Performance of a particulate filter for diesel engine for off-road applications operating with high sulfur content fuel

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Exposure to Diesel exhaust fumes and gases is considered the most frequent form of workplace exposure to a carcinogen in France. The International Agency for Research on Cancer (IARC) classifies these emissions as probably carcinogenic for humans (Group 2A). They are moreover recognised as responsible for transient irritations, inflammation and alterations of the pulmonary function.

Diesel emission generates chemically complex pollution containing gases (CO, NO_x, SO_2, HC, acidic compounds) and fine carbon particles, on which complex composition organic compounds are adsorbed. These particles form the main pollutant of Diesel fumes and, at present, their emission can only be sufficiently reduced by resorting to a Diesel Particulate Filter (DPF), despite the fact that not all technologies are effective in overcoming the specific problem of off-road diesel engines.

In particular, employees can be exposed to this pollution when working in confined spaces or when performing underground work. At present, mobile construction machinery emission is not fully controlled in France, although prevention regulations exist in a certain number of work situations. There are examples of countries that have made the fitting of particulate filters to construction machinery compulsory. In France, off-road diesel engines use fuel with a maximum sulphur content of 1000 ppm. It is well known that this chemical compound can cause serious malfunctions in the operation of certain types of filter, especially those based on CRT technology.

INRS (Institut National de Recherche et de Sécurité), in association with CRAMIF (Caisse Régionale d'Assurance Maladie d'Ile de France) [French regional health insurance fund], has conducted site tests on different filter types fitted to diesel engines to check their initial and long-term performance characteristics. The results presented here are based on an operation, conducted with the technical support of TTM (Technik Thermische Machinen), involving a filter actively regenerated by an electrical system (Mann Hummel SMF-AR) and an additive (Satacen-3), which was fitted to an Ammann-Yanmar Midi vio 57 hydraulic excavator. The filter was operating under difficult conditions because the machine used high sulphur content fuel (600 - 650 ppm of sulphur). Measurements were taken from all pollution emitted by the machine exhaust, i.e.

Gases: CO, NO/NO_2, SO_2, HC
Aerosols: elementary and organic carbon, non-volatile nanoparticles > 10 nm, H_2SO_4, HNO_3 acid volatile aerosol.

The study confirmed that an active regeneration particulate filter represents an efficient means of reducing Diesel engine soot emissions, even operating with high sulphur fuel. However, there remains the problem of other pollutants not collected by the filter and even generated by the process (secondary emissions): gases, in particular NO_2, the sulphuric acid aerosol, iron nanoparticles from the additive, even though the filter contributes greatly to overcoming this problem. Our measurements show that the filter has no impact on the emission gases, i.e. gas concentrations are the same upstream and downstream of the filter.
The potential impact of the acid aerosol on the health of exposed workers is more difficult to establish because of the volatility of sulphuric acid particles. This pollution could nevertheless affect persons working in a confined environment immediately next to the Diesel pollutant emission. Use of low sulphur content (< 20 ppm) fuel should curtail production of this acid aerosol, even though the relationship between sulphur content and sulphate emission has not been clearly established [Mayer A., 2008]. Moreover, this emission is of discontinuous nature, which may explain the observed variations. Filters using precious metals as soot oxidation catalysts are also likely to increase SO_2 to SO_3 oxidation.
Emission of metal nanoparticles, whose toxicity has been proven [Karlsson H.L., 2009], has been studied in detail by Mayer et al. (2010). This study confirms that resorting to a particulate filter is an efficient means of limiting metal nanoparticle emission into the atmosphere.
This active regeneration filtering process could and should henceforth be widely implemented in France on Diesel machines, especially those operating underground or in confined spaces.

References

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Résumé:

Diesel emission generates chemically complex pollution containing gases, vapours and fine carbon particles. Particle emission of off-road diesel engines can be sufficiently reduced by resorting to a Diesel Particulate Filter (DPF), despite the fact that not all technologies are effective in overcoming this specific problem.

INRS in association with CRAMIF, has conducted site tests on different filter types fitted to diesel engines to check their initial and long-term performance characteristics.

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Performance of a particle filter for off-road diesel engine operating with fuel with high sulfur content.

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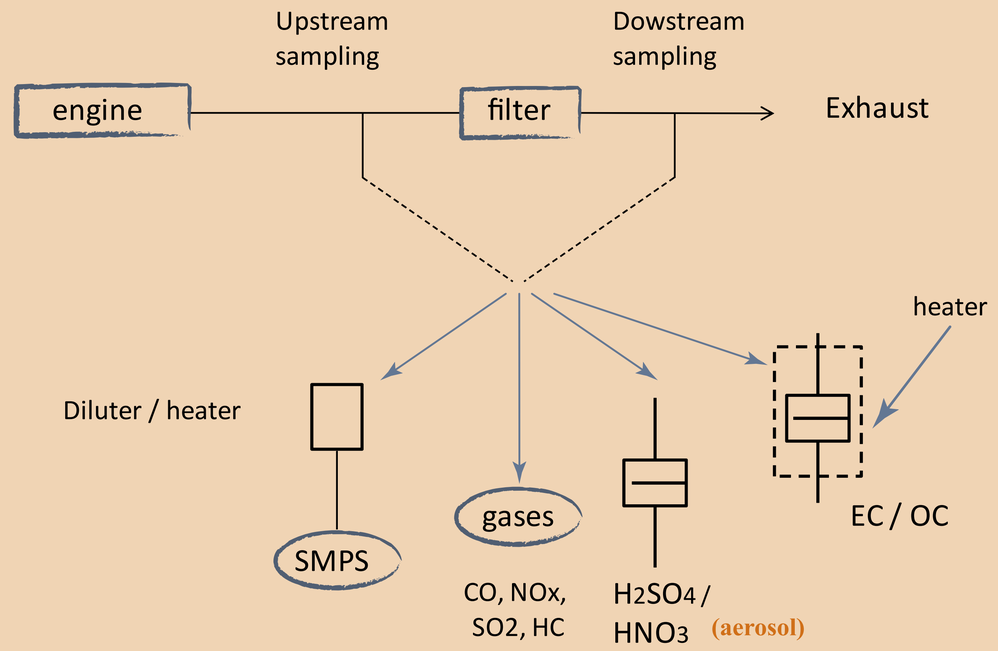
MATERIALS

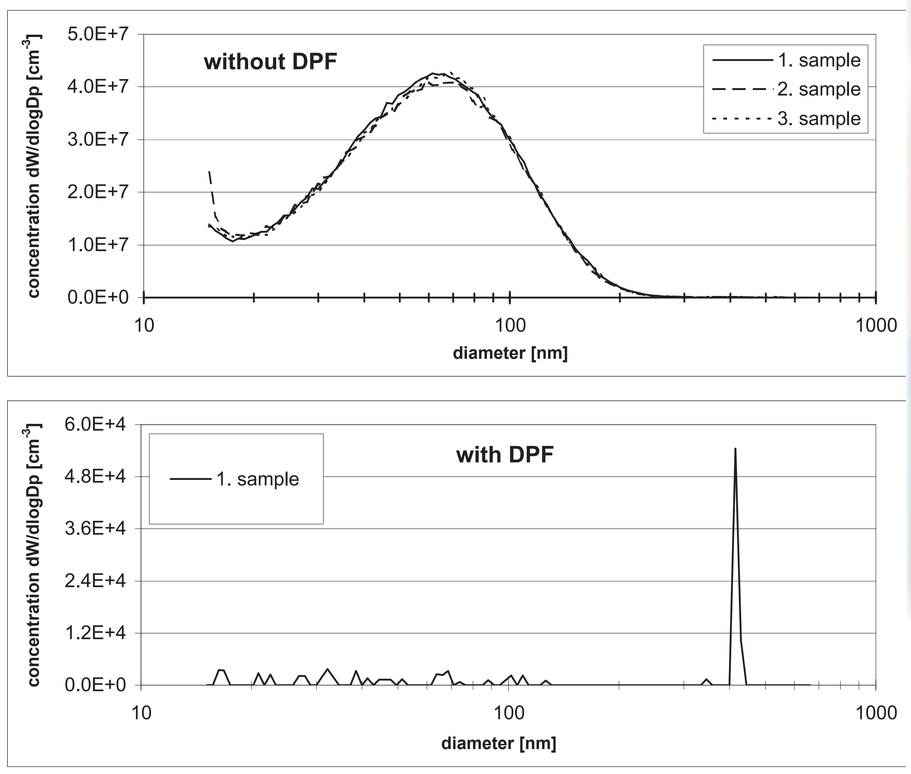
- ✓ Filter type : Mann+Hummel, HJS-SMF-AR 1.8, sinter metal
- ✓ Trap regeneration by electric heating
- ✓ Fuel additive (Satacen 3 - Iron) for self-ignition of the soot
- ✓ Engine : Ammann-Yanmar VIO 45 excavator
- ✓ Diesel fuel : 610 ppm sulphur content

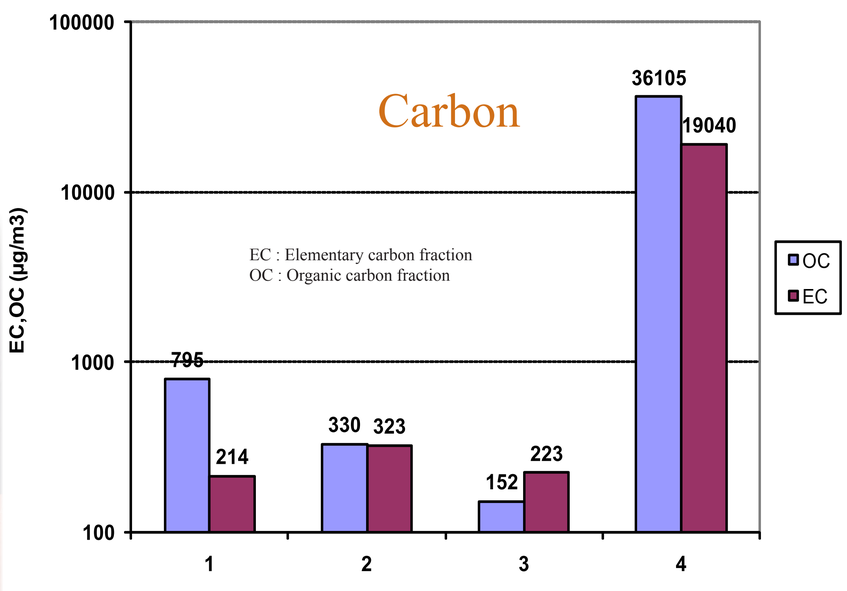
experimental set-up



RESULTS

particle concentrations





During generation