Evaluating the performance of low-cost Alphasense OPC-N3 in an indoor environment

A. Doldi[1], L. Verdolotti[2], G. C. Lama[2], F. Recupido[2], P. Mantecca[1], R. Bengalli[1], M. Gualtieri[1], N. Losi[1], A. M. Cefalì[1], I. Gini[1], L. Ferrero[1]
[1]GEMMA and POLARIS Centre, Dept. Earth and Environmental Sciences, Università degli Studi di Milano-Bicocca, 20126 Milano, Italy
[2]Institute for Polymers, Composites and Biomaterials-CNR, 80055 Portici (NA), Italy

INTRODUCTION AND OBJECTIVE

The following work is part of the "BIOMAT" project, an Open Innovation Test Bed that aims to accelerate a sustainable European bioeconomy by developing nano-enabled and advanced PUR (Polyurethane) foams for Building, Construction, Automotive, Furniture & Bedding industries. In this context, a measuring campaign was conducted at the National Research Council (CNR) site in Portici (Naples, Italy), where a pilot facility of the BIOMAT project was installed. This monitoring campaign was aimed to assess the potential environmental exposure to harmful particulate matter (PM) and nanoparticles during the production process of nano-enabled PUR foams.

For this purpose, four low-cost optical particle counters (Alphasense, OPC-N3) were deployed alongside two reference instruments (OPC Grimm 1.107), allowing a comparison with scientific-grade reference instrumentation.

METHODS

Data were collected over a two-day period, following a series of test runs of the PUR foam production process.
PM_{10}, $PM_{2.5}$ and PM_1 measurements inside the BIOMAT pilot facility in Portici (Naples, Italy) were carried out deploying 2 Portable Aerosol Spectrometer (Grimm, model 1.107) and 4 low-cost Optical Particle Counter (Alphasense, OPC-N3).

The instruments were placed in two different locations inside the facility to detect any variability in concentrations within the site (Figure 1).

- *Near-field*: directly next to the PUR foam production site (n°1 OPC Grimm, n°2 OPC-N3)
- *Far-field*: on the opposite side of the room from the PUR foam production site (n°1 OPC Grimm, n°2 OPC-N3)

Two intercomparison periods, at the beginning and end of the first day of analysis with no PUR production processes in place, were carried out among the four OPC-N3 to evaluate the instruments' precision.

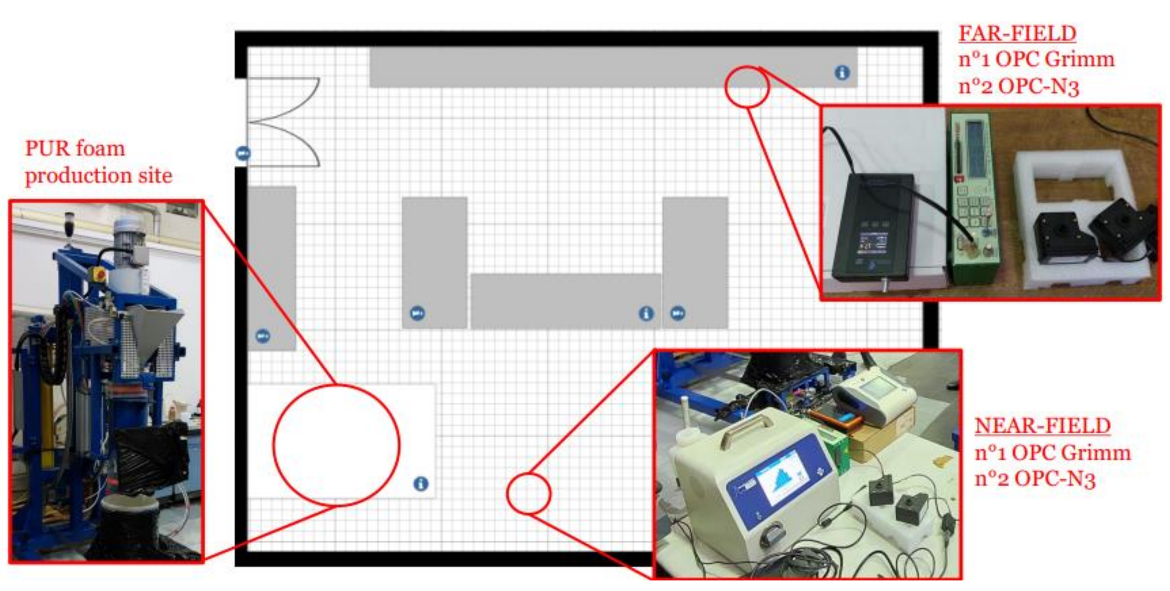

Figure 1 - Experimental setup of the BIOMAT facility in Portici (NA) with the positions of the instruments and the PUR foam production site.

RESULTS

INTER-COMPARISON: the inter-comparison between the four OPC-N3 (1-min average) carried out at the end of the analysis period showed how the overall trend in concentration over time is followed by all four sensors.
For PM_{10}, the variability between the values appears to be higher, as shown by the relative standard deviation in Figure 2.
This is in line with the scientific literature, as the OPC-N3s show inter-sensor variability, especially for the coarser fraction[1].

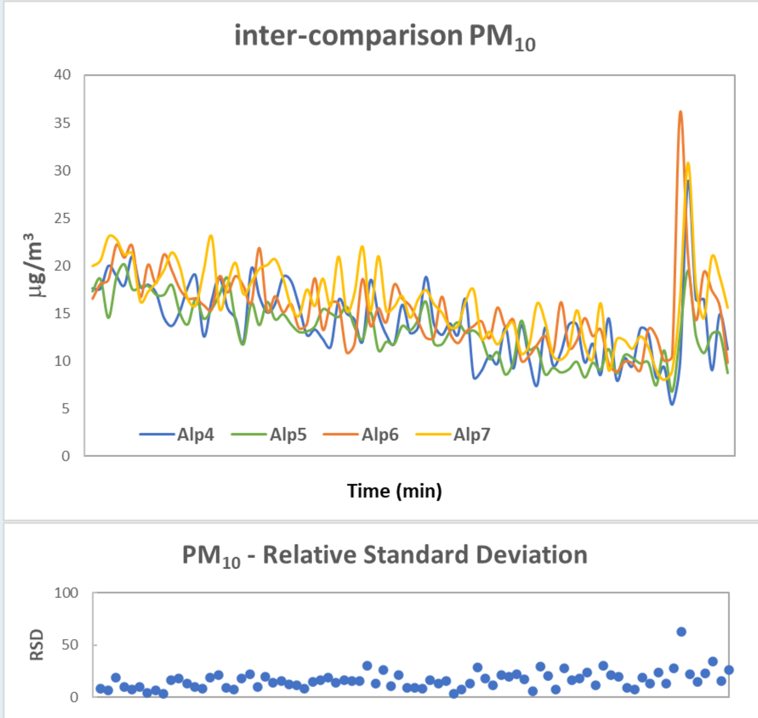

Figure 2 - Trends over time of the four OPC-N3 during the inter-comparison and relative standard deviation for PM_{10}

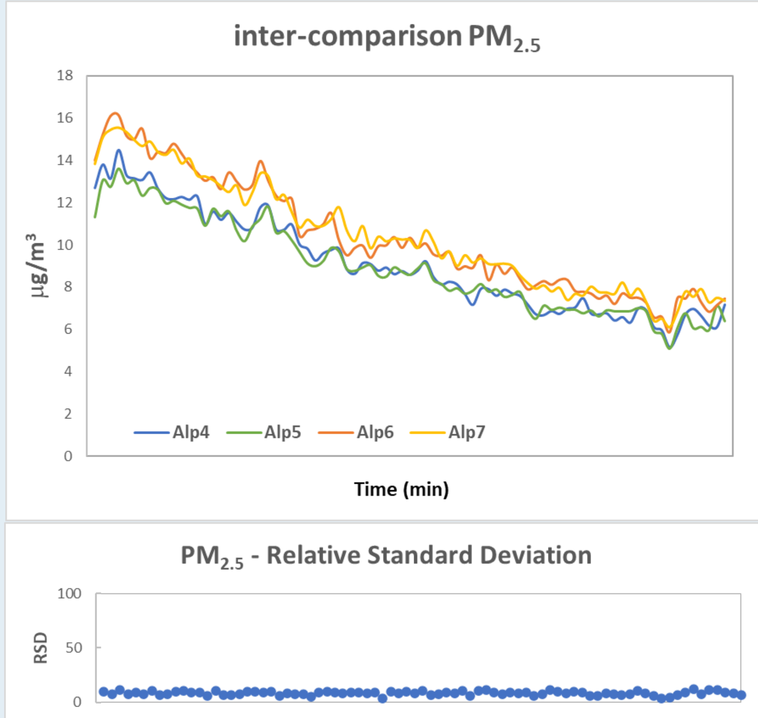

Figure 3 - Trends over time of the four OPC-N3 during the inter-comparison and relative standard deviation for $PM_{2.5}$

A correlation can be observed (Figure 4 to 6) between the trends of the two OPC-N3s and of the reference OPC Grimm (all in far-field position) for each PM fraction (PM_{10}, $PM_{2.5}$, PM_1).
Both OPC-N3s appear to consistently underestimate PM concentrations, with an average concentration difference ranging from 15 to 25 $\mu g/m^3$. In particular, the OPC-N3s tend to underestimate particulate levels at high PM_{10} concentrations, indicating a greater difficulty of the instruments in detecting the coarser fraction.

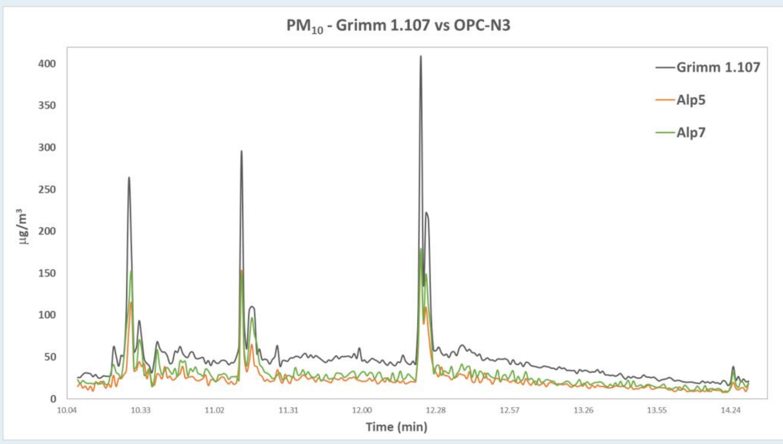

Figure 4 - Trends of PM_{10} concentrations over time for one OPC Grimm and two OPC-N3 (in far-field position)

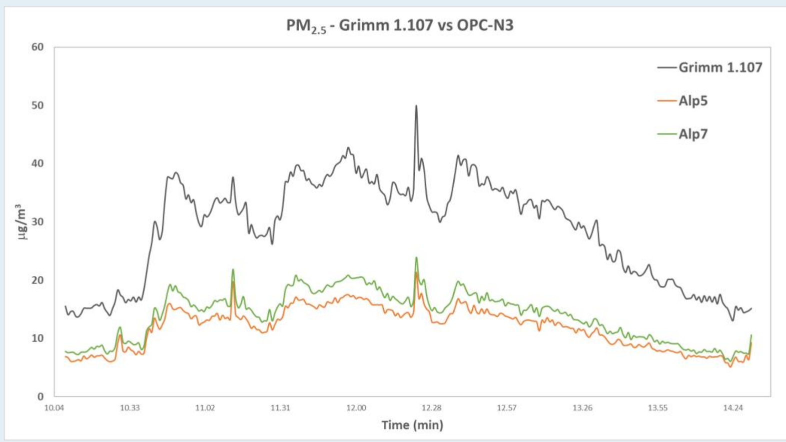

Figure 5 - Trends of $PM_{2.5}$ concentrations over time for one OPC Grimm and two OPC-N3 (in far-field position)

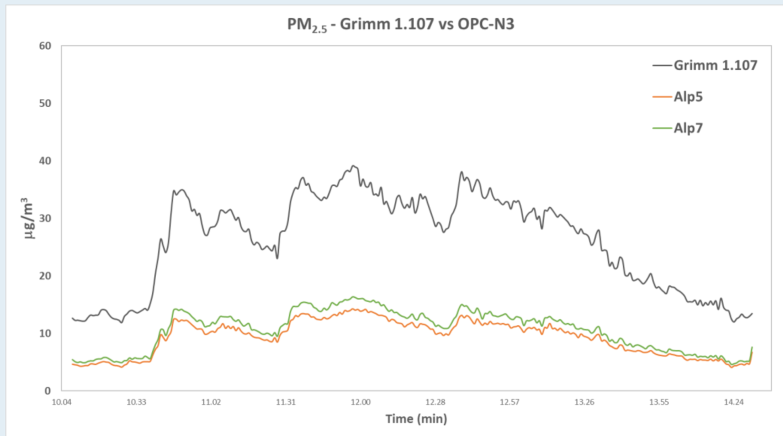

Figure 6 - Trends of PM_1 concentrations over time for one OPC Grimm and two OPC-N3 (in far-field position)

PM_1 and $PM_{2.5}$ concentrations obtained for the two OPC-N3 (in far-field position) correlated well with the reference instrument Grimm 1,107 ($R^2 \sim 0.98$ and $R^2 \sim 0.95$, respectively). The R^2 obtained for $PM_{2.5}$ is in line with the target value suggested by EPA ($R^2 \geq 0.70$)[2] for low-cost sensor testing. For PM_{10} (Figure 8), the OPC-N3s show good correlation, with $R_2 \sim 0.89$. This lower value is in line with field tests performed for OPC-N3 and described in literature, indicating increased difficulty in detecting coarse particles.

R^2	Alp5 vs GRIMM	Alp7 vs GRIMM
PM_{10}	0.9106	0.8743
$PM_{2.5}$	0.9595	0.9577
PM_1	0.983	0.9816

Figure 7 – Coefficient of determination values for the OPC-N3 vs GRIMM 1.107

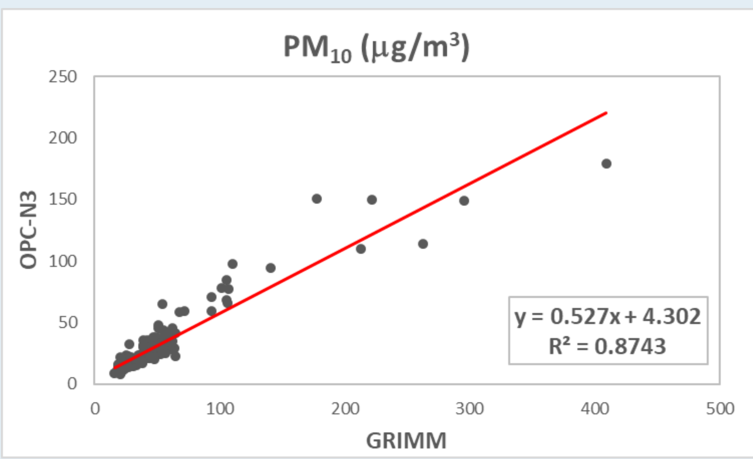

Figure 8 – Grimm 1.107 PM_{10} concentrations vs OPC-N3 (Alp7) concentrations

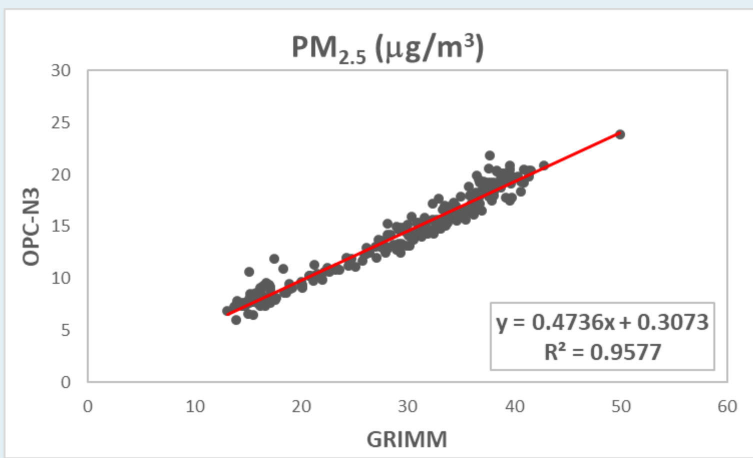

Figure 9 – Grimm 1.107 $PM_{2.5}$ concentrations vs OPC-N3 (Alp7) concentrations

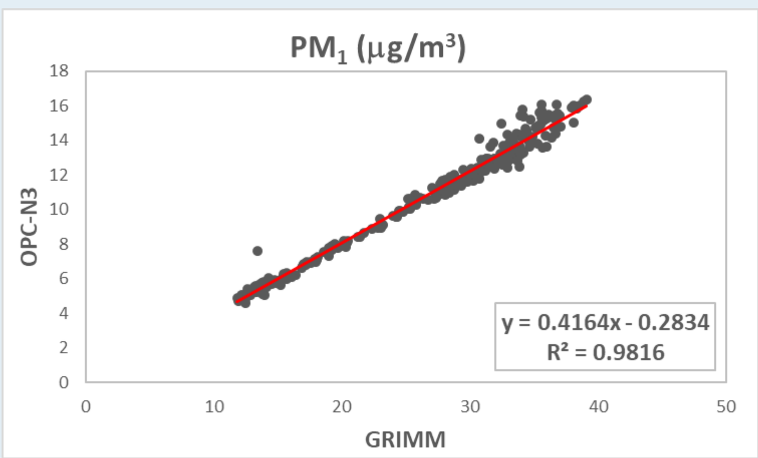

Figure 10 – Grimm 1.107 PM_1 concentrations vs OPC-N3 (Alp7) concentrations

CONCLUSION

- The overall concentration trend over time was detected consistently by all four OPC-N3 deployed.
- The inter-comparison of the four OPC-N3 showed inter-sensor variability, in agreement with the scientific literature regarding this PM sensor.
- All OPC-N3s consistently underestimated PM concentrations, most significantly in peaks with high PM_{10} values. This indicates a higher difficulty of the sensors in correctly estimating the concentrations of the coarser particulate fraction.
- Data obtained from the OPC-N3s correlated well with the research-grade instrument (GRIMM 1.107), in line with the target value suggested by EPA[2].

AKNOWLEDGEMENTS:
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REFERENCES:
1) Kaur, K., & Kelly, K. E. (2023). Laboratory evaluation of the Alphasense OPC-N3, and the Plantower PMS5003 and PMS6003 sensors. Journal of Aerosol Science, 171. https://doi.org/10.1016/j.jaerosci.2023.106181

2) Duvall, R., A. Clements, G. Hagler, A. Kamal, Vasu Kilaru, L. Goodman, S. Frederick, K. Johnson Barkjohn, I. VonWald, D. Greene, AND T. Dye. Performance Testing Protocols, Metrics, and Target Values for Fine Particulate Matter Air Sensors: Use in Ambient, Outdoor, Fixed Site, Non-Regulatory Supplemental and Informational Monitoring Applications. U.S. EPA Office of Research and Development, Washington, DC, EPA/600/R-20/280, 2021.