SECONDARY AEROSOL EMISSIONS FROM DIESEL AND NATURAL GAS VEHICLES

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INTRODUCTION

Exhaust from combustion engine vehicles is a mixture of gas phase and particle phase pollutants. It is known that these pollutants cause negative health effects to humans as well as deteriorate air quality. One way to cut down on the pollutants is to use alternative fuels, for example compressed natural gas (CNG) which produces lower carbon dioxide and volatile organic compound (VOC) emissions compared to gasoline vehicles (Zongyan et al., 2023). Yet, it is less known how the emissions evolve in the atmosphere when the exhaust is diluted and exposed to sunlight. For example, VOCs that exit the tailpipe in gas phase, can oxidize and then condense to form particles (see e.g. Karjalainen et al., 2016; Hartikainen et al., 2023). These particles are called secondary organic aerosol particles. Fuel affects the VOC composition of the exhaust, which leads to different potentials to form secondary aerosol particles.

In this study, we analyzed secondary aerosol formation comparing a diesel and a CNG vehicle. Diluted exhaust was aged in an aging chamber and the secondary particle mass was measured after the chamber. VOCs were measured from the fresh exhaust with a proton-transfer-reaction mass spectrometer to see which organic molecules contribute most to secondary aerosol formation.

METHODS

Two cars, 2006 Toyota Rav4 (diesel, Euro 4, no DPF) and 2020 Skoda Octavia (compressed natural gas with gasoline as backup, Euro 6), were measured on a chassis dynamometer, which was in a temperature-controlled test cell. The used simulated real driving emissions (RDE) cycle was 72 min and 47 km long, and the test temperatures were -9, 23, and 35 ˚C. The exhaust was sampled from the tailpipe, diluted with a combination of a porous tube diluter (PTD), a residence time tube (RTT) and an ejector diluter (ED) to simulate dilution in the atmosphere. Fresh exhaust was characterized with multiple particle and trace gas instruments, for example a VOC mass spectrometer (PTR-ToF-CIMS, Aerodyne Research, US).

The diluted exhaust entered a Potential Aerosol Mass (PAM, Aerodyne Research, US) chamber, which uses ozone, added water vapor and UV lights to simulate aging of the aerosol in the atmosphere. With the used settings, the equivalent age of the aerosol was 2-4 days, estimated with carbon monoxide as a trace gas. In addition to PAM, we also had a high time-resolution chamber called Dekati Oxidation Flow Reactor

(DOFR, Dekati Ltd., Finland). The aged aerosol was diluted with an additional ED and the particle size distribution was measured with an Electrical Low-Pressure Impactor (ELPI+, Dekati Ltd., Finland).

RESULTS

Based on preliminary analysis, an influence from the fuel was observed on the secondary particle mass produced. Fig. 1 shows average secondary particle mass distributions for the two vehicles over the driving cycle as a function of particle size.

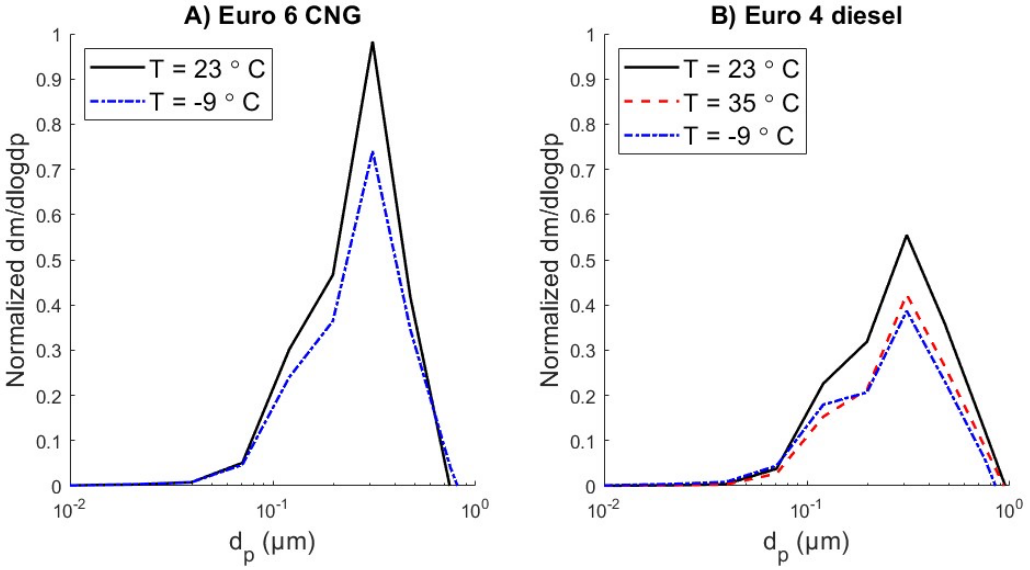

Figure 1. Particle mass size distributions of aged exhaust aerosol from a) Euro 6 CNG vehicle and b) Euro 4 diesel vehicle. Distributions are measured after PAM chamber and averaged over the driving cycle.

As seen from Fig. 1, the aged aerosol mass distributions are bimodal with modes at 100 and 300 nm. The Euro 6 CNG vehicle seems to produce more particle mass than the Euro 4 diesel.

CONCLUSIONS

Preliminary analysis showed that the Euro 6 CNG vehicle produced more aged particle mass than the Euro 4 diesel vehicle. The work continues with analysis of the VOC composition, which can explain the difference between the vehicles. However, the temperature of the test cell had only a small influence on the secondary particle mass emissions.

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