Atmospheric Aerosols

Lecture 3

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AEROSOLS IN THE ATMOSPHERE

Aerosols are tiny solid or liquid particles suspended in the atmosphere.

Aerosols are generated both naturally and as a result of human activities.

INTRODUCTION

Particles are one of the most important and certainly the most visible aspects of air pollution.

The effects span the areas of health (1% increase in mortality per 10 μg m^{-3}); acid rain, visibility degradation, radiation and photochemistry and cloud microphysics changes (and thus climate changes), and the Antarctic ozone hole.

NOMENCLATURE

Particle refers to a solid or liquid, larger than a molecule, diameter > 0.01 μm, but small enough to remain in the atmosphere for a reasonable time, diameter < 100 μm.

Aerosol is a suspension of particles in a gas

This animation shows the different sources of aerosols, how they mix in the Earth's atmosphere, and finally disappear by creating sediment or raining out.

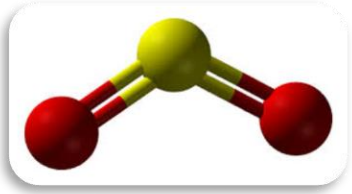
Atmospheric Aerosol

75% of total mass from natural or anthropogenic sources (primary)

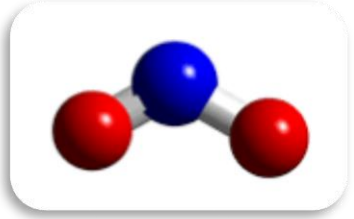
Sea spray (40%)

Combustion and other industry (5%)

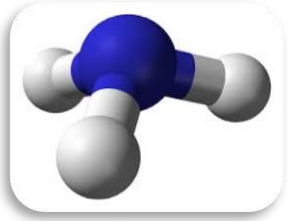
25% of total mass from conversion of gaseous constituents to small particles by photochemical and other chemical processes.



SO_2



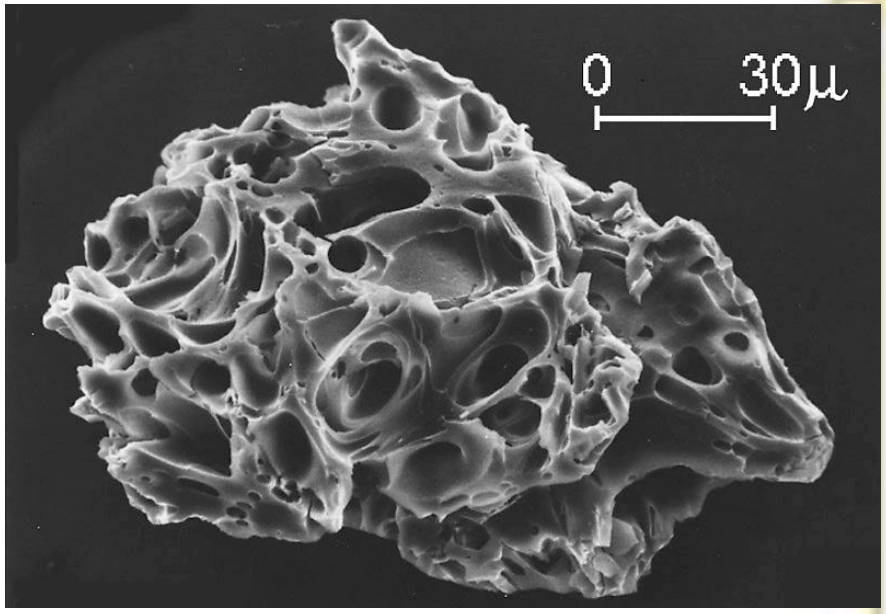
NO_2



NH_3

Aerosols are complex particles; they can occur in nature but can also be generated by humans.

One source of naturally-occurring aerosols is volcanoes. Large-scale volcanic activity may last only a few days, but the massive outpouring of gases and ash can influence climate patterns for years.

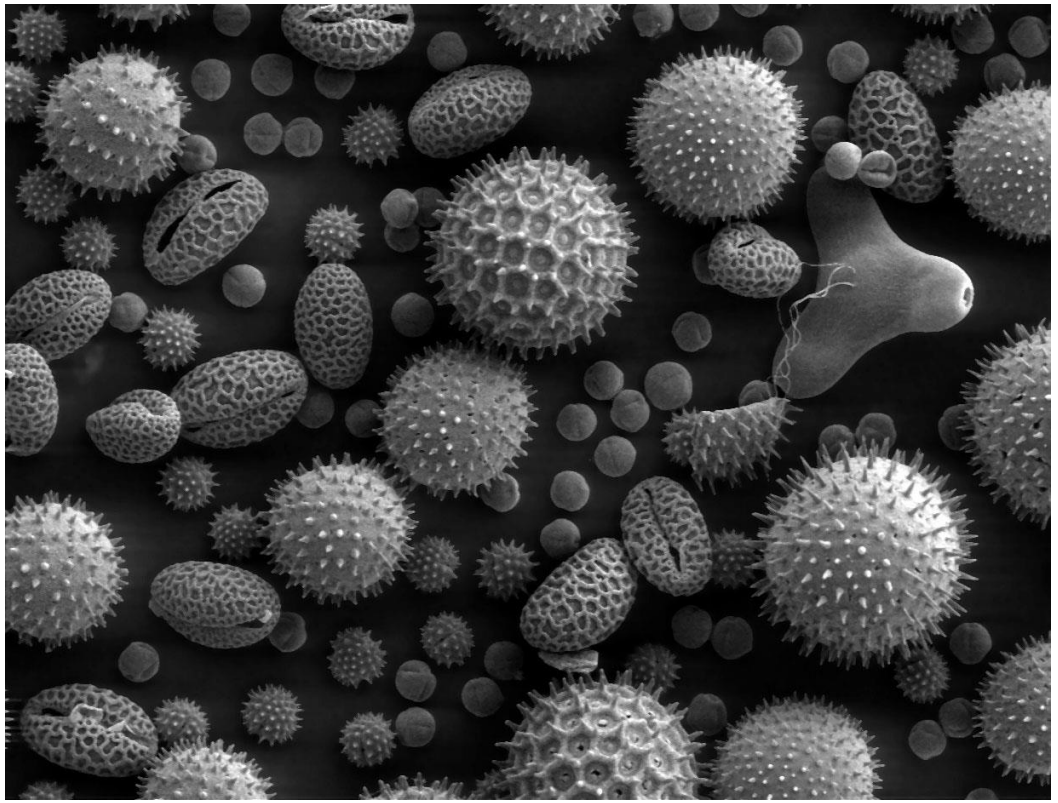


Microscope image of volcanic ash

Sulfuric gases convert to sulfate aerosols, sub-micron droplets containing about 75 percent sulfuric acid.

Following eruptions, these aerosol particles can linger as long as three to four years in the stratosphere. Still image courtesy of United States Geological Survey.

Scanning Electron Microscopic image of pollen grains from sunflower, morning glory, prairie hollyhock, oriental lily, evening primrose, and castor bean.



Pollen effect human health, but researchers do not consider these aerosols to be part of the climatologically important population of tropospheric aerosols.

Aerosols such as salt, dust and black carbon come in numerous shades depending on their chemical composition.

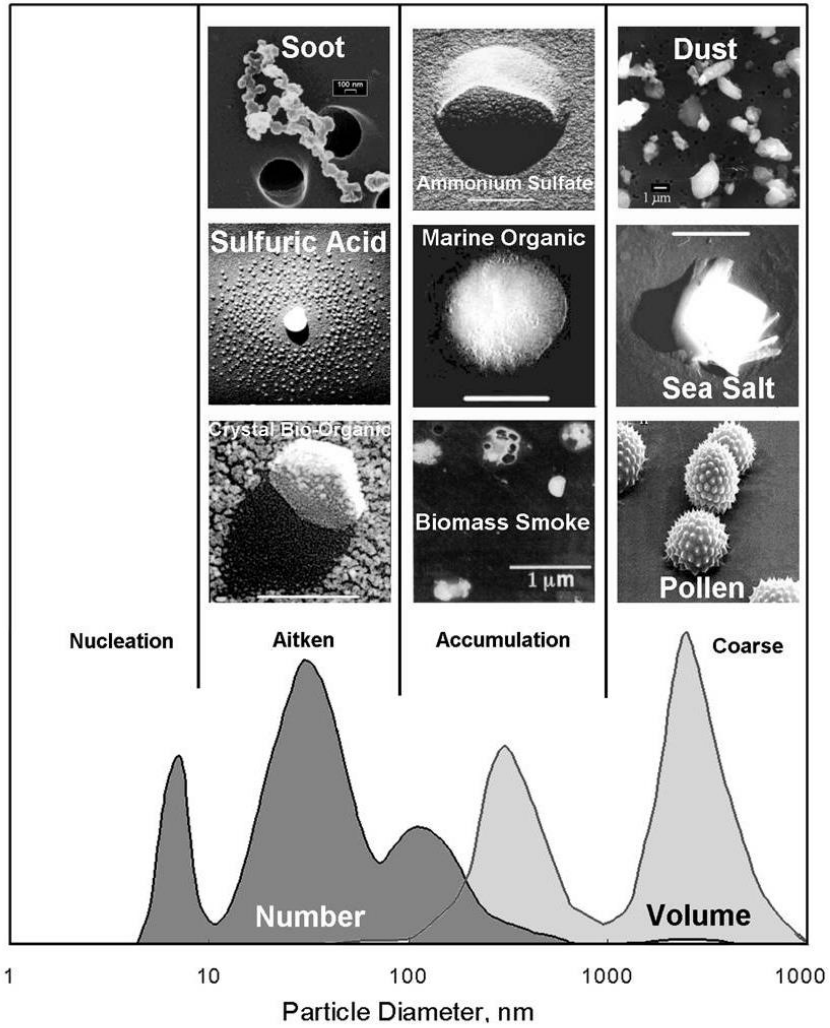
The Aerosol Modes

Aitken mode – 0.01-0.1 μm

Accumulation mode (Large Nuclei) – 0.1-1 μm

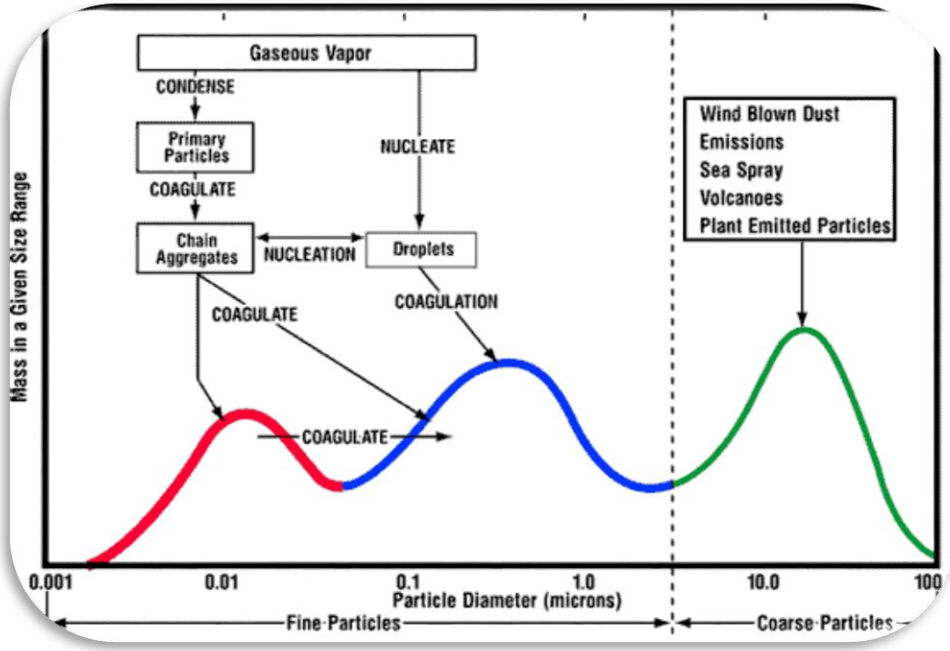
Coarse mode - >1 μm

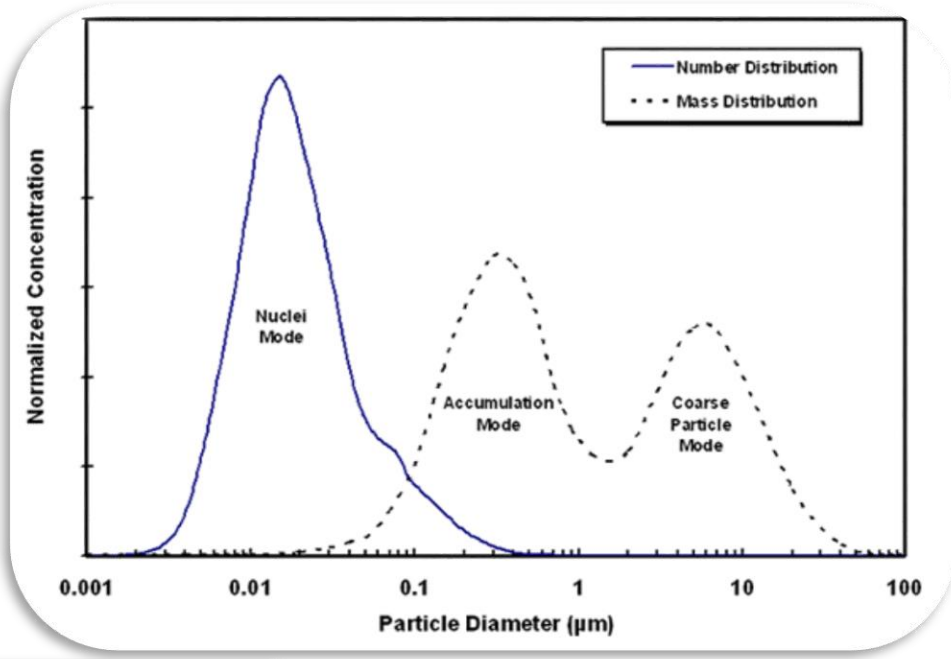
and sometimes, the elusive
nucleation mode <0.01 μm

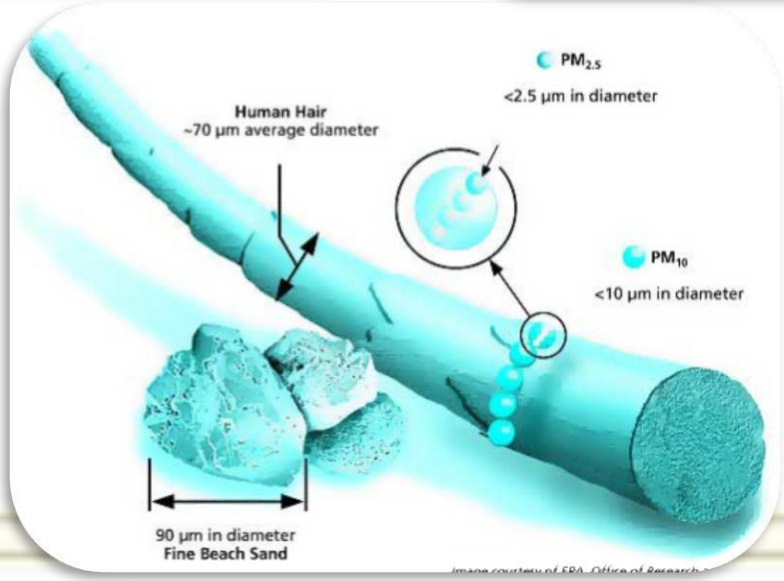


Thought accumulation mode to be most important in natural cloud formation

These particles range in size from less than 0.01µm to greater then 10µm



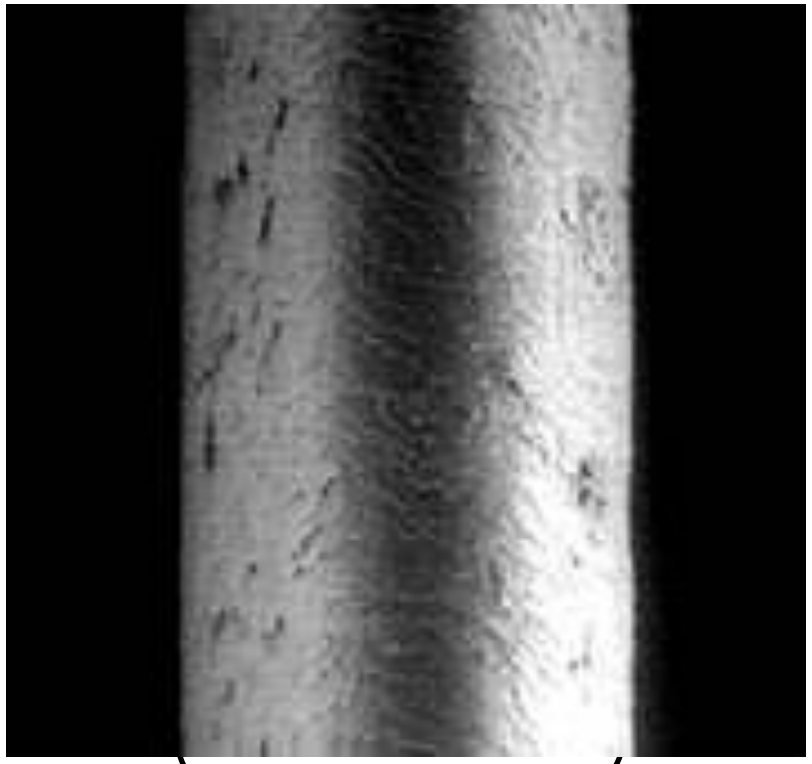




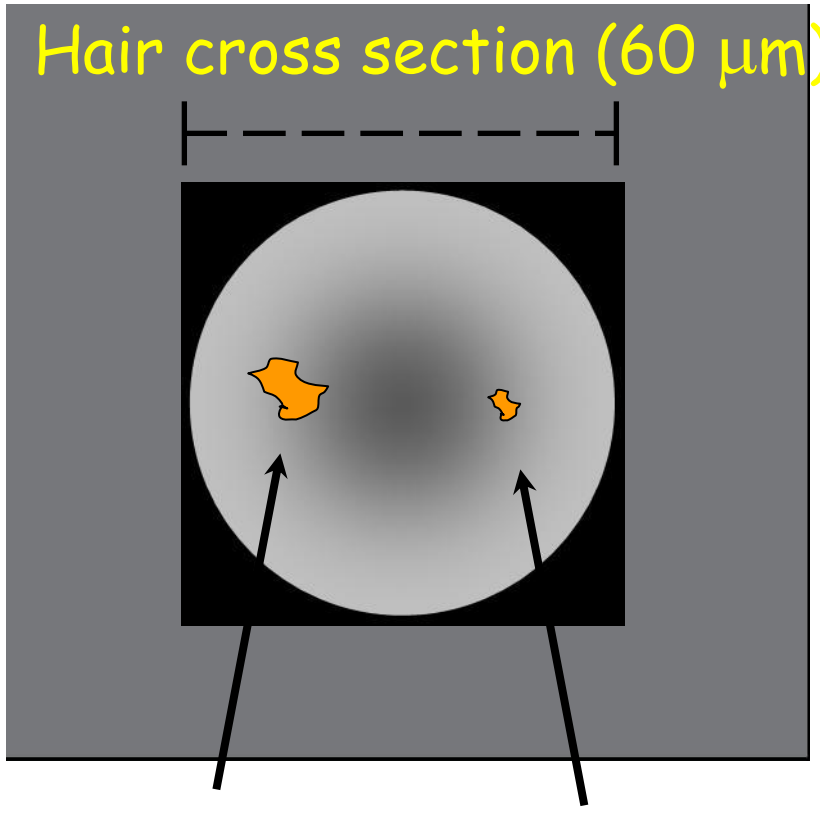
Atmospheric Aerosol Sizes

Aerosol can be as small as 0.001 μm to as large as 10 μm. They vary spatially due to the local conditions.

Air Quality Monitoring



Human Hair
(60 μm diameter)



PM_{10}
(10 μm)

$PM_{2.5}$
(2.5 μm)

Total suspended particles (TSP)

PM_{10} – thoracic particles

$PM_{2.5}$ – respirable particles

There are two PM_{10} standards,

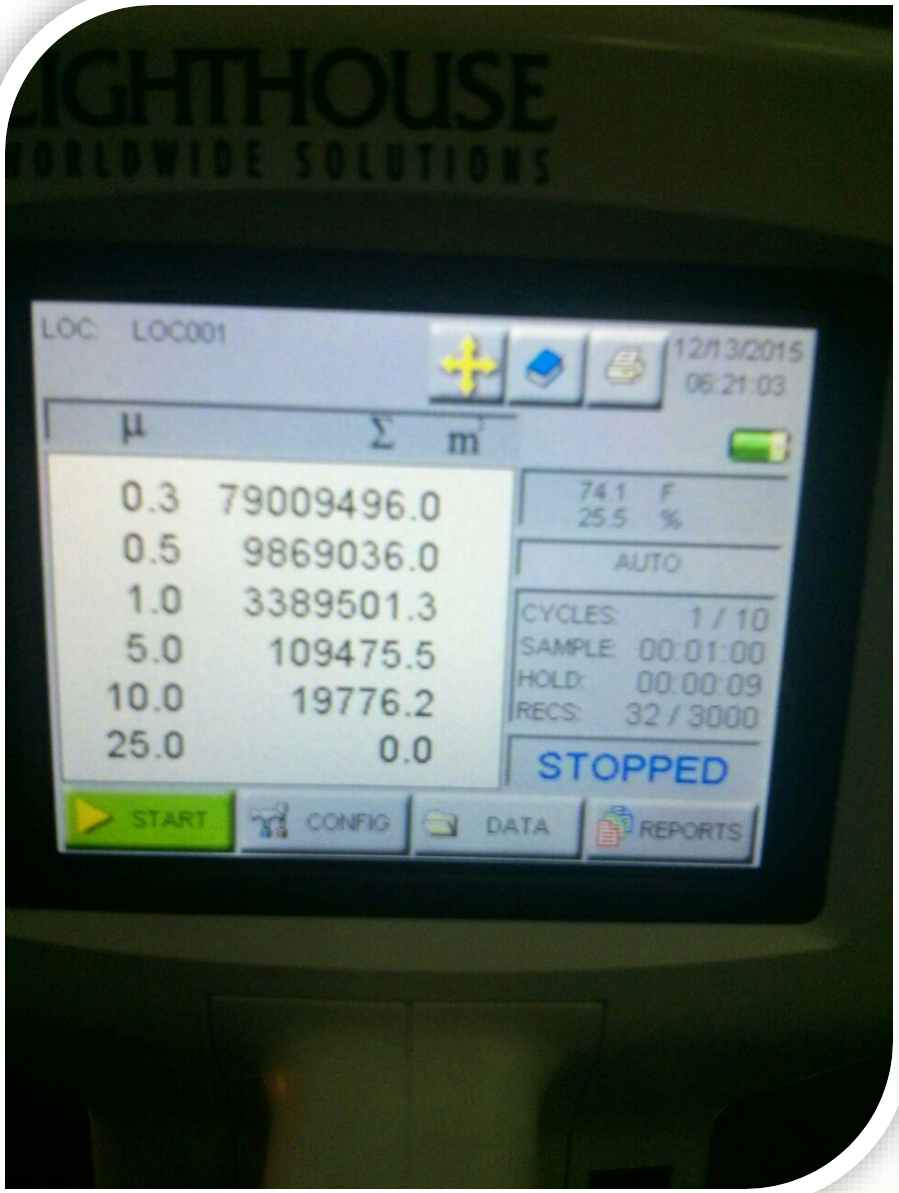
a 24-hour standard and an annual standard.

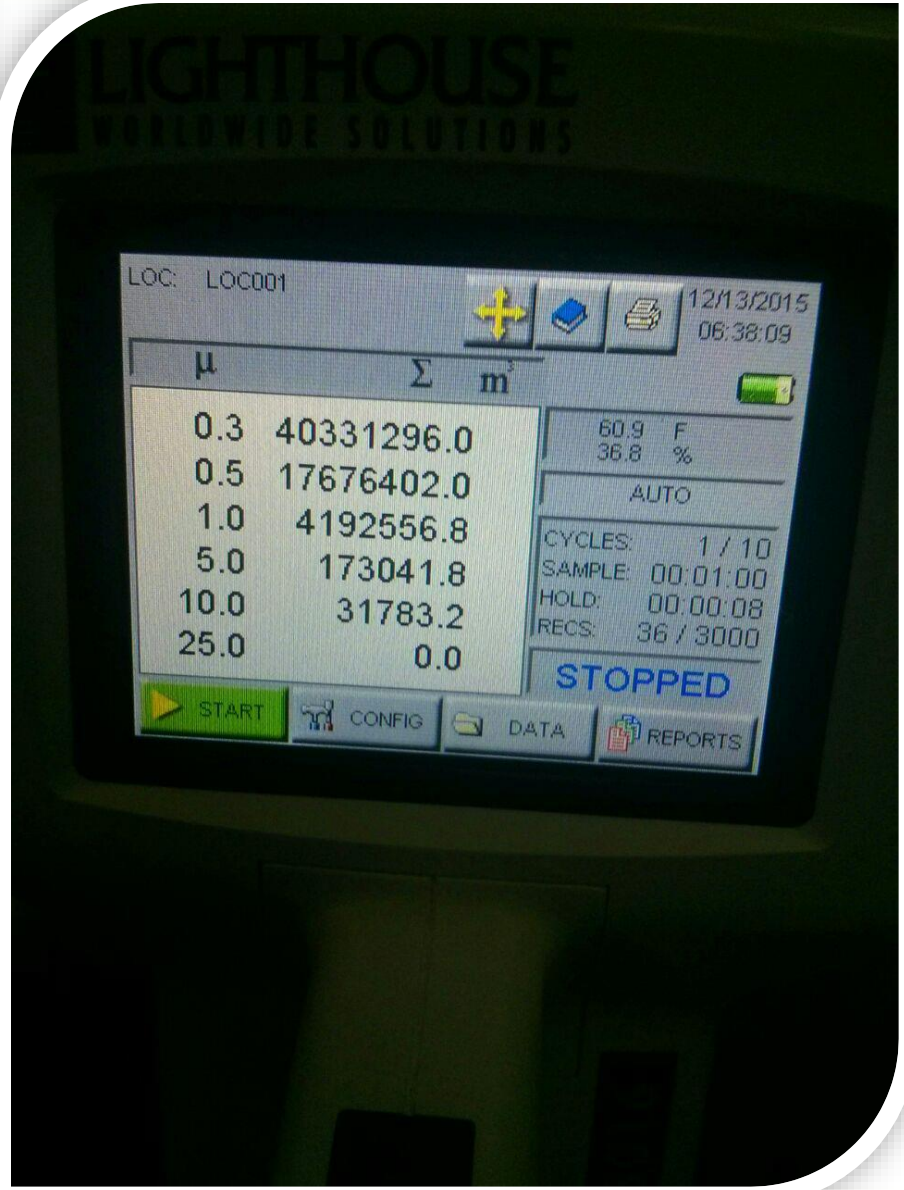
These standards are:

150 micrograms per cubic meter ($\mu g/m^3$) for the 24 hour standard

50 micrograms per cubic meter ($\mu g/m^3$) for the annual standard

Primary/ Secondary	Indicator	Averaging Time	Level (1)
Primary	TSP (2)	24-hour	260 μg/m^3
		Annual	75 μg/m^3
Secondary	TSP	24-hour	150 μg/m^3
		Annual	60 μg/m^3
Primary	$PM_{2.5}$	Annual	12.0 μg/m^3
Secondary		Annual	15.0 μg/m^3
Primary and Secondary		24-hour	35 μg/m^3
Primary and Secondary	PM_{10}	24-hour	150 μg/m^3


LOC: LOC001
12/13/2015
06:21:03
μ Σ m³
0.3 79009496.0
0.5 9869036.0
1.0 3389501.3
5.0 109475.5
10.0 19776.2
25.0 0.0
74.1 F
25.5 %
AUTO
CYCLES: 1 / 10
SAMPLE: 00:01:00
HOLD: 00:00:09
RECS: 32 / 3000
STOPPED
START
CONFIG
DATA
REPORTS


LOC: LOC001
12/13/2015
06:38:09
μ Σ m³
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0.5 17676402.0
1.0 4192556.8
5.0 173041.8
10.0 31783.2
25.0 0.0
60.9 F
36.8 %
AUTO
CYCLES: 1 / 10
SAMPLE: 00:01:00
HOLD: 00:00:08
RECS: 36 / 3000
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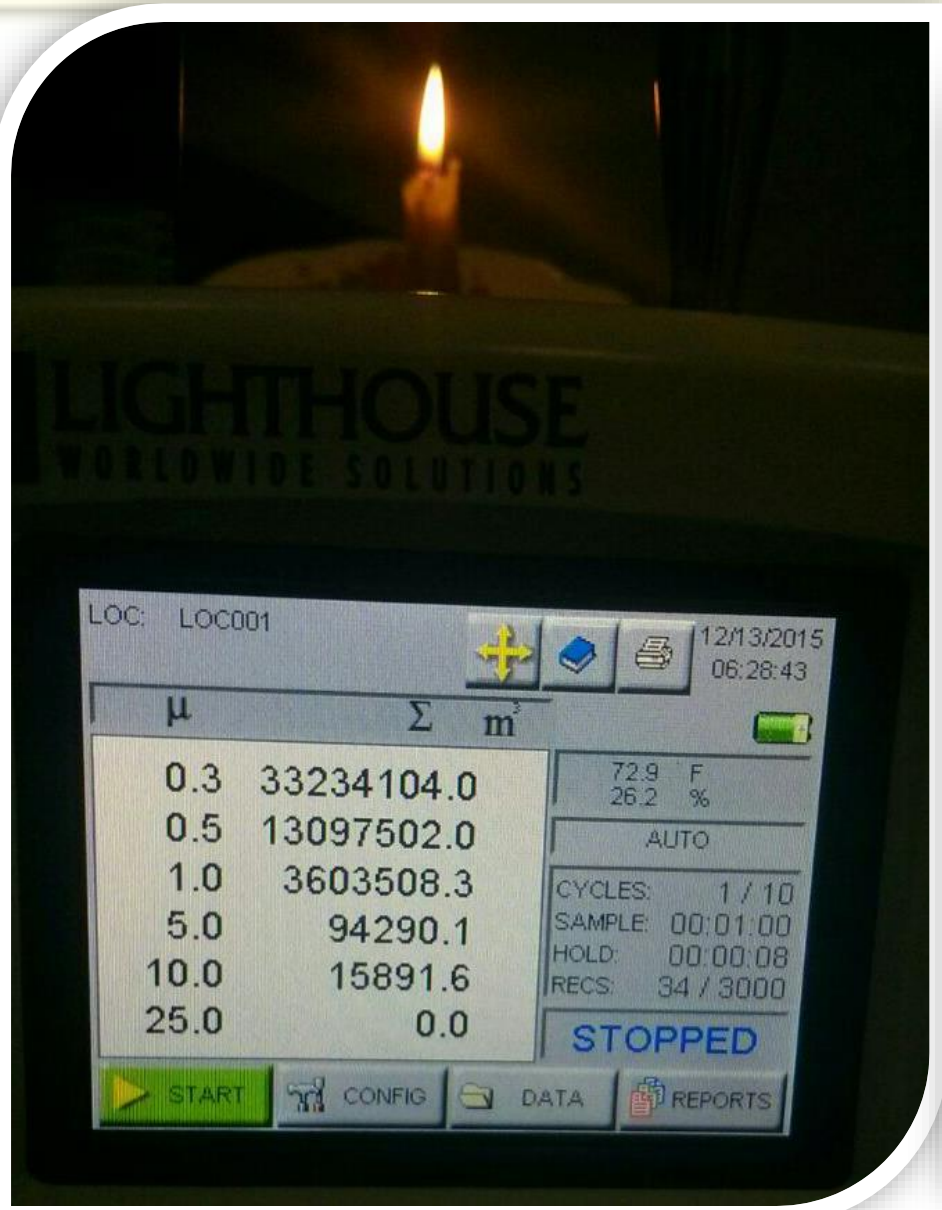
START
CONFIG
DATA
REPORTS


LIGHTHOUSE
WORLDWIDE SOLUTIONS
LOC: LOC001
12/13/2015
06:28:43
μ Σ m³
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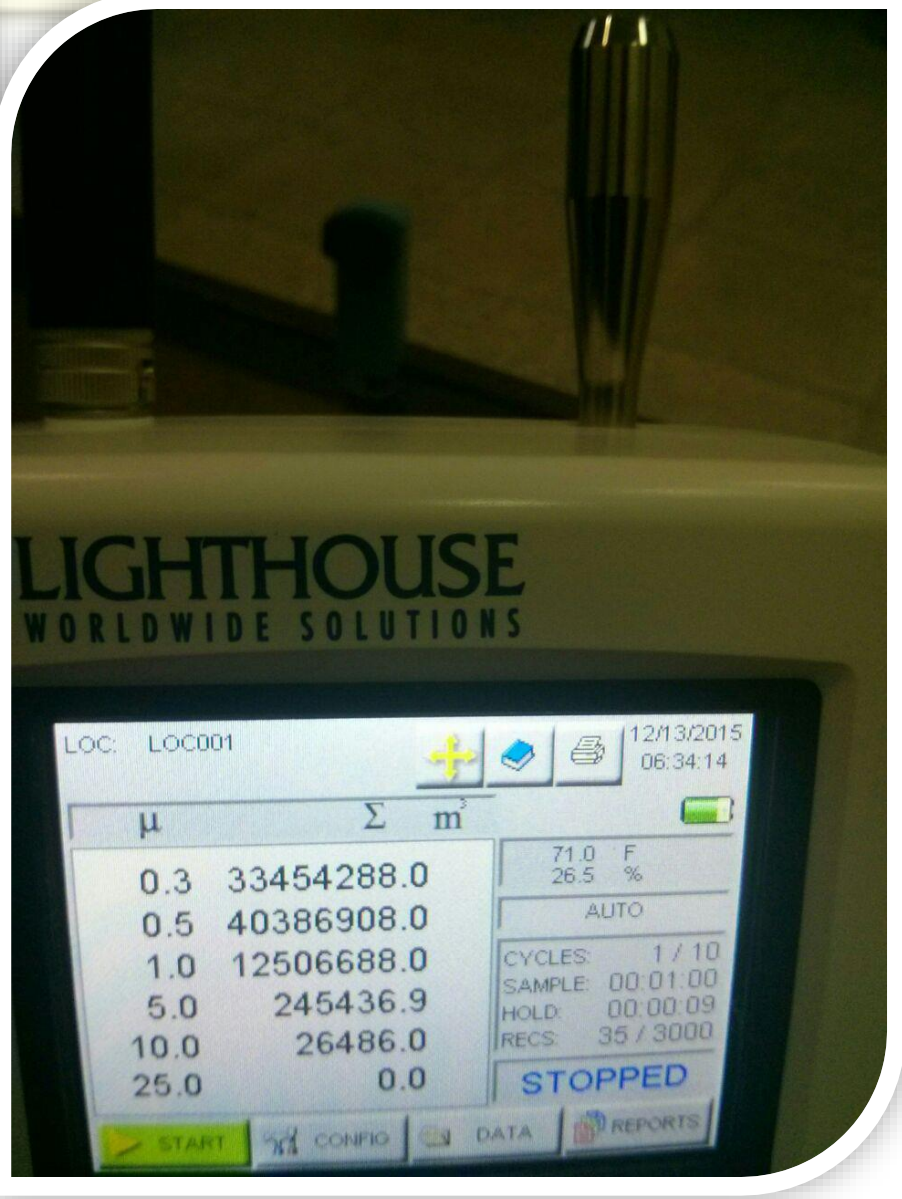
0.5 13097502.0
1.0 3603508.3
5.0 94290.1
10.0 15891.6
25.0 0.0
72.9 F
26.2 %
AUTO
CYCLES: 1 / 10
SAMPLE: 00:01:00
HOLD: 00:00:08
RECS: 34 / 3000
STOPPED
START
CONFIG
DATA
REPORTS


LIGHTHOUSE
WORLDWIDE SOLUTIONS
LOC: LOC001
12/13/2015
06:34:14
μ Σ m³
0.3 33454288.0
0.5 40386908.0
1.0 12506688.0
5.0 245436.9
10.0 26486.0
25.0 0.0
71.0 F
26.5 %
AUTO
CYCLES: 1 / 10
SAMPLE: 00:01:00
HOLD: 00:00:09
RECS: 35 / 3000
STOPPED
START
CONFIG
DATA
REPORTS

Urban Aerosol

Anthropogenic sources

Stationary sources: power plants, refinery plants, mines, etc.

Motor vehicles

Combustion – very important source

Particle concentration

A few tens of $\mu g/m^3$ to 1 mg/m^3 in heavily polluted areas

Hazes produced by the urban aerosol in Mumbai, India and Guangzhou, China

Data from: W.C. Hinds, Aerosol Technology, 2nd Edition