TNA User Report

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Project title	Assessment of the Influence of Photochemical Aging on the Physical, Chemical, and Optical Properties of Black Carbon Particles
Name of the accessed chamber	MAC-MICC
Number of users in the project	5
Project objectives (max 100 words)	An experimental campaign to evaluate the response of a source of BC emissions over a wide range of nanoparticle diameters and coating thicknesses is envisaged. A sophisticated photochemical aerosol chamber at the University of Manchester will be used to simulate atmospheric processing of emissions using a range of emissions sources and fuel properties, and simulating conditions from freshly emitted BC to fully aged aerosols. The emissions will be characterised using state-of-the-art diagnostic instruments, including new and prototype instruments supplied from industrial partners. Current instrumentation will be challenged with atmospherically relevant particles, and the uncertainty of instrument performance with respect to aerosol aging will also be studied.
Description of work (max 100 words):	Regulatory measurements of BC emissions from mobile sources are typically performed through extractive sampling at the engine exit plane or downstream in a dilution tunnel or from an exhaust stack. However, as the exhaust plume cools and dilutes with ambient air, the characteristics of BC at the downstream location vary significantly from those measured at the engine exit plane. This is primarily caused due to the nucleation and condensation of volatile species on to the surface of BC. Hence the local, regional, and global impacts of BC emissions are the result of not just BC emissions alone, but BC coated with volatile species and oxidised through photochemical reactions. From an impact assessment perspective, it is critical to understand the physical, chemical, and optical characteristics of these aged BC emissions. Such characterisation can be best performed in a controlled chamber where atmospheric processes of multicomponent aerosols, such as formation and transformation of secondary organic aerosols (SOA), can be investigated in a systematic manner.

Principal Investigator's and group's information	
First name	Martin
Family name	Irwin
Nationality	British

Activity domain[1]	Earth Sciences & Environment
Home institution	Catalytic Instruments GmbH
Institution legal status[2]	
Email	martin.irwin@catalytic-instruments.com
Gender	Male
User status[3]	
New user	Yes

User 1 Information[4]	
First name	Hans-Joachim
Family name	Schultz
Nationality	German
Activity domain	Earth Sciences & Environment
Home institution	Catalytic Instruments GmbH
Institution legal status	
Email	hans-joachim.schulz@catalytic-instruments.com
Gender	Male
User status	
New user	Yes

User 2 Information	
First name	Greg
Family name	Smallwood
Nationality	Canadian
Activity domain	Earth Sciences & Environment; Combustion & Emissions
Home institution	National Research Council Canada
Institution legal status	
Email	Greg.Smallwood@nrc-cnrc.gc.ca
Gender	Male
User status	
New user	New

User 3 Information	
First name	Brett
Family name	Smith
Nationality	Canadian

[1] *PLEASE CHOOSE ONLY ONE DOMAIN* Physics; Chemistry; Earth Sciences & Environment; Engineering & Technology; Mathematics; Information & Communication Technologies; Material Sciences; Energy; Social sciences; Humanities.
[2] UNI= University and Other Higher Education Organisation;
RES= Public Research Organisation (including international research organisations and private research organisations controlled by public authority);
SME= Small and Medium Enterprise;
PRV= Other Industrial and/or Profit Private Organisation;
OTH= Other type of organization.
[3] UND= Undergraduate; PGR= Post graduate; PDOC= Post-doctoral researcher; RES= Researcher ENG= Engineer; ACA= Academic; TEC= Technician.
[4] Reproduce the table for each user who accessed the infrastructure

Activity domain	Earth Sciences & Environment; Combustion & Emissions
Home institution	National Research Council Canada
Institution legal status	
Email	Brett.Smith@nrc-cnrc.gc.ca
Gender	Male
User status	
New user	New

Trans-National Access (TNA) Scientific Report

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Instructions

Please limit the report to max 5 pages, you can include tables and figures. Please make sure to address any comments made by the reviewers at the moment of the project evaluation (if applicable, in this case you were informed beforehand). Please do not alter the layout of the document and keep it in Word version.
The report will be made available on the eurochamp.org website. Should any information be confidential or not be made public, please inform us accordingly (in this case it will only be accessible by the European Commission, the EUROCHAMP-2020 project partners, and the reviewers). Please include:

- Introduction and motivation
- Scientific objectives
- Reason for choosing the simulation chamber/ calibration facility
- Method and experimental set-up
- Data description
- Preliminary results and conclusions
- Outcome and future studies
- References

Name of the PI: Dr Martin Irwin
Chamber name and location: MAC-MICC, Manchester
Campaign name and period: 25/11/2019—13/12/2019
Text:

• Introduction and motivation

Black carbon (BC) emissions from transportation sources, generated as by-products of incomplete combustion, are important pollutants in the urban environment, and there are substantial concerns about the negative effect of combustion generated BC particles on public health.

Regulatory measurements of BC emissions from mobile sources are typically performed through extractive sampling at the engine exit plane or downstream in a dilution tunnel or from an exhaust stack. However, as the exhaust plume cools and dilutes with ambient air, the characteristics of BC at the downstream location vary significantly from those measured at the engine exit plane. This is primarily caused due to the nucleation and condensation of volatile species on to the surface of BC. Hence the local, regional, and global impacts of BC emissions are the result of not just BC emissions alone, but BC coated with volatile species and oxidised through photochemical reactions. From an impact assessment perspective, it is critical to understand the physical, chemical, and optical characteristics of these aged BC emissions. Such characterisation can be best performed in a controlled chamber where atmospheric processes of multicomponent aerosols, such as formation and transformation of secondary organic aerosols (SOA), can be investigated in a systematic manner.

Further, Catalytic Instruments would test a new commercially viable thermodenuder. The aim of the project was to build and evaluate an *improved* thermodenuder that incorporates best practices from the literature, yet adds features such that it incorporates a simple design that is easy and inexpensive to manufacture. It is compact and mobile compared to the previous state of the art.

• Scientific objectives

The key scientific objectives were to compare instrumental responses to a variety of different BC sources. The photochemical aerosol chamber at the University of Manchester was used to simulate atmospheric processing of emissions using a range of emissions sources and fuel properties, and simulating conditions from freshly emitted BC to fully aged aerosols.

For example, Catalytic Instruments are testing new instrumentation with the aim of bringing a suitable product to market, and are also using semi-volatile organic particles to challenge the Catalytic Stripper (CS). The efficacy of the CS will be determined for a wide range of particle composition and size. While the CS has been robustly evaluated against simple laboratory generated particles (e.g. tetracontane ; Swanson and Kittelson, 2010) and gases (e.g. propane), this will be possibly the first instance in which the CS is evaluated in a controlled laboratory using a wide range of atmospherically relevant particles.

• Reason for choosing the simulation chamber/ calibration facility

The facilities in Manchester allow for a somewhat flexible experimental process, in that daily morning meetings during chamber preparation allow short-term changes to be made to experimental design, without significant impact. This allowed the systematic measurement of BC particles generated using three different methods, including diesel engine emissions, flame soot generator and nebulised BC stanadard (Aquadag). After studies on bare BC, we conducted experiments investigating the effect of SOA condensation on the measurement of these BC types.

To the latter point, the Manchester Aerosol Chamber (MAC) facility has been designed to study atmospheric processes of multicomponent aerosols under controlled conditions, such as formation and transformation of secondary organic aerosols (SOA), investigations of the direct and indirect effects of multicomponent aerosols on climate and air quality studies of combustion sources including aging of diesel exhausts.

Further to the experiments outlined above Catalytic Instruments used the facility to compare The University of Manchester's research grade thermodenuder to their latest prototype thermodenuder, in its commercial viability phase, and to test sulphur loading on their catalytic strippers.

• Method and experimental set-up

Date	Source	Condition	SOA	CS	Description
25-Nov-19					Unpack and discuss experiment plan
26-Nov-19					Setup
27-Nov-19	Engine	Cold Idle	N	N	Setup and Engine run
28-Nov-19	Engine	Hot	N	N	
29-Nov-19	Aquadag		N	N	
30-Nov-19			No Testing		
1-Dec-19			No Testing		
2-Dec-19	Aquadag		α-pinene	W and W/O	
3-Dec-19	Aquadag		α-pinene	W and W/O	SP2 calibration with CS
4-Dec-19	Aquadag		cresol	W and W/O	SP2 calibration without CS
5-Dec-19	Engine	Cold Idle	α-pinene	W and W/O	
6-Dec-19			Chamber Cleaning/Side experiments		
7-Dec-19			No Testing		
8-Dec-19			No Testing		
9-Dec-19	Engine	Hot	α-pinene	W and W/O	
10-Dec-19	MISG		α-pinene	W and W/O	
11-Dec-19	MISG		cresol	W and W/O	
12-Dec-19	Engine/Aquadag/MISG size selected		N		
13-Dec-19			Chamber Cleaning/Side experiments		

The installation, checking, and calibration of instrumentation was scheduled for the first couple of days in the first week. Central to the experimental setup are the use of catalytic strippers (CS) which remove semi-volatiles from an aerosol stream. This means that when placed in-line downstream of the Diesel engine, bare Diesel BC particles are injected into the chamber directly. These particles can then act as seed particles for SOA formation. Further CS were employed in the aerosol lab upstream of various instrumentation to allow the sampling of stripped (i.e. bare) BC aerosol before analysis with a variety of techniques.

The first set of experiments were using the Engine in either cold idle or hot conditions, and then bare Aquadag was used (without CS). Week 2 had SOA as the focus, with Aquadag then Engine exhaust acting as a seed for a-pinene and cresol SOA.

In the final week further experiments were conducted with the engine and also a novel mini inverted soot generator (MISG), capable of producing BC particles with a wide range of properties (Kazemimanesh et al., 2019; Moallemi et al. 2019).

Several instruments were used to characterize the physical, chemical, and optical properties of the BC. These included the Artium LII 300, AVL MSS, Aerodyne CAPS, TSI SMPS, DMT SP2, DMT PASS, and Aerodyne AMS.

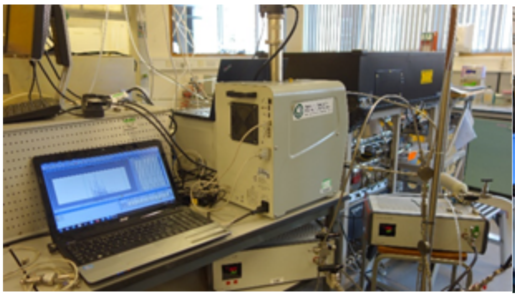
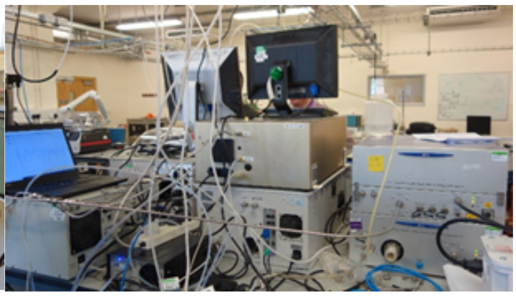



Figure 0: Layout of instruments used for the experiments

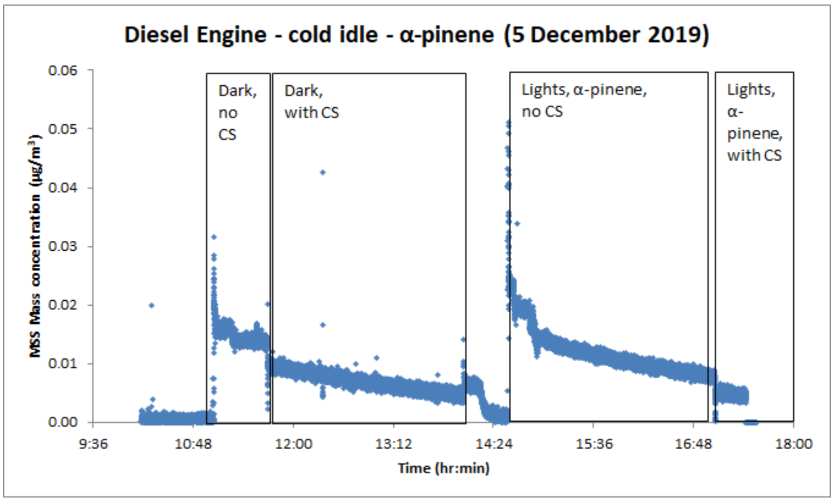
Alongside the key chamber experiments, thermodenuder and CS testing was conducted. Some results are shared below.

• Data description

All instruments used recorded data in real-time, in timestamped log files. The data files were time synchronized to be able to compare instruments for a given set of conditions. The data for a given condition was averaged over a time period (typically 2 minutes) where stable conditions prevailed. The data from all instruments was tabulated corresponding to each test condition, which was then used for subsequent analysis.

• Preliminary results and conclusions

A typical time series for the MSS on 5 December 2019 is shown in Figure 4. The source of emissions was the diesel engine operating at the cold idle condition. The SOA used was α-pinene. The experiment was first performed with no lights turned on in the chamber to obtain a baseline measurement of the BC mass concentration (with and without the Catalytic Stripper). Following these measurements, α-pinene was injected into the chamber and the UV lights were turned on.



Preliminary observations indicate that the response of different instruments was dependent on the source of the emissions, and coating of VOCs on the surface of BC.

Particle volatile profiles were measured as a function of particle size and composition, using the University of Manchester's SMPS.

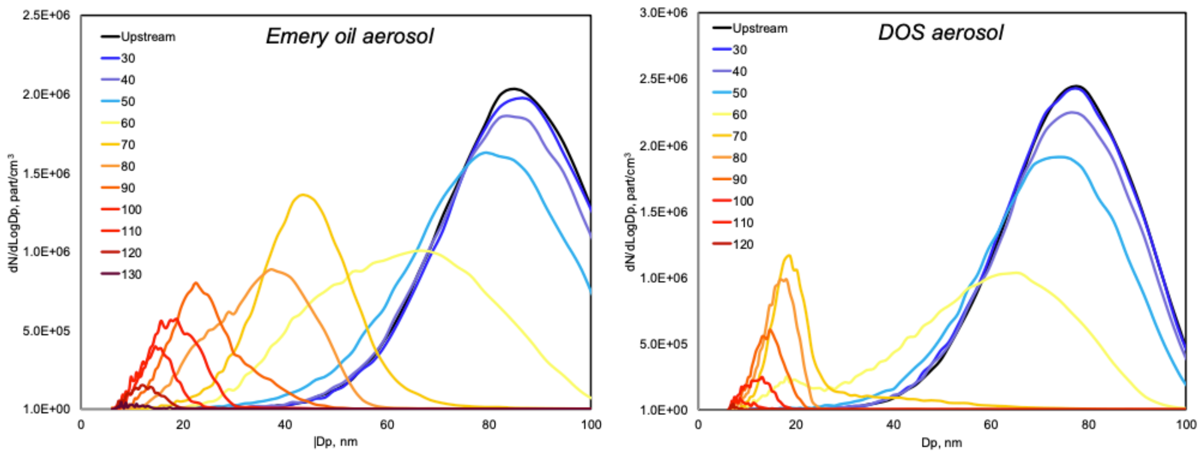


Figure 1: Volatility profiles of Emery oil (left) and DOS (right) aerosol

The emery oil and DOS aerosol exhibit distinctly different volatility profiles. Some modelling work is required in order to draw conclusions to the accuracy and effectiveness of the thermodenuder's performance, but the data agree with literature results.

• Outcome and future studies

The preliminary results of the study indicate that the different instruments used to measure BC mass concentration are influenced by the source of BC and the type and coating of VOCs.

• References

Alfarra et al., Water uptake is independent of the inferred composition of secondary aerosols derived from multiple biogenic VOCs, Atmos. Chem. Phys., 13, 11769-11789, 2013.

Kazemimanesh, et al., A novel miniature inverted-flame burner for the generation of soot nanoparticles, Aerosol Sci. Technol., 53 (2), 184-195, 2019.

Moallemi, A., et al., Characterization of black carbon particles generated by a propane-fueled miniature inverted soot generator, J. Aerosol Sci., 135, 46-57, 2019.Pereira et al., Technical note: Use of an atmospheric simulation chamber to investigate the effect of different engine conditions on unregulated VOC-IVOC diesel exhaust emissions, Atmos. Chem. Phys., 18, 11073-11096, 2018.

Wyche et al., Emissions of biogenic volatile organic compounds and subsequent photochemical production of secondary organic aerosol in mesocosm studies of temperate and tropical plant species, Atmos. Chem. Phys., 14,

15/04/2020

Martin Irwin
Business Development Director, Catalytic Instruments GmbH