Institute of Hydrochemistry

Evaluation of Volatile Particle Remover Devices for Exhaust Particle Quantification

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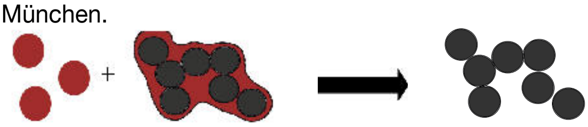
Motivation

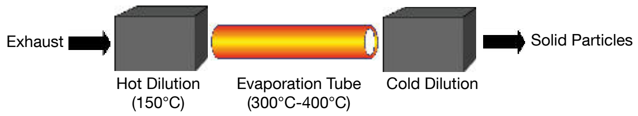
- Diesel exhaust is an important source of harmful particles with diameters below 100 nm.[1]
- In 2011, a new legislation was introduced in the EU to limit the emission of fine diesel particles on the basis of the particle number (N_p).[2]
- Before determination of N_p with a condensation particle counter (CPC_{23nm}, 50 % counting efficiency for 23 nm particles), volatile particles have to be removed from the exhaust gas with a volatile particle remover (VPR).
- Evaporation tube (ET) and catalytic stripper (CS) are two possible VPR types with different functional principles.
- Investigate influence of VPR functional principle on volatile particle removal efficiency with devices constructed at TU-München.



a) Volatile Particles (red), b) Soot agglomerate covered with volatile compounds, c) Agglomerate after treatment in VPR.

VPR Set-Up

Evaporation Tube: Application of thermal treatment and subsequent dilution to separate volatile exhaust components from the particle phase.



Set-up of VPR with evaporation tube.

Catalytic Stripper: Application of catalytic oxidation (diesel oxidation catalyst) and chemical binding (sulfur trap) to remove volatile particle forming components from exhaust gas.

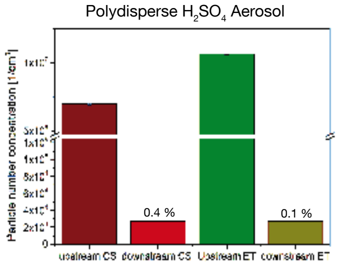
Diesel oxidation catalyst: $HC + x\,O_2 \longrightarrow y\,CO_2 + z\,H_2O$

Sulfur trap: $x\,H_2SO_4 + y\,BaO \longrightarrow y\,BaSO_4 + x\,H_2O$

VPR Removal Efficiency

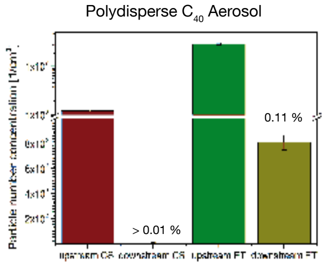
- Application of polydisperse sulfuric acid and tetracontane (C_{40}) aerosols in mass concentrations higher than in real exhaust gas (< 200 µg/m³).[3,4]
- Comparison of ET (green) and CS (red) efficiency in removing volatile particles.

Polydisperse H_2SO_4 Aerosol



Count median diameter: 40 nm
Mass concentration: > 0.8 mg/m³
VPR = 350°C

Polydisperse C_{40} Aerosol



Count median diameter: 70 nm
Mass concentrations: > 0.4 mg/m³
VPR = 350°C

Reduction of particle number concentration to less than 1 % with ET and CS possible!

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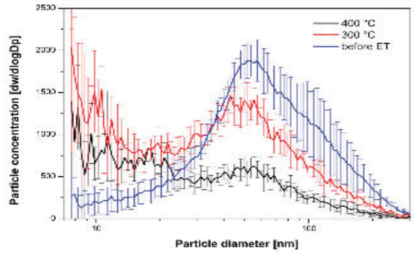
Dilution Ratio Reduction

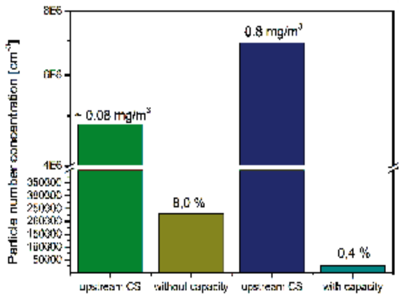


Particle size distribution of diesel exhaust particles before and after treatment in ET.

Insufficient dilution in ET leads to formation of nucleation mode (NM) particles (D_P < 23 nm).

Reduction of Sulfur Storage Capacity

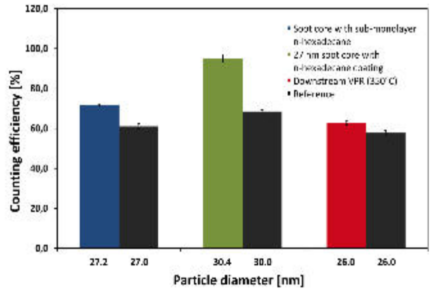
Comparison of CS devices with and without sulfur storage capacity applying polydisperse H_2SO_4 aerosol.



Missing storage capacity leads to reduced removal efficiency and formation of NM particles (D_P < 23 nm) is possible.

Particle Composition

Ratio of detected nucleation mode particles (D_P < 23 nm) depends on CPC_{23nm} counting efficiency (CE) and consequently also on particle chemical surface composition.[5]



CPC_{23nm} counting efficiency for soot particles coated with a defined n-hexadecane layer.

Average CE for NM particles (10 nm > D_P < 23 nm): 49 % (sulfuric acid) and 29 % (soot).[5]

Summary

- Successful removal of C_{40} and H_2SO_4 aerosol particles (more than 99 %) in concentrations higher than in real exhaust!
- Reduction of dilution ratio (ET) and storage capacity (CS) may lead to formation of nucleation mode particles (D_P < 23 nm).
- Chemical composition of nucleation mode particles is the crucial factor considering the ratio of NM particles detected with a CPC_{23nm}!

[1] J. Rissler, E. Swietlicki, A. Bengtsson, C. Boman, J. Pagels, T. Sandström, A. Blomberg, J. Löndhal (2012) *J. Aerosol Sci.*, 48, 18- 33.
[2] Commission Regulation (EU) No. 566/2011.
[3] J. Swanson, D. Kittelson, B. Giechaskiel, A. Bergmann (2013) *SAE Technical Paper* 2013-01-1570.
[4] F. Arnold, L. Pirjola, T. Rönkkö, U. Reichl, H. Schlager, T. Lähde, J. Heikkilä, J. Keskinen (2012) *Environ. Sci. Technol.*, 46, 11227-11234.
[5] B. Kiwull, J. Wolf, R. Niessner (2015) *Aerosol Sci. Technol.*, 49, 98-108.

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