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Non-combustion exhaust particles observed during decelerations of heavy duty diesel vehicles

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Background

Particle emissions from vehicles have been studied and regulated extensively during the last 20 years mainly due to the adverse health and environmental effects associated with combustion generated nanoparticles. Recent studies (Rönkkö et al., 2014; Karjalainen et al., 2014) have reported vehicle nanoparticle emissions also during engine braking when the simultaneous fuel consumption is zero. New road diesel engines are equipped with diesel particle filters (DPFs) in Europe and the US, whereas there are no particle filters in the majority of heavy-duty vehicles currently operating. With particle filters the particle emissions during engine braking are considered negligible whereas for the vehicles without the filters these emissions are reality. Here, two heady-duty diesel vehicles operating in Helsinki (Finland) area were studied in terms of particle emissions under engine braking conditions.

Experimental

Two vehicles (Table 1) were tested in the heavy-duty chassis dynamometer facilities of VTT. Test runs consisted of controlled 40-20 km/h and 80-20 km/h deceleration routines and standardized World Harmonized Vehicle Cycle (WHVC) test. The acceleration/deceleration routines were driven in order to study the phenomena related the particles during engine braking in detail. The WHVC test was driven to estimate the role of engine braking related particle emissions over a standardized driving routine.

Table 1. Studied heavy-duty vehicles. EL = emission level, EC = emission control, EGR = exhaust gas recirculation, DOC = diesel oxidation catalyst.

Vehicle	Year	EL	EC	Transmission
Bus	2005	Euro III	EGR	Automatic
Truck	2007	Euro IV	EGR+DOC	Manual

The particle sampling was executed with a system consisting of a porous tube diluter, ageing chamber and an ejector diluter. Exhaust particles were measured in real-time with condensation particle counters (CPCs), a high-resolution low pressure impactor (HR-LPI) and an engine exhaust particle sizer (EEPS).

Figure 1. Test facilities and equipment.

Results

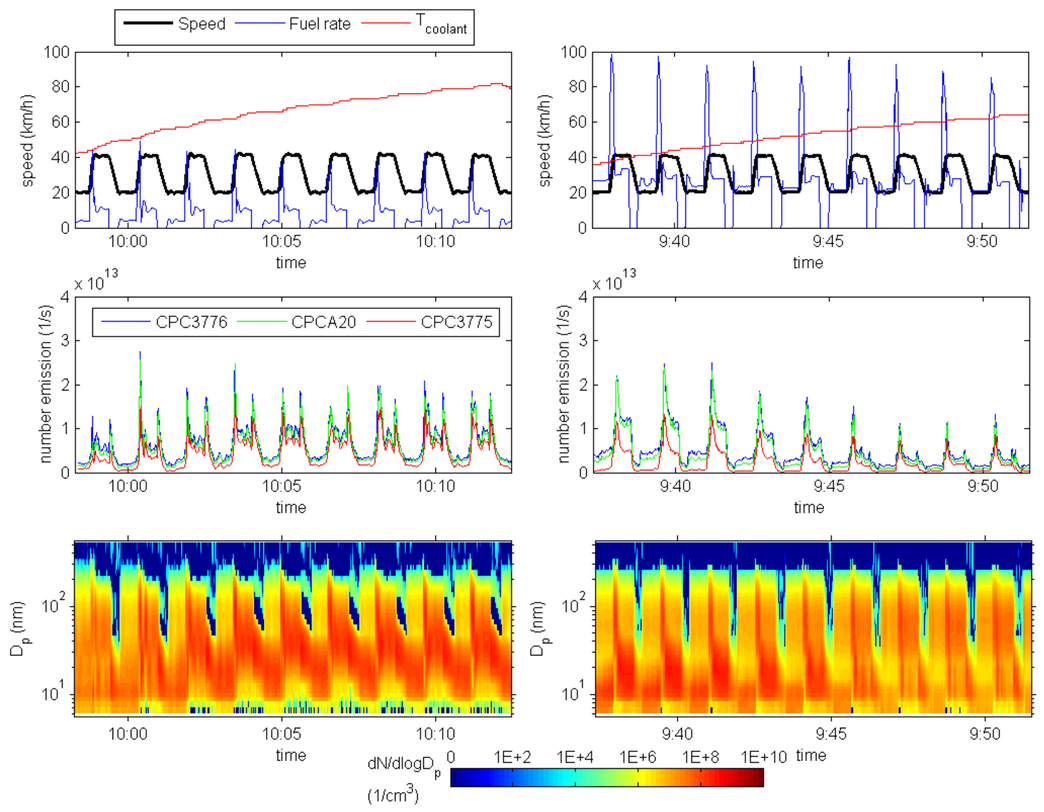

Figure 2. Particle emission profiles (concentrations (CPCs) and size distributions (EEPS) over the 40-20 km/h test cycle including a cold start: the truck (left panel) and the bus (right panel). Cut-sizes for CPCs were: 2.5 nm (CPC3776), 7 nm (CPCA20) and 23 nm (CPC3775).

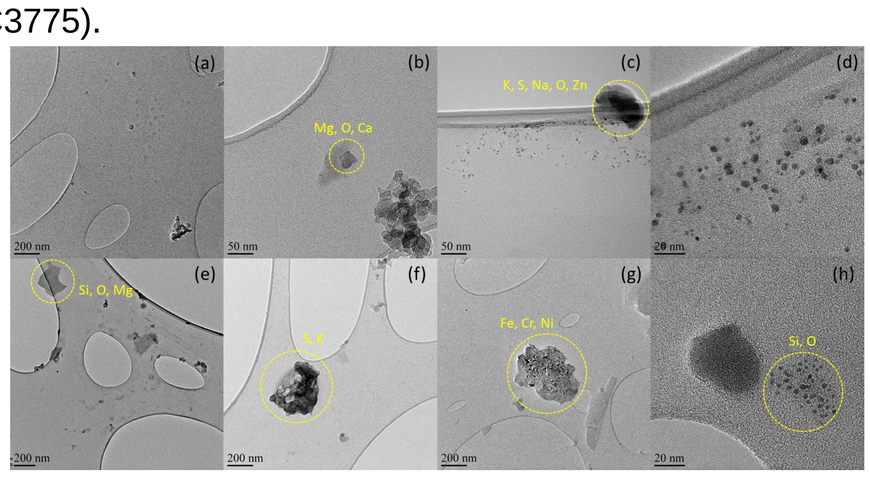

Figure 2. Transmission electron microscope images of typical particles observed during engine deceleration events. Main elements for each particle are designated in the figure.

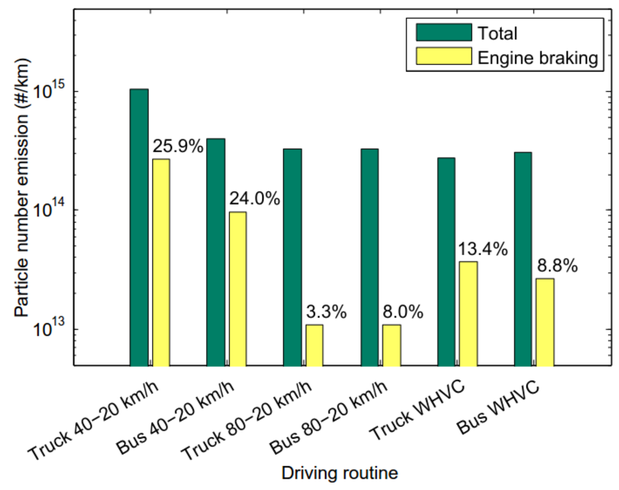

Figure 3. Particle number emission factors (CPC3776 data) for all particles and particles during engine braking. Engine braking related particle percentage is shown above the yellor bars.

Summary

- Particles emitted during engine braking form a significant fraction of total particle number emissions (here 3.3–25.9%)
- Engine braking particle emissions are systematic and experimentally repeatable
- Engine/exhaust temperatures affect the phenomenon; at high temperatures the emissions are higher
- Most of the particles are small (< 20 nm) but the size distribution is bi-modal (another peak at ~100 nm)
- Elemental analyzes indicate that particles contain same elements as found in lubricant oil

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References
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Rönkkö T. et al. (2014). Environmental Science & Technology, 48, 2043-2050.

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