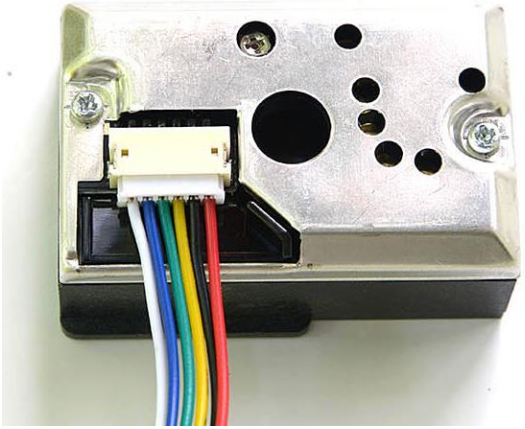
Low cost PM sensors; are they suitable for measuring subtle particle variations in ambient or indoor air?

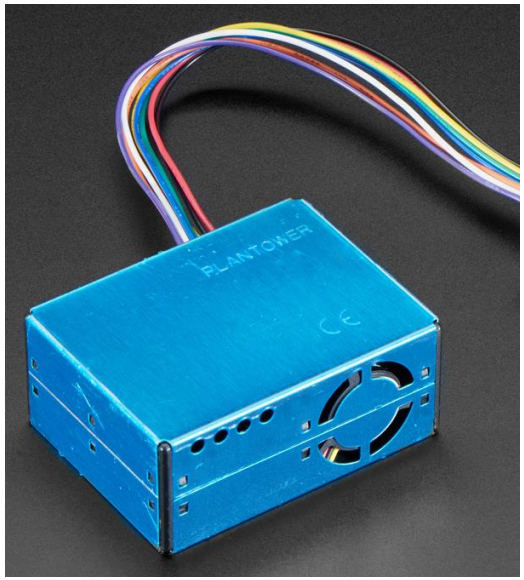
28.06.2019

Scott Lowther PhD Student

What are low cost PM sensors?

- <£1000
- Lightweight
- Portable
- Robust
- Easily operated

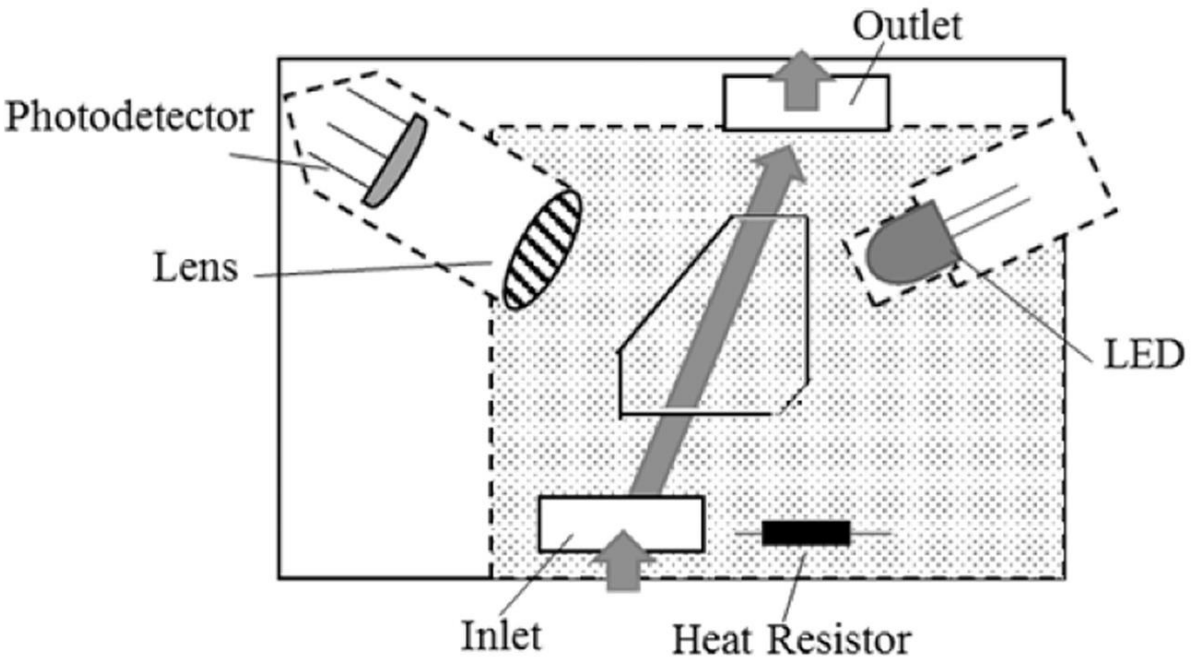




What has driven the development of low-cost sensors?

- Need for
  - High-spatial distribution measurements
  - Low cost personal exposure measurements for epidemiology
  - Detecting pollution hotspots and supplementing emission inventories
- Increasing public awareness of air pollution
- Technology advancements have allowed for miniaturisation of sensors and reductions in cost

Principle of operation

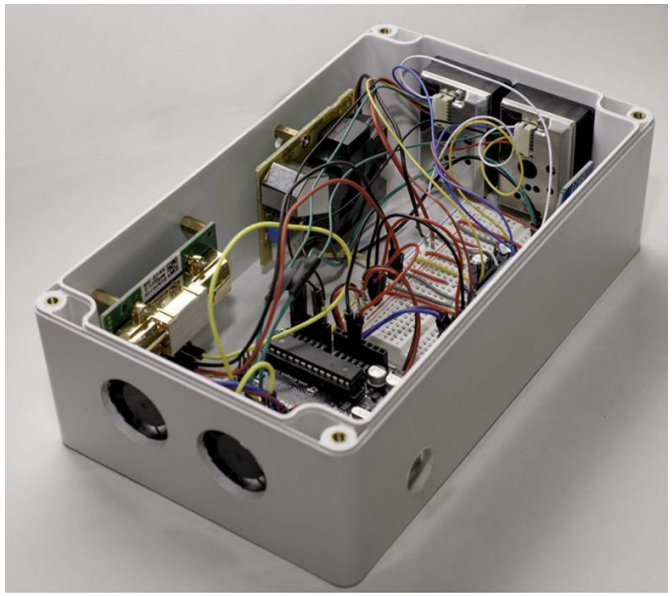


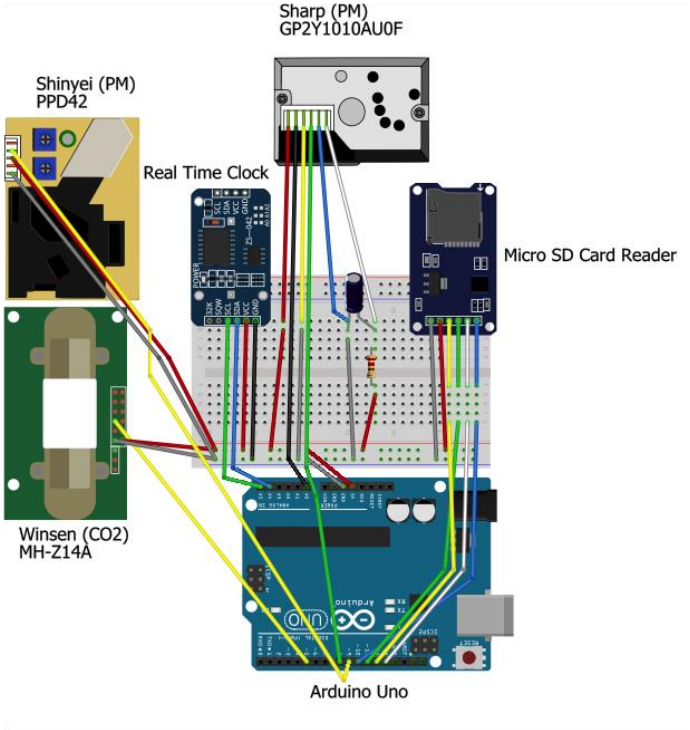
- Detection Limit = 300nm<

- Measurement of scattered light
- LED illuminates particles
- Scattered light is measured by a photodetector at ~90-120°
- Scattered light can infer particle number or particle mass

Integrating low-cost sensors

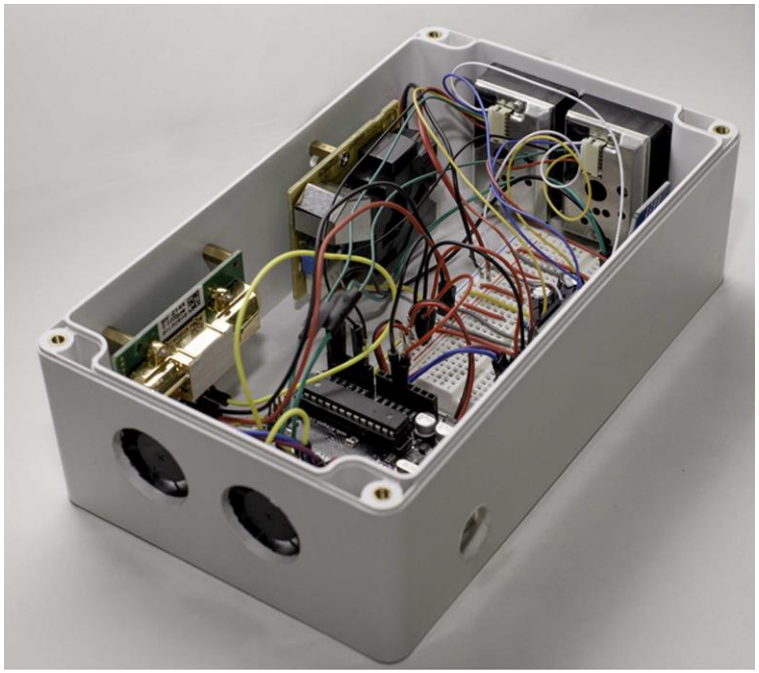
- Require
  - Integration with a microcontroller
  - Data management system





Advantages

- Low cost
- Good linearity vs Reference grade
- Portable lightweight
- Easily operated (important for community measurement/engagement)
- Allow for spatial distribution measurements



Linearity vs Reference Grade

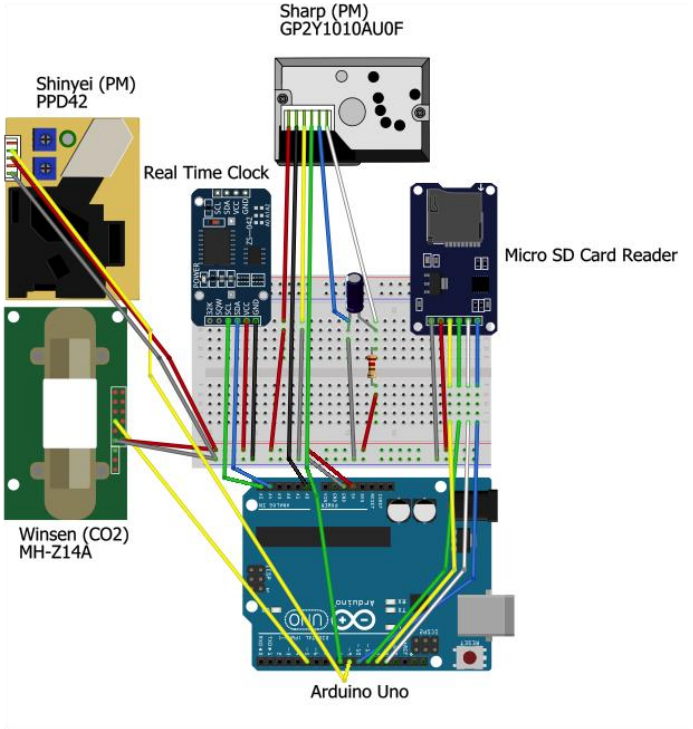
- Laboratory evaluations R^2=0.90-0.99 [1]
- Real world performance R^2=0.4-0.90 [2]
  - These are much lower than Laboratory tests which often cannot reflect the variable nature of PM or meteorological conditions present in the real world.

1 Wang, Y., Li, J., ... Biswas, P., 2015. Laboratory Evaluation and Calibration of Three Low-Cost Particle Sensors for Particulate Matter Measurement. Aerosol Science and Technology 49, 1063–1077. doi:10.1080/02786826.2015.1100710

2 Sayahi, T., Butterfield, A., Kelly, K.E., 2019. Long-term field evaluation of the Plantower PMS low-cost particulate matter sensors. Environmental Pollution 932–940. doi:10.1016/j.envpol.2018.11.065

Limitations

- Need integration into a separate system
- Low limits of detection
- Meteorological effects
  - Limited response to temperature
  - High response to humidity
- No set flow rate
- The high costs of low cost sensors
- Short lifetimes (6 months-years)
  - Due to lifetimes of optics
- Unable to detect UFPs

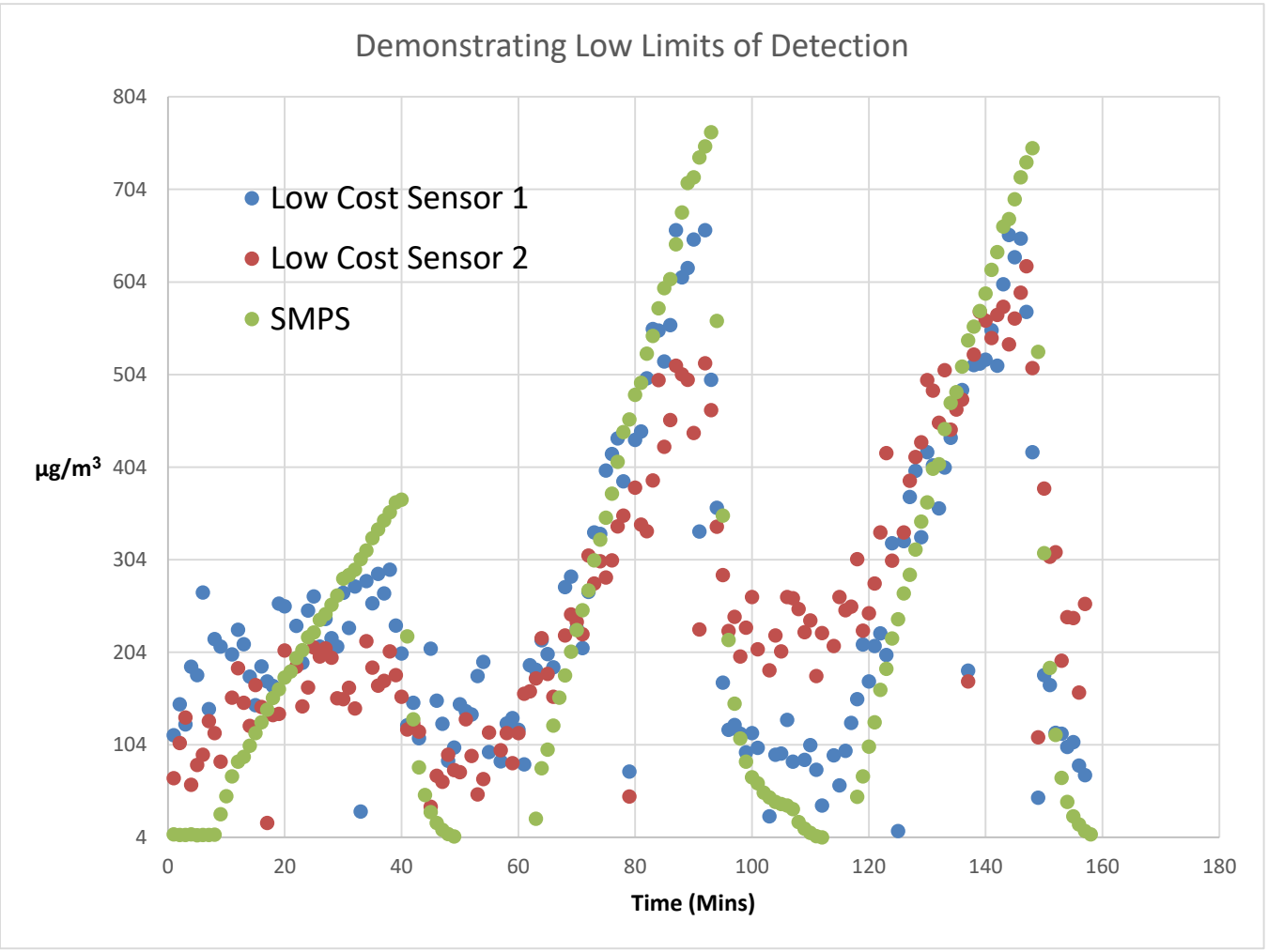


Low Limits of Detection

- The lowest limit that deviates significantly from blank measurements.
- In laboratory experiments: 6-30µg/m^3 [1]
- This limitation reduces the viability of the sensors in measuring exposures, which will often be lower than this threshold

1 Wang, Y., Li, J., ... Biswas, P., 2015. Laboratory Evaluation and Calibration of Three Low-Cost Particle Sensors for Particulate Matter Measurement. Aerosol Science and Technology 49, 1063–1077. doi:10.1080/02786826.2015.1100710

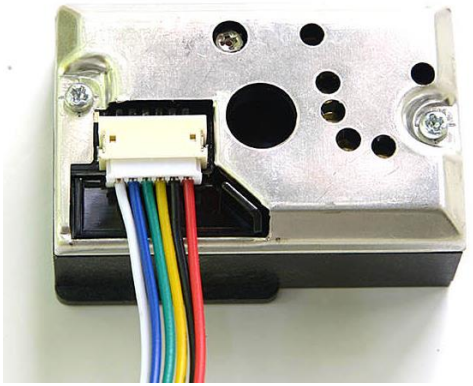
Low Limits of Detection



Extremely low sensitivity at low concentrations

The high costs of low cost sensors

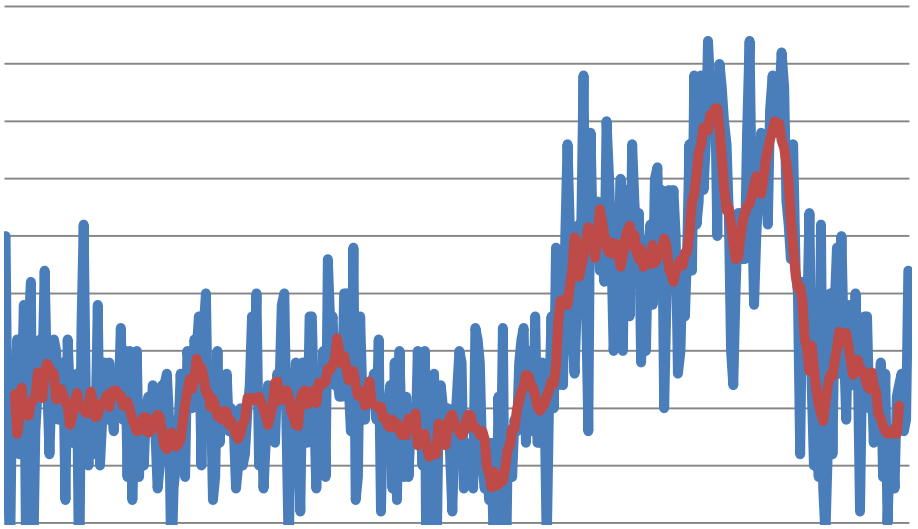
- Integration into a device
- Individual calibration of devices
- Servicing costs (replacing batteries)
- Data processing



These far exceed costs of the sensors themselves

Data Processing

- Low cost sensors commonly have low signal to noise ratios
- Therefore digital filters often need to be applied to the data before it is useful
- Common filters include
  - Sliding window filters
  - Low-pass filters



Indoor Applications

- Smart Homes
  - Air purifiers
  - Ventilation systems
  - Energy efficiency vs Indoor Air Quality
- Measuring exposures to high pollution events
- Spatial distributions in high pollution environments
- As it stands these sensors appear unable to detect subtle differences in concentrations in indoor environments

Conclusions (Future Outlook)

- Improvement of sensors
  - Limits of detection
  - Sensitivity to UFPs
  - Lifetimes
  - Understanding performance under ambient Environmental Conditions
  - Improving data handling
- Accepting limitations and understanding applications
- Importance to public awareness and participation

We are grateful to EuropeAid project SEW-REAP (ECRIP ICI+/2014/348-010) for financial support