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Atmospheric Measurement Techniques Discussions



# *Interactive comment on* "Facility for generation of ambient-like model aerosols in the laboratory: application in the intercomparison of automated PM monitors with the reference gravimetric method" *by* Stefan Horender et al.

**Stefan Horender et al.**

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We would like to thank Reviewer 1 for the positive comments and feedback that have helped to improve the manuscript. Below please find the response to each comment as well as the sections of the manuscript that were adapted.

Reviewer 1: Are there studies that look at each of the instrument's reaction to the ambient chemical on their own and not aggregated into a standardized aerosol? Line 367 alludes that this needs to be done and is an evidence gap in the literature. Is this



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true?

Answer: It is true that more experiments are needed to characterise the instruments' response to single-component aerosols, especially in the mobility size range 150 nm 300 nm where the lower cut-off of the efficieny is expected to be in the case of the light-scattering instruments.

Reviewer 1: This device seems like a nice way to incorporate more ambient aerosols into calibrating instruments, but there seems to be relatively large unknowns such as needing to understand each component's influence on the instrument separately and how particle density influences instrumentation response. Will this presumably expensive aerosol generator have improvements to the aerosol modelling field even with these unknowns? Can this be corrected for during post-processing?

Answer: This manuscript is meant as a proof of concept that synthetic ambient-like aerosols can be produced in the laboratory and used for instrument calibration. We agree with the Reviewer that a systematic characterisation of the instruments' response with respect to each aerosol chemical component/density would be valuable and we intend to pursue such a study in the near future.

Reviewer 1: What is the lowest sample flow that this device can adhere to?

Answer: The aerosol flow through the homogeniser is about 180 L/min (120 L/min dilution air + 60 L/min from the three turbulent air jets + 2-5 L/min from the different aerosol generators). The devices under test, e.g. PM monitors, to be connected at the bottom part of the homogeniser can have a sample flow ranging from a few hundred mL/min up to about 40 L/min.

Reviewer 1: Would this type of system require knowledge about the ambient chemical composition in order to tailor the device to a calibration setting relevant to the geographical area? If so, to what degree is required for accurate results?

Answer: Yes, the calibration aerosol needs to simulate the chemical properties of the

specific ambient aerosol(s) in the location where the PM monitor will be installed. In other words, it is important to know the average % mass fraction of elemental carbon, organic mass, dust and inorganic ions of the ambient aerosol (with an uncertainty of about 30% or, if possible, better), so that the composition of the calibration aerosol can be tuned accordingly. The design of the experimental facility will remain the same, but the set-points of the different aerosol generators will need to be adjusted.

Reviewer 1: Can the designed device be taken out into the field for calibration outside of the lab? Or does it require a built-in power source, lots of set up or a highly stable environment (such as a study platform, etc.). In figure 6b, there are two different injection tubing types (L-shape and a bent elbow shape). What was the reason for the difference in this design? Does the L-shape influence the incoming primary aerosols differently than the turbulent air jet?

Answer: The current facility is not transportable, but we are currently working on the miniaturisation of the flow tube homogeniser in order to reduce the overall dimensions of the set up. The idea behind the design of this facility was to perform laboratory-based calibrations in order to avoid the laborious field campaigns. In Figure 2b), the L-shaped inlets are meant for the primary aerosols which are delivered centrally and downwards in the homogeniser. The inlets with a 60 degree angle are specially designed for the turbulent air jets. The 60 degree angle helps to create vortices which are necessary for an efficient mixing of the different aerosol components.

Reviewer 1: Most of these parts are custom made and look very expensive. I assume that this device is going to be patented and sold, but in the case that it is not, how will other researchers be able to recreate these results? Will it be obtainable for using in a lowcost setting?

Answer: Indeed, some parts of the facility (e.g. homogeniser and isokinetic sampling probes) are custom-made. The material costs less than 2'000 € in total, but the construction must be carried out by a trained technician. The facility will not be patented,





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which explains why we actually present the CAD-design of the homogeniser in the manuscript. Our aim is to share our know-how with the community, receive feedback and improve the design of the facility even further. Other researchers are free to reproduce the facility as long as they cite the current manuscript.

Reviewer 1: Line 37 – “most important metric to monitor”, should be changed to “regulated pollutant” or something similar, as health studies are not conclusive about what particle characteristic is the most damaging to human health (PM, particle number, surface area, surface chemical composition, etc.). PM2.5 and PM10 is significantly easier to measure than surface area or PN for fine particles.

Answer: The reviewer is absolutely right. The sentence now reads: "most important regulated metric to monitor...".

Reviewer 1: Line 47 – Could the authors give a quick description of what the references found in regards to the limitations of measuring PM due to the volatile component of particles?

Answer: Concerning the TEOM, the larger the percentage of volatile material the higher the risk of material loss on the filter of the TEOM. The losses depend of course on the ambient temperature and the temperature of the TEOM’s measurement cell, with the losses being higher when TTEOM» Tambient (see, for instance, Mayer et all 2000, Lee et al. 2005, Sofowote et al. 2014 and Su et al. 2018 cited in the manuscipt). Concerning the PM monitors based on light scattering, we believe that it’s mostly the hygroscopic growth of particles that could create measurement artefacts, that’s why PM monitors installed at air quality monitoring stations are typically equipped with a drier or a heated inlet.

Reviewer 1: Throughout – “PM mass” is redundant, as PM stands for particulate mass.

Answer: PM can either stand for Particulate Matter (see, for instance, definition of PM2.5 and PM10) or Particulate Mass. In the manuscript (abstract), we have defined

PM as Particulate Mass. If the Reviewer agrees, we would like to keep the term PM mass.

Reviewer 1: Line 49 – Is this last sentence saying that PM has a 25% uncertainty with the measurement techniques? This sentence could be structured differently to avoid confusion to the reader.

Answer: The Reviewer is right. We have restructured the sentence: "The measurement uncertainties for PM mass concentration in the Directive (European Parliament, 2008, 2015) are 25%, and thus much higher than those for gaseous pollutants (typically 15%)".

Reviewer 1: Line 60 – would the standard to which instruments need to be standardized be different depending on where/when/how PM is being measured? What about the influence of elevation in this standardization process?

Answer: The calibration aerosol needs to simulate the properties of the real ambient aerosol(s) at the location in which the PM monitor will be installed. This means that the calibration aerosol must be realistic in terms of both chemical composition and size distribution. Concerning th question about "elevation", we believe that most PM monitors have a temperature and pressure sensor to calculate the sampled volume.

Reviewer 1: Line 87 – Add “detailed below” after “aerosol generator system” so it reads: Apart from the aerosol generator system (detailed below), . . .

Answer: We have modified the text according to the Reviewer’s suggestion. The sentence now reads: "Apart from the aerosol generation system (detailed below), ...".

Reviewer 1: Line 87- Refers to a “new setup”. Is there an old setup that precedes this setup that should be referenced?

Answer: Here, we just wanted to highlight that the setup is novel (and does not rely on a previous facility).

Reviewer 1: Line 105 – roman numeral should be iii) at the end of the line.

Answer: We thank the reviewer for spottting this mistake. We have corrected the text accordingly.

Line 111 – was there a specific reason for choosing GMD of 90 nm?

Answer: The GMD was chosen to be 90 nm to simulate soot particles emitted by diesel vehicles.

Reviewer 1: Line 113 – Was the aggregated particle size actually measured or is this an assumption based off of particle growth theories?

Answer: The particle size (i.e. mobility diameter of 120 nm) was measured with a Scanning Mobility Particle Sizer (SMPS). We have added a clarification in the text.

Reviewer 1: Line 119 – Is this mixing protocol to adhere gaseous particles to the soot particles? A brief sentence about this would be helpful.

Answer: The aerosol flow through the MSC was set to 1.2 L/min to allow enough time for the ozonolysis of the $\alpha$-pinene and subsequent condensation of the SOA onto the soot surface. Higher aerosol flows through the MSC would lead to a too short residence time in the reactor and should be avoided. We have added an explanation in the text.

Reviewer 1: Figure 1 is very nice. It would be helpful to emphasize the intake air. How it is currently makes it look like a closed loop system rather than drawing air into the system. Is the recycled water from the aerosol mixture chamber just used for cooling, is it cleaned for reuse, or is that unnecessary?

Answer: We thank the Reviewer for the positive feedback. The aerosol does not flow in a closed loop. The dilution air is introduced at the top of the homogeniser and the primary aerosols are injected a few cm downwards. The aerosol is homogenised, part of it is sampled by the PM monitors and the reference gravimetric method, and the rest exits the homogeniser through the exhaust outlet (see explanation in Lines 191-

192). In Figure 1, the exhaust outlet is shown close to the bottom right edge of the homogeniser. The water used for cooling (or heating) of the homogeniser does not need to be cleaned but needs to be replenished every few weeks depending on the hours of operation.

Reviewer 1: Line 272 – what is the purpose of the charring correction?

Answer: When organic carbon undergoes charring, it could mistakenly be classified as elemental carbon. A charring correction is performed to correct for this artefact and improve the accuracy of the EC/OC split in thermal-optical methods.

Reviewer 1: Line 285 – Missing “an” before “example”

Answer: We have corrected the text. The sentence now reads: "As an example, ...".

Reviewer 1: Line 306 – Here would be a good place to include the uncertainty of these PM calculation technique (+/- 20%?).

Answer: The measurement uncertainty depends on the composition of the aerosol, the environmental conditions and the calibration technique used by the manufacturer. The uncertainties can be much higher than 20% (deviations up to a factor of 3 from the reference gravimetric method have been reported in the literature).

Reviewer 1: Line 332 – Is there any possibility the fresh soot was aggregating which caused a decrease in PN? Or was this variable accounted for in the design?

Answer: The size of the soot particles was monitored with an SMPS and was shown to remain stable. We believe that the decrease in the soot particle number concentration was due to the decreasing flow of the soot aerosol injected into the homogeniser.

Reviewer 1: Line 369-371 – is this sentence out of place? It seems relevant to include it with the previous paragraph.

Answer: Since "the large range of the positive systematic bias (factor of 1.2−3)..." refers specifically to the DustTrak and not the TEOM, we cannot shift the sentence to

the previous paragraph. If the Reviewer agrees, we would prefer to leave the sentence at the current position.

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