NON-EXHAUST EMISSIONS OF ROAD VEHICLE: QUANTITATIVE AND MORPHOLOGICAL ANALYSIS.

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Abstract

Pollution in large cities is a recurring problem which governments and private companies are trying to answer. Control pollution issued by vehicles is a regularly expressed element, but this concerns the case of pollutants from exhaust emissions, non-exhaust emissions are very rarely studied. The non-exhaust emission sources include brakes, clutches, tires, road and resuspension of particles on road. These different elements emit particles due to their wear by abrasion, corrosion or even tear. These sources contribute to the concentration of particles in the atmosphere with some differences of chemical characterizations, sizes and quantities. This article presents our project and the first experiments and some results.

Keywords: non exhaust emissions, fine and ultrafine particle, size range.

Nomenclature

Particle number concentration: #/cm^3

1. Preface

Like all European cities, French cities suffer from air pollution and road traffic. This represents between 14 and 17% of particulate emissions in 2012 in metropolitan France (*MEDDE, 2014*) and is often dominant to other sources in urban areas. The tailpipe emissions are widely studied and implicated in these urban pollution, which give European standards in constant evolution, even if the reduction of air pollution is still not satisfactory. By contrast, the non-exhaust emissions are rarely studied and regulated. Still they also emit fine and ultrafine particles with known health and climate risks. Thus, PM_{10}, particles with an aerodynamic diameter less than 10µm, include the fine and ultrafine particles and are being breathed by humans and penetrate the bronchi. $PM_{2.5}$ and $PM_{1,0}$ being smaller, they progress to the alveoli and can cross the alveolar-capillary barrier, making their health impacts even more important.

Particles in the atmosphere have very different characteristics on their size, morphology and chemical composition. This affects their concentration, their residence time in the atmosphere which can vary from minutes to months as well as on their health and climate impacts (*Morawska et al., 2008*).

As said earlier, the exhaust emissions are highly studied and technological advances have been carried and are still developing on filtering particles in the exhaust. Their proportion tends to decrease, which will make the non-exhaust particles most important or even dominant in road emissions by 2020 (*Pant and Harrison, 2013*). Europe and the France wish therefore reduce particulate emissions and in order to have effective regulations, it is necessary to understand the different mechanisms and physical processes in non-exhaust emissions.

The CAPTATUS project involves studying the physical characterization of non-exhaust particles near field by vehicles. Our experiments will focus on particle size analysis and this in three different environments:

- In the laboratory with a dynamometer test bench, in a clean environment with parameters of use of the vehicles checked.
- On test track where the environment is simplified (atmospheric noise limited in the absence of traffic) and vehicle operating parameters are controlled.
- In a real situation, roadside, with an urban background sound of relatively high which can influence the near field measurements.

These experimentations will lead to a better understanding of the mechanisms of creation of its particles and their behaviour, in order to build a more suitable framework for a concerted and coherent environmental policy.

2. Experimental model

Currently, our experiments have allowed us to analyze the particles emitted by the wear of brake pads. These experiments consisted of performing braking profiles with a vehicle on a dynamometer test bench. Different analyzers were connected to an aluminium sampling cone positioned closer to the front vehicle wheel. Figure 1 shows the performed experiments.

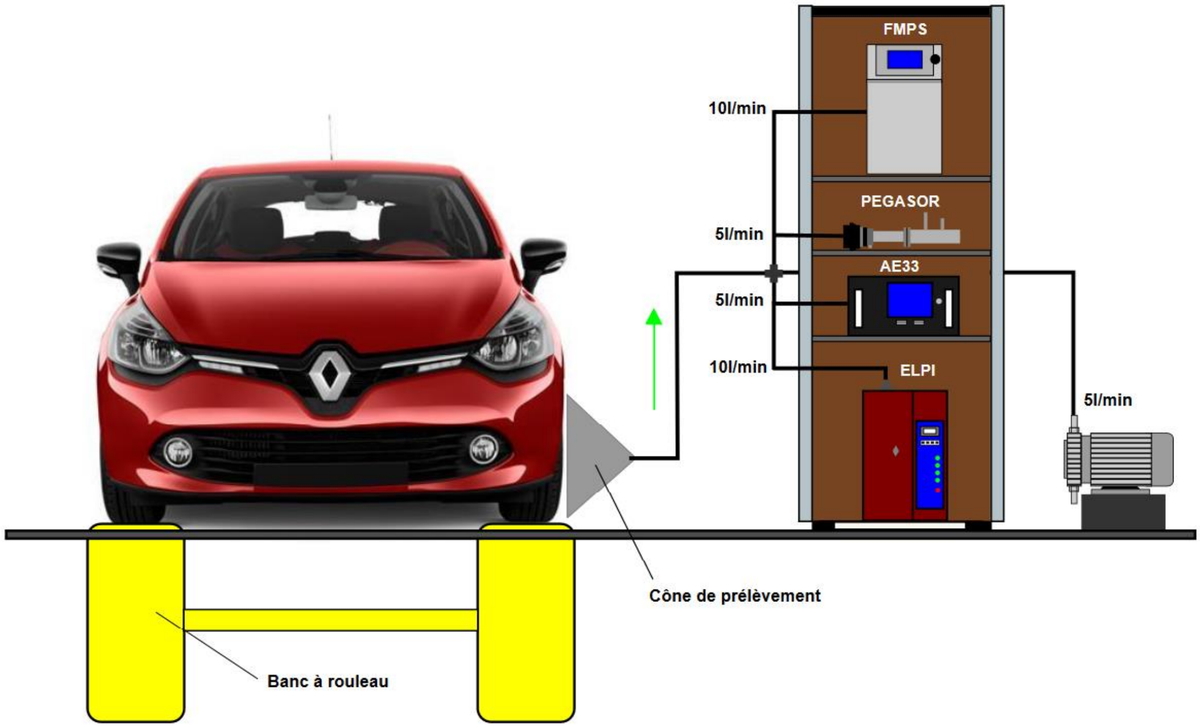


Figure 1: Diagram of the experiments, realize by P. TASSEL

Four analyzers were used: ELPI (Electrical Low Pressure Impactor), le FMPS (Fast Mobility Particle Size), the Pegasor (real time analyzer PPS-M) and the AE-33 (black carbon analyzer). These appliances measure in real time the particles of different size ranges. The outputs data of the analyzers also differ in their unit. Table 1 shows the various characteristics of the analyzers and the Tables 2 and 3 the different channels of measures of ELPI and FMPS.

Analyzers	Size range	Different channels of measures
ELPI	7nm-10µm	Yes
FMPS	10-560nm	Yes
Pegasor	5nm-3µm	No
AE-33	370-950nm	Yes

Table 1: Characteristics of analyzers

Channel	1	2	3	4	5	6	7	8	9	10	11	12
Size range (nm)	22	42	78	132	208	319	505	802	1273	2004	3154	6408

Table 2: Different channel of measures of ELPI

Channel	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Size (nm)	6.04	6.98	8.06	9.31	10.8	12.4	14.3	16.5	19.1	22.1	25.5	29.4	34.0	39.2	45.3	52.30
Channel	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**	**25**	**26**	**27**	**28**	**29**	**30**	**31**	**32**

Size (nm)	60.4	69.8	80.6	93.1	107.5	124.1	143.3	165.5	191.1	220.7	254.8	294.3	339.8	392.4	453.2	523.30

Table 3: Different channel of measures of FMPS

2.1 Realists profiles

The profiles consist of a braking sequence to represent a realistic driving. For this, we used the Artemis cycles. These are based on a statistical survey in Europe which has achieved in 4 cycles representative of different driving conditions: urban, rural and motorway (two cycle: one with a maximum speed of 130 km/h and another of 150 km/h). These profiles are usually used by car manufacturers to better understand the actual driving conditions, but are not those used for pollution certification or fuel consumption (*André 2004*). We used the cycles urban, rural and highway (with up to 130 km/h).

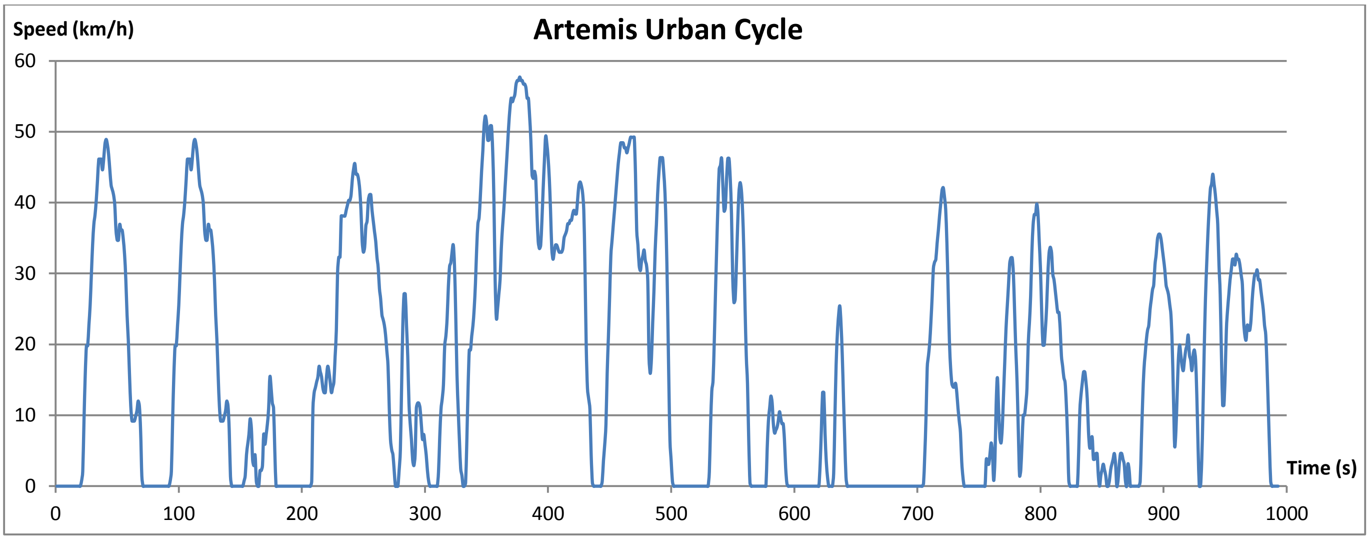


Figure 2: example of an Artemis cycle

Wishing to study particles from braking, the constant speed portions and acceleration do not interest us. So we have changed these profiles by removing regions at constant speeds and we have reduced the time of acceleration to a minimum. The ventilation being stopped during the experiments, these changes have allowed us to reduce the time of the profiles and thus the overheating of the engine. The following figure shows one of the profiles obtained and used in our experiments.

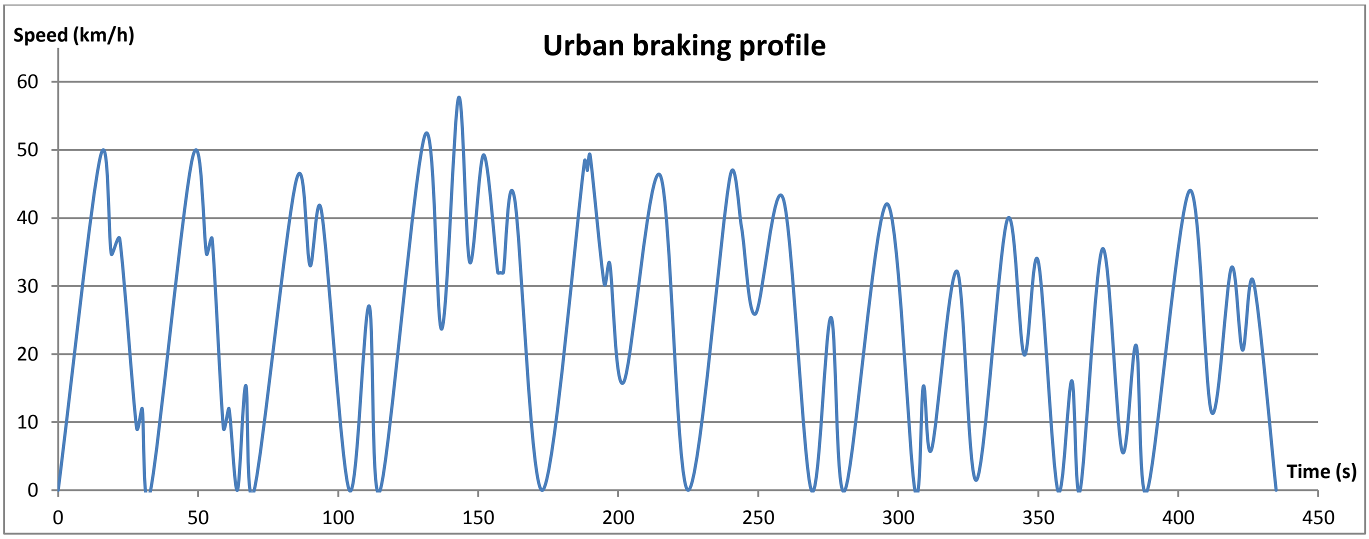


Figure 3: Urban braking profile created

2.2 Stepwise profile

In addition to these braking profiles representative of real driving, we also created a stepwise braking profile. This last is characterized by braking of 50 km/h on 5 seconds as shown in Figure 4.

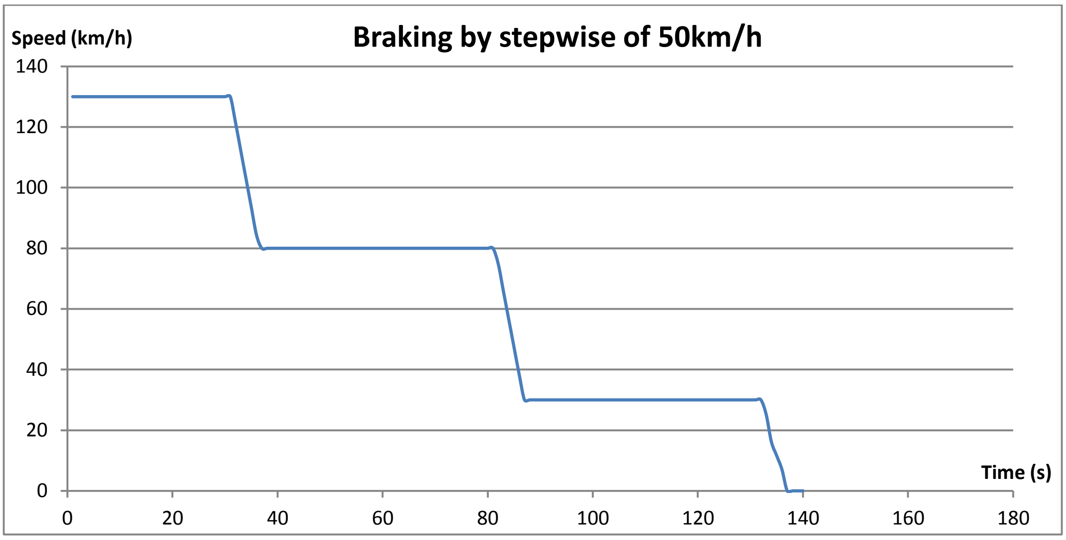


Figure 4: Stepwise braking profile

3. Results

Data from the AE-33 have not finished being processed. The data presented below are the results of pre-manipulations of the analyzers ELPI, FMPS and Pegasor. The results are the fruit of pre-experiments, so we will be very cautious about the conclusions to be drawn of the values obtained. The results presented are the measured concentrations for the driving profiles in urban and stepwise.

3.1 Urban Profile

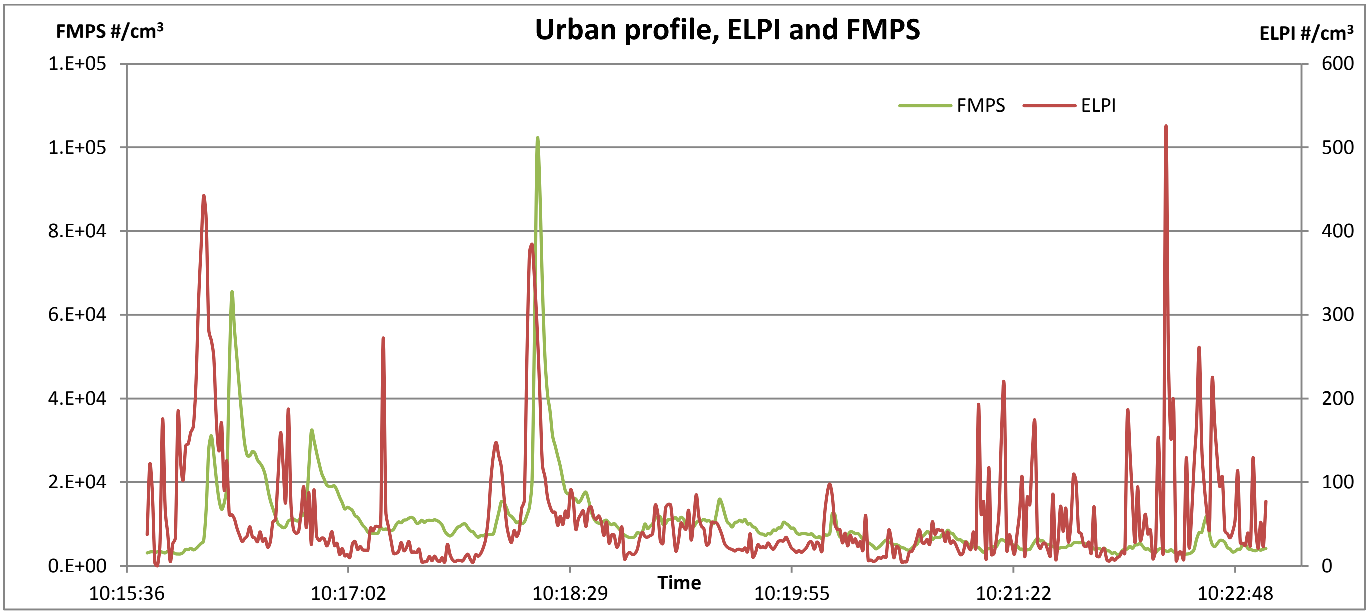


Figure 5: number of particles per cm^3 measured by the ELPI and the FMPS on all their particle size for urban profile.

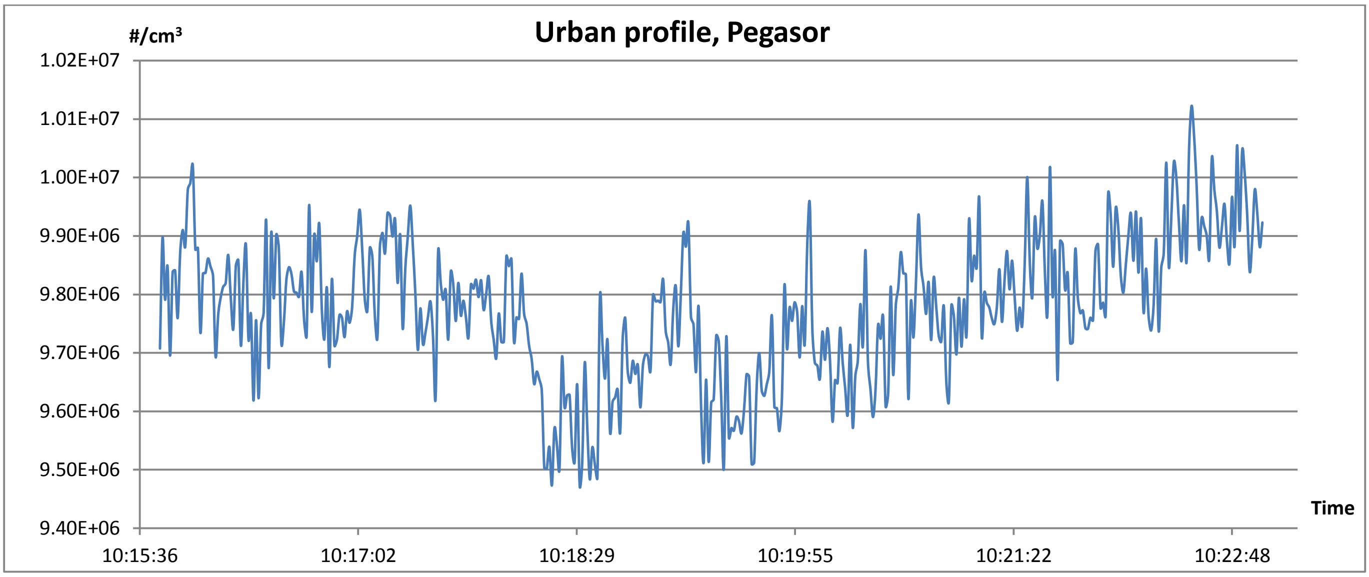
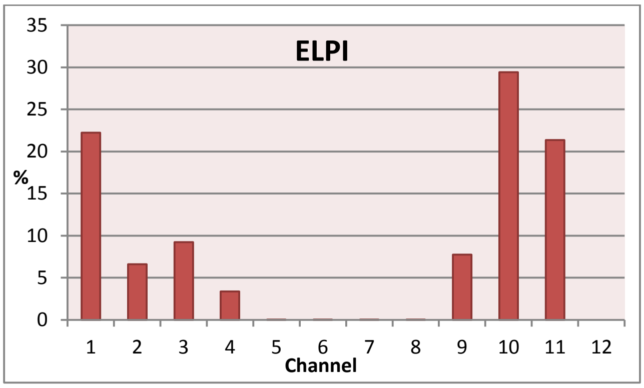


Figure 6: number of particles per cm^3 measured by the Pegasor throughout its size range for urban profile.

Now here is the concentration for the different channels of sizes of the FMPS and the ELPI.



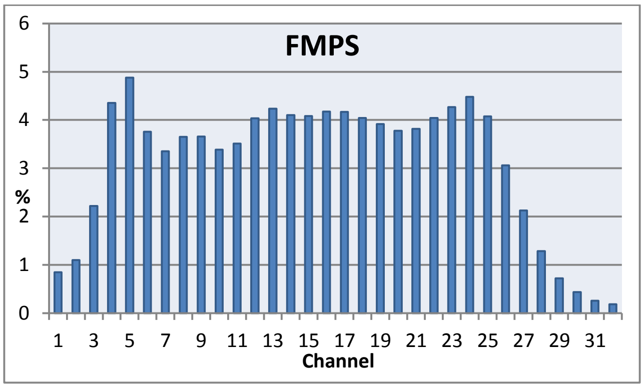


Figure 7: total concentration on a cycle for the different channels of the ELPI and FMPS. The concentration is expressed in % of total concentration over the entire size range.

3.2 Stepwise profile

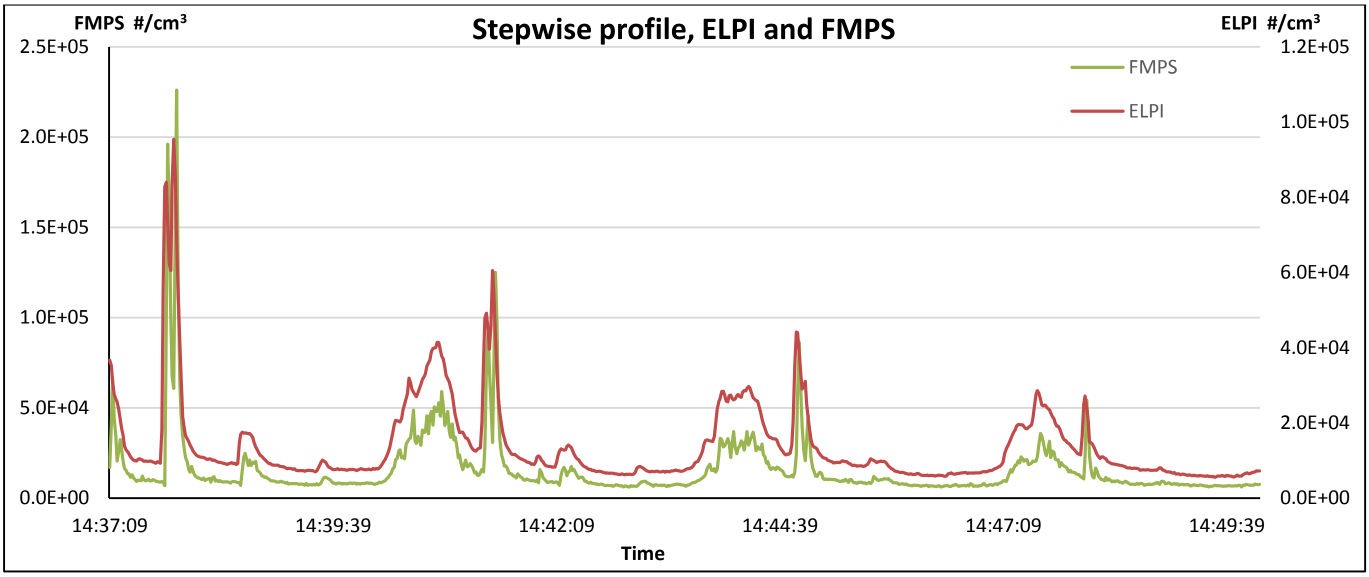


Figure 8: number of particles per cm^3 measured by the ELPI and the FMPS on all their particle size for stepwise profile.

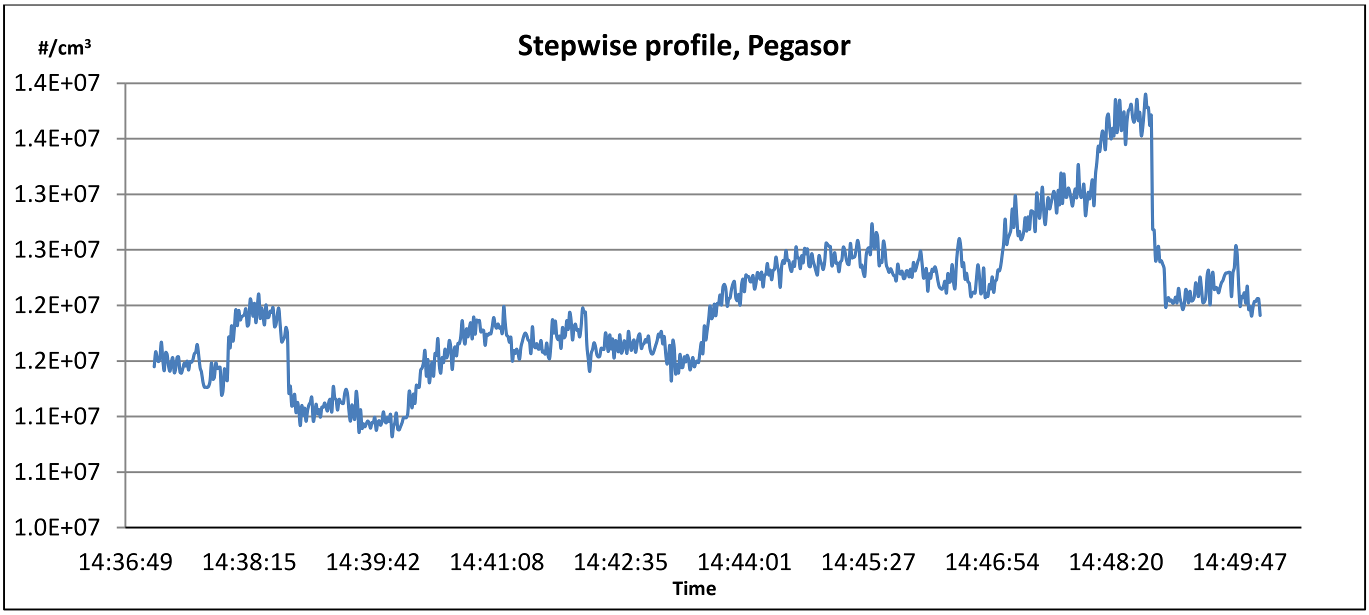
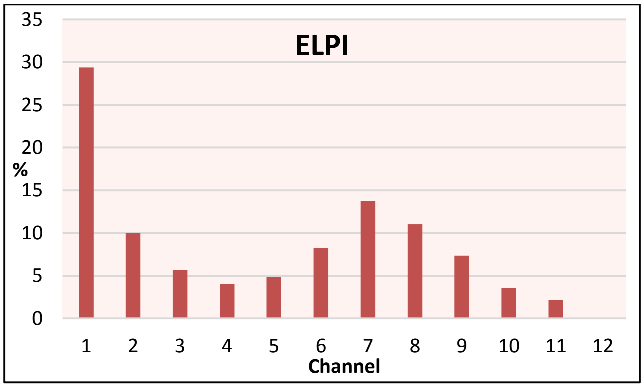


Figure 9: number of particles per cm^3 measured by the Pegasor throughout its size range for stepwise profile.

Now here is the concentration for the different channels of sizes of the FMPS and the ELPI.



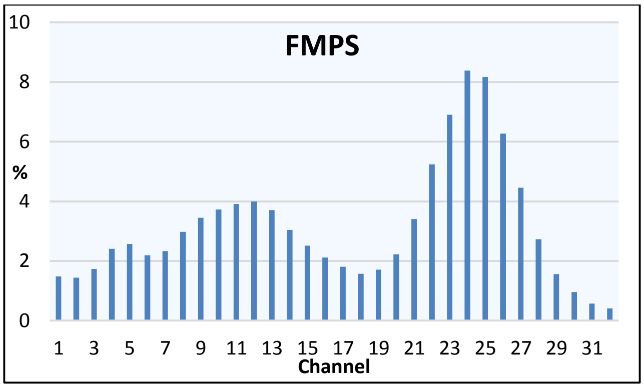


Figure 10: total concentration on a cycle for the different channels of the ELPI and FMPS. The concentration is expressed in % of total concentration over the entire size range.

4. Analysis of results and conclusions

It is observed that the three appliances used have analyzed a number of different particles, a few hundred particles for the ELPI, in the case of urban profile, to a few million for the Pegasor, for both profiles. These differences can be partly explained by the difference in size of particles analyzed by the appliances, yet this assumption seems not sufficient to explain such differences. The graphs of ELPI and FMPS show peaks of concentrations that can be connected to the braking profile, although in the case of the urban profile, it will be difficult to associate with a peak to a braking. It is easier to try to make this in the case of stepwise braking profile, due to a more intensive and spaced in time braking. We can also notice that for a same braking, in terms of duration and level (50 km/h in 5 seconds), does not lead in same concentrations. Measurements by the Pegasor are much more difficult to understand and require further tests to be performed.

The concentrations for the different channels (size range) provide us with some additional information. Thus, for the urban profile, the ELPI has mainly analyzed ultrafine particles smaller than 132nm (41% of total measured) and greater than 1273nm particles (58% of total measured). The distribution is more homogeneous in the case of FMPS, but all these channels are in the range of ultrafine particles. To the stepwise braking profile, the ELPI has mainly measured ultrafine particles of the order of 22nm. Measurements of the FMPS are always well balanced between these different channels, although a slight trend is emerging around channels 22 to 27 (from 124.1 to 254.8).

Currently, we are not able to explain the differences in measurements between different analyzers, but we still have experimentations to be performed and some data to be processed.

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