EUROCHAMP 2020

TNA User Report

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Project title	Characterization of a Blaustein Atomizer system
Name of the accessed chamber	CESAM
Number of users in the project	2
Project objectives (max 100 words)	The main goal of the present project, is the characterization of the aerosol produced by the Blaumstein Atomizer system (BLAM), namely the size distribution of the particles produced and the nebulization efficiency, according to different parameters (i.e. feed rate, pressure, air flow) and set up (expansion plates). The results of the project will make available for PM_TEN valuable information for the correct and exhaustive use of the BLAM atomizer nebulization system.
Description of work (max 100 words):	We have characterized the size distribution of the aerosol produced by the BLAM atomizer using different saline solutions (e.g. NaCl and $(NH_4)_2SO_4$) at different concentration to produce the poly-disperse particles. We test the atomizer in standard condition, i.e. the typical conditions of use in terms of set up (i.e. the expansion plate), airflow and liquid feed rate, and then chancing these parameters. The nebulization efficiency was evaluated using commercial SiO_2 spherical particles, with known diameter, with different expansion plate and operative conditions. Tests were carried out through the CESAM chamber, equipped with different particle counters (SMPS, OPCs and CPC) and using two driers in series directly connected to the SMPS and the CPC.

Principal Investigator's and group's information	
First name	Dario
Family name	Massabò
Nationality	Italian
Activity domain[1]	Material Sciences, Physics & Environment
Home institution	PM_TEN srl
Institution legal status[2]	PRV
Email	dario.massabo@pm10-ambiente.it
Gender	Male
User status[3]	RES
New user	No

User 1 Information[4]	
First name	Dario
Family name	Massabò
Nationality	Italian
Activity domain	Material Sciences, Physics & Environment
Home institution	PM_TEN srl
Institution legal status	PRV
Email	dario.massabo@pm10-ambiente.it
Gender	Male
User status	RES
New user	No

User 2 Information	
First name	Silvia Giulia
Family name	Danelli
Nationality	Italian
Activity domain	Chemistry & Environment
Home institution	INFN
Institution legal status	RES
Email	sdanelli@ge.infn.it
Gender	female
User status	PGR
New user	yes

[1] 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

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: Dario Massabò
Chamber name and location: CESAM, Creteil
Campaign name and period: Characterization of a Blaustein Atomizer system, 25/01/2019 – 01/02/2019
Text:

- **Introduction and motivation**

PM_TEN is involved in the production and distribution of custom substrates for collecting aero-disperse particles (http://www.pm10-ambiente.com). These substrates include filtering matrix and impaction stages, both needing characterization about size-dependent retention efficiencies. In particular, PM_TEN is currently producing an impaction stage for the collection of the PM_{10} coarse fraction and a filter matrix for the collection of $PM_{2.5}$. In order to evaluate the efficiencies of both the systems, PM_TEN would use a peculiar nebulization system, able to produce poly-disperse particles with size in the range from few nm to some microns: the Blaumstein Atomizer system (BLAM, single-jet model, CH Technologies; Zhen et al., 2014). This atomizer has a modular design, composed of five interchangeable plates (see Table 1) that allow it to house liquids of various properties to produce aerosols in specific size and concentration ranges. As reported in the user's manual, various expansion cone diameters combined with various cavity depth could provide a fine control on the output of the device and particle size distribution of the aerosol. Actually, nebulization efficiency and the real size range of aerosols produced by the BLAM are not clearly known since there is no detailed characterization of this object in the literature nor in the technical documentation of the manufacturer.

Table 1. Characteristics of BLAM's Expansion plates.

Plate ID	Cavity Depth (inch)	Cone Diameter (inch)
1-20	0.001	0.020
1-30	0.001	0.030
4-30	0.004	0.030
4-40	0.004	0.040
10-40	0.10	0.040

- **Scientific objectives**

The main goal of the project is the characterization of the aerosol produced by the BLAM, namely the size distribution of the particles produced and the nebulization efficiency, according to different parameters (i.e. feed rate, pressure, air flow) and set up (expansion plates). The results make available for PM_TEN valuable information for the correct and exhaustive use of the BLAM atomizer nebulization system.

- **Reason for choosing the simulation chamber/ calibration facility**

In order to characterize the nebulization system we have chosen the CESAM simulation chamber because of its instrumentation allowing to monitor both submicronic and supermicronic particles, because of the long lifetime of particles in this chamber and because the possibility of manual cleaning the chamber in case of "dirty" injection events (Wang et al., 2011). A secondary purpose is to learn how to program and carry out experiments, manage and correctly and efficiently use a complex structure such as an atmospheric simulation chamber. Future activities could be carried out at the Italian atmospheric simulation chamber in Genoa, and about it, the CESAM facility, inside the Eurochamp2020 consortium, is the most similar chamber to the Italian ChAMBRe atmospheric simulation chamber, in terms of structure, material, shape and volume.

- **Method and experimental set-up**

We have characterized the size distribution of the aerosol produced by the BLAM atomizer using different saline solutions (NaCl and $(NH_4)_2SO_4$) at different concentration to produce poly-disperse particles. We test the atomizer in standard condition, i.e. the typical conditions of use in terms of set up (i.e. the expansion plate), airflow and liquid feed rate, and then changing these parameters. The nebulization efficiency was evaluated using commercial SiO_2 spherical particles (concentration 5%) of known dimensions (Monodisperse silica nanospheres and microspheres, Corpuscular Inc.). Tests were carried out through the CESAM chamber, equipped with different particle counters: a Scanning Mobility Particle Sizer comprising a Differential Mobility Analyzer TSI® model 3080, coupled with a Condensation Particle Counter TSI®, model 3010; two different Optical Particle Counters Grimm® 1.108 SubMicron Aerosol Spectrometer) and a single CPC. Some tests were also carried out using two driers in series directly connected to the SMPS.

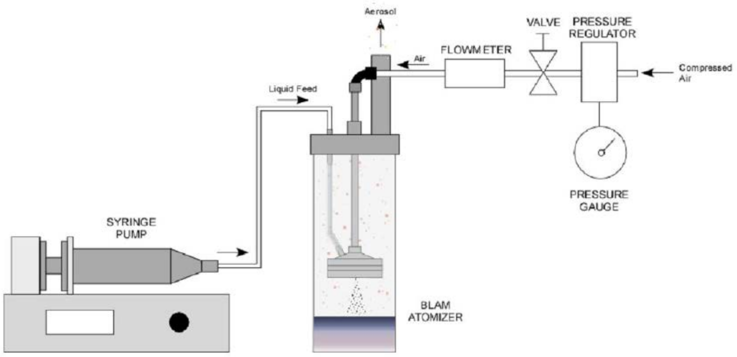

Figure 1. Scheme of the BLAM's set-up

We spent three days for the characterization tests and two days for nebulization efficiency tests.
For the first aim, we tested three different BLAM plates, the 1:20, the 4:40 and the 10:40 plate as reported below:

28/01/2019:

- Injection $(NH_4)_2SO_4$ 0.01 M (20 µg/m3), with injection feed rate of 0.4 ml/min, airflow 2 lpm, expansion plate 1:20, dry condition (i.e. standard condition)
- Injection of NaCl 0.9 g/L (0.015 M) (15 µg/m3), standard condition
- Injection of NaCl 9 g/L (125 µg/m3), standard condition
- Injection of NaCl 9 g/L (117 µg/m3) , injection feed rate 0.4 ml/min, airflow 3 lpm, expansion plate 1:20, dry condition
- Injection of NaCl 9 g/L (53 µg/m3) , injection feed rate 1 ml/min, airflow 2 lpm, expansion plate 1:20, dry condition

29/01/2019 :

- Injection of NaCl 9 g/L (45 µg/m3), injection feed rate 0.4 ml/min, airflow 2 lpm, expansion plate 1:20, 60 RH %)
- Injection of NaCl 9 g/L (30 µg/m3), injection feed rate 0.4 ml/min, airflow 2 lpm, expansion plate 4:40, dry condition
- Nebulization of NaCl 9 g/L, injection feed rate 0.4 ml/min, airflow 2 lpm, expansion plate: 10:40, 1:20, 1:30, 4.30, and 4.40. Tests of all expansion plates measuring directly at the output of the BLAM with the OPC. In these tests, the connecting pipe normally present at the end of the BLAM was removed.
- Injection of NaCl 9 g/L (60 µg/m3), injection feed rate 0.4 ml/min, airflow 2 lpm, expansion plate 1:20. To avoid losses of the larger particles along the connecting pipe between the chamber and the BLAM, we carried out one test removing the aforementioned tube and connecting the nebulizer directly to the chamber using one of the flanges in the lower dome, through a small Teflon connection.

30/01/2019

Tests with two driers in series and SMPS+CPC (RH at the output of the BLAM is around 60%; RH at the end of the driers is around 4%):

- NaCl 9 g/L [a) plate 1:20, 0.1 ml/min, 2 lpm, 1,5 ml nebulized (1000 µg/m3); b) plate 1:20, 0.4 ml/min, 2 lpm, 6 ml nebulized, (4000 µg/m3)]
- NaCl 0.9 g/L [plate 1:20, 0.1 ml/min, 2 lpm, 200 µg/m3]
- NaCl 0.09 g/L [a) plate 1:20, 0.1 ml/min, 2 lpm, 15 µg/m3; b) plate 1:20, 0.1 ml/min, 3 lpm, 15 µg/m3; c) plate 10:40, 1 ml/min, 2 lpm, 100 µg/m3]

31/01/2019

To determine the nebulization efficiency, we used spheres with diameter of 300 nm, 500 nm and 1 µm and we tested three plates, the 1:20, the 1:30 and the 4:30 plate.

First test (expansion plate 1:20):

- 500 nm (2 ml of 5% suspension + 8 ml of MilliQ), plate 1:20, 0.4 ml/min, 2 lpm, 2 ml injected
- After half an hour, injection of 300 nm spheres (1 ml of 5% suspension + 9 ml of MilliQ), plate 1:20, 0.4 ml/min, 2 lpm, 2 ml injected
- After half an hour, injection of 1 µm spheres (3 ml of 5% suspension + 7 ml of MilliQ), plate 1:20, 0.4 ml/min, 2 lpm, 3 ml injected.

Second test (same suspensions and condition of the previous test, with expansion plate 1:30):

- Injection of 1 µm spheres (3 ml of 5% suspension + 7 ml of MilliQ), plate 1:30, 0.4 ml/min, 2 lpm, 3 ml injected
- After half an hour, injection of 500 nm spheres (2 ml of 5% suspension + 8 ml of MilliQ), plate 1:30, 0.4 ml/min, 2 lpm, 2 ml injected
- After half an hour, injection of 300 nm spheres (1 ml of 5% suspension + 9 ml of MilliQ), plate 1:30, 0.4 ml/min, 2 lpm, 2 ml injected).

  Third test (same suspensions and condition of the previous tests, with expansion plate 4:30):
- Injection of 1 µm spheres (3 ml of 5% suspension + 7 ml of MilliQ), plate 4:30, 0.4 ml/min, 2 lpm, 3 ml injected
- After half an hour, injection of 500 nm spheres (2 ml of 5% suspension + 8 ml of MilliQ), plate 4:30, 0.4 ml/min, 2 lpm, 2 ml injected
- After half an hour, injection of 300 nm spheres (1 ml of 5% suspension + 9 ml of MilliQ), plate 4:30, 0.4 ml/min, 2 lpm, 2 ml injected

- **Data description**

Characterization tests:

28/01/2019:

OPC data of the first day show a change in size distribution with the concentration of the solution. With the most diluted solution, we observe a final part of a similar bell-shaped curve, with a maximum below 200 nm. With the most concentrated solutions, we observe a particles distribution with two visible peak, at 0.57 and 0.40 µm, and a part of a bigger peak with a maximum below 0.20 µm. Otherwise, data from the SMPS seem to show an unchanged dimensional distribution: all the NaCl solutions have the same distribution, with a peak at 50 nm, and the $(NH_4)_2SO_4$ solution seems to have a peak slightly shifted to 60 nm.

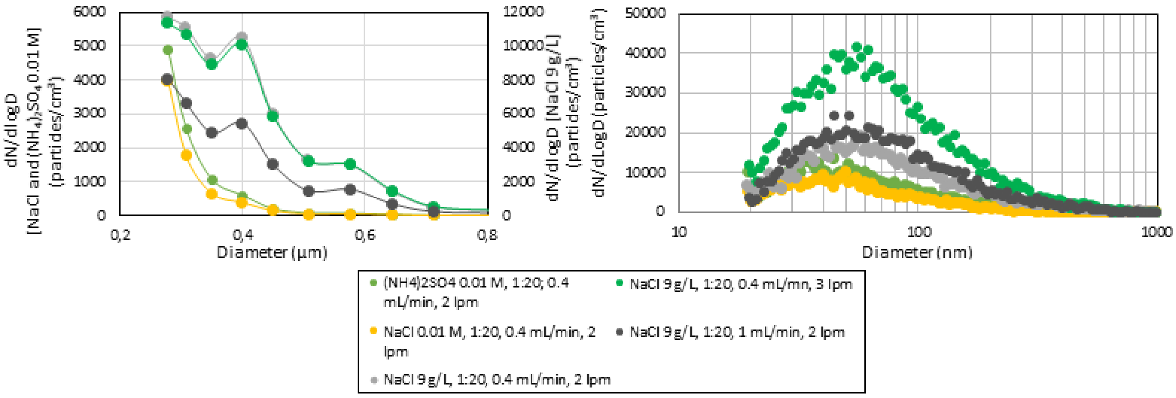

Figure 2. OPC data (left) and SMPS data (right) of 28/01/2019

29/01/2019

OPC and SMPS data of the second day show the same behavior of the previous experiments with NaCl 9 g/L. In Figure 3, we observe again a particle distribution with two visible peaks, at 0.57 and 0.40 µm, and a part of a bigger peak with a maximum below 0.20 µm. SMPS data show approximately the same distribution for all the injection conditions: particle distribution has a peak around 60 nm. The experiments performed with Relative Humidity around 60% seem to have a distribution shifted to smaller particles (peak at 40 nm).

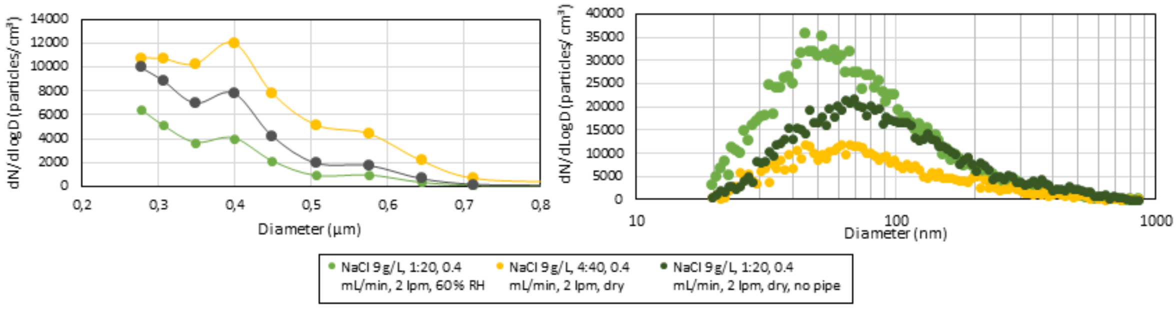

Figure 3. OPC data of 29/01/2019

Data from the nebulization of NaCl 9.0 g/L directly to the OPC show a very similar distribution for all the expansion plates, we observe the same bimodal particles distribution with two peaks at 0.57 and 0.40 µm.

30/01/2019

From the tests carried out using two driers in series directly connected to the SMPS we observe a different behavior only if we change the concentration of the injected solution. With the same solution, varying the parameters (liquid feeding speed, plate diameter and airflow), size distribution of the produced aerosol does not change. Figure 4 shows that there is a slight shift of the maximum varying the concentration of the solution. Taking into account the large number of particles it is possible that larger particles are the result of coagulation and growth phenomena in general.

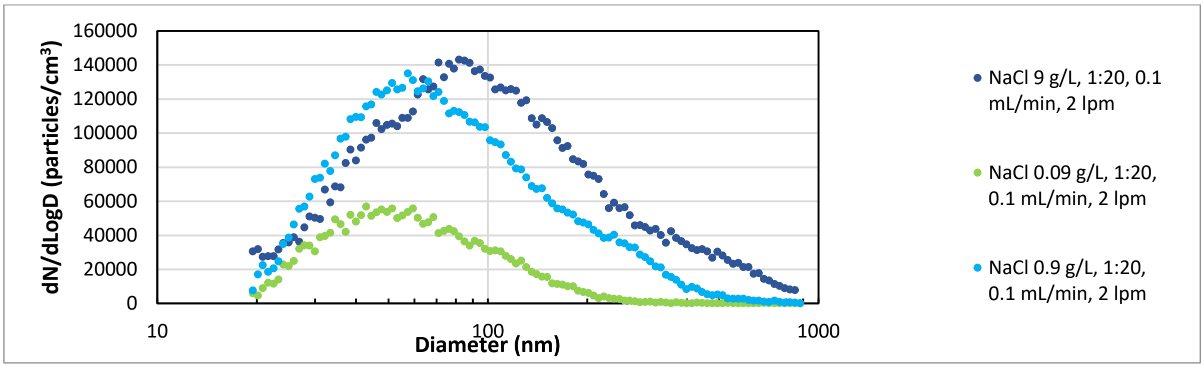

Figure 4. SMPS data of 30/01/2019

Nebulization efficiency:

31/01/2019

Figure 5 shows SMPS data obtained after the nebulization of the 300, 500 nm and 1.0 µm SiO_2 spheres. The measurement range of SMPS covers from 19.5 to 850 nm, therefore, only peaks of 300 and 500 nm spheres are clearly visible. These tests seem to show the same nebulization efficiency between 1:20 and 1:30 plates, while the 4:30 plate seems to generate less particles, despite is characterized by a cone with bigger cavity depth and larger diameter. The corresponding OPC data, reported in Figure 6, confirm the same behavior between 1:20 and 1:30 plates and a less quantity of particles generated by the 4:30 plate. The optical measurement of SiO_2 spheres involves a shift in the corresponding diameter, particles with 1.0 µm diameter, correspond to particles with 0.58 µm diameter, particles with 500 nm to 350 nm and 300 nm to spheres with a diameter less than 270 nm. In addition, the two instruments have a disagreement on the number of particles measured.

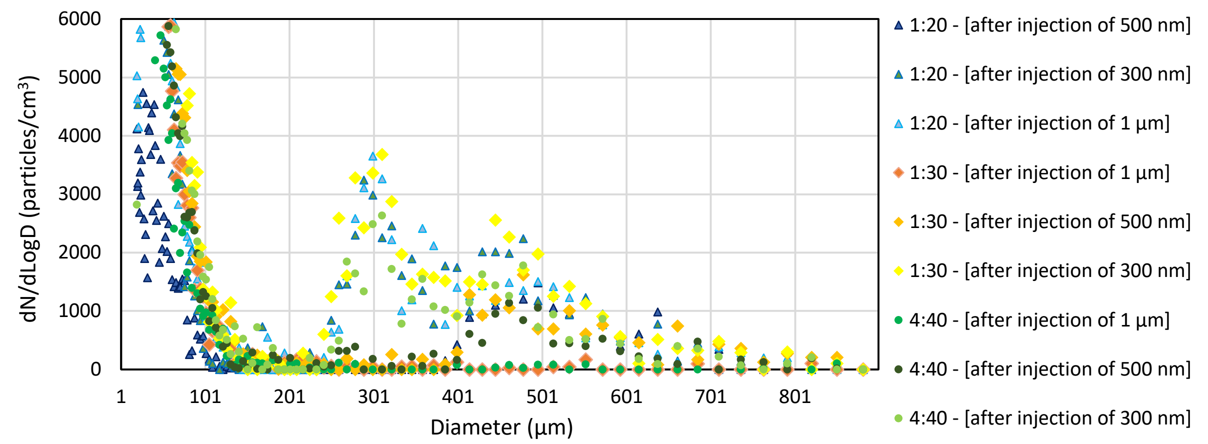

Figure 5. SMPS - 31/01/2019

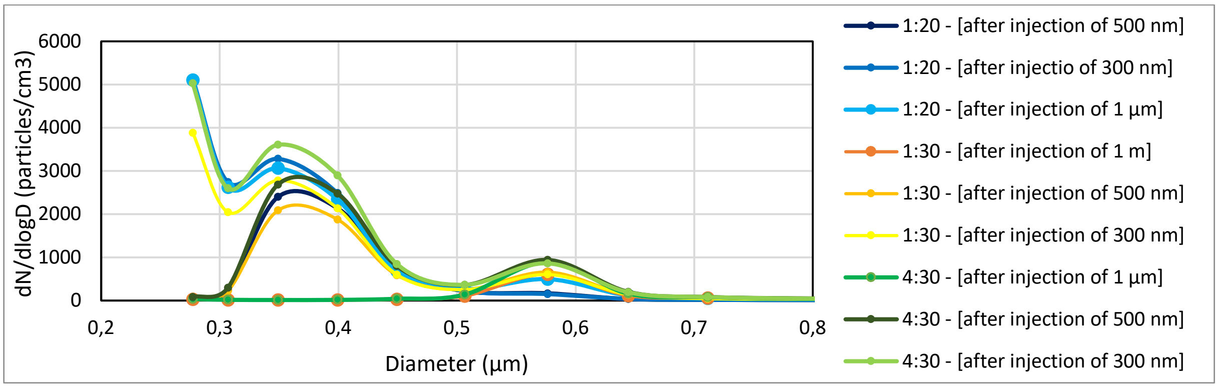

Figure 6. OPC - 31/01/2019

• Preliminary results and conclusions

From the tests carried out at the CESAM simulation chamber it is clear that the size distribution of the aerosol produced of the BLAM system are almost independent to the operative parameters (i.e. feed rate and air flow) and set up (expansion plates) that can be set. Taking into account very small variations, the size distribution has a peak around 60-70 nm, and the number of particles nebulized, with different dimension, is very similar between the plates tested. In addition, the nebulization efficiency, estimated between 2 and 8 %, seems to be independent from the different expansion plates used, since we obtain a good reproducibility of the aerosolized particles number.

• Outcome and future studies

The results of these tests have made available for PM_TEN valuable information on the BLAM atomizer nebulization system. The properties, but also the limits, of this system are now better known, allowing PM_TEN to perform an appropriate use of this nebulizing system and provide data for the characterization of the materials used in the filtration systems, essential for their commercialization.

• References

Zhen, H., Han, T., Fennell, D. E., and Mainelis, G.: A systematic comparison of four bioaerosol generators: Affect on culturability and cell membrane integrity when aerosolizing Escherichia coli bacteria, J. Aerosol Sci., 70, 67–79, 2014.

Wang, J., Doussin, J. F., Perrier, S., Perraudin, E., Katrib, Y., Pangui, E., and Picquet-Varrault, B.: Design of a new multi-phase experimental simulation chamber for atmospheric photosmog, aerosol and cloud chemistry research, Atmos. Meas. Tech., 4, 2465–2494, https://doi.org/10.5194/amt-4-2465-2011, 2011.