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# Characterisation of low-cost particulate matter sensors in an urban area

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# Characterisation of low-cost particle sensors in an urban area

# FINE PARTICLES AND LOW-COST SENSORS



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- Air Pollution in a few figures
- In the world:
  - –9 million deaths per year (*Burnett et al. 2018*)
- In UK, outdoor air pollution alone: about 40,000 deaths/year (*COMEAP 2010*)
- Air pollution varies across small spatial and temporal scales



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## Particulate Matter Size and deposition



Kim et al. 2015 A review on the human health impact of airborne particulate matter





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# Air pollution monitoring stations

• In UK: about 300 sites



Location of AURN stations nearby Southampton (40km radius) - DEFRA 2017



Automated Urban and Rural Network (AURN) station - DEFRA 2017

- Robust and reliable data "Reference level"
- Roadside and background concentrations
- Expensive and require expertise



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# PM reference instruments

- Most common instruments measure PM mass directly, e.g.:
  - Tapered Element Oscillating Microbalance (TEOM) analysers
    - hourly measurements
    - most commonly used in the UK



Figure 2. Schematic diagram of the TEOM ambient particulate monitor.

7



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Low-cost PM sensors – how they work





#### Principle

Sensitive to?

#### Plantower PMS5003

- Aerosol composition
- PM concentrations
- Meteorological factors (humidity, temperature, ...)



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9

## Why low cost sensors?









10

# Low cost PM sensors - limitations

- Count particles and infer mass concentration: limited accuracy
- Assumption on particles characteristics
- Susceptible to a range of environmental factors, mainly to aerosol composition:
- Intra-model variability
- Potential degradation of performances over time

When can we trust the data they produce and when cannot we trust them?





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# Measurements from 10 PM sensors at the same location



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# DESIGN OF THE AIR QUALITY MONITORS



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Johnston, S. J. *et al.* City Scale Particulate Matter Monitoring Using LoRaWAN Based Air Quality IoT Devices. *Sensors* **19**, 209 (2019).



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# Main characteristics

- 15W with a 12V alimentation for up to 10 sensors
- OS: Raspbian
- Data: ~4Mb per day
- Communication:
  - LoRaWAN for 15min averages
  - Raw data logged on the SD card (Ethernet, mobile network, data mule, ...)







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# Characterisation of low-cost particle sensors in an urban area

# DEPLOYMENTS OF SENSORS IN TWO SCHOOLS



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# Objectives of the study

- Collocating multiple models of low-cost PM sensors in a field setting
- Conducting a year long comparison to account for seasonal variations
- Comparing sensors against each other
- Comparing the sensors with the closest reference stations



-1.40



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Inter-model comparison

## Inter-model coefficient of variation (CV): 0.11<CV<0.26 Inter-model Pearson coefficients 0.77<r<0.99, p<0.0001





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## Comparison with the reference station



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22

# Comparison with the reference station

• The sensors compared to the reference station obtained Pearson coefficients **0.61**<**r**<**0.88**, **p**<**0.001**.





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## Comparison with the reference station



![](_page_23_Figure_1.jpeg)

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# Capturing short-lived events of pollution

![](_page_23_Figure_6.jpeg)

![](_page_24_Picture_0.jpeg)

![](_page_24_Figure_1.jpeg)

![](_page_24_Picture_3.jpeg)

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# Potential uses for network of low-cost sensors

- Provide localised information with additional spatiotemporal resolution
- Track local sources of pollution especially if coupled with:
  - Wind data
  - Road vehicle data
  - Shipping data
- Report hourly data to inform the public
- Engage with the public with data they can relate to

![](_page_25_Picture_0.jpeg)

![](_page_25_Picture_1.jpeg)

![](_page_25_Picture_3.jpeg)

# Future direction

- Extension of the existing network (15 locations, total of 130 sensors):
  - other locations in the city (>10 locations)
  - around the port (~10 locations)
- Characterisation under controlled laboratory conditions:
  ->50 of PM sensors.
- Characterisation at Southampton reference station (on-going):
   40 PM sensors
- Deployment (on-going) in Morocco and Vietnam

![](_page_26_Picture_0.jpeg)

![](_page_26_Picture_1.jpeg)

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# Thank you for your attention

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