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► **To cite this version:**

Marie-Laure Aix, Bertrand Baudeur, Gilles Mertens, Dominique J Bicout, Didier Donsez. Low-cost sensors for particulate matter measurement. Workshop IoT platforms for indoor air quality, May 2023, Paris, France. hal-04852581

**HAL Id: hal-04852581**

**<https://hal.science/hal-04852581v1>**

Submitted on 20 Dec 2024

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# Low-cost sensors for particulate matter measurement

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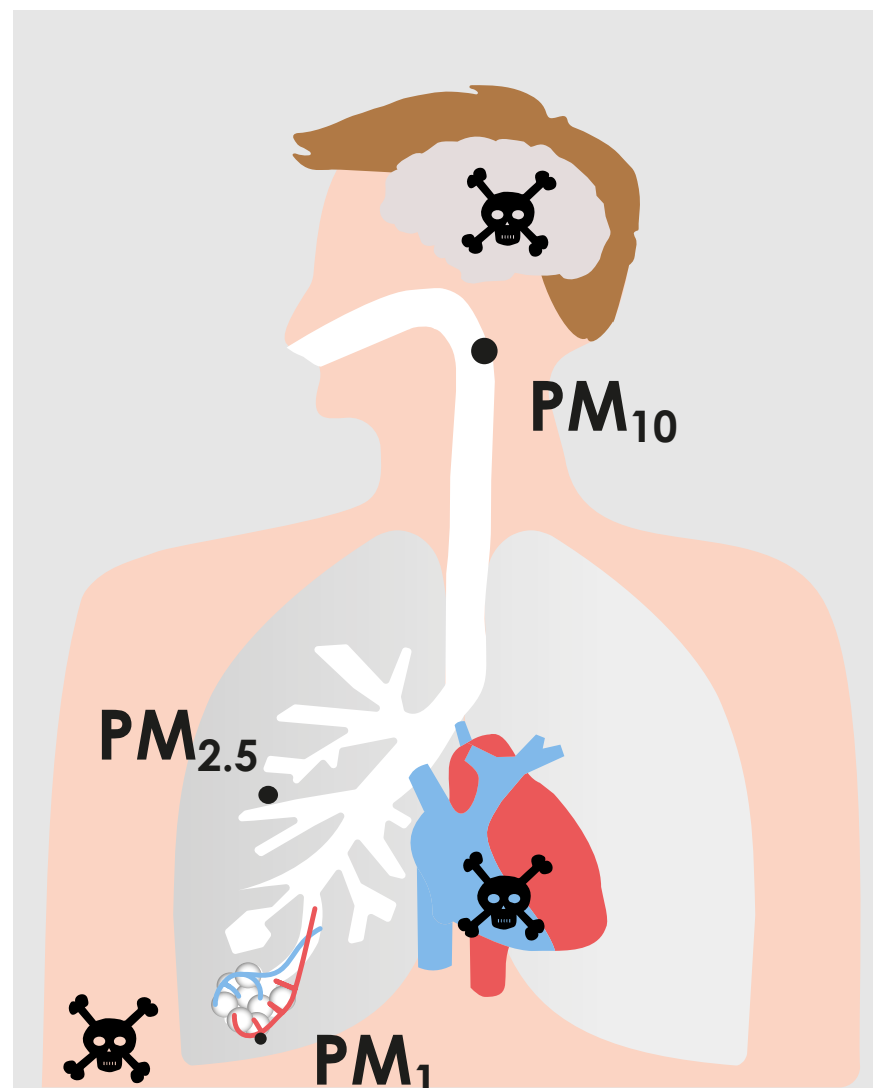
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## INTRODUCTION

Particulate matter (PM) is a global threat to human health, associated with respiratory, cardiovascular, and neurological diseases, as well as premature mortality. PM toxicity depends on several factors, size being a crucial determinant. PM<sub>10</sub> (<10µm), typically remains in the upper tract and is less hazardous than PM<sub>2.5</sub>, which can penetrate deeper into the lungs and PM<sub>1</sub>, which can enter the bloodstream. Accurate measurement of fine PM is critical, and low-cost sensors (LCS) represent a cost-effective complement to official monitoring networks. This feasibility study aims to compare the performance of a Wi-Fi and two LoRaWAN air quality stations (AQ stations) using LCS to measure PM, with the goal of determining whether the LoRa AQ stations can deliver accurate measurements.



## MATERIAL & METHODS

### 1. Prototyping

A first Wi-Fi AQ station was designed and calibrated with a reference monitor (REF) from Atmo Auvergne Rhône-Alpes. This Wi-Fi AQ station performed well in measuring fine PM [1]. Then a LoRaWAN AQ station was developed to eliminate the dependence on Wi-Fi and allow broader deployment. Both stations were equipped with different temperature (T) and relative humidity (RH) sensors. BME280 should perform better than DHT 22 in high-humidity situations. The firmware used for the Wi-Fi AQ station was developed by sensor.community (<https://firmware.sensor.community/airrohr/flashing-tool/>) and enabled reporting of PM<sub>1</sub>, PM<sub>2.5</sub>, PM<sub>10</sub>, T, and RH. For the LoRaWAN AQ stations, a novel firmware using RIOT OS (<https://github.com/RIOT-OS/RIOT>) was developed ([https://github.com/airqualitystation/firmware\\_for\\_bmx280\\_pms7003](https://github.com/airqualitystation/firmware_for_bmx280_pms7003)), allowing the extraction of additional parameters, particularly PM counts within different size ranges.

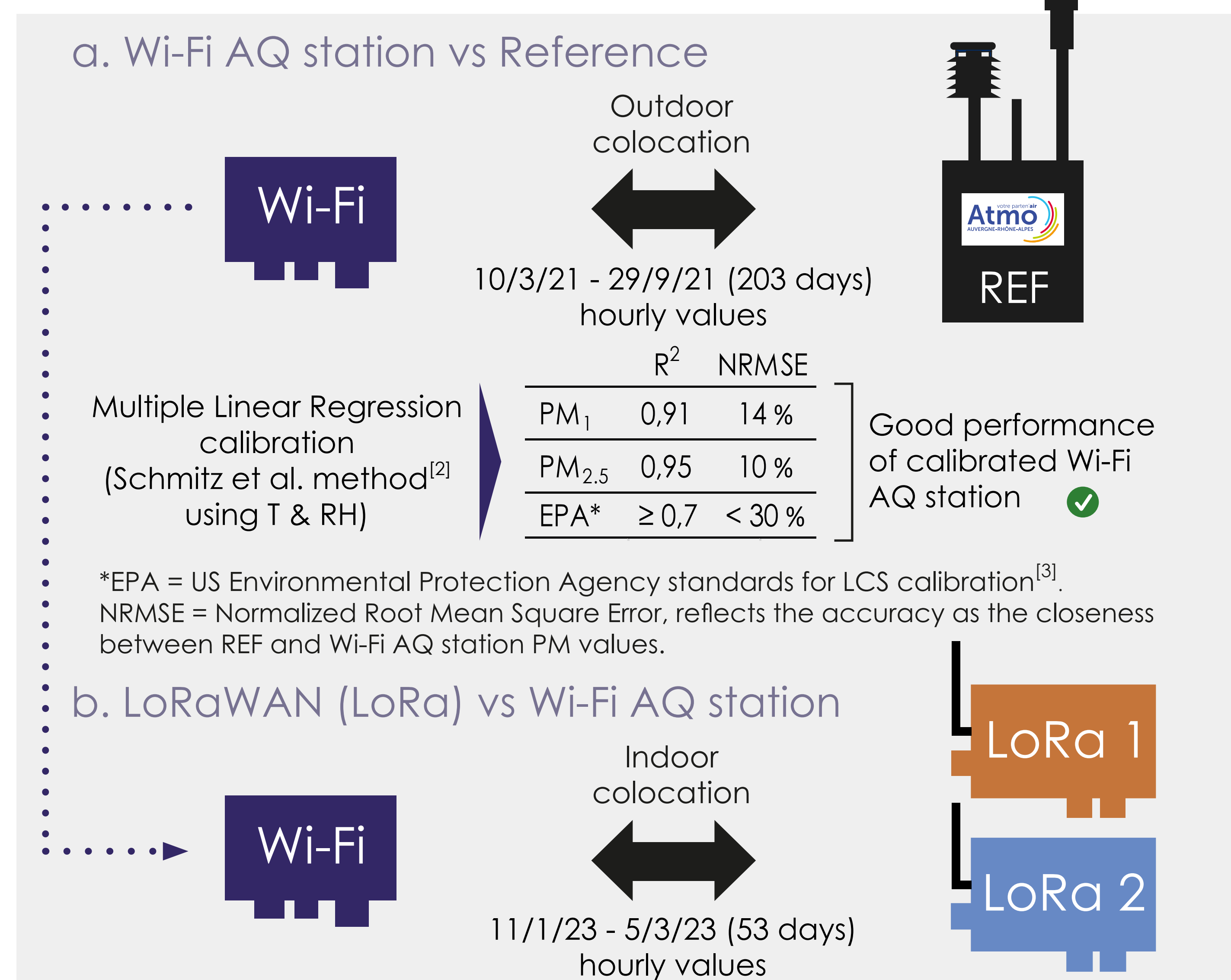
Wi-Fi AQ station			
Variables :	Component	Price (€)	
PM <sub>10</sub> , PM <sub>2.5</sub> , PM <sub>1</sub> , RH, T	PMS7003 (PM sensor)	23,8	
	DHT22 (RH & T sensor)	10,9	
<b>Frequency :</b>	NodeMCU ESP8266 microcontroller	12,3	
Every 150 s	Polycarbonate IP66 outer case	15,9	
	Euromas II wall brackets	3,2	
	USB / USB-A 2m flat cable	11,9	
	5V USB power supply	6,9	
		<b>84,9</b>	

LoRaWAN AQ station			
Variables :	Component	Price (€)	
PM <sub>10</sub> , PM <sub>2.5</sub> , PM <sub>1</sub> , RH, T, pressure, particles count	PMS7003 (PM sensor)	23,8	
	BME280 (RH & T sensor)	19,9	
	LoRa-E5 mini board	27,9	
(>0.3 µm, >0.5 µm, >1 µm, >2.5 µm, >10 µm)	Polycarbonate IP66 outer case	15,9	
	Euromas II wall brackets	3,2	
<b>Frequency :</b>	USB-C / USB-A 3m flat cable	14,9	
8 s median (99,4 % of time intervals < 150 s) *	5V USB power supply	6,9	
		<b>112,5</b>	

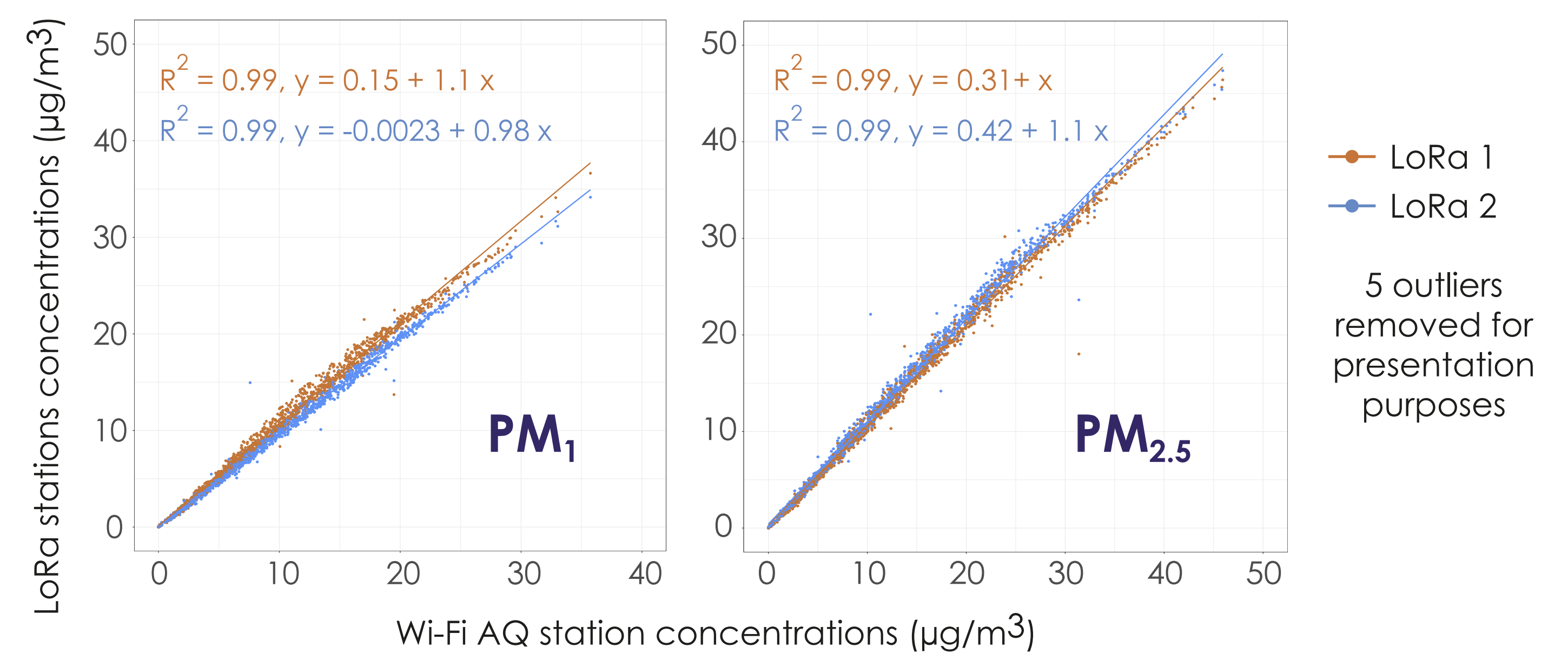
\* According to ESTI regulation, the measurement period is adapted to the datarate depending on the range between the LoRaWAN AQ station & the gateways (5 to 160 s).

### 2. Calibration



## RESULTS

### 1. LoRaWAN performance vs. Wi-Fi AQ station



➔ R<sup>2</sup>, slope & intercept conform to EPA standards ✓

➔ Additional metrics :

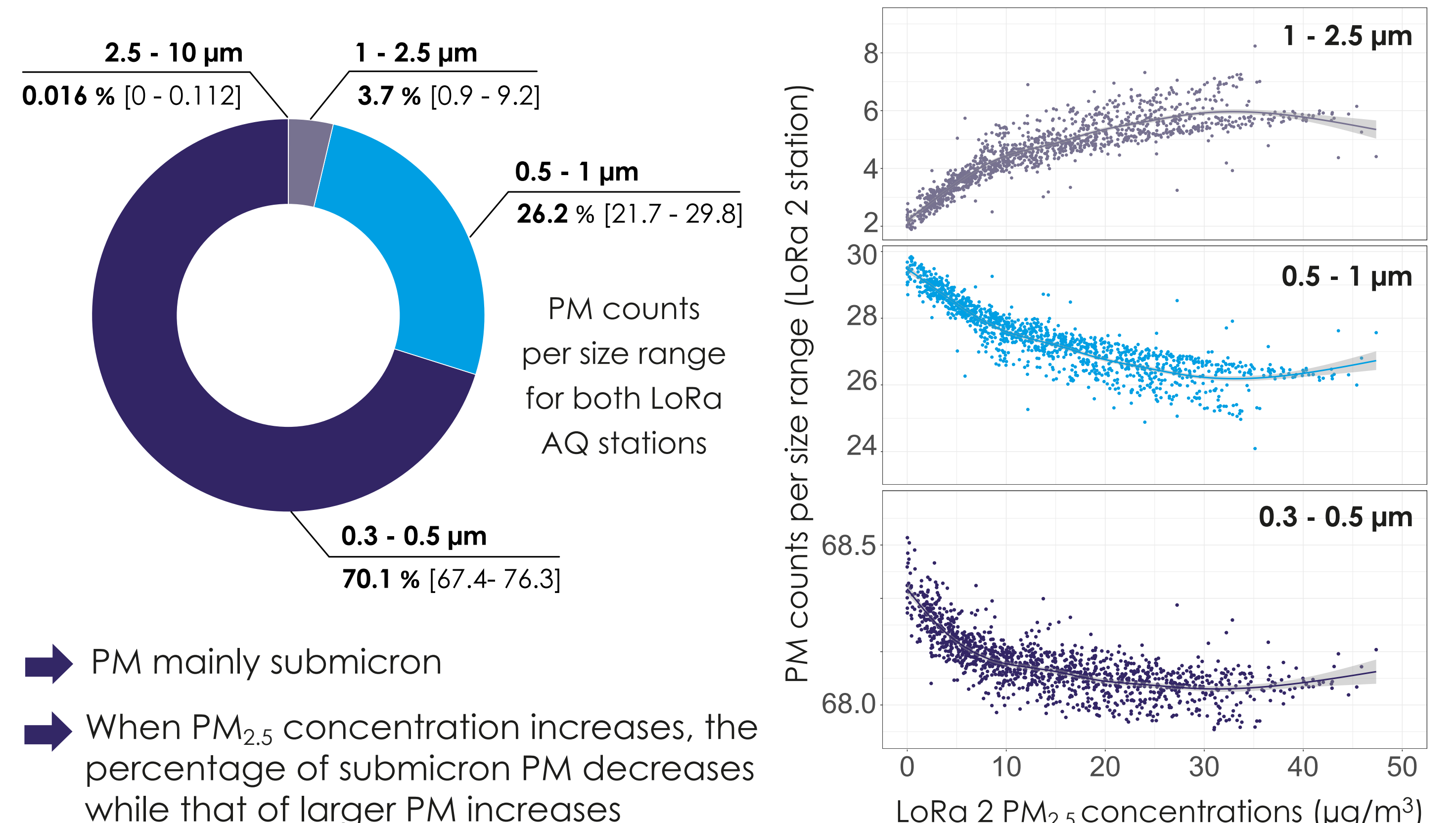
	NRMSE (%)	SD (µg/m <sup>3</sup> )	CV (%)
PM <sub>1</sub>	9	0,7	6,6
PM <sub>2.5</sub>	11	0,6	4,2
EPA	< 30	< 5	≤ 30

+ NRMSE Wi-Fi / REF (refer part 2.a)

LoRaWAN AQ stations : sensor - sensor precision ✓  
 SD: standard deviation  
 CV: coefficient of variation

LoRaWAN AQ stations : sensors accuracy vs REF ✓

### 2. Particle counts



## CONCLUSION

- LoRaWAN AQ stations performance metrics conform to EPA standards.
- LoRaWAN AQ stations deliver precise & reliable particulate matter measurements.
- The firmware allows particles counts extraction, which will be useful for further research.

## REFERENCES

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- Schmitz S, et al. (2021). Unravelling a black box: An open-source methodology for the field calibration of small air quality sensors. Atmos. Meas. Tech. 4:7221–41.
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