Real-world nanoparticle emissions of passenger cars and heavy duty diesel vehicles

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Vehicle exhaust has been frequently reported to contain nanoparticles which differ from soot particles by their chemical composition, physical characteristics and formation mechanisms. These nanoparticles are usually seen in exhaust particle size distribution as a separate mode, frequently called *nucleation mode*. Mixing, dilution and cooling of vehicle exhaust are in a critical role in nanoparticle emission formation i.e. the initial formation of the nanoparticles and the condensation of semivolatile exhaust compounds on the existing nanoparticles can take place during those processes. Typically the exhaust particle studies have been conducted in laboratory conditions, where the exhaust dilution does not equal exactly the real-world process, especially from the viewpoint of the nanoparticle formation. Due to that, the knowledge of real exhaust emissions and e.g. the human exposure on vehicle emissions require studies conducted on road and in real-world driving and exhaust dilution conditions.

The development of the nucleation mode and local dilution ratio within the vehicle exhaust was reviewed and the findings of studies comparing real-world and dynamometer measurements were analysed (Keskinen and Rönkkö, 2010). A series of on-road exhaust measurements were conducted, focusing on the exhaust nanoparticle emissions and the effects of vehicle technologies on those emissions. Measurements were conducted for passenger cars and heavy duty diesel trucks equipped with different exhaust after-treatment devices. Particle measurements were performed exploiting the "Sniffer" laboratory vehicle (Pirjola et al. 2004) equipped with two SMPSs, an ELPI, a CPC, a thermodenuder and gas analyzers for CO_2, CO and NO_x. In addition, the data related to driving parameters and weather conditions was collected.

Exhaust nanoparticle observations have been frequently connected to fuel and lubricant oil sulphur levels. On the other hand, the particle formation has been explained by nucleation of sulphuric acid and water during cooling dilution of exhaust in the atmosphere. However, nanoparticles seem to be an essential part of real particle emissions also when the fuel sulphur level is low, in our measurements below 10 ppm. The exhaust plume nanoparticles form at low dilution ratios ≤ 10 or even before the dilution process in high temperature conditions. Anyway, nanoparticle mode (or nucleation mode) seems to be fully developed at a dilution ratio of approximately 100. In regard to driving conditions, especially the transients of engine load were observed to be in important role in emission formation. In addition, exhaust after-treatment affect the nanoparticles; e.g. the use of a partial diesel particle filter, here the combination of a diesel oxidation catalyst (DOC) and a particle oxidation catalyst (POC), decreased significantly the real-world nanoparticle emissions of heavy duty diesel truck (Figure 1).

The effect of the DOC+POC on exhaust plume nanoparticles is a qualitative example of a correlation between real-world nanoparticle emissions and emission studies conducted in the laboratory conditions; e.g. Heikkilä et al. (2009) reported similar effects for a DOC+POC system. In addition, the review indicated that the trends in the vehicle exhaust nanoparticle formation, including those caused by differences in vehicle speed and engine load, engine and after-treatment technology and fuel and lubricant formulation can be mimicked in laboratory conditions. However, laboratory studies of vehicle exhaust nanoparticles require proper exhaust sampling and dilution methods and comparisons with real-world studies.

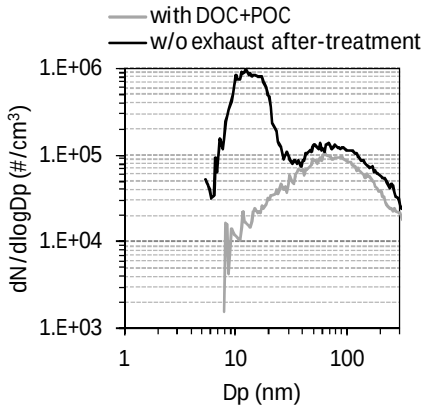

Figure 1. Real-world particle size distributions measured from exhaust plume of heavy duty diesel truck equipped with partial diesel particle filter and without exhaust after-treatment. Measurement was conducted at medium engine load conditions.

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