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LIST OF ACRONYMS

ASC: atmospheric simulation chamber

BC: Black Carbon

EC: elemental carbon

HVO: Hydrotreated Vegetable Oil

MAC: mass absorption coefficient

MISG: Mini-Inverted Soot Generator

MWAA: Multi-Wavelength Absorbance Analyzer

OC: organic carbon

PAX: Photoacoustic Extinctiometers

PM: Particulate Matter

TC: total carbon

1. INTRODUCTION

This deliverable is prepared in the context of the ITINERIS project, within Work Package 4 that deals with the integration of Research infrastructures working in the atmospheric domain through synergistic approaches and cross boundaries developments. This deliverable reports the implementation plan of Task 4.13.2. The main objective of this task is the release of datasets on compositional and optical aerosol characterization at the ChAMBRe facility. In this context, we performed several experiments by using the ASC. Here we described those experiments, and the results obtained which generate the datasets: each experiment corresponds to a single dataset. Data will be uploaded on the ITINERIS hub soon.

2. EXPERIMENTAL ACTIVITY

In this section, different applications of ChAMBRe for the combined compositional and optical characterization are here presented. The first application concerns the investigation of properties of carbonaceous aerosols produced by the combustion of different fuels, the second is about the production of controlled samples to characterize a new optical offline instrument which has been developed in our laboratory. A different application on compositional characterization regarded the effects of different atmospheric conditions bacteria viability. By the pure optical point of view, we performed the first campaign with two new instruments (i.e., nephelometer and aethalometer) acquired in the ITINERIS frame.

2.1 Carbonaceous aerosols produced by the combustion of different fuels particles

This study investigates the optical properties and variability of the mass absorption coefficient (MAC) of carbonaceous aerosols produced by the combustion of different fuels. Soot particles were introduced into ChAMBRe and were monitored using online instrumentation and sampled for offline analysis at various time intervals to investigate the concentration of emitted particles and optical properties. Injections of fresh soot particles inside ChAMBRe were performed alternatively by a mini-inverted soot generator (MISG; Argonaut Scientific Corp., Edmonton, AB, Canada; model MISG-2), fueled with propane and by a 12 HP 4-stroke diesel engine (Electrical Generator 65230 – 6 kW - Hyundai), fueled alternatively with regular fossil diesel (B7) and Hydrotreated Vegetable Oil (HVO). A total of 10 experiments were performed to investigate the properties of carbonaceous aerosols, in particular, three conditions were investigated as summarized in Table 1.

Table 1: Investigated combustion conditions.

Type of fuel	Soot particle sources
Propane [air: 7 lpm – fuel: 80 mlpm]*	MISG-2
DIESEL	65230 – 6 kW - Hyundai
HVO	65230 – 6 kW - Hyundai

*Particle characterization in (Vernocchi et al., 2022)

At the beginning of each experiment, soot particles were injected into ChAMBRe, and sampling began once the soot concentration stabilized. This typically occurs in approximately 3 minutes, corresponding to the chamber mixing time. Once injected, the soot particles were left in suspension for defined timeframes and monitored with online instrumentation and sampled for offline analysis. Both optical and thermal-optical techniques were used for measurements. For the optical characterization different methods were used, both online and offline: photoacoustic extinctiometer

(PAX - Droplet Measurement Technologies) at 870 nm measured the online absorption coefficient, Giano_BC1 (Dadolab srl) allowed for the continuous monitoring of BC concentrations on filter during the PM sampling and the multi-wavelength absorbance analyzer (MWAA, Massabò et al., 2013, 2015) for the offline direct quantification of aerosol absorption coefficients at five different wavelengths. The same filter collected by the Giano_BC1 can be used for the thermal-optical OC and EC quantification. Emissions were also characterized in terms of concentrations of elemental (EC) and organic carbon (OC) by the EC/OC thermal optical method (see Deliverable 4.9.2) using the NIOSH protocol. The combination of optical and thermal-optical analyses offers several advantages, such as the ability to determine the MAC value using the relation: $b_{abs} = MAC \times [EC]$, where b_{abs} (Mm^{-1}) is the absorption coefficient, MAC ($m^2\ g^{-1}$) is the mass absorption coefficient, and EC ($\mu g\ m^{-3}$) is the elemental carbon concentration.

2.2 Characterization of a new instrument for offline optical analysis

We developed a new instrument to measure spectral light absorption by aerosol particles: BLAnCA (Broadband Light Analyzer of Complex Aerosol), an automatic laboratory instrument for offline measurement of aerosol collected on suitable media. BLAnCA uses a white light source and a fiber-optic spectrometer to measure aerosol light absorption over a wide spectrum ranging from 375 to 1000 nm, with a 5 nm resolution.

To characterize and validate this new instrument, we carried out an aerosol sampling campaign within ChAMBRe to produce PM samples on quartz filters, covering a wide range of loadings to compare the optical performance of BLAnCA against a benchmark instrument. Artificial soot was produced by incomplete propane combustion in a MISG, with an air flow of 7 lpm and a fuel flow of 75 mlpm, according to the specifications in (Vernocchi et al. 2022). The injection time was varied, across the different experiments, between 30 s and 2 min, according to the desired soot concentration inside the chamber. The atmosphere inside the chamber was homogenized for 3 minutes by a fan placed on the bottom of the volume. After that, the aerosol was sampled on 47 mm quartz fiber filters (Pall Tissuquartz, 2500QAO-UP). We used a low-volume sampler (TCR Tecora, Italy) at different rates and sampling duration. The sampling variability, coupled with changes in soot concentration both within the same experiment (due to dilution induced by sampling) and across different experiments (due to different injection times), led to a very wide range of soot loading on the filters. A total of 30 samples were produced. The performance of BLAnCA is evaluated by comparison with the MWAA analysis. A subset of 11 samples produced in ChAMBRe was analyzed with a thermo-optical EC/OC analyzer (Sunset Laboratory Inc.) to quantify the concentration of elemental carbon (EC) load on each filter. This information, coupled with the optical data, allowed to determine the MAC of the aerosol on filters.

Another experiment was conducted in identical conditions as described above, with the additional deployment of three PAX (Droplet Measurement Technologies, Inc., USA). Each of the three units works at a specific wavelength, namely 407, 532 and 870 nm. In this experiment, a total of 15 filter samples were produced.

BLAnCA is fully described in (Isolabella et al., 2025).

2.3 Evaluation of effects of atmospheric conditions on bacteria viability

As a step forward from deliverable 4.13.1, we applied the described procedure to investigate the effects of different concentrations of NO and NO_2 on the viability (in terms of culturability) of three different bacteria strains: E. coli, B. subtilis, and P. fluorescens. Here, we briefly summarize the experimental approach since it was already described in the previous deliverable. Before being introduced into ChAMBRe, the bacteria samples were characterized using three different methods to determine the ratio of viable to total bacteria; then the bacteria suspension was aerosolized and introduced into ChAMBRe, where it was exposed to two different concentrations of NO and NO_2 (900 and 1200 ppb): the culturability of the bacteria was assessed by collecting bacteria samples directly onto Petri dishes by an Andersen impactor at various time intervals after the end of injection. Finally, the formed bacteria colonies were counted after 24–48 h of incubation to measure their culturability and the temporal trend. Effects on bacteria viability are evaluated in relation to “baseline experiments”, in which the viability of airborne bacteria is determined in clean-air conditions, using the lifetime parameter following the equation $C(t) = C_{\$} e^{\%\frac{!}{"}}$ where C_0 is the total or culturable bacteria concentration at t = 0 and t is the total or culturable lifetime. The experimental procedure and the obtained results are published in (Vernocchi et al., 2023) and (Gatta et al., 2025).

2.4 First campaign of new optical instruments

Thanks to the ITINERIS project, we acquired two new instruments for the aerosol optical characterization: the Aethalometer (model AE33, Magee Scientific) and the Polar Nephelometer (model Aurora 4000, ecotech). In particular, the Aethalometer measured absorption at seven wavelengths (370, 470, 520, 590, 660, 880, 950 nm) while the Nephelometer measured scattering at three wavelengths (450, 525 and 635 nm) for three angles (0°, 45°, and 90°).
As source to inject particles inside the chamber, we used a 12 HP 4-stroke diesel engine (Electrical Generator 65230 – 6 kW - Hyundai), fueled alternatively with regular fossil diesel (B7) and HVO. A concentration range of 260 – 500 μg m ^{3} of BC was considered. In addition, two different aging methods were applied: ozone (O_3, 300 ppb) and a solar simulator were applied to promote oxidative and photochemical transformations.

3. RESULTS

3.1 Characterization of carbonaceous aerosols

The optical properties of the aerosol produced from each fuel were characterized by determining the absorption coefficient (b_{abs}). The b_{abs} definition applies both to measurements directly performed on the aerosol dispersed in the atmosphere and to offline analysis on aerosol collected on filters. The b_{abs} values were calculated offline by the MWAA analysis, at 635 and 850 nm, on the sampled filters during each experiment and online by Giano_BC1, at 635 nm, and the PAX, at 870 nm.
The EC:TC concentration ratio resulted to be (0.7 ± 0.1) for propane, (0.15 ± 0.05) for diesel and (0.4 ± 0.2) for HVO; indicating a higher proportion of OC in the diesel and HVO samples.
The b_{abs} values thus derived at different wavelengths, along with the elemental carbon (EC) concentration measured on the filters, were used to calculate the MAC of the aerosol. All the measured MAC values are summarized in Table 2.

Table 2: Summary of the measured MAC values (m2 g-1).

Instrument	Wavelength	Propane - MISG	Diesel - Hyundai	HVO - Hyundai
MWAA	635 nm	6.1 ± 0.2	9.4 ± 0.3	8.0 ± 0.3
Giano_BC1	635 nm	7.8 ± 1.1	9.4 ± 0.4	8.4 ± 0.6
MWAA	850 nm	5.2 ± 0.5	6.8 ± 0.2	6.0 ± 0.3
PAX	870 nm	5.5 ± 0.1	6.2 ± 0.5	5.8 ± 0.2

In general, the optical properties of the investigated aerosols, in terms of b_{abs} and MAC, revealed differences in absorption characteristics across different fuels: particles generated by diesel combustion were found to be more light absorbing than those produced by propane and HVO. The MAC parameter values were higher for diesel, indicating more absorbent particulate matter.
These results are going to be published in (Danelli et al., 2025, in review).

3.2 Characterization of BLAnCA

The b_{abs} of the samples collected are compared between BLAnCA and MWAA at the common wavelengths (375, 407, 532, 635 and 850 nm), performing a linear regression on the entire dataset: the slope of the regression line on the entire dataset is 0.97 ± 0.01 (Figure 1).

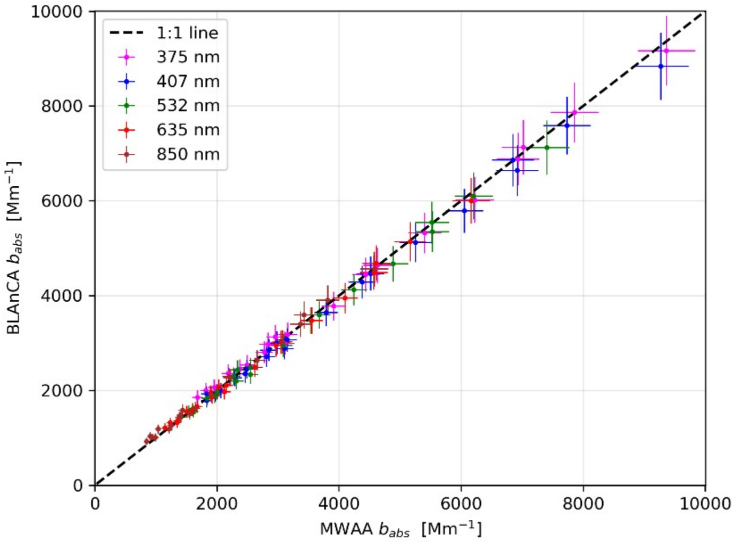

Figure 1: Comparison of b_abs values measured by MWAA and BLAnCA.

As seen before, coupling optical and compositional (i.e., thermal-optical analysis) data, the MAC can be retrieved. The MAC values obtained for selected wavelengths are summarized in Table 3.

Table 3: Summary of some measured MAC values (m2 g-1).

Wavelength (nm)	375	550	635	1000
MAC (m^2 g^{-1})	11.5 ± 0.2	8.7 ± 0.1	7.5 ± 0.1	4.7 ± 0.1

The improvement in the spectral range and in the resolution of BLAnCA can be better appreciated if absorption spectra of BLAnCA and MWAA are compared as in Figure 2.

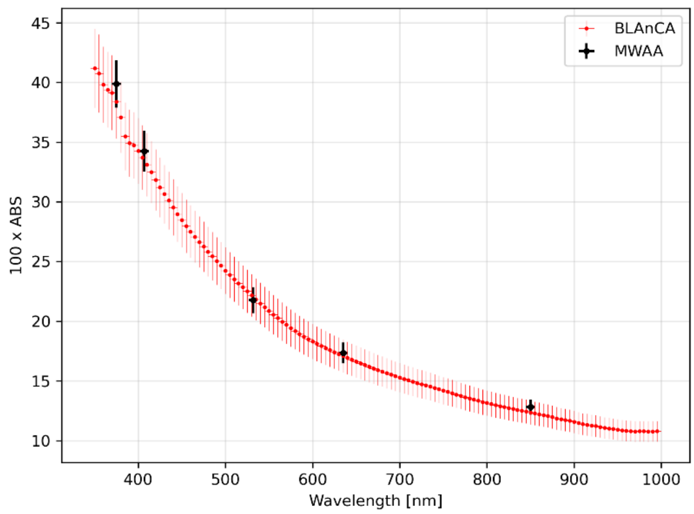

Figure 2: Comparison of absorption spectra by MWAA and BLAnCA.

The optical absorption coefficient of the artificial soot samples collected during the ChAMBRe campaign was measured offline with BLAnCA. The b_abs of each filter sample was compared with the average of the online PAX measurement, taken over the filter sampling period. The comparison was made at the three common wavelengths (405, 532 and 870 nm) performing a linear regression on the entire dataset: the slope of the regression line on the entire dataset is 0.96 ± 0.01 (Figure 3).

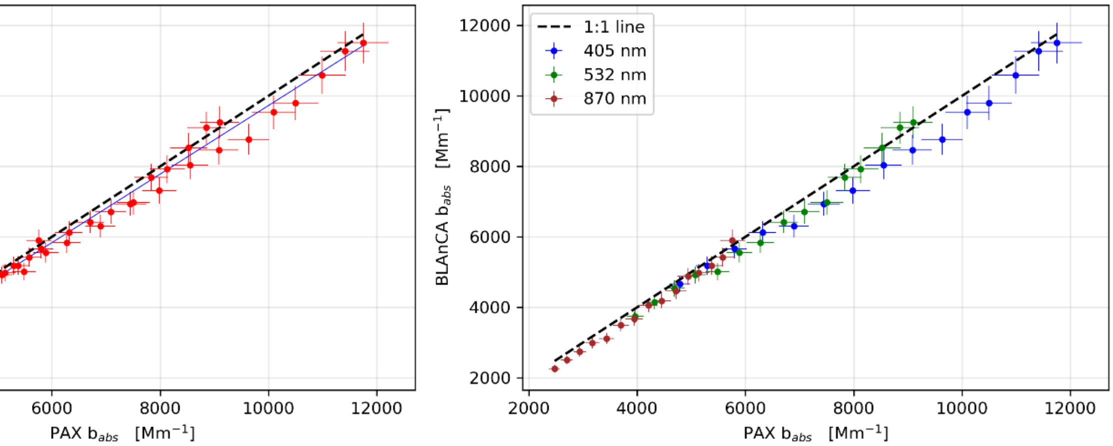

Figure 3: Comparison of b_abs values measured by PAXs and BLAnCA.

3.3 Effects of atmospheric conditions on bacteria viability

Effects of different gases in different concentrations are evaluated in terms of culturable lifetime changes compared to the baseline result, as reported in Figure 4. The light blue rectangles mark the uncertainties of each normalized baseline. The P-value of T student test was calculated between pollutant experiments and baseline conditions for each bacteria strain. "NS" stands for "Not Significant", * $p < 0.05$, ** $p < 0.01$). The lower concentration of NO did not show an impact on the bacteria's culturability inside the chamber. However, at a concentration of 1200 ppb, NO reduced the culturability of E. coli, B. subtilis, and P. fluorescens of about 32%, 20%, and 26%, respectively. On the other hand, NO_2 had a different effect on bacteria. Both concentrations of NO_2 reduced the culturability of B. subtilis and P. fluorescens by about the same factor (on average about 57% and 68%, respectively). However, for E. coli, higher concentrations of NO_2 increased the loss of culturability. It is important to note that NO_2 reduced the bacteria culturability more than NO. The study demonstrated that, for the airborne bacterial strain P. fluorescens, NO_2 is far more hazardous than NO at comparable doses. Finally, E. coli was significantly susceptible to the bactericidal effects of NOx in the gas phase. These results are published in (Gatta et al., 2025).

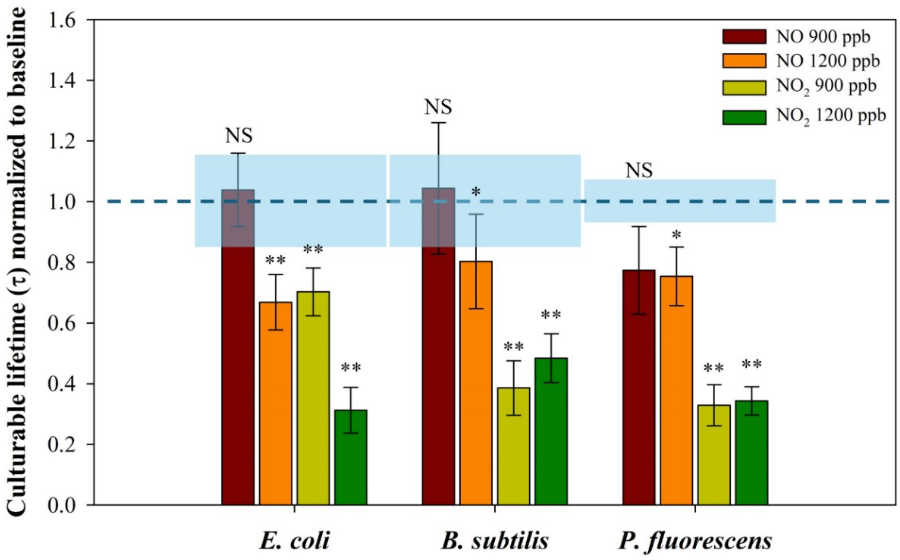

Figure 4: Average culturable lifetime of NOx experiments, normalized to the value of baseline for all bacteria strains (Gatta et al., 2025).

3.4 Test of new optical instruments

Here we reported the results of the testing campaign performed by two optical instruments, aethalometer and nephelometer, measuring respectively aerosol absorption and scattering.
Absorption data are presented normalized to the highest value of each series, to better compare the different situations. Figure 5 shows results for diesel emitted particles, an increase in the wavelength dependence can be observed as consequence of the aging processes.

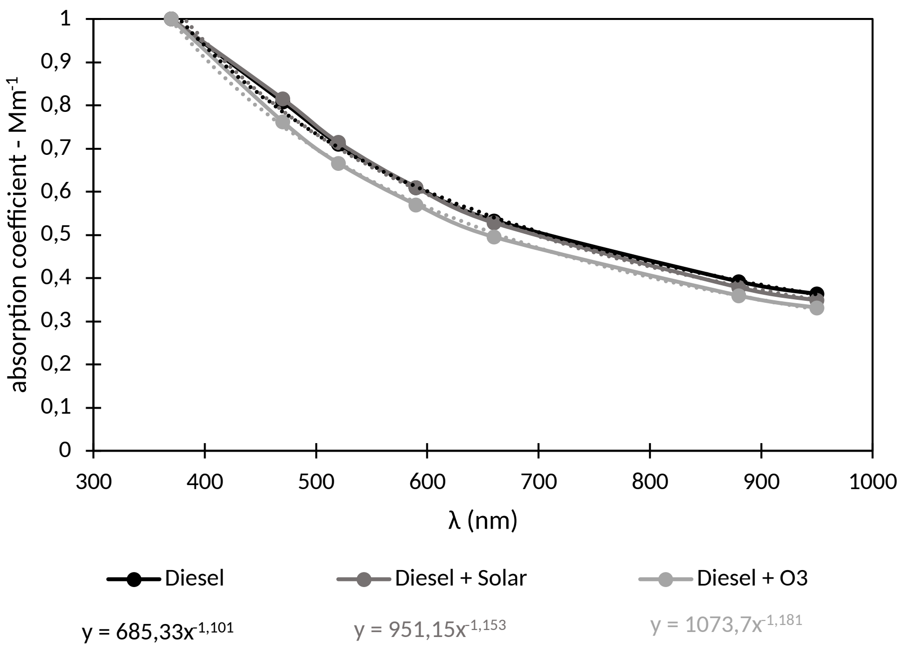

Figure 5: Absorption coefficients for diesel experiments, normalized to the highest value.

Figure 6 shows results for HVO emitted particles, no significant differences can be observed due to the ozone aging while the solar radiation aging leads to a relative increase in the absorption at the longer wavelengths.

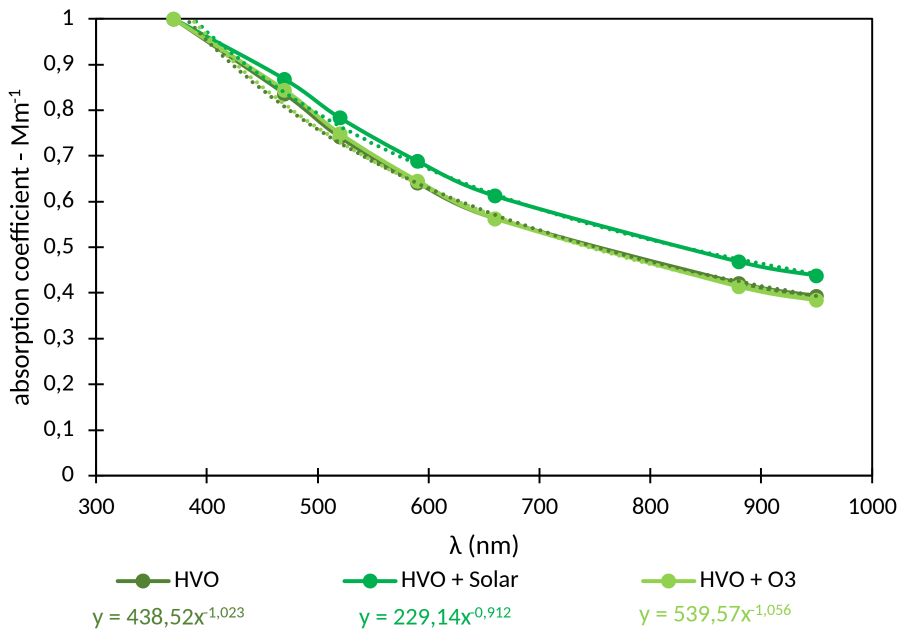

Figure 6: Absorption coefficients for HVO experiments, normalized to the highest value.

For the scattering measurement, here we reported only the graph of the scattering coefficients measured at the 0° angle (Figure 7) since the trend is very similar for the other two considered angles. Results show a general increase in scattering properties for diesel respect to HVO; in addition, aging processes seem to more affect the properties of diesel generated particles, leading to an increase, in particular with the presence of ozone.

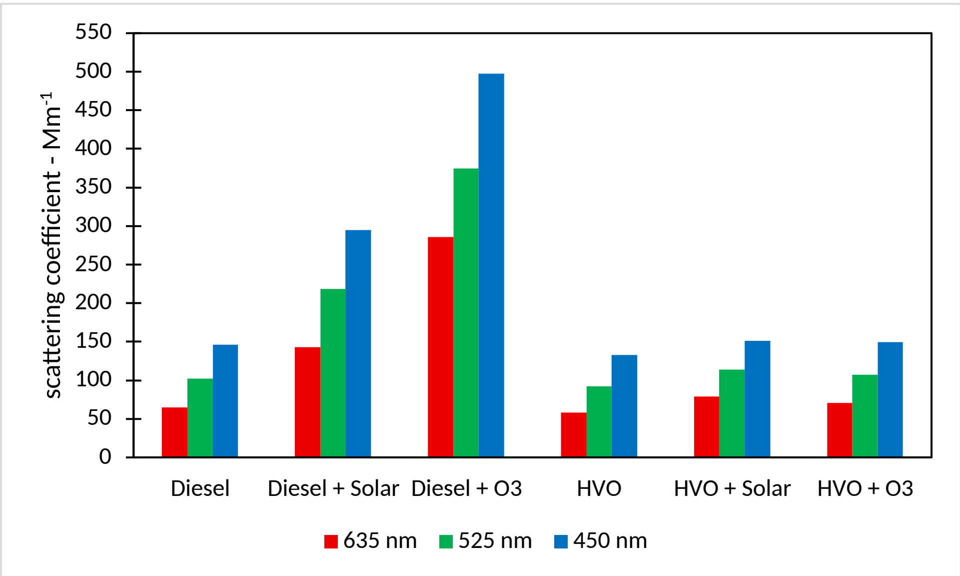

Figure 7: Scattering coefficients at 0° for the three wavelengths.

CONCLUSIONS

The development of ChAMBRe facility, in large part thanks to ITINERIS investment but also due to the research activity to build new instruments and approaches, reaches today an ample amount of available methods to study and characterize components of atmospheric aerosols. New research lines have been started, and further research will follow well beyond the ITINERIS conclusion.

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