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Can diesel particulate filter retrofits improve health?

Diesel emissions consist of soot particles surrounded by condensed organic compounds, and trace metals from lube oil and fuel additives. Elemental carbon (EC) is considered as the dominant species of diesel exhaust PM, often exceeding the concentrations of organic carbon (OC). Hopanes and steranes, along with higher EC content, distinguish diesel engine emissions from other carbonaceous combustion sources, such as gasoline vehicle, wood smoke, cooking, etc. The organic species, including polycyclic aromatic hydrocarbons (PAHs), hopanes, steranes and alkanes, and sulfate are associated with heavy volume of diesel trucks and they dominate the composition of the ultrafine size range (Dp<180 nm). Exposure to diesel exhaust particles (DEPs) has been associated with adverse health effects. The particle phase PAHs and metallic constituents trigger oxidative stress in murine macrophage and transform human bronchial epithelial cell lines with redox activity. DEPs are classified as toxic air contaminants by the governments around the world. The new Emission Standards (US 2007 for PM and US 2010 for NO_x) augured well for the development of after-treatment devices for in-use heavy-duty diesel vehicles (HDDVs), e.g. diesel particulate filter (DPF) and Selective Catalytic Reduction (SCR) retrofits to reduce the PM and NO_x emissions, respectively. However,the after-treatment retrofit devices significantly reduce the mass emission rates, but not necessarily the number of particulate having similar potency.

Several PM control technologies for diesel vehicles employ catalysts, either in the form of a diesel oxidation catalyst (DOC) in combination with a diesel particulate filter (DPF) or by adding a catalytic wash coat to the filter itself, or some combination of both. The catalysts will oxidize total hydrocarbons and carbon monoxide. Nitrogen oxide (NO) in the exhaust will also be oxidized by the catalyst to form NO_2, which will then combust the PM captured on the DPF to regenerate the filter. PM mass emissions from DPF-equipped diesel vehicles can be significantly reduced (>90%) especially for the accumulation mode soot particles. However, along with the reduction of PM mass emissions, the after-treatment devices may increase the number of particulates of smaller size and also alter the chemical PM composition by changing particle formation pathways. The catalyst will likely oxidize SO_2 to SO_3, which may lead to the formation of nucleation mode sulfate particles. The effective removal of soot particles will reduce the overall PM surface that is available for the condensation of semi-volatile compounds in the exhaust, thereby promoting the formation of nano-particles by means of nucleation of these species.

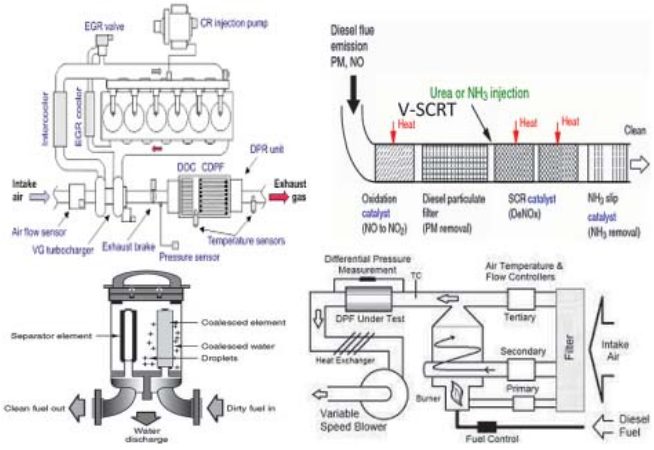

Fig. Cross-sections of various diesel filters and their modes of action

In a study with six emission control technologies (CRT®, V-SCRT®, Z-SCRT®, Horizon, DPX and CCRT®) ,while comparing with a baseline vehicle, significant reduction (>90%) in mass, EC, OC and Water soluble OC emissions is achieved for vehicles with retrofits. The vehicles with significant nucleation (CRT®, V-SCRT®, Z-SCRT® and DPX) mode particles produced considerable amount of sulfates especially during steady state operations. On the contrary, the non-nucleating configurations (Horizon, CCRT and Z-SCRT-UDDS) were associated with higher amount of total carbon in the form of OC. The noticeable presence of ammonium in nucleation modes suggests ternary nucleation as a possible mechanism for particle formation. In general, the transient cycles were associated with higher EC and OC. Soluble fraction of OC was highest for Horizon followed by SCRTs, DPX and baseline.

Reference and further reading: S. Biswas,et al. “Chemical speciation of PM emissions from heavy-duty diesel vehicles equipped with diesel particulate filter (DPF) and selective catalytic reduction (SCR) retrofits”, Atmospheric Environment, April 2009.