PERFORMANCE AND DURABILITY OF THE PSA PEUGEOT CITROËN'S DPF SYSTEM ON A TAXI FLEET IN THE PARIS AREA [*]

Patrick COROLLER & Gabriel PLASSAT

French Agency fort he Environment & Energy Management (ADEME)
Air & Transport Division

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ABSTRACT

The use of Diesel engines has strongly increased during the last years and now represents 40% of the sales in Europe and up to 50% of the number of cars in circulation fro some countries. This success is linked not only to the economical aspect of the use of such vehicles, but also to the recent technological improvements of these engines. The new technical solutions (high pressure direct injection, turbocharger…) have indeed allowed the increase of these engine performances while decreasing their fuel consumption, pollutant emissions and noise level.

From an environment point of view, Diesel engines are nevertheless penalized by their particulates and NOx emissions. The study and the treatment of the particulate, highly criticized for their potential impact on health, are the subject of numerous works of characterizations and developments.

PSA Peugeot Citroën has recently (2000) launched its particulate filter technology on several types of vehicles (500 000 vehicles with DPF have been sold today). In order to evaluate the durability of this technology over a long period of time, a study program has been set-up by ADEME (French Environmental Agency), IFP Powertrain, PSA Peugeot Citroën and Taxis G7 (a Parisian taxis Company).

The objective is to study the evolution of five taxis and their after-treatment system performances over 80000km mileage - which corresponds to the recommended mileage before the first DPF maintenance - in hard urban driving conditions, as well over 120000km, after the DPF maintenance and remanufacturing.

More specifically, the following evaluations are being performed at regular intervals (around 20 000km): regulated gaseous pollutant emissions on NEDC cycle, particulate emissions and unregulated pollutant emissions.

The results obtained until now have not shown any degradation of the particulate filter efficiency (more than 90%). This paper presents the methodology set-up, and the explanation of the first results obtained. Indeed, a more specific study has shown that most of the aerosols, measured with SMPS are composed of liquid fractions, mainly sulphates due to the sulphur coming from the fuel but also from the lubricant. The impact of sulphates stored on the catalyst surface during low temperature running phases and removed during high temperature running phases has been also outlined.

INTRODUCTION

The use of Diesel engines has strongly increased for private vehicles during the last years. They now represent half of the sales and nearly 40% of the number of private cars in circulation in France. This success is linked not only to the economical aspect of the use of such engines but also to their technological improvements in the last few years. The new technological solutions (high pressure direct injection, variable geometry turbocharger) have indeed allowed the increase of these engine performances while decreasing their intrinsic fuel consumption, pollutant emissions and noise level.

From an environmental point of view, Diesel engines are however penalised by their particulate emissions. These solid compounds, that are visible during exhaust and highly criticised for their potential impact on health, are the object of many characterisation studies and numerous system implementations allowing their elimination.

In May 2000, PSA Peugeot Citroën launched its Peugeot 607 HDi equipped with Diesel particulate filters System (**figure n°1**) **[1]**.

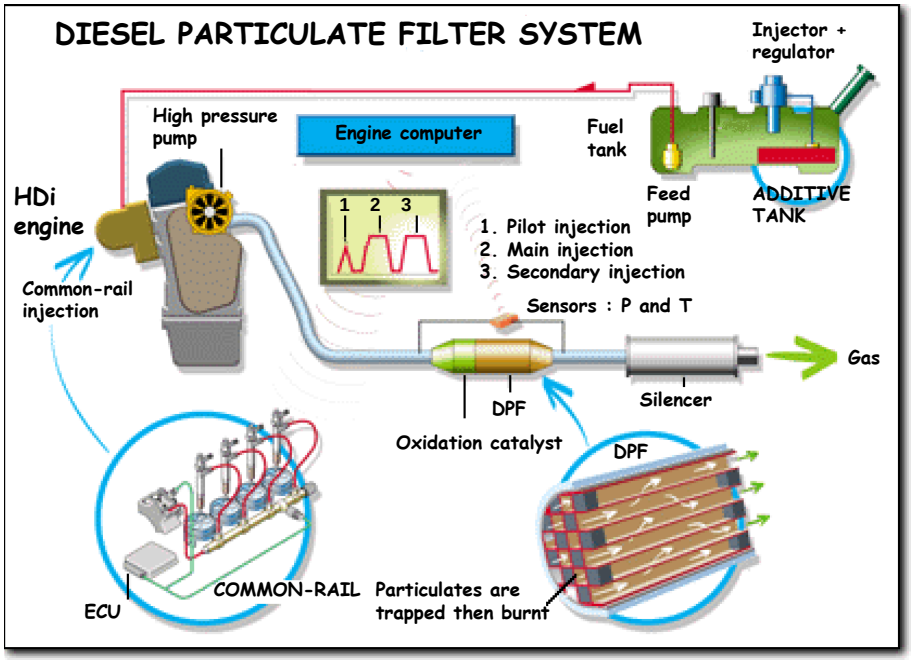

Figure 1: The PSA Peugeot Citroën's DPF System

This new after-treatment technology has been recently adapted to several types of vehicles within its range (visit the site www.psa.fr for a complete description of the system). Given that this device presents a major environmental interest, the Paris taxi company G7 decided to purchase and to test six 607 vehicles equipped with particulate filters. An agreement on the follow-up of the performances was signed between the ADEME, G7 taxis fleet, Peugeot Parc Alliance and the French Institute of Petroleum (IFP).

TEST PROGRAM

In order to constitute a technical and economical database and to valorise the results, a follow-up campaign was run over a minimum period of 14 months in order to evaluate fuel consumption and to analyse the regulated and non-regulated pollutant emissions (**figure n°2**).

The aim of the study was to follow during this period the evolution of the vehicles performances in urban taxi use conditions. The program is focussing on:

- the follow-up of a taxi fleet composed of 5 Peugeot 607 equipped with particulate filters that were put into service and normally assigned within the G7 taxi fleet. A sixth 607 with DPF was also used for replacement.
- the evaluation of regulated and non-regulated pollutant emissions on the MVEG cycle. The evaluation of all five vehicles during the whole follow-up was divided into four stages. Detailed analysis of the size and composition of particles were also run (follow-up of instantaneous emission of 3 different given sizes of particles).
- an analysis of the vehicles lubricants and a composition study of the ashes trapped in the particulate filter when cleaned (after approximately 80,000 kilometres) were made.

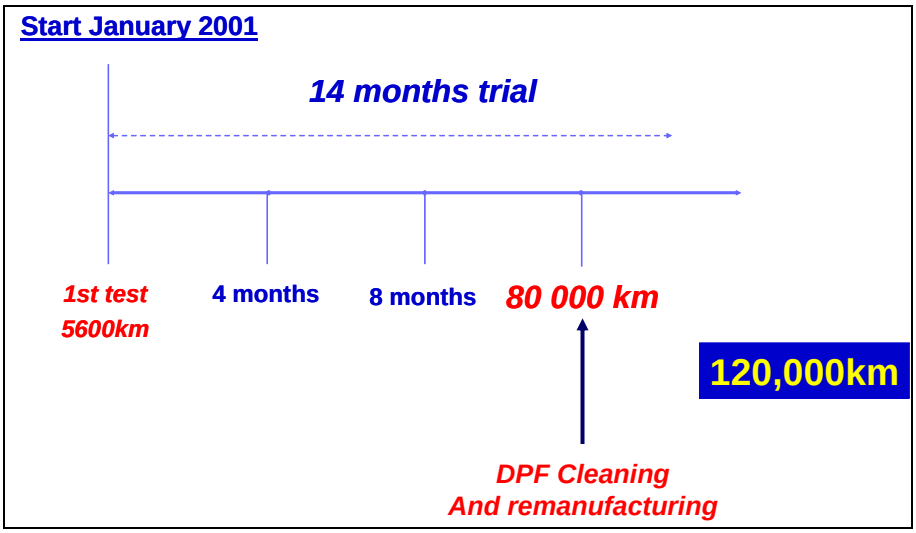

Figure 2: The Evaluation methodology over 120,000km

Preliminary results (*first and second phases*) were already presented in October 2002 at the SAE Powertrain & Fluid Systems Conference **[2]**.

The present situation in mileage taxis fleet is summarized on the **Table 1**, where average fleet mileage is also reported.

This report shows the results of this follow-up evaluations and durability over the 80,000km, as well as several elements in order to evaluate the environmental impact of this solution for taxi use.

- the measurements of pollutant emissions over MVEG cycle made at the IFP at different stages.
- the follow-up results corresponding to the final 80,000 km average period.

TAXI	phase1	phase2	phase3	phase4
N°2089	7500 km	26900 km	73400 km	91200 km
N°5039	4500 km	12700 km	30560 km	80000 km
N°2041	2100 km	9900 km	-	78204 km
N°7016	7700 km	23200 km	-	76959 km
N°7083	8100 km	17300 km	-	-
Average	***5970 km***	***18000 km***	***51980 km***	***81591km***

Table 1: Present mileage situation with average fleet mileage

EVALUATIONS OVER THE MVEG CYCLE

The mean values of regulated pollutant emissions are shown on the tables and diagrams below at the 1st stage (average of 6,000km) and after 80,000 km field operation in Paris area. All values are given in g/km for polluting emissions (**figures n°3, 4, 5 and 6**).

The EURO 3 standard limits are reported in comparison, without ageing factor. In the case of PM, the future EURO 4 PM standard is also reported.

The results below are the averages of two or three measurements (if the results of the first two are dispersed).

- during test stages, a very similar behaviour appeared on three vehicles (2041, 2089, 5039). On a same vehicle, the variations in polluting emissions between two consecutive test cycles are below 10% for CO, 30% for HC and 5% for NOx. These results are very good in regard with the low mean levels (below regulations). For particulate, given the low levels measured downstream of the particulate filter, the variations can not be considered as significant.

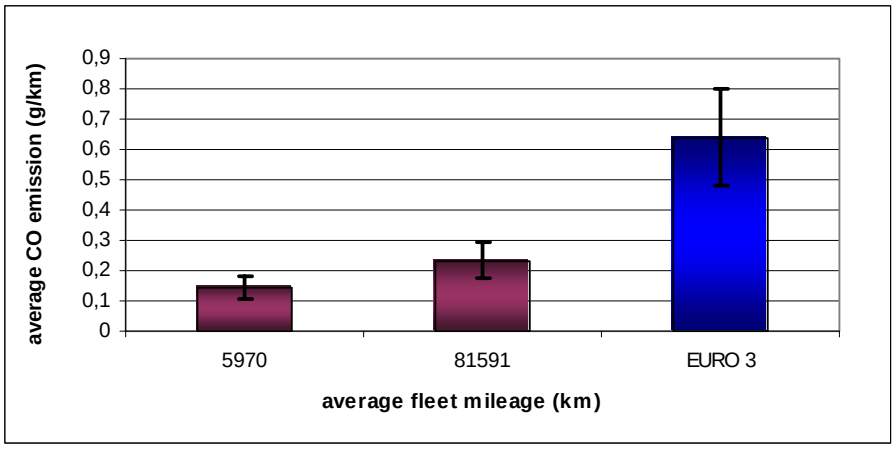

Figure 3: Efficiency and durability on CO exhaust emission control

- the overall very low emissions of un-burnt CO and HC are mainly produced during the first phase of the MVEG cycle (i.e. from cold). The total CO emission is produced during the first three minutes of the cycle as well as 50% of HC (the total circuit lasts 20 minutes).

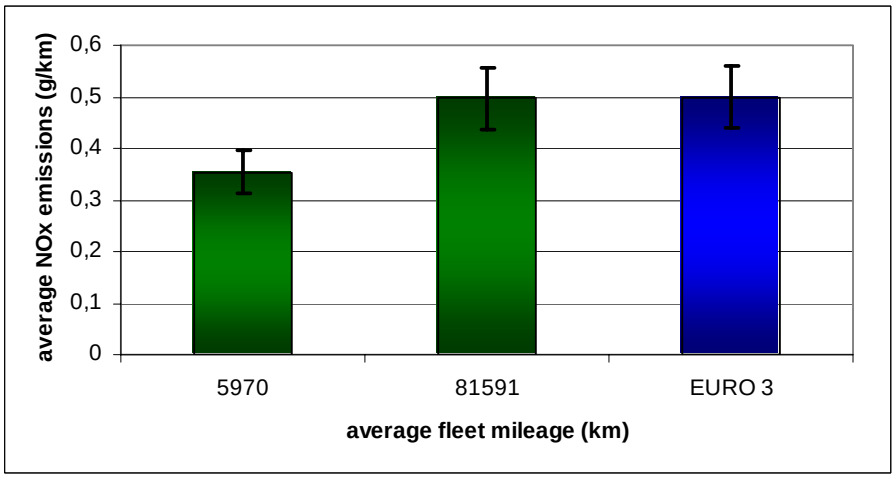

Figure 4: Efficiency and durability on NOx exhaust emission control

- NOx emissions are relatively close to the regulatory level. A slight drift can be recorded over 80,000km (approximately 15%).

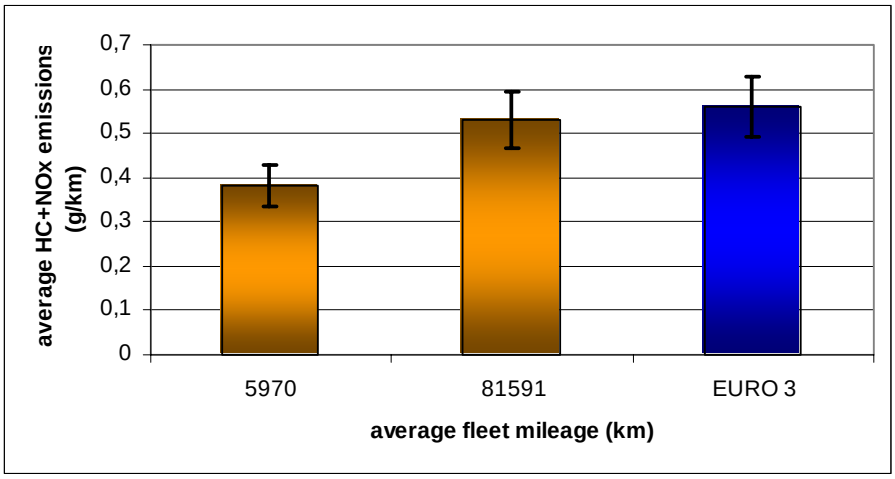

Figure 5: Efficiency and durability on HC+NOx exhaust emission control

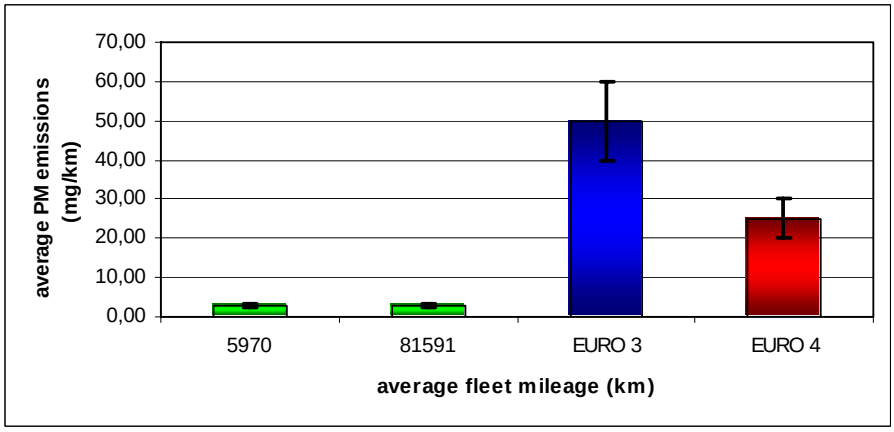

Figure 6: Efficiency and durability on PM exhaust emission control

- Particulate emissions are very low; their precise measurement required the implementation of a specific cleaning method for the sampling organs in order to reduce parasite emissions. In that case, the PM level is far below the next future EURO 4 PM standard (25mg/km).
- All the vehicles remain under the EURO 3 durability requirement, even after 80,000 km.

DIESEL FUEL CONSUMPTION

The follow-up focussed on Diesel fuel consumption during the MVEG cycle, and during the real field operation in Paris area over the 80,000km operation (expressed in l/100km) (**figure n°7**).

- the mean Diesel fuel consumption is close to 9 litres in Paris area, with a scattering below 1 litre/100 km from one vehicle to another. No consumption drifts during that period.
- the mean Diesel fuel consumption is around 6,50 litres over the MVEG Cycle, without evolution over the 80,000km period of evaluation.
- even after 80,000km, over MVEG cyle, as well as through the real field operation in Paris area, the Diesel fuel consumption was not significantly affected by the ash accumulation phenomenon into the DPF.

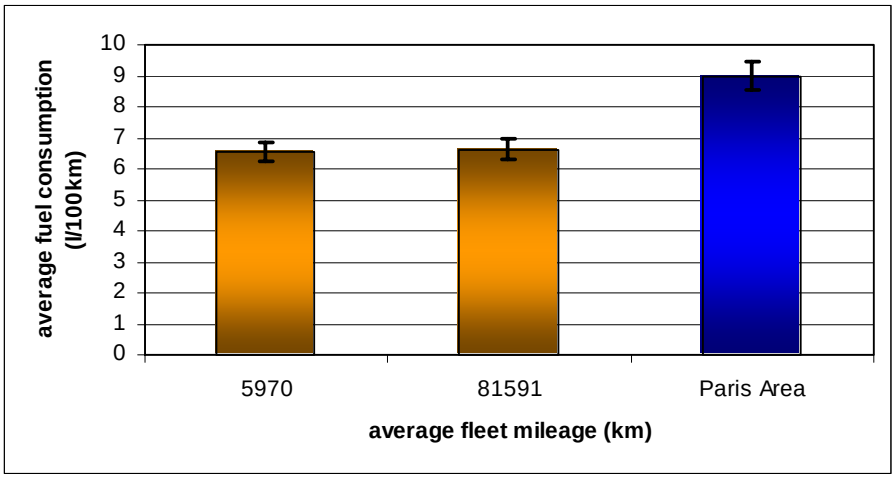

Figure 7: Average Diesel fuel consumption (MVEG Cycle, Paris area)

EMISSION DURING REGENERATION STAGES

Filter regeneration is obtained by soot burning. This phenomenon involves a modification of the engine setting. Emissions are therefore likely to be damaged. The diagram below shows the results obtained on a vehicle on a MVEG cycle (**figure n°8**).

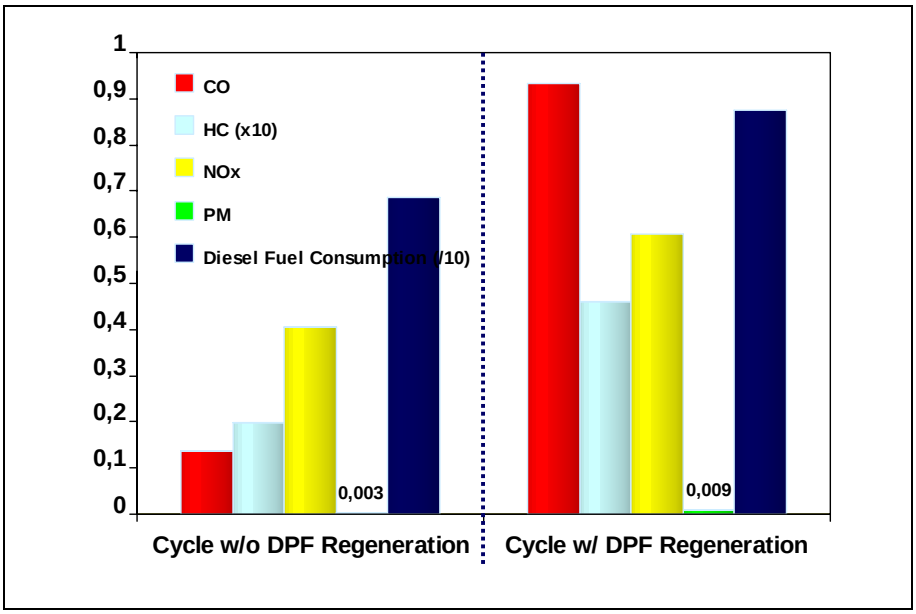

Figure 8: Emissions without and with DPF regeneration (over MVEG Cycle)

The regeneration phase is characterised by a significant increase of regulated pollutant emissions (CO, HC, NOx and PM) which can be explained:

- soot combustion inside the filtering media occurs downstream of the oxidation catalyst, HC and CO emissions caused by this combustion are not treated.
- the regeneration process notably involves a deferred additional fuel injection and different engine settings leading to an increase of NOx emissions.

Consumption is calculated from carbon results: therefore, the 25% increase shows a CO2, CO and HC over-emission due to:

- the regeneration strategy (actual over-consumption)

- the combustion of soot trapped in the DPF

The actual fuel penalty during the DPF regeneration is less than what was measured above. The share of burnt filtered carbon is estimated at 15% of the measured over-consumption (3% of CO2, CO and HC over-emissions). Therefore, actual over-consumption during regeneration comes to 22%. It must be outlined that the average regeneration lasts 6 minutes every 700 kilometres in usual running conditions. Therefore, the mean over-consumption is approximately 2%.

RESULTS CONCERNING NON-REGULATED POLLUTANTS

The tests concern:

- a detailed analysis of light hydrocarbons (from C1 to C12) as well as aldehydes and cetones on MVEG cycle.
- an analysis of sulphur and nitrate proportions contained in the particles on ECE and EUDC cycle (already presented in **[2]**).
- an analysis of the metals contained in the particles. Specific polycarbonate filters were used to run those tests to prevent cross-contaminations.

The results highlight the following points:

- Non regulated emissions from the two tested vehicles are very similar (**figure n°9**). The unit spreading of each kind is qualitatively similar to the one observed on recent Diesel vehicles: hydrocarbon emissions are mainly made of ethane (approximately 1/4 of total), ethylene (1/3 of total) and light hydrocarbons in C3 or C4. Concerning aldehydes emissions, formaldehyde (50%), acetaldehyde (25%) and acetone (12%) are predominant. Contrary to total HC emissions, these components are mainly rejected in start from cold conditions.

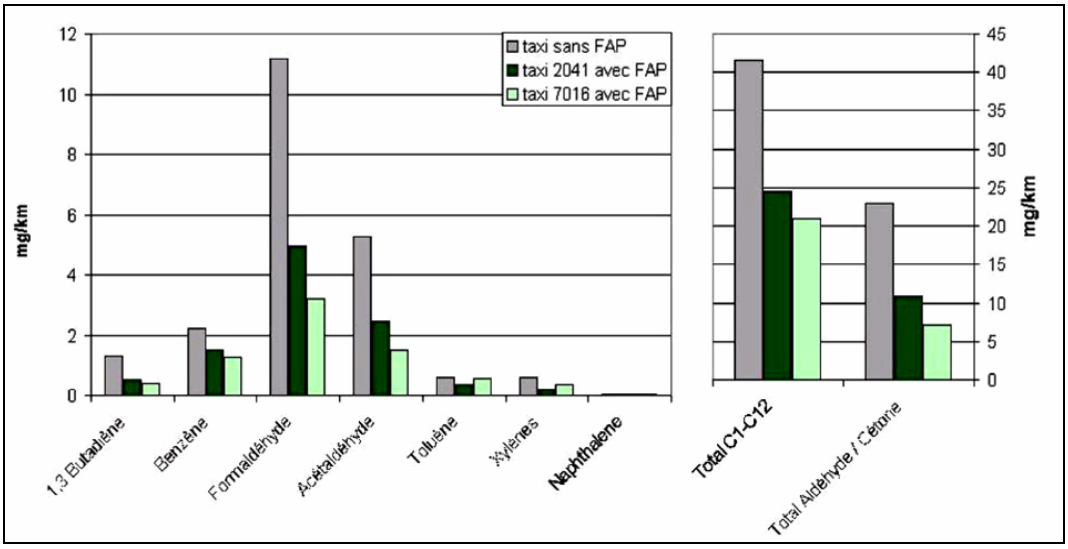

Figure 9: Non-regulated Gaseous Emissions (TAC) over the MVEG cycle

- Despite low quantities, the analysis of metals trapped on the filters also shows a very strong predominance of sulphur (from 2 to 7 nano-grams according to the vehicles). Other metal quantities (0.2 ng for potassium and calcium) as well as iron and nickel traces are very low. Very precise PIXE (Particle Induced X Ray Emission) measurements showed the absence of cerium in the exhaust stream. It must be outlined that these concentrations do not change significantly during a regeneration phase, with the exception of sulphur concentration which strongly increased (100 ng) (**figure n°10**).

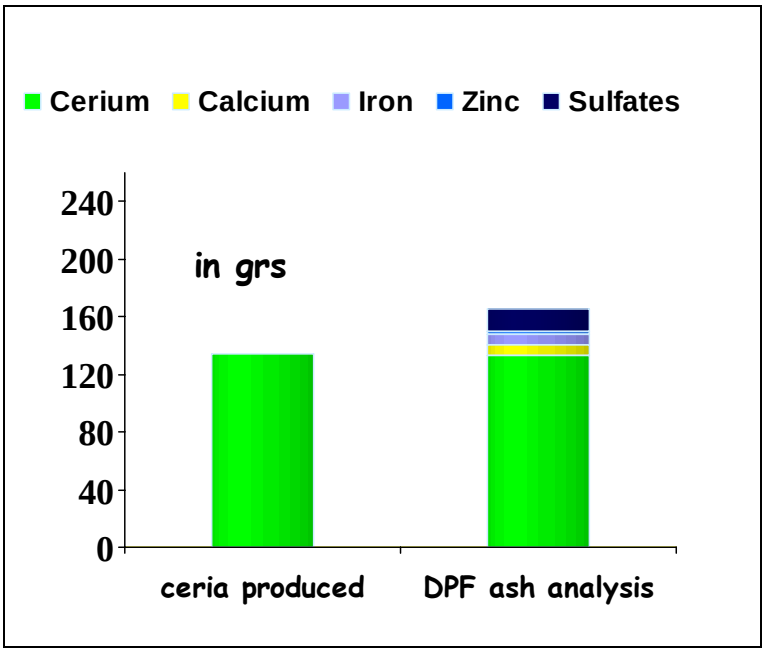

Figure 10: Solid particle emissions

Finally, in the case of Cerium, the DPF cleaning and remanufacturing maintenance confirm the good agreement between the consumed Cerium (based on the average Diesel fuel consumption and the dosing rate of 25ppm in Diesel fuel) and the mass of the Ceria found during the cleaning stage. Extra ash was found in the DPF, directly correlated to the lubricant ash production, as found in previous evaluations **[3]**.

CONCLUSIONS

For this study running over two years and testing five vehicles, some temporary conclusions can be formulated concerning the Peugeot 607 DPF performances in taxi use conditions:

- The particle measurements on MVEG cycles remain constant during the test at 80,000 km and far below the EURO 3 limit of 0.05 g/km.
- The particle granular measurement on MVEG cycle confirms this result, with quantities 10,000 times less than the values observed on a Diesel engine with no DPF and similar to the values of a petrol-powered engine. The size distribution is also close to the one of a petrol-powered engine. Given the emissions sulphur content, the decrease of the fuel sulphur content should allow a reduction of the particle quantity.
- There is no measurable cerium emission during exhaust.
- During the 80,000km period of evaluation under real field operation in Paris area, there was no particular problem or incident concerning the DPF System.

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