Low cost low tech (LCLT) sensors: Field Evaluations and multi-sensor approaches for emissions factors

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What is Meant By:

• **Low-Cost**
  – 100’s of $’s

• **Low-Tech**
  – Existing Technology
  – Tried and True Technique
‘Airpocalypse’ Hits Harbin, Closing Schools

(Mia Li, NYT, Oct. 21, 2013)
Beijing to more accurately monitor air quality

By LOUISE WATT | Associated Press – Sun, Oct 7, 2012

BEIJING (AP) — Beijing authorities have completed a network of monitors that will more accurately measure air quality in the smog-ridden city after being pushed into it by public pressure and pollution reports from the U.S. embassy.

The Beijing Municipal Environmental Monitoring Center said Saturday that another 15 monitoring stations had begun releasing real-time data on small particulates known as PM2.5. The tiny pollution particles that may result from the burning of fuels in vehicles and power plants can penetrate deep into the lungs, so measuring them is considered a more accurate reflection of air quality than other methods.

Chinese citizens have prodded their government into publishing more detailed pollution data since the U.S. Embassy started publishing PM2.5 readings taken from its rooftop on Twitter.
Household Cooking in LDR’s

(Aprovecho, 2008)
PM of 1000 ug m^{-3} Last Winter in India
Why Do We Need Sensors?

• Enhance our understanding of temporal and spatial variability of PM
• Better estimate personal exposure to PM
• Determine emissions and sources of PM
• Supply critical air quality information to policy makers and the public
Typical Air Quality Monitoring Station in the US
Railyard Location

- Inman and Tilford Railyards are located in urban Atlanta
- Fire Station 8 (FS) Georgia EPD monitoring site on the edge of the yards
Determining Railyard Emissions with Monitoring Stations

- CO₂ (Thermo 41i Analyzer)
- BC (Thermo MAAP Analyzer)
- PM₂.₅ (R&P TEOM Analyzer)
BC Events (Slope Method)

09/17/2011 2:14 p.m.

Graph showing the concentration of BC (black carbon) and CO₂ over time. The inset graph illustrates a linear relationship with the equation $y = 2.194x - 2.169$ and an $R^2$ value of 0.9.
Using Measurements to Estimate Impacts
In-Vehicle Measurements

Handheld particle counter calculated PM2.5 mass

2-stage Cascade Impactor coarse and fine mass, metals

47 mm filter organic speciation

25 mm filters EC/OC, ions, WSOC

Aethalometer black carbon particles

Manifold for filter holders

Condensation particle counter particle number concentration

PAH meter particle-bound PAHs

Noise Dosimeter sound level
BC: In-Vehicle vs. Stationary Site

BC in Atlanta, Georgia on 9/5/2012

- EPD Site
- In-Vehicle

(Time: 7:30 to 9:30)

(ACE Study, Emory/Gatech; In Progress)
BC In Atlanta Rush Hour

(R. Greenwald, Emory Univ.)
Light Scattering Methods: Single Particle

Single Particle Counting

(Wilson, J., 1983)
Light Scattering Methods: Volume Scattering

Scattering by volume of particles
Nephelometer-TEOM Comparison

\( R^2 = 0.80 \)

(Carrico et al., 2003)
Low Cost PM Sensors: Many Options

- Shinyei PPD42NS ($20)
- Shinyei PPD20V ($350)
- Sharp ($12)
- Shinyei PPD60V ($760)
Do They Work?

Low accuracy and precision (no problem):
• Is the air quality in my region bad?
• Is my indoor air filter working?
• Are there high-emitting sources in my neighborhood?

Higher accuracy and precision (to be determined):
• What are the specific health impacts of PM?
• Is my region out of EPA attainment?
• What are the source contributions to PM concentrations?
Comparing Sensors, Georgia Tech Roof

1 Shinyei PPD42NS ($20)
   • Shinyeidig

3 Shinyei PPD20V ($350)
   • Shinyei1, Shinyei2, Shinyei3

1 Shinyei PPD60V ($700)
   • Shinyei60

3 1” fans to provide air flow through sensors and box
Comparing Sensors: Preliminary Results

- Shinyei 1-3 (PPD20V) $r^2 = 0.8 - 0.9$
- $r^2 < 0.3$ for all Shinyei’s and TEOM
Near Road Low Cost Sensor Evaluation

- COZIR-CO$_2$ Sensor
- Shinyei-PM Sensor
- microAeth-Black Carbon
- Arduino-microcontroller
- Temperature and humidity sensor
Atlanta Roadside $CO_2$ Comparisons

- Thermo 410i $CO_2$ Analyzer (~9k$) and COZIR $CO_2$ (~$100) $r^2 = 0.62$
Atlanta Roadside PM Comparisons

• TEOM (~20k$) and Shinyei Analog (~$300) $r^2 = 0.31$, $\Delta PM = 3.6 \mu g m^{-3}$
A Low Cost Way to Estimate Emissions Factors (EF)

- \( \text{PM}_{2.5} \) EF = 0.39 g per kg fuel (for ~$500!)
Hyderabad, India
Hyderabad India (High PM) Comparisons

- EBAM PM$_{2.5}$ (15k$) and Shinyei (~$300) $r^2 = 0.75$
Estimating High-End Concentrations for Shinyei PPD20V’s

Apply linear regression to data to convert from analog output into concentration.
Other Sensors Clearly do not work as well!
Work In Progress

• Further characterization of existing PM sensors both in the lab and field
• Development of new sensors for specific applications
• Deployment of sensors to form meaningful network of air quality measurements for both public and policy makers
• Data QA/QC, management
• Integration with modeling framework to develop high resolution temporal and spatial information on air pollutants
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