INFLUENCE OF WEATHER AND CHEMICAL COMPOSITION ON PM_X MICROSENSORS MEASUREMENTS

P. Espina, C. Bossuyt, S. Li, E. Perdrix, L.Y. Alleman, S. Crunaire, N. Redon*

CERI EE (SAGE), IMT Nord Europe, Université de Lille, 59000 Lille, France
*nathalie.redon@imt-nord-europe.fr

RESUME

Plusieurs microcapteurs de PM_x commerciaux ont été déployés sur le territoire de Douaisis Agglo dans le nord de la France, de mars à mai 2021, dans le cadre du projet AIRRURAL. Des mesures complémentaires de PMx et de spéciation chimique des $PM_{2.5}$ ont été effectuées au moyen d'un instrument de référence FIDAS et d'un système de mesure chimique MARGA, sur un site multi-instrumenté situé à Bugnicourt. Les comparaisons entre le FIDAS et les microcapteurs concernant PM_{10}, $PM_{2.5}$ et PM_1 montrent que les microcapteurs surestiment les concentrations d'environ 10% à 30%, avec une meilleure corrélation pour les fractions fines et très fines ($R^2 > 0.85$) que pour la fraction grossière ($R^2 = 0.4$). La cause principale de ces différences semble liée aux précipitations importantes et aux périodes d'humidité relative élevée (RH > 90%), car les gouttelettes d'eau peuvent interférer sur le comptage optique. Concernant l'influence de la composition chimique des particules fines, les microcapteurs commerciaux tendent à sous-estimer les $PM_{2.5}$ en présence de Na^+ et Cl^- dans l'atmosphère, en lien avec la fraction grossière des aérosols marins qui est moins bien détectée par les microcapteurs. A l'opposé, la présence de concentrations élevées en NO_3^- est associée à une surestimation des $PM_{2.5}$ par les microcapteurs. Ce phénomène peut être dû à l'humidité élevée (RH) qui est souvent associée à la formation de NH_4NO_3, ou à l'augmentation de la teneur en eau des $PM_{2.5}$ due à l'hygroscopicité accrue des aérosols en présence de nitrate d'ammonium.

ABSTRACT

Commercial PM_X microsensors sensors were deployed over the territory of Douaisis Agglo in the North of France from March to May 2021 within the AIRRURAL project framework. Additional measurements of PM_X and $PM_{2.5}$ chemical speciation were provided by a FIDAS and a MARGA system at a technical park located in Bugnicourt. The comparisons between the microsensors and the FIDAS for PM_{10}, $PM_{2.5}$ and PM_1 showed that the microsensors overestimated all PM concentrations between 10% and 30%, although the correlation between instruments for the fine fractions was much higher ($R^2 > 0.85$) compared to the coarse fraction ($R^2 = 0.4$). The main cause of this deviation seems to be related to intense rains and RH > 90% periods, as water droplets may interfere with the microsensors optical counter. Regarding the influence of the particle's chemical composition, the commercial microsensor tends to underestimate $PM_{2.5}$ when high concentrations of Na^+ and Cl^- are present in the atmosphere, associated with coarse marine aerosols that may be not well measured by the microsensor. On the contrary, the presence of high NO_3^- levels are associated to overestimation of $PM_{2.5}$. This may be linked to the high RH conditions that are necessary for NH_4NO_3, or to an increased liquid water content in the $PM_{2.5}$ due to the increased hygroscopicity.

MOTS-CLÉS : Microcapteurs, PM_x, RH, erreur, composition chimique **KEYWORDS:** Microsensors, PM_x, RH, error, chemical speciation

1. Introduction

Benelux and the North of France areas have been submitted to recurrent particulate matter (PM) episodes, especially during spring. This PM episodes are mainly characterized by secondary inorganic aerosols (SIA), linked to the high concentrations of inorganic precursor gases coming from residential sources, traffic, industry and agricultural activities in the region and bordering territories (Roig et al., 2019, Espina-Martin, 2020). High levels of PM are known to cause several problems in human health, therefore their monitoring is essential. A common misperception is that air quality in rural areas is much better than in urban ones, but the abundance of agricultural sources in rural sites can make up for the lack of high population density related sources. Within this context, the AIRRURAL project was carried out during spring 2021 in the rural area of the community of Douaisis Agglo in order to study the effect of anthropogenic activities, particularly agricultural ones, over NH_3 and PM_x levels.

Among a variety of methods and instruments used for measuring atmospheric pollutants, PM_x microsensors were used over the Douaisis Agglo territory in order to monitor the levels of PM_x and their variation on a temporal and spatial scales to determine potential sources and activities affecting their levels. This type of sensors has proven to be useful as a way to have cost-effective high time resolution data across large extensions of the terrain. However, they require a permanent power supply, an internet connection to send and save the collected data to the main servers and they are sensitive to environmental high relative humidity (RH) conditions (Badura et al., 2018). Hence, this work aims to show the extent of the errors associated to high RH conditions over the different PM_x fractions, and the impact that chemical composition of the particles may have over the bias found between a reference method and the particle sensors.

2. Methods

The measurement period lasted from 23/03/2021 until 17/05/202. A multi-instrumented measurement site was installed in the rural village of Bugnicourt as described in Figure 1.

Instrument	Species	Time resolution
Atmotrack (PM_x microsensor)	PM_1, $PM_{2.5}$, PM_{10}	1 min
FIDAS (PM_x reference analyser)	PM_1, $PM_{2.5}$, PM_{10}	1 min
MARGA ($PM_{2.5}$ speciation monitor)	Inorg. gas: NH_3, HCl, HONO, HNO_3, SO_2 WSI: NH_4^+, Na^+, K^+, Ca^{2+}, Mg^{2+}, Cl^-, NO_3^-, SO_4^{2}	(1 h)
Online OC-EC analyzer	OC, EC	(1 h)

Figure 1. Location of the sampling site and instrumentation used in the campaign.

WSI: Water soluble ions
MARGA: Monitor for ambient gases and aerosols

Data on the ambient air T and RH were measured by a local meteorological station as well as the FIDAS and the Atmotracks. The error estimation between the commercial microsensor and the FIDAS was calculated as shown in Equation 1:

$$PM_x \text{ Error} = [\text{Atmotrack}] - [\text{FIDAS}] \text{ (in } \mu g\ m^{-3}) \qquad \text{Equation 1}$$

A positive error indicates a possible overestimation of the concentrations by the Atmotracks, while a negative error means an underestimation. The error was calculated for all PM fractions, but only the $PM_{2.5}$ error was used in the estimation of the influence of the chemical species.

3. Results

Figure 2 shows the linear regressions of the PM_x fractions between the reference method (FIDAS) and the Atmotrack in Bugnicourt. The slope does not change between PM_1 and $PM_{2.5}$ fractions, with the microsensors overestimating PM_1 and $PM_{2.5}$ concentrations by 30%, although the R^2 decreases from 0.88 to 0.76. On the contrary, the PM_{10} slope and R^2 decreased to 1.13 and 0.40, respectively. All correlations show that most of the Atmotrack data points deviated from the 1:1 line when RH ≥ 90%, showing rapid increases in concentration compared to the FIDAS.

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This has been seen in previous studies conducted with PM microsensors, most likely related to the limitations in the sampling flow and measuring system under rain and/or high RH conditions (Crilley et al., 2018). However, although the regressions suggest an overestimation of the PM concentrations, when the RH conditions are below 60%, the Atmotrack tends to underestimate the PM levels, especially in the PM_{10} fraction.

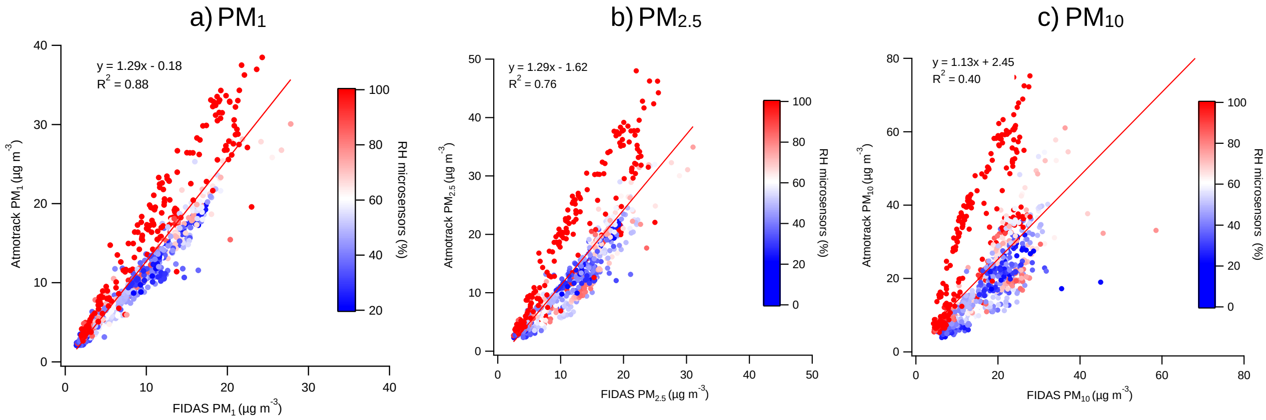

Figure 2. PM_1 (a), $PM_{2.5}$ (b) and PM_{10} (c) FIDAS (x) vs commercial microsensor (y) concentrations (in µg m^{-3}) coloured by $RH_{microsensor}$ (in %). The red line represents the 1:1 line.

To further understand the reasons behind the differences between size fractions, the $PM_{2.5}$ error was plotted against RH and coloured by the different chemical species measured by the MARGA and the OCEC. Figure 3a & b show that when marine aerosols are present, the Atmotrack underestimates $PM_{2.5}$ concentrations, most likely linked to the fact that marine aerosols are mostly in the coarse fraction. The Atmotrack tend to underestimate these coarse particles, due to its relatively lower air sampling flowrate. On the contrary, the error quickly increases above RH ≥80%, which may be attributed to the typical artefact linked to high RH or rainy conditions. However, from an aerosol chemistry point of view, this overestimation occurs also when high concentrations of NH_4NO_3, a highly hygroscopic submicronic salt, are present in the atmosphere.

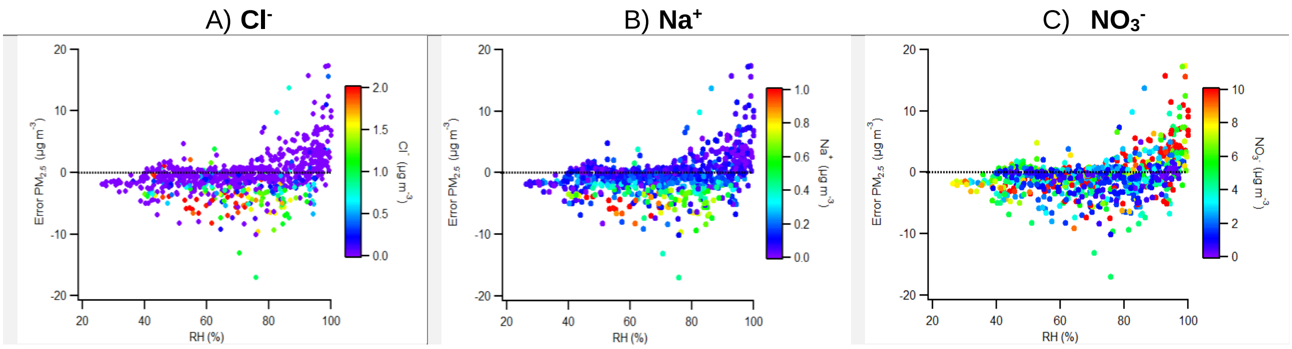

Figure 3. $PM_{2.5}$ error vs $RH_{Atmotrack}$ coloured by a) Cl^-, b) Na^+ and c) NO_3^- concentrations in µg m^{-3}.

These results suggest that concerning PM_x microsensors, not only the concentrations under high RH conditions need to be corrected, but also the periods when the atmosphere may be charged with high concentrations of coarse particles such as marine aerosols or hygroscopic particles like ammonium nitrate.

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