Real-time Characterization of Particle and Gas Emissions from Construction Equipment during Operation

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Introduction

The hazardous effect of combustion-generated particles is generally recognized and well documented in the scientific literature. In particular, exposure to nanoparticles is suspected to have a significant negative impact, since nanoparticles can penetrate deep into the lungs (alveoli).

For improving the air quality, it is necessary to reduce the number of nanoparticles as well as NO_x. For example, the health related EU exposure level for NO_2 (40 µg/m^3) has been exceeded several times in the vicinity of one of Copenhagen's major boulevards. Construction equipment is responsible for a significant part of the total particle and NO_x pollution in urban areas, partly because non-road machinery is not subject to the same regulatory emission standards (Stage standards) as road traffic (Euro standards). An important issue relating to construction equipment is also that the construction site workers are close to the emission source, and hence significantly exposed (Figure 1).

Figure 1: Typical exposure cases for construction site workers close to the machines

The goals of this work are to develop suitable and effective retrofit technology for selected construction machines as well as to develop a method for online emission characterization during realistic operating conditions. In this context, shown here is real-time emission data from three diesel-driven, medium-sized construction machines during realistic operating conditions. Machinery included is: One asphalt paver (without DPF) and two similar asphalt millers (with and without DPF).

Experimental

Measurements are carried out from a van driving right next to the machines on a test facility (Figure 2). Measurement probes are connected from the construction equipment exhaust to measurement equipment inside the van.

Particle size distribution (PSD) and number concentration (PNC) are measured in the size interval 10-420 nm in 13 size bins using a NanoScan SMPS (TSI) connected after a rotating disc diluter (Matter) heated to 150 °C and a catalytic stripper heated to 350 °C (Catalytic Instruments) for removing the semi-volatile particle fraction.

Gas emissions (CO, CO_2, THC, NO, NO_2 and NO_x) are measured using standard laboratory gas measurement equipment.

Figure 2: Experimental setup with measurement equipment inside the van driving next to the construction equipment of interest

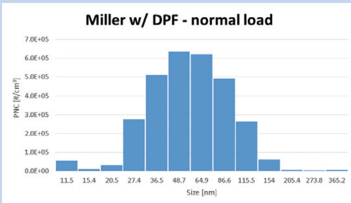
Results and conclusions

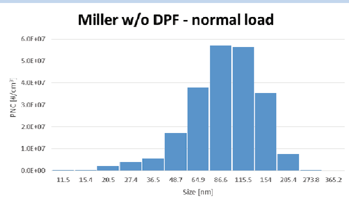
Average emission data from the three construction machines is shown in Table 1. Each number is an average of 2-3 measurement cycles, each with a duration of ~15 minutes, representative of normal use and typical engine loads for the three machines. Representative size distributions can be observed in Figure 3.

The measured nanoparticles are about 60-90 nm in average, and very few solid particles are observed near and below the PMP (Particle Measurement Program) cut at 23 nm. Note that the measured particle concentration for the miller w/ DPF is about a factor of 10 above the reference value that is being suggested by the Swiss Federal Office for the Environment FOEN (2.5x10^5 particles/cm^3), indicating damaged DPF.

Emission measurements	Miller w/ DPF	Paver w/o DPF	Miller w/o DPF
PNC, normal load [#/cm³]	**2.9E+06**	**9.9E+07**	**2.2E+08**
PNC, idle [#/cm³]	**3.0E+05**	**9.1E+07**	**8.1E+05**
Mean diameter, normal load [nm]	**61**	**73**	**90**
Mean diameter, idle [nm]	**86**	**68**	**77**
NO [ppm]	**200-250**	**300-400**	**700**
NO_2 [ppm]	**40-50**	**20-30**	**10-20**
NO_x [ppm]	**250-300**	**300-450**	**700**
CO [ppm]	**5-10**	**100**	**1,000-10,000**
CO_2 [%]	**8-9**	**8**	**8-11**

Table 1: Average particle and gas emissions, averaged over 2-3 cycles of realistic operating conditions. For gas emissions, steady-state values are given which is not practical for PNC due to the often fluctuating nature; hence, average values are stated for PNC (size interval ~23-420 nm)





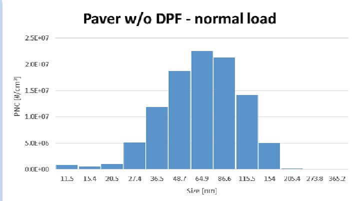


Figure 3: Average PSD for the three construction machines of interest, averaged over 2-3 measurement cycles of normal operating conditions and measured with NanoScan SMPS. PSD are shown in the full measuring range 10-420 nm.
Note the different scales on the y-axes

In conclusion, the measurement approach and setup with a van driving next to the construction equipment was successful and real-time emission data were acquired during real-life operating conditions.

This preliminary work is followed by development and implementation of DPF and SCR (Selective Catalytic Reduction) technology for the asphalt paver, and technologies with different catalytic coatings will be compared. The developed DPF+SCR solution by Purefi A/S during spring 2015 can be observed in Figure 4. The effect of these approaches will be documented and further optimized by similar on-site, real-time emission measurements. In addition NH_3 will be measured by using fourier transform infrared (FTIR) spectroscopy for measuring gas emissions.

Figure 4: The developed DPF+SCR solution for the asphalt paver.

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