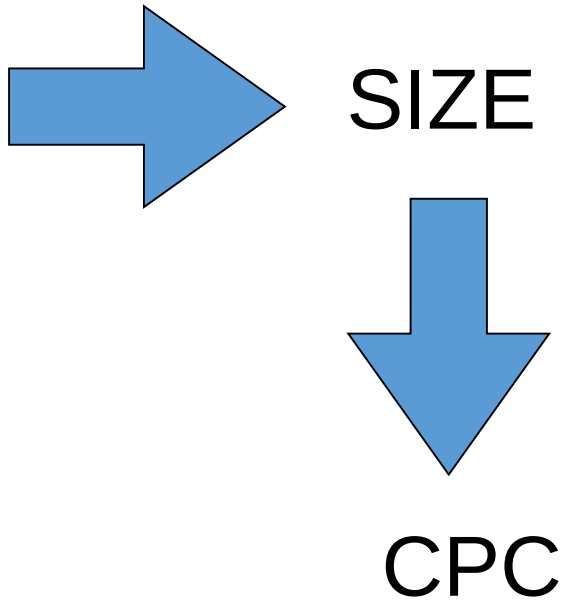
Sizing of Particles

Instrumentation

- Inertial Impactors
  - Mass based (> 56 nm)
- Optical Particle Counters
  - Number based (> 100 nm)
- Electrical Mobility
  - Sizing (> 3 nm)
  - Counting (Condensation Nuclei Counters)

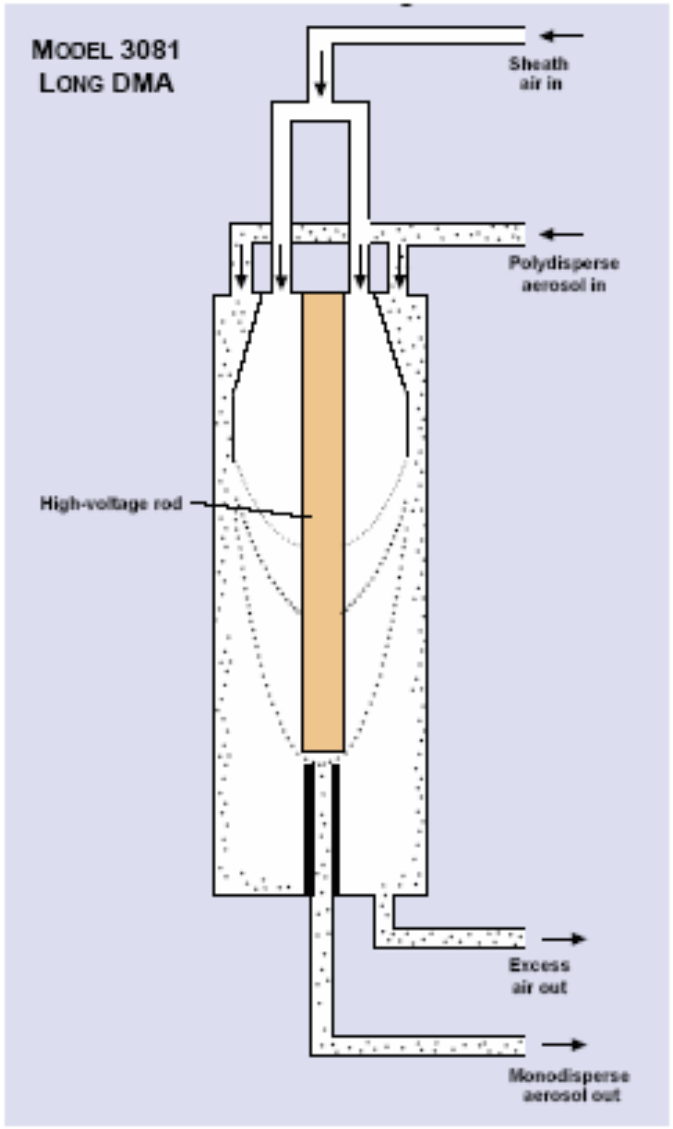
Electrical Mobility Analysers

- Charge particles
- Electrical Field



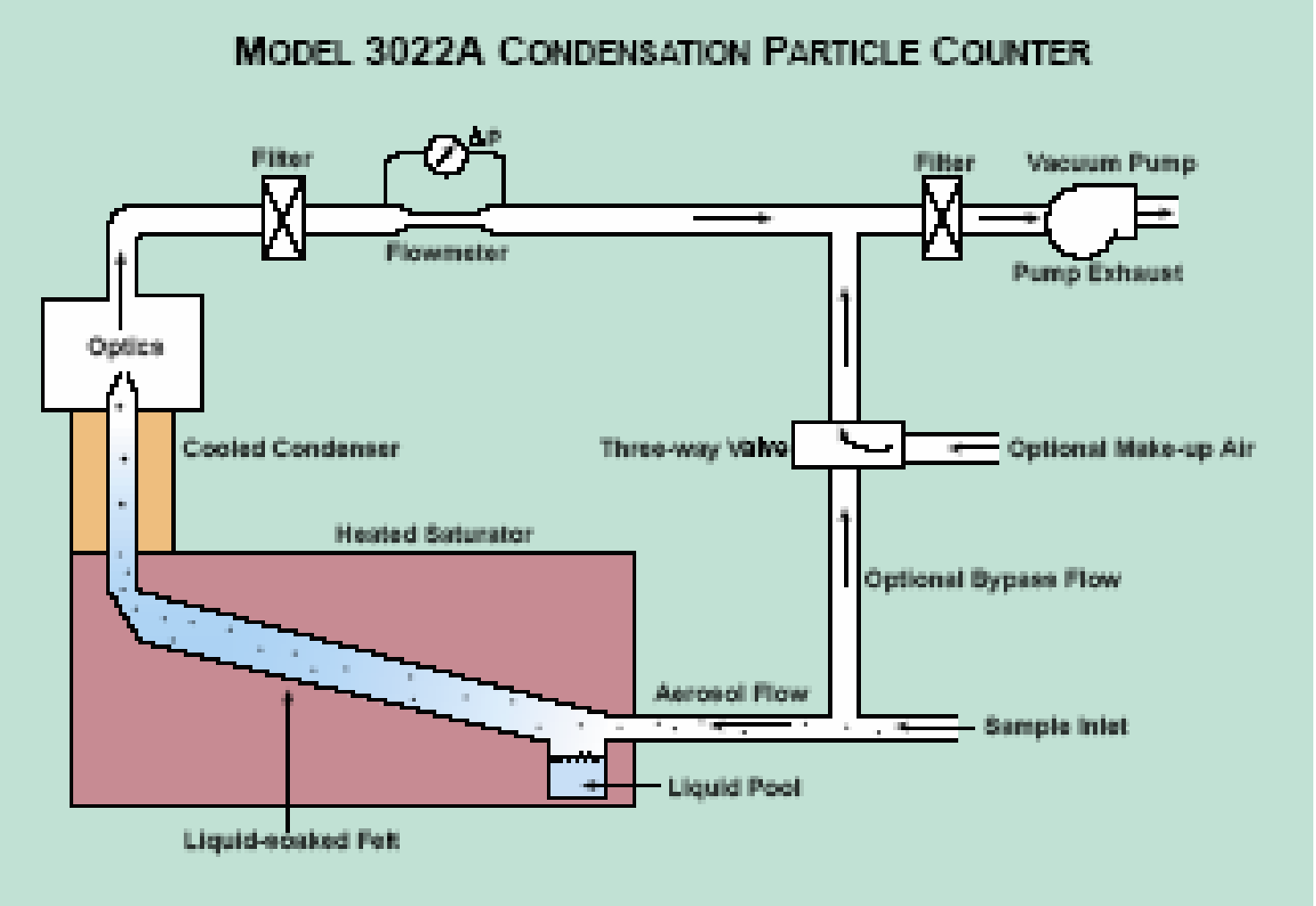
OPC in Principle – Alcohol used to grow size

Differential Mobility Analyser (For size separation using electrical mobility)



Source : TSI Inc.

Condensation Particle Counter (For growing the size separated particles and detecting them using light scattering)



Source : TSI Inc.

Scanning Mobility Particle Sizer

Field Instruments

- High Volume Samplers (~2 Lakhs)
  - Regulatory (RSPM, SOx, NOx)
- Mini-vol Samplers (~5 Lakhs)
  - Regulatory (PM10, PM2.5)
- Dust Trak (~7 Lakhs)
  - Real time (1 minute resolution)
  - PM_x (x = 1, 2.5, 4, 10)

Measuring Gaseous Pollutants

- Wet Chemistry (8 hour averages)
- Electrochemical sensors (Real time)
- Spectroscopy (Real time)
- Standard Methods (SPCB’s Analytical Labs)

x

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Controlling Air Pollutants

at the SOURCE

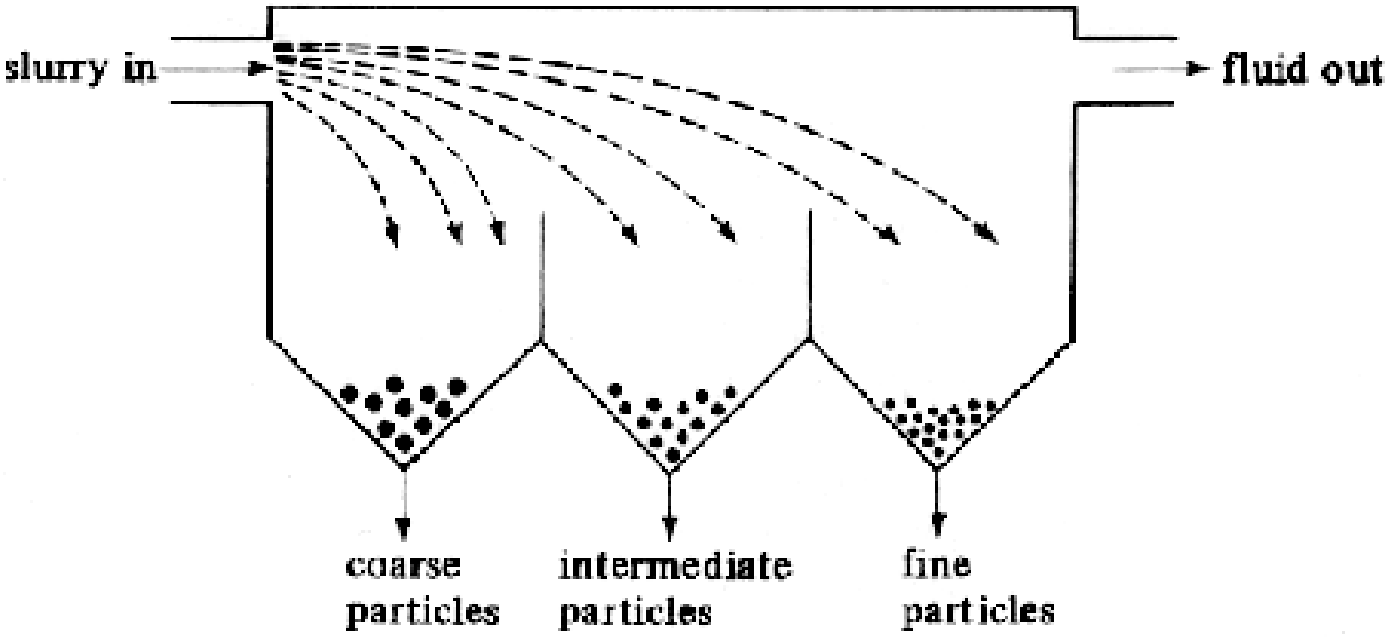
Particulate Matter

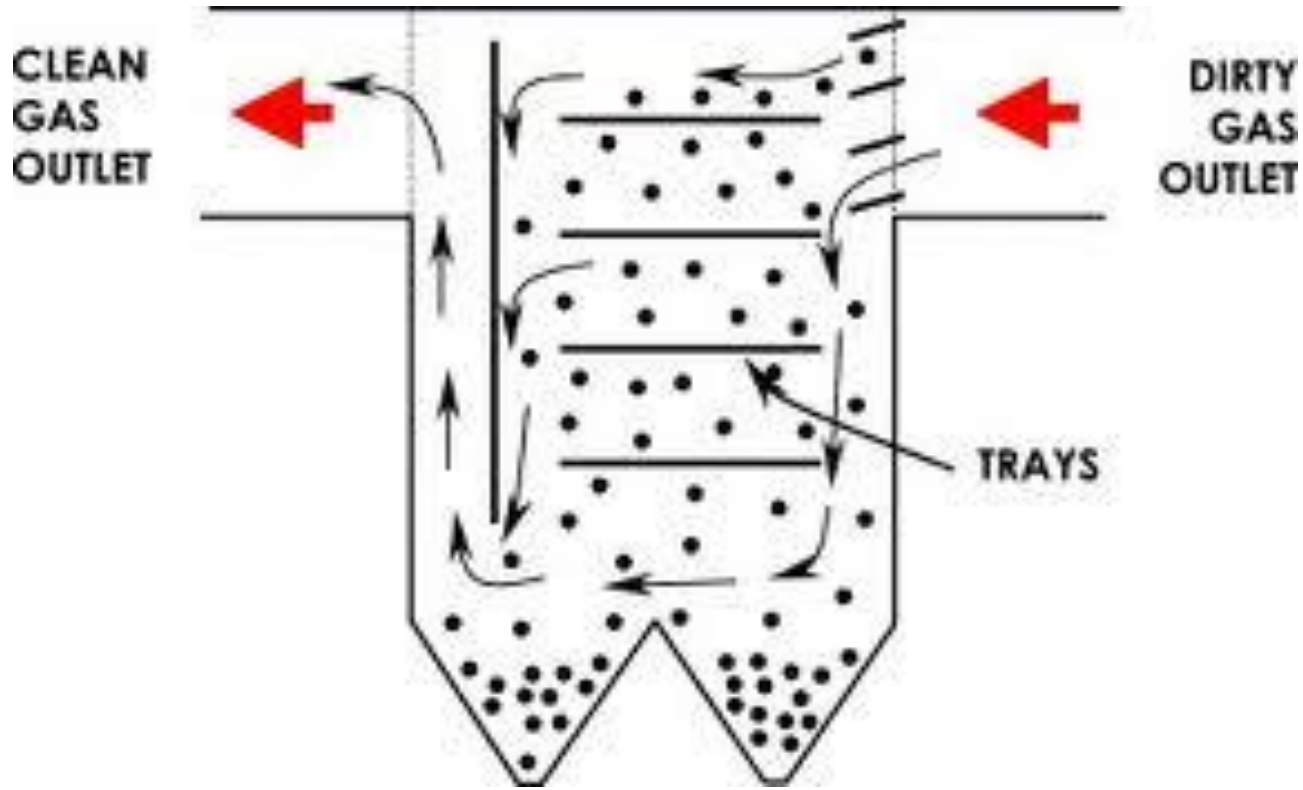
Air Pollution Control - PM

- MECHANICAL
  - Gravity – Settling Chambers 20 -100 μm
  - Inertia - Cyclones > 25 μm
  - Diffusion – Filters > 0.1 μm
- ELECTRICAL
  - Electrostatic Precipitators > 0.1 μm

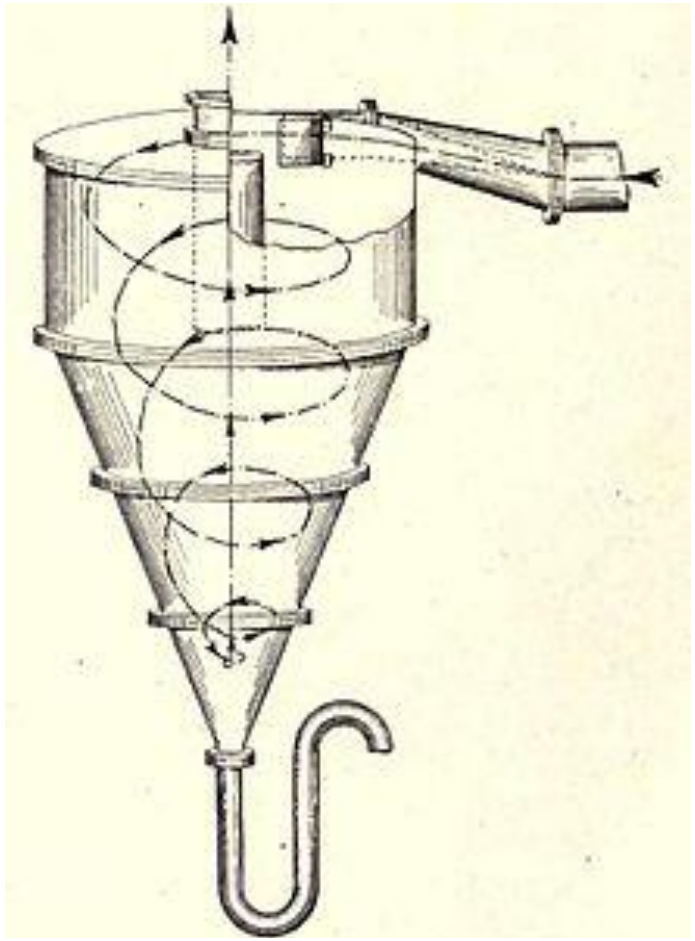
Mechanical

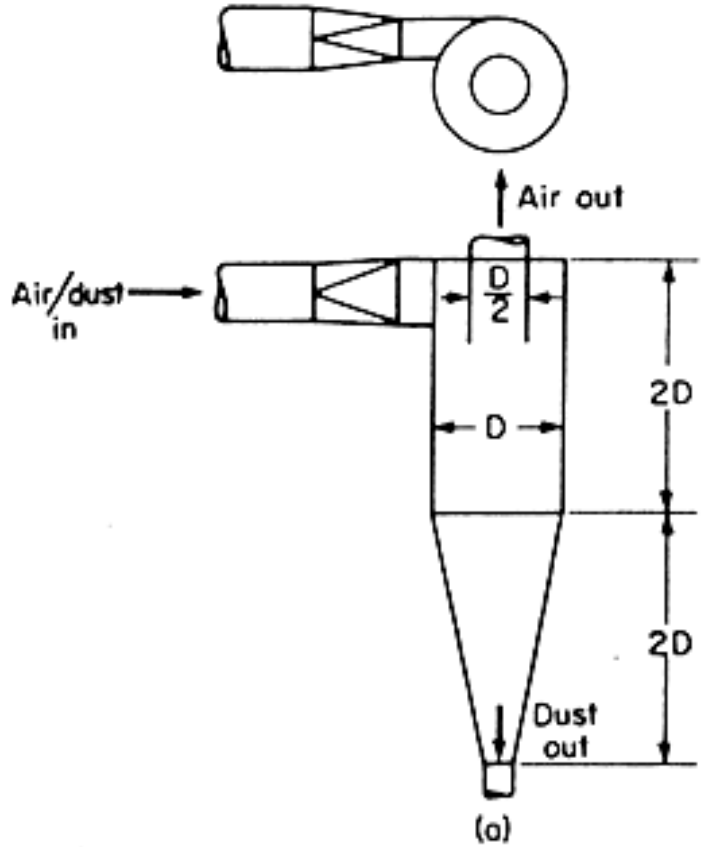
- Gravitational Settlers

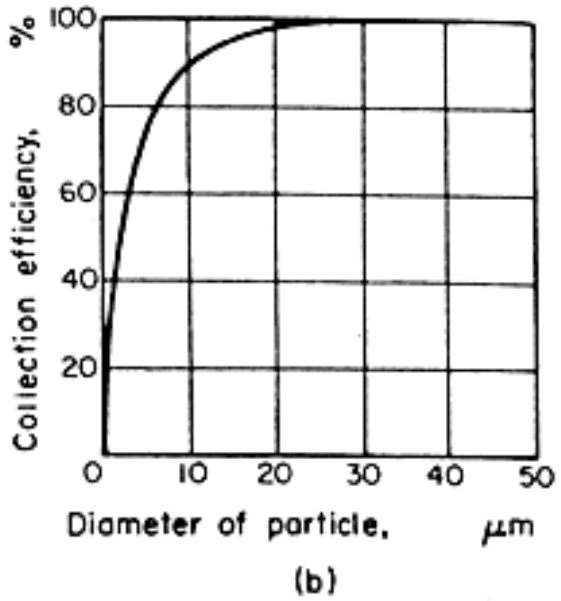



CLEAN
GAS
OUTLET
DIRTY
GAS
OUTLET
TRAYS

Mechanical - Inertia







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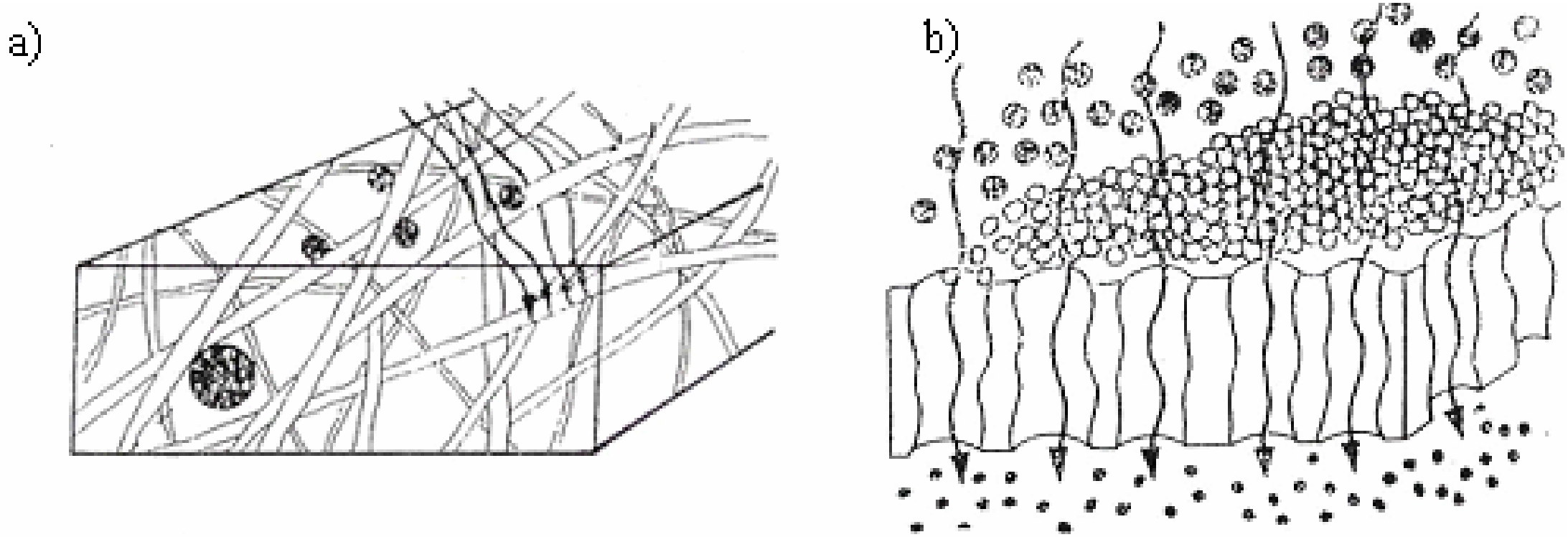
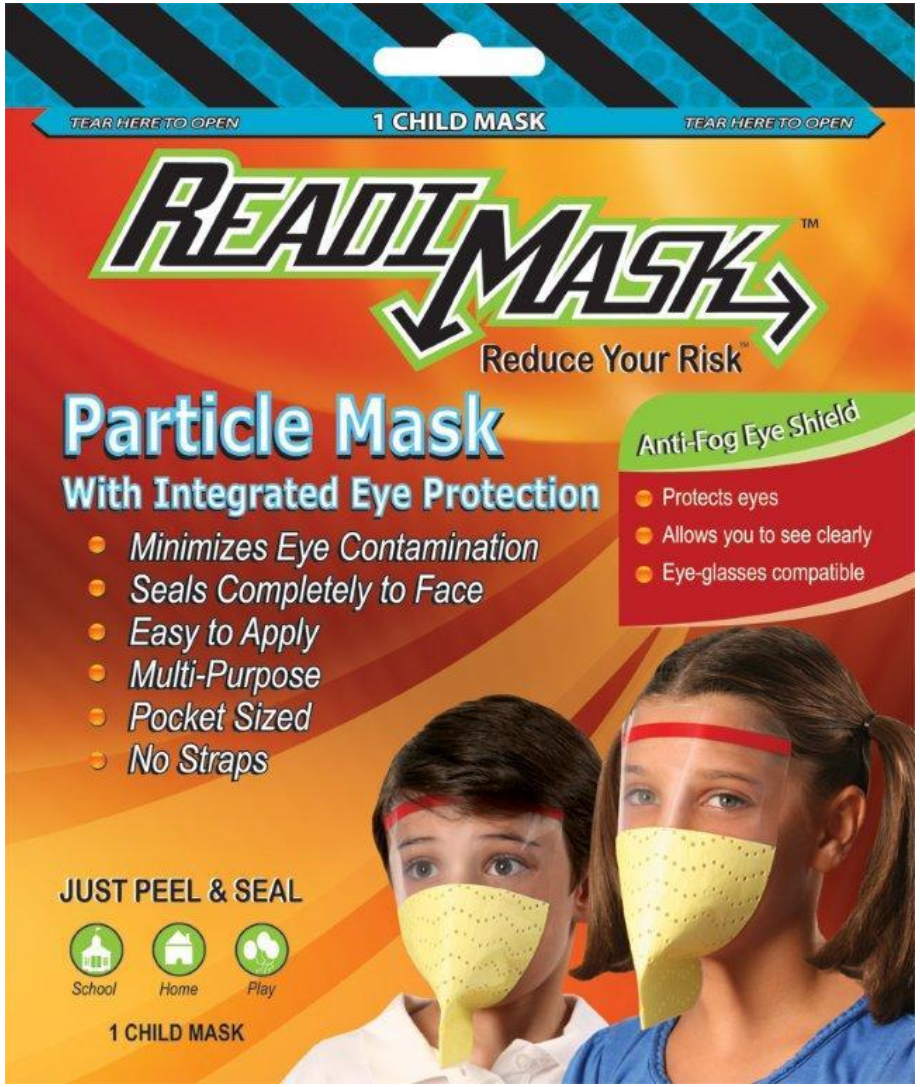
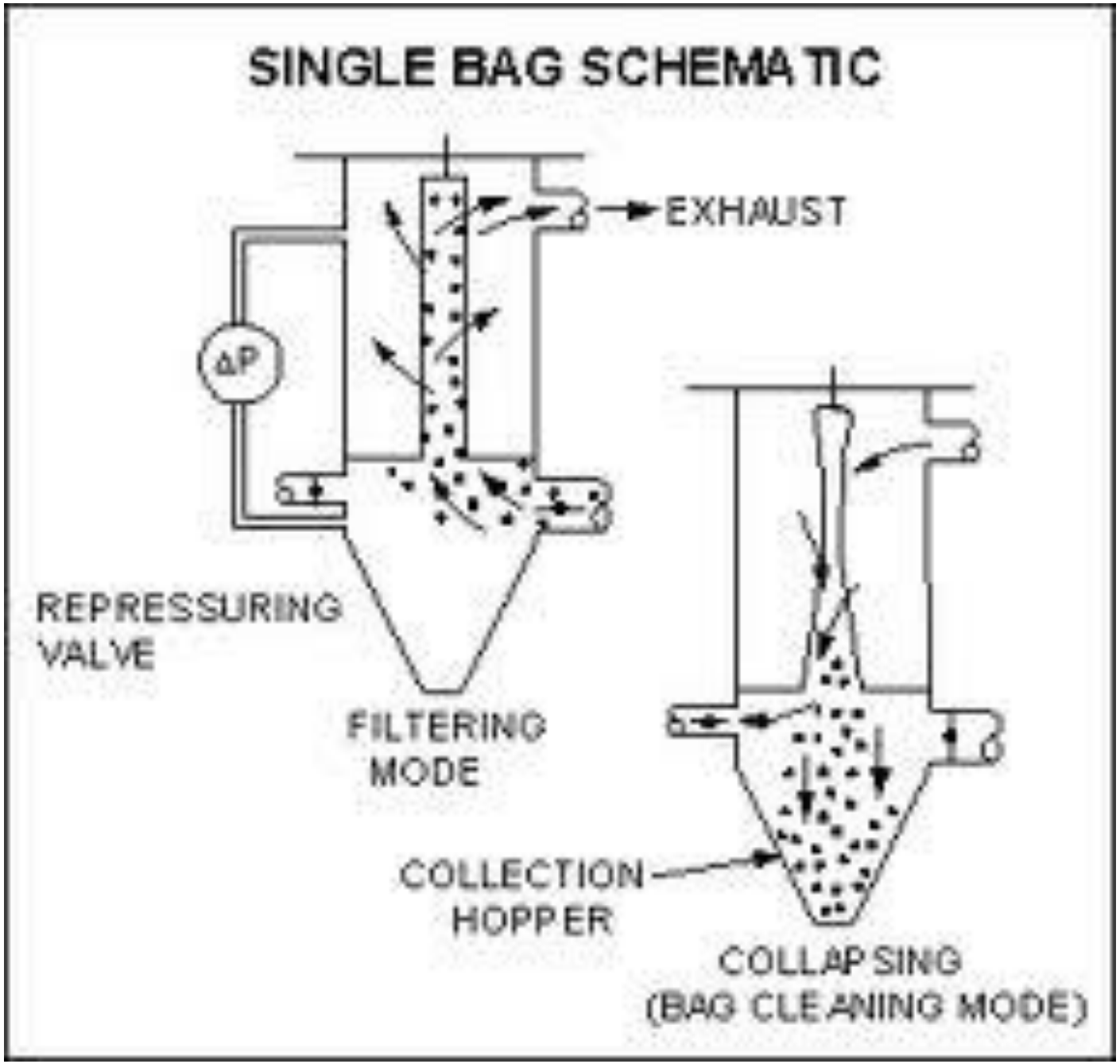
Mechanical - Filtration

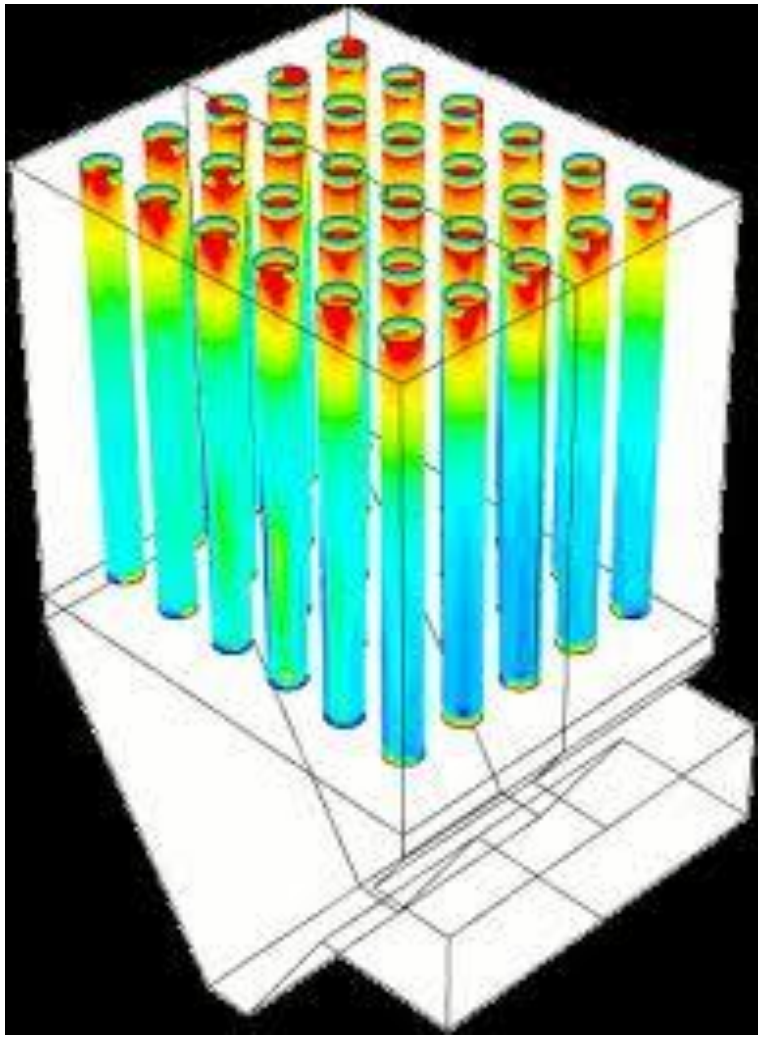



N95
PARTICULATE RESPIRATOR
MASQUE
RESPIRATOIRE
ANTIPOUSSIÈRES
3


TEAR HERE TO OPEN
1 CHILD MASK
TEAR HERE TO OPEN
READI MASK™
Reduce Your Risk™
Particle Mask
With Integrated Eye Protection
Minimizes Eye Contamination
Seals Completely to Face
Easy to Apply
Multi-Purpose
Pocket Sized
No Straps
Anti-Fog Eye Shield
Protects eyes
Allows you to see clearly
Eye-glasses compatible
JUST PEEL & SEAL
School
Home
Play
1 CHILD MASK


EFFICIENT PAPER
SILICON ANTI-DRAINBACK VALVE

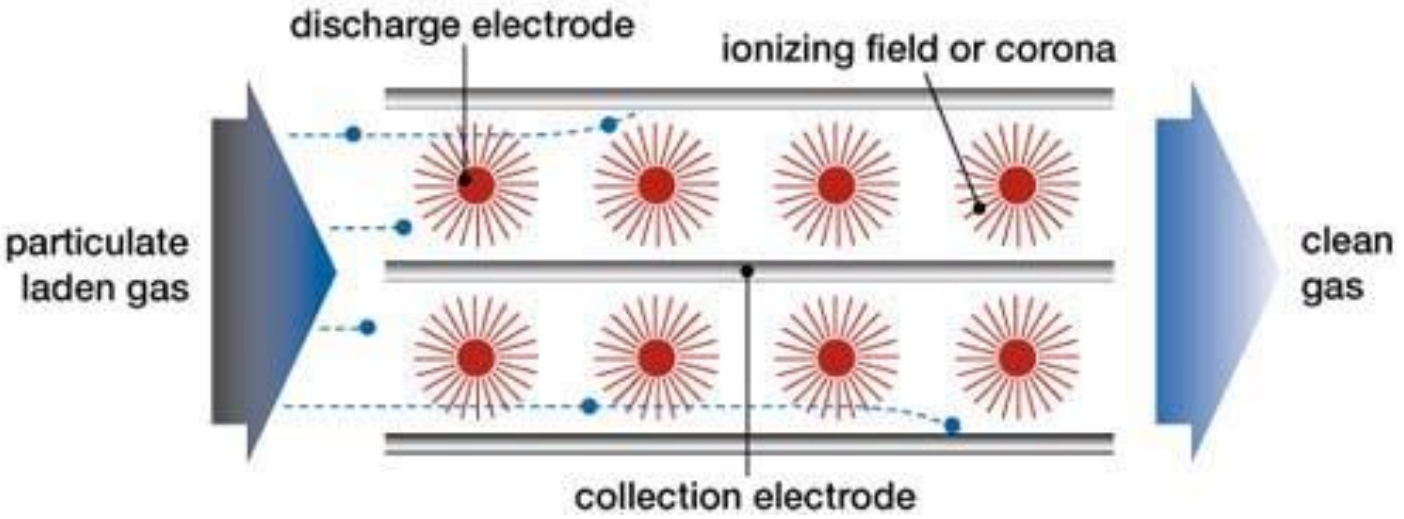

SINGLE BAG SCHEMATIC
EXHAUST
ΔP
REPRESSURING VALVE
FILTERING MODE
COLLECTION HOPPER
COLLAPSING (BAG CLEANING MODE)



- Through Fibrous Material :
  - FILTERED by
    - Diffusion
    - Impaction
    - Interception

    - (NOT SIEVING)

Electrostatic Precipitators



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Controlling Air Pollutants

at the SOURCE

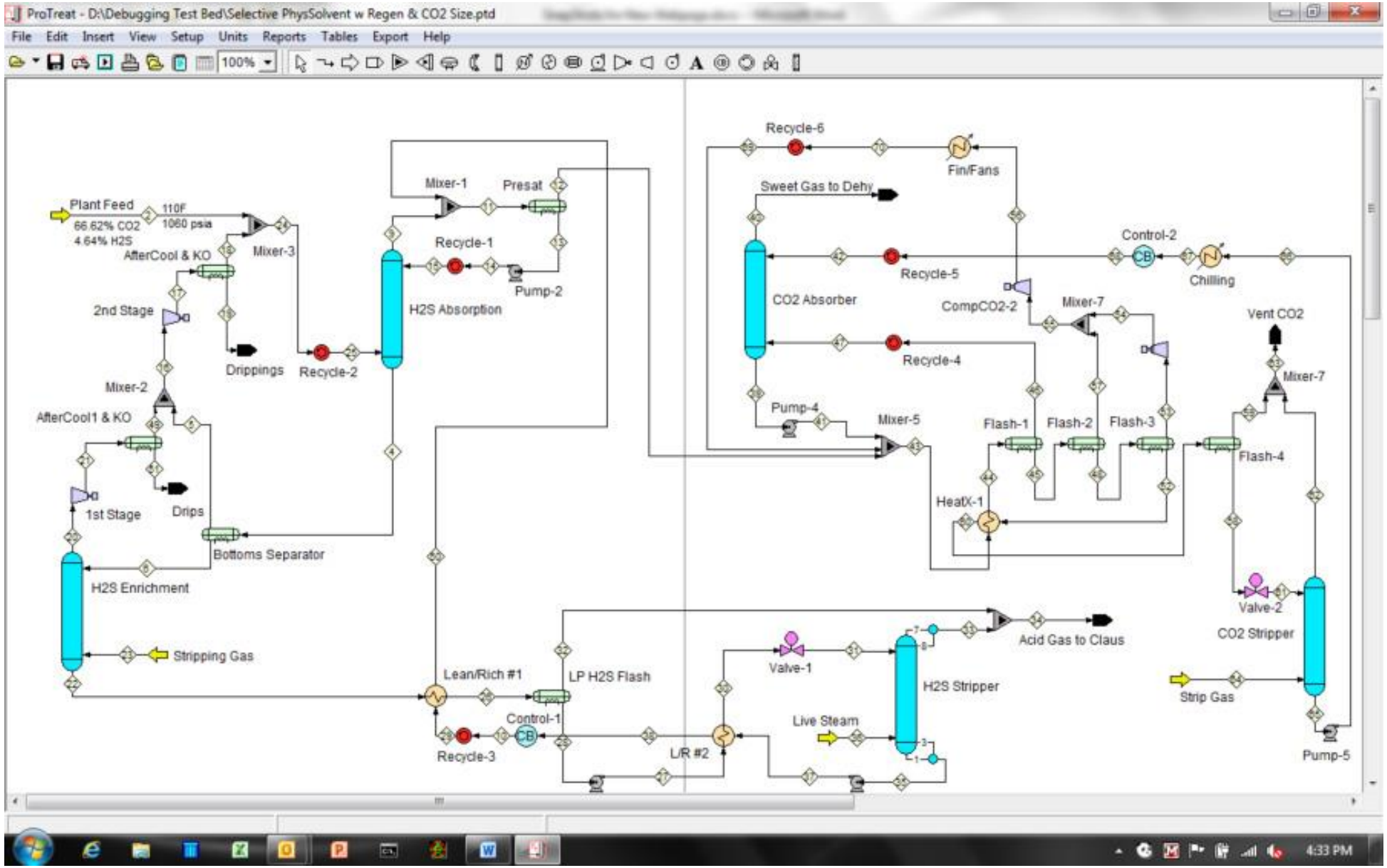
Gases

Air Pollution Control - Gases

- Absorption
- Adsorption
- Incineration
- Chemical Reactions
  - Catalysts
  - Flue gas Desulphurisation


Pingxiang Dier Chemical Packing Co., Ltd


SCANIA


ProTreat - D:\Debugging Test Bed\Selective PhysSolvent w Regen & CO2 Size.ptd
File Edit Insert View Setup Units Reports Tables Export Help
100%
Plant Feed
66.62% CO2
4.64% H2S
110F
1060 psia
AfterCool & KO
Mixer-3
Mixer-1
Presat
Recycle-1
Pump-2
H2S Absorption
2nd Stage
Drippings
Recycle-2
Mixer-2
AfterCool1 & KO
1st Stage
Drips
Bottoms Separator
H2S Enrichment
Stripping Gas
Lean/Rich #1
LP H2S Flash
Control-1
Recycle-3
L/R #2
Valve-1
Live Steam
H2S Stripper
Acid Gas to Claus
Recycle-6
Fin/Fans
Sweet Gas to Dehy
Control-2
Chilling
Recycle-5
CO2 Absorber
CompCO2-2
Mixer-7
Vent CO2
Recycle-4
Pump-4
Mixer-5
Flash-1
Flash-2
Flash-3
Flash-4
HeatX-1
Valve-2
CO2 Stripper
Strip Gas
Pump-5
4:33 PM

Adsorption


10" GAC FILTER
REPLACEMENT
PURE100
GRANULAR
ACTIVATED
CARBON FILTER

Incinerators - Flares

Thank you for your Time and Attention

Best Wishes

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