The “Micro” Aethalometer®:
an enabling technology for new applications in measuring Aerosol Black Carbon

Anthony D. A. Hansen, Magee Scientific, California
Griša Močnik, Aerosol d.o.o., Slovenia
Aerosol Black Carbon: “Soot”

- Formed in all combustion of carbon fuels
- **Small** particle size (typically < 0.3 µm)
- Graphitic microstructure is **black** (~10 m²/gram)
- **Inert**: not destroyed by in-atmosphere processes: removed from the atmosphere only by deposition
- **Active Surface** may be highly porous and covered with chemically-active functional groups and **toxics**
- May act as a **condensation nucleus** and interact with **cloud nucleation and precipitation**
Aerosol Black Carbon: Sources & Emissions

- BC emission factors can be very different (factor $10^6$): emissions depend on quality of combustion
- BC not directly related to CO$_2$ emission
- Climate forcing depends on both CO$_2$ and BC
- Local BC concentrations that affect public health can be highly variable

- BC emissions can not be predicted: must be measured
- Both Climate and Health require more data in all dimensions - BC ($X, Y, Z, t$)
Aerosol Black Carbon : Global Measurements

WORST : Asia, BC = 10 ~ 100 µg/m³. Exposure of 2 x 10⁹ people
Aerosol Black Carbon : Global Measurements

BEST : Antarctica, BC ~ 100 pg/m³. Exposure of 200 people
Aerosol Black Carbon covers continents

Picture taken at ~ 1000 m. altitude over New Delhi, India: early morning.

**City is invisible:** solar radiation reaching the ground is reducing ~ 5% per decade over the entire country.

~ 12% of Delhi population ( > 3 million people) have **respiratory disease**.
Climate Change Effects of Aerosols

*Climate Effects of Black Carbon Aerosols in China and India*
S. Menon, J. Hansen et al.  *Science* 27 Sep 02: 2250-2253

Haze over Asia: up to 40% of sunlight absorbed. Agriculture affected; local rainfall changed.
Air Pollution Economic Effects

THE COST OF AIR POLLUTION
Cost of particulate emissions as % of national income (GNI)

SOURCE: World Bank 2002
Optical Analysis Method for Black Carbon

- Instantaneous
- Non-destructive
- Mobile / Portable
- Added dimension - time
- Added dimension - wavelength

Light Source $\rightarrow$ BC $\rightarrow$ Light Detectors

Filter with Sample

Reference $I_0$ $\rightarrow$ Sensing $I$
Analytical Instrument : Aethalometer®

- Collect sample **continuously**
- Measure optical absorption **continuously**
- May use multiple wavelengths 370 nm ~ 950 nm.
- Convert **optical absorption** to **mass of BC**
- Determine **increment of mass** in each time period
- Measure air flow rate; convert **mass** to **concentration**.
- Real-time data: 1 second / 1 minute
  - Dynamical, real-time measurement, updated each period
Real-Time Optical Absorption Analysis
Analytical Instrument : Aethalometer®

“Large” : 19-inch rack mount chassis
Fixed stations for air-quality monitoring

- Measurements at a fixed point
- Analyze data patterns to determine source contributions
- **Different** locations can have **different** temporal patterns
“Micro” Aethalometer: same principle

.. but smaller size
Micro Aethalometer applications

- Personal exposure monitoring
- Vertical profile – balloons, aircraft
- Indoor monitoring in ‘special’ locations
- Direct measurement of source emissions
Mobile measurements – Barcelona, Spain 2009

“Micro” Aethalometer model AE51
Mobile measurements – Barcelona street study

Micro Aethalometer data: streets of Barcelona, Spain.
Raw 1-second data exactly as recorded

Data courtesy of Audrey de Nazelle, Mark Nieuwenhuijsen, Centre for Research in Environmental Epidemiology (CREAL), Barcelona; Dane Westerdahl; Scott Fruin, Univ. Southern California.
Vertical profiling

California - idea

Italy – tethered balloon

Colorado, USA – released balloon
Vertical profiling - results

Tethered balloon – Milan, Italy
December 2008

Balloon operations courtesy of Dr. L. Ferrero & Prof. E. Bolzzachini,
Dept. of Environmental Science, University of Milano – Bicocca, Italy

Released balloon – Colorado, USA
December 2009

Data courtesy of R. C. Schnell, E. Hall, A. Jordan
NOAA/GMD Boulder CO
Measurements in commercial aircraft – estimates of BC at 10 ~ 12km. altitude

BC measurement in cabin of commercial aircraft: SFO-NYC

Wednesday, 2-Dec-09
depart from San Francisco
at 12 km. altitude in air-traffic zone over Chicago
approach New York

BC ng/m3

9:30 10:00 10:30 11:00 11:30 12:00 12:30 13:00 13:30 14:00

0 100 200 300
Infiltration monitoring in museum

Indoor/Outdoor Monitoring of BC Infiltration
Convent of Santa Maria delle Grazie (Refectory), Milan

Data courtesy of Dane Westerdahl, Univ. Southern California

Griša Močnik
Direct measurement of source emissions

Diesel engine - raw exhaust

Optical BC, thermal EC vs. engine load

Stove Emissions Testing
AITCC Bangkok, 17-Nov-09

BC, ug/m³

Engine Load

0% 20% 40% 60% 80% 100%

0 10,000 20,000 30,000 40,000 50,000 60,000 70,000 80,000 90,000 100,000

AE91 Optical BC
NIOSH 5040 Thermal EC

BC, EC ug/m³
Summary

• Black Carbon has serious effects on Health and Climate

• BC is highly variable and must be measured

• “Large” Aethalometers are suitable for fixed stations

• The “Micro” Aethalometer allows for measurements
  • On individual people
  • On balloons and aircraft
  • In ‘special’ indoor locations
  • Of direct source emissions

BC ( X, Y, Z, t )
Thank you for your attention,
I’ll be happy to answer any questions.
\( \mu Aeth \Rightarrow BC (X, Y, Z, t) \)

for further information:  www. MageeScientific. com