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Atmos. Chem. Phys., 8, 4729-4739, 2008
www.atmos-chem-phys.net/8/4729/2008/

Nanoparticle formation in the exhaust of vehicles running on ultra-low sulfur fuel

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Abstract. The concern of adverse health impacts from exposure to vehicle-emitted nanoparticles has been escalating over the past few years. In order to meet more stringent EPA emission standards for particle mass emissions, advanced exhaust after-treatment systems such as continuously regenerating diesel particle filters (CRDPFs) have to be employed on vehicles and fuel with ultra-low sulfur is to be used. Although CRDPFs were found to be effective in reducing particle mass emissions, they were revealed to increase the potential of volatile nanoparticle formation. Significant nanoparticle concentrations have also been detected for vehicles running on ultra-low sulfur fuel but without CRDPFs. The main focus of this paper is the formation and evolution of nanoparticles in an exhaust plume under ultra-low sulfur conditions. Such a study is necessary to project future nanoparticle emissions as fuel compositions and after-treatment systems change. We have carried out a comprehensive quantitative assessment of the effects of enhanced sulfur conversion efficiency, sulfur storage/release, and presence of non-volatile cores on nanoparticle formation using a detailed composition resolved aerosol microphysical model with a recently improved H_2SO_4-H_2O homogeneous nucleation (BHN) module. Two well-controlled case studies show good agreement between model predictions and measurements in terms of particle size distribution and temperature dependence of particle formation rate, which leads us to conclude that BHN is the main source of nanoparticles for vehicles equipped with CRDPFs. We found that the employment of CRDPFs may lead to the higher number concentration of nanoparticles (but smaller size) in the exhaust of vehicles running on ultra-low sulfur fuel compared to those emitted from vehicles running on high sulfur fuel. We have also shown that the sulfate storage and release effect can lead to significant enhancement in nanoparticle production under favorable conditions. For vehicles running on ultra-low sulfur fuel but without CRDPFs, the BHN is negligible; however, the condensation of low volatile organic compounds on nanometer-sized non-volatile cores may explain the observed nucleation mode particles.

Final Revised Paper (PDF, 844 KB) Discussion Paper (ACPD)

Citation: Du, H. and Yu, F.: Nanoparticle formation in the exhaust of vehicles running on ultra-low sulfur fuel, Atmos. Chem. Phys., 8, 4729-4739, 2008. Bibtex EndNote Reference Manager