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Study

Evaluation of TEQOYA technology performance in a truck tractor cab
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Introduction

CERTAM has been asked by the Carcept - Prev Foundation to evaluate the depollution performances of TEQOYA devices in the cabs of truck tractors.

The purpose of the study is to quantify the performance of PM1 particulate aerosols, major contributors to cabin pollution and sources of discomfort and potentially of cardiorespiratory disorders.

The concentration of particulate matter as well as its nature is likely to evolve strongly over the course of a day's driving: passing through a tunnel, driving on busy roads, taking rests on motorway rest areas or along the road, can strongly influence the levels recorded over the course of a day and over the course of a working week, including periods of sleep in the cab.

CERTAM has built an evaluation based on a temporal follow-up of the concentration in number of combustion aerosols after pollution of the cabin, reproducing the diversity of the situations by passing from a polluted cabin at the exit of a tunnel, (seeding of the cabin), to that corresponding to the periods of sleep on a rest area, (asymptotic phase of the concentration). The use of the TEQOYA device to evaluate the natural decay vs. the assisted decay

To do this, the following means of measurement were used:

- Particle measurement using a Dekati ELPI+ granulometer, following a measurement protocol similar to the one used for the measurement of CADR in the United States and in China (protocol which will allow in particular the quantification of this index)

Means of testing and measuring

The **ELPI particle size analyzer** allows to measure the particle concentration of an aerosol by size class. The result obtained is the particle size distribution of the aerosol studied. The spectrum covered extends from 10 nm to 10 µm. The particle size is obtained by inertial classification by means of a cascade of impingers operating at low pressure. The particle concentration is calculated from the measurement of the electric charge carried by the particles.

This system uses the inertial and aerodynamic properties of the particles (Stokes diameter or aerodynamic diameter), contrary to the electrical mobility analyzers (SMPS and DMS type) which rely on their electrical and aerodynamic properties (electrical mobility diameter). To sort the particles according to their inertial properties, the ELPI uses a ramp of impactors mounted in cascade. There are 13 of them, which allows to obtain 13 size classes. The 13 impactors are all different. The first one is the widest, it collects only the biggest particles while the last one, much narrower, recovers particles of a few tens of nanometers. Figure 1 illustrates this principle. The foot of the ramp is maintained at a very low pressure (40 mbar), which makes it possible to increase the speed of the particles in order to impact the finest. A conventional impactor operating at atmospheric pressure does not generally allow the study of particles whose size is lower than a few hundred nanometers. The 13-impactor ramp is completed by a filtration stage allowing to reach the size of 10 nm (0.01 µm), i.e. 14 classes in total.

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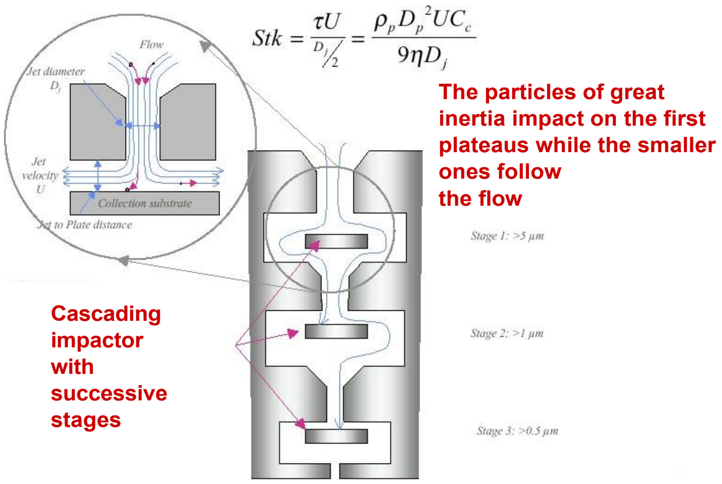

• figure 1 ELPI impactor *(after DEKATI)*

CERTAM proposes to build an evaluation on the basis of a combustion aerosol produced by a cigarette. This type of seeding has the advantage of being :

- Well controlled and sufficiently reproducible
- Representative in terms of size of the particles present in the air (pollutants related to the automobile, industrial emissions, domestic environments).
- Easy to implement

We aim to reproduce reasonable concentrations, with respect to human exposure, with target values of about 80 to 100,000 particles per cm^3 , which is about 10 times the average background level. Such values are commonly achieved in the passenger compartment of road vehicles,
especially in urban areas but can also be in professional or residential premises (cooking, smoking, presence of combustion sources ...).

This level of concentration is largely reached by the complete combustion of a cigarette in the tractor cab: the levels measured after total combustion of a cigarette were between 500 000 and 750 000 particles per cm^3 .

For your information, we can give the following benchmarks:

- Very clean air (in mid-altitude mountains, far from any anthropogenic source): <1000 p/cm^3
- Normal" air: indoor or outdoor: approx. 3,000 to 6,000 p/cm^3
- Polluted air: > 10.000 p/cm^3
- Urban air near traffic routes: 10,000 to 100,000 p/cm^3
- Road tunnel: 50.000 to 500.000 p/cm^3

Of course, these values are only "guide" values based on our experience. They may not be representative of some exceptional circumstances.

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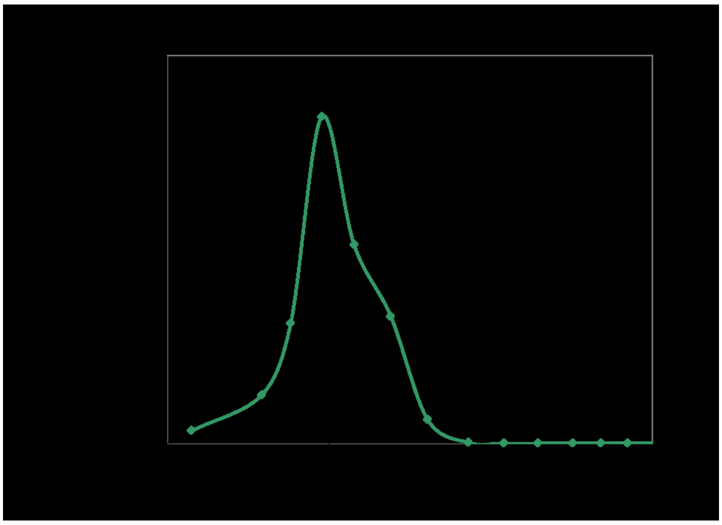
The aerosol number distribution is centered on 80 nm and ranges from a few tens of nm to 400 nm :



The vehicle tested in this study, a standard Renault Trucks tractor-trailer, is housed in the closed parking lot of CERTAM. The metrological devices were moved to the level of the tractor for the realization of the experiments.

The passenger compartment of the vehicle (2.3m x 1.9m x 1.9m or approximately 8.3m^3) is seeded with primary smoke from the combustion of a cigarette in such a way as to obtain a stabilized concentration at the level of the driver's head (~500,000#/cm^3 to 600,000#/cm^3).

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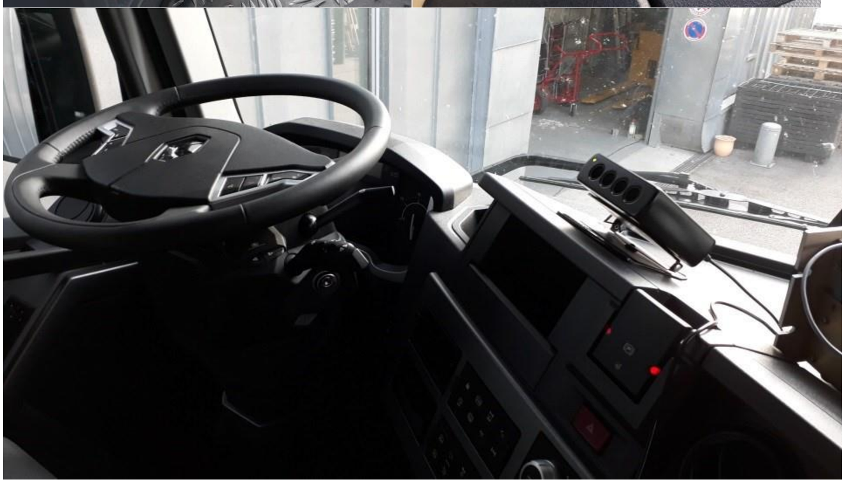

The monitoring of the particulate concentration in the cabin is monitored for these different experimental conditions using an ELPI+ granulometer (Dekati):

- Natural decay (ventilation = 0)
- Natural decay with an active ionizer in the cabin
- Recirculation mode ventilation (30% of maximum speed)
- Recirculation mode ventilation (30% of maximum speed) with an active ionizer in the cabin
- Recirculation mode ventilation (60% of maximum speed)
- Recirculation mode ventilation (60% of maximum speed) with an active ionizer in the cabin

Results

The results were analyzed using a methodology for determining half-life times of decays in particulate concentration. This analysis allows to determine

- the time needed to reach a target concentration in the cabin: decrease of 50%, 75%, 87.5%, 93.8%...
- the residual pollution level after a fixed time after cabin pollution (e.g. 5 minutes) allowing to build exposure scenarios.
- The CADR (Clean Air Delivery Rate), calculated from particle measurements over time (in our case, the CADR is calculated by estimating the volume of the cabin at 8.3 m^3)

CADR calculation:

$$CADR = V \times (k_e - k_n)$$

where V is the volume of the treated space, k_n is the exponential decay coefficient for the abatement natural, and k_e is the exponential decay coefficient for the tested configuration.

K is from the particle count measurements :

$$k = \frac{\sum_1^n t_i \times \ln(C_{ti}) - \frac{\sum_1^n t_i \times \sum_1^n \ln(C_{ti})}{n}}{\sum_1^n t_i^2 - \frac{(\sum_1^n t_i)^2}{n}}$$

where Cti is the number of particles at time ti for each measuring point i, from 1 to n.
With V expressed in m^3 the time expressed in hours, the CADR unit is m^3/h.

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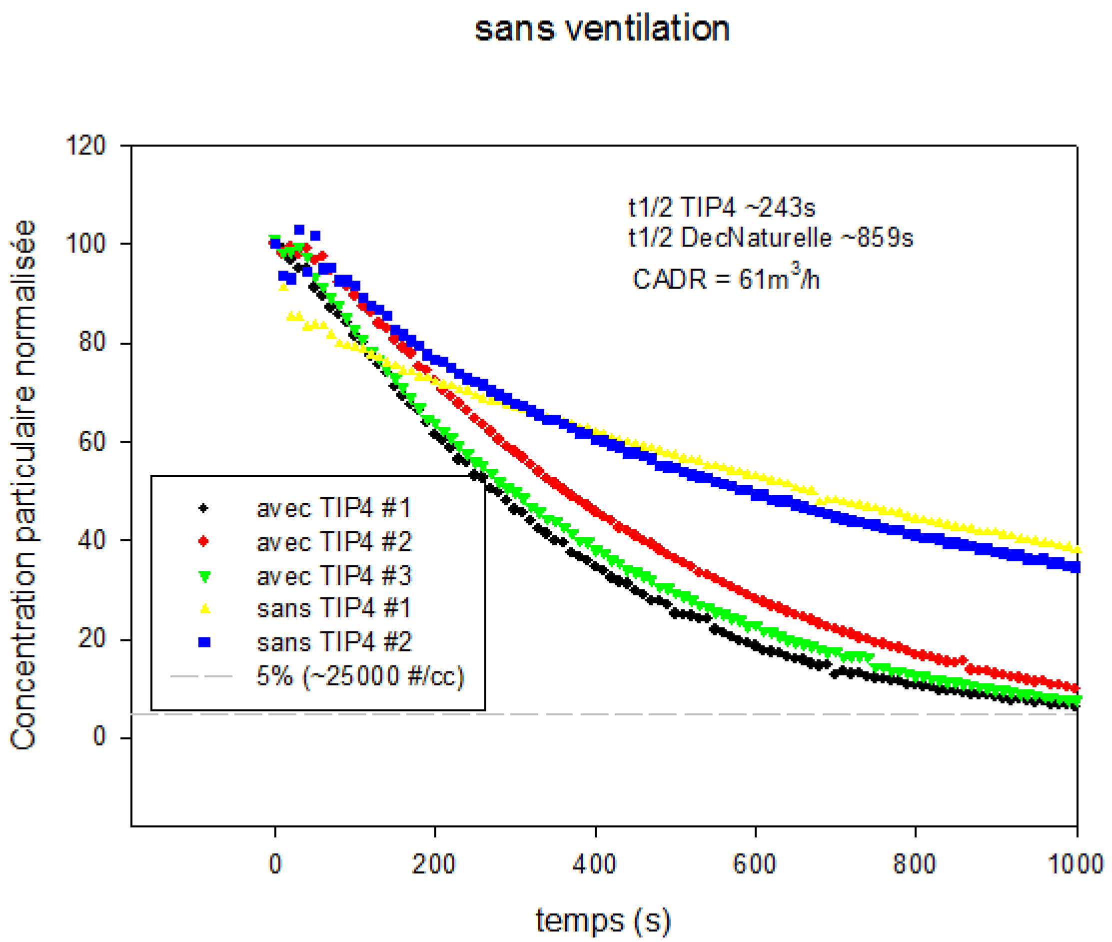
A. Without ventilation



The gain in terms of CADR (Clean Air Delivery Rate) brought by the TIP4 in this condition is 61m^3 /h or 7.35 cabin volumes per hour.

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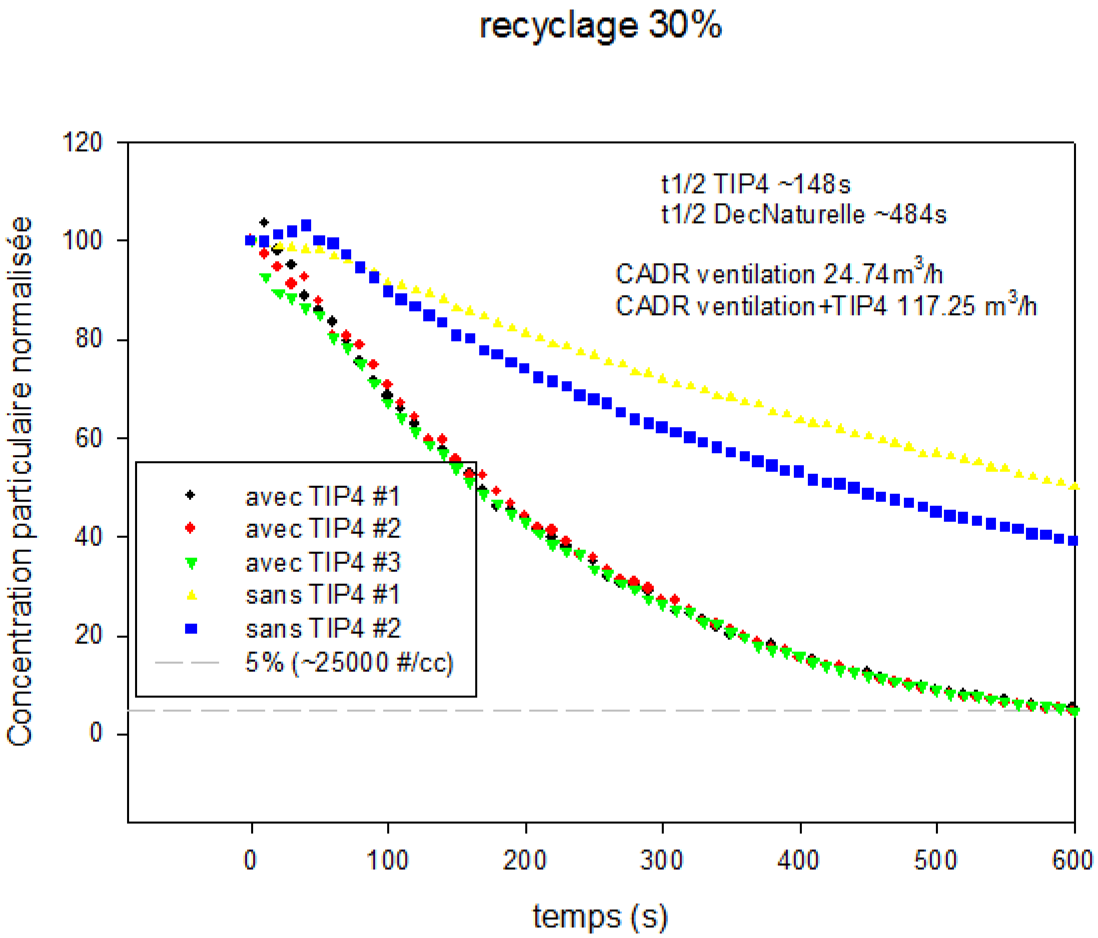
B. Ventilation recirculation mode 30%.



The gain in terms of CADR attributable to TIP4 is estimated at 93 m^3 /h or 11.2 cabin volumes per hour.

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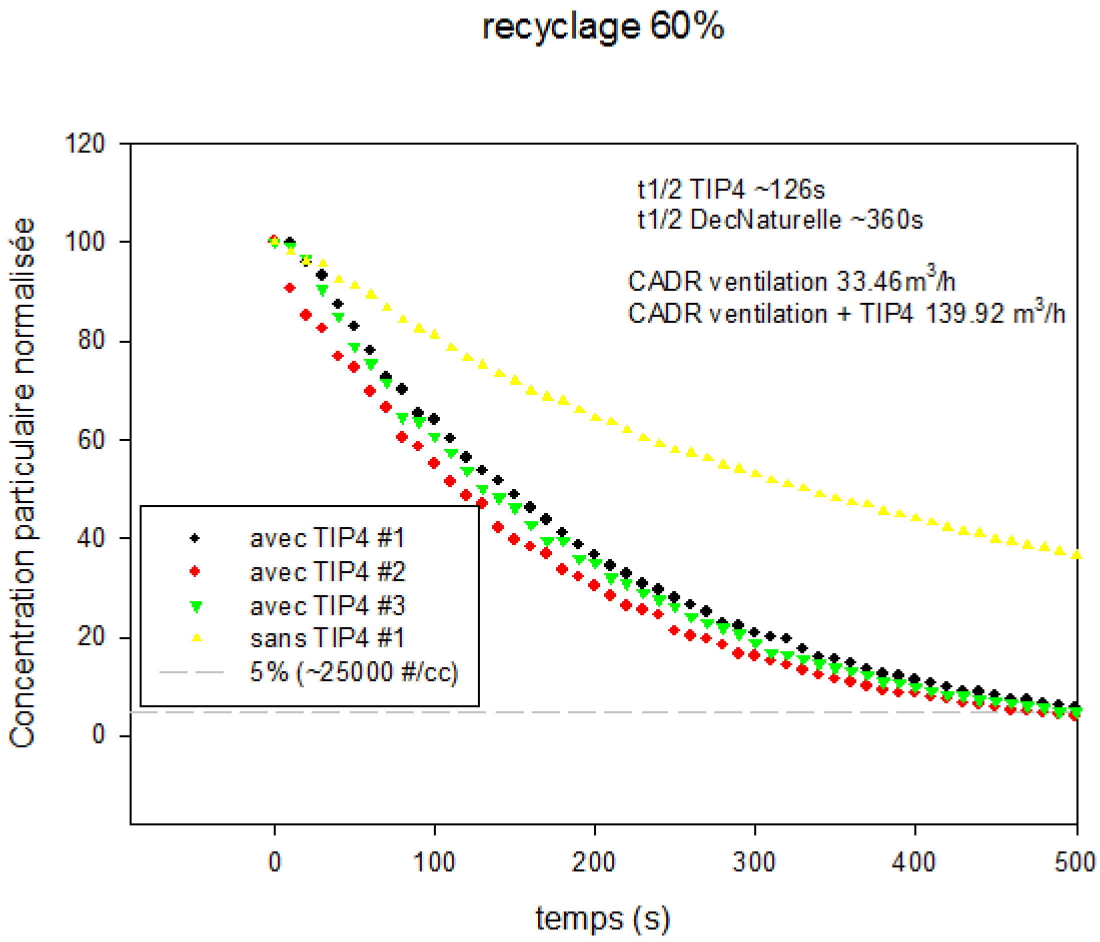
C. Ventilation recirculation mode 60%.



The gain in terms of CADR attributable to TIP4 is estimated at 106.5 m^3 /h or 12.8 cabin volumes per hour.

Conclusions

We analyze the results according to the following criteria:

- Cleanup time to achieve 90% reduction in particulate matter
- Pollution rate (number of particles) at t=300 seconds after ventilation and/or ionizer start-up
- CADR (*Clean Air Delivery Rate*) to be understood as a calculation of the purification power in *clean air flow* equivalent

Here are the comparative tables according to these 3 criteria:

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Time (in seconds) to reach 90% clearance

	No ventilation	Recycling 33%.	Recycling 66
Without ionizer	2780	1700	1300
With ionizer	895	490	400
gain	68%	71%	69%

Number of particles at t=300 seconds

	No ventilation	Recycling 33%.	Recycling 66
Without ionizer	335 250	334 750	264 500
With ionizer	255 950	135 500	92 166
gain	23.6%	59.5%	65%

CADR (in m^3 /h)

	No ventilation	Recycling 33%.	Recycling 66
Without ionizer		25	33
With ionizer	61	117	140

The results obtained from this experimentation allow to define the following aspects:

- In 5 minutes, the use of the TIP4 allows to divide the level of pollution in the cabin by a factor between 1.3 and 3 depending on the ventilation conditions considered.
- To reduce pollution by a factor of 10 with a TIP4, it is necessary to count between 400 and 900s, i.e. less than 15 minutes.

If we consider the exposure scenario in which a cabin is subjected to a particulate pollution of 500 000 particles/cm^3 (i.e. 1 cigarette consumed) and an air quality objective in terms of particulate concentration of 10 000 particles/cm3 (i.e. 2% of the initial concentration); the time of exposure to concentrations higher than this objective is between 10 and 25 minutes in the case of the use of a TIP4 and between 40 minutes and 1 hour and a half without the use of a TIP4

Moreover, it was found during these outdoor tests that the asymptotic particle concentration when using TIP4 was 3 times lower than the ambient particle concentration (2000 particles/cm^3 against 6000 particles/cm^3). This finding may be representative of the reduction of particulate pollution during the night breaks of the road driver, for which it may be beneficial to benefit from a better air quality in a polluted environment (proximity of road traffic :
>10,000 particles/cm^3).

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