Physicochemical Assessment of Biodiesel Vehicle Fuel Exhaust Emissions and the Effect of New Emission Control Devices: The EMITTED Study

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Study Overview

Background

The **E**xhaust **M**easurement and **I**nhalation **T**oxicology **T**esting for **E**merging **D**iesel Fuels (**EMITTED**) Study exists to address the effects of advancements in diesel technology on the **toxicologically relevant** characteristics of exhaust.

Specifically, the EMITTED Study will answer the following questions:
(1) How does diesel fuel type (petroleum, biodiesel) affect the physicochemical characteristics of the exhaust?
(2) How do emission control technologies, such as oxidation catalysts (DOCs) and filters (DPFs) affect the physicochemical characteristics of the exhaust?

Research Objectives

(1) Develop a comprehensive measurement program (shown below) to characterize engine emissions considering regulated pollutants and **unregulated pollutants**.

(2) Quantify the effects of **emission control technologies** (DOCs, DPFs) on engine emissions when combusting alternative diesel fuels (biodiesels).

Diesel Fuel Type:

- Ultra-low sulphur diesel (ULSD)
- 20% Animal fat biodiesel (AF-B20)
- 20% Soybean biodiesel (S-B20)

Test Engine:

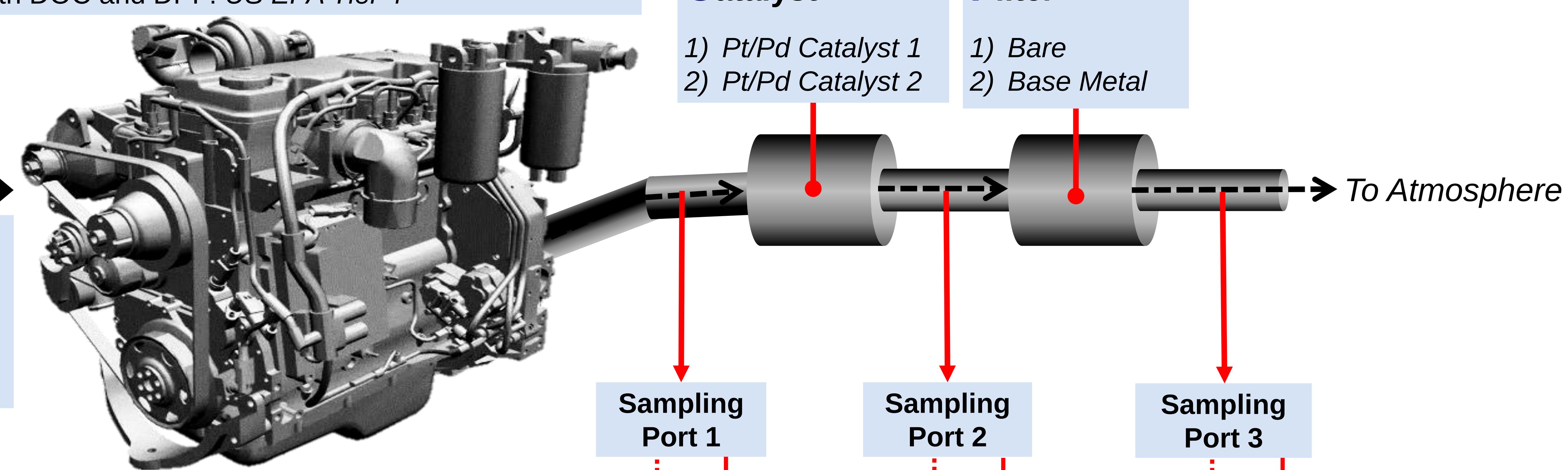
1997 Cummins B3.9 Off-road Engine
Engine Out Emissions: *US EPA Tier 1*
With DOC and DPF: *US EPA Tier 4*

Diesel Oxidation Catalyst

1) Pt/Pd Catalyst 1
2) Pt/Pd Catalyst 2

Diesel Particulate Filter

1) Bare
2) Base Metal



ISO8178 Engine Operation:

- Mode 2: 2500 rpm, 254 N-m *(75% Max. Torque)*
- Mode 9: 1400 rpm, 106 N-m *(25% Max. Torque)*

Pre-treatment:

- **Volatile phase removal** : Dekati Thermodenuder (*left*). Volatile compounds are removed through vaporization in an aerosol heater (up to 300°C) and adsorption in active charcoal.
- **Engine exhaust dilution**: TSI Rotating Disk Thermodiluter (*right*). Dilution ratios ranging from 80-120

Online Particulate Phase Characterization:

- **Quantitative particle mass loading and chemical composition:** Aerosol Chemical Speciation Monitor, Aerodyne (*top left*)
- **Black carbon mass concentrations**: Aethalometer, Magee Scientific (*bottom left*)
- **Particle number, mass and surface area concentrations:** Engine Exhaust Particle Sizer (EEPS) and Fast Mobility Particle Sizer (FMPS), TSI (*right*).

Offline Particulate Phase Characterization:

Filter Analyses
Particulate Loading: Gravimetric measurement, Sartorius SE-2F microbalance
EC/OC: Quartz filter sample collection, Sunset EC/OC analyzer
Cations/Anions: Water extraction, Ion Chromatography
Trace Metals: Particle sample acid digestion, ICP-AES
PAH, oxy-PAH, nitro-PAH: Solvent sample extraction; GC-MS

- **Filter collection:** Exhaust Filter Holder System (Thermo Electron Corporation).
- **Two filter holders**: one for a primary and secondary quartz filter (Pall Tissuequartz) and another for a Teflon filter (Pall Teflo).

Online Gas Phase Characterization:

- **Unregulated gas compound measurement:** FTIR measuring NO, NO_2, N_2O, naphthalene, aldehydes, carbonyls, SO_2, and SO_3, MKS (*left*)
- **Regulated gas compound measurement:** Emissions Bench measuring NO_x, THC, CO, CAI (*right*)

Particle Sizer Equivalency Study

The Engine Exhaust Particle Sizer (EEPS) and Fast Mobility Particle Sizer (FMPS) are used to measure particle number, mass and surface area concentrations upstream and downstream of the DPF, respectively. An equivalency study using diluted ISO8178 Mode 9 exhaust was used to determine size bin specific correction factors for the EEPS (Figure 1).

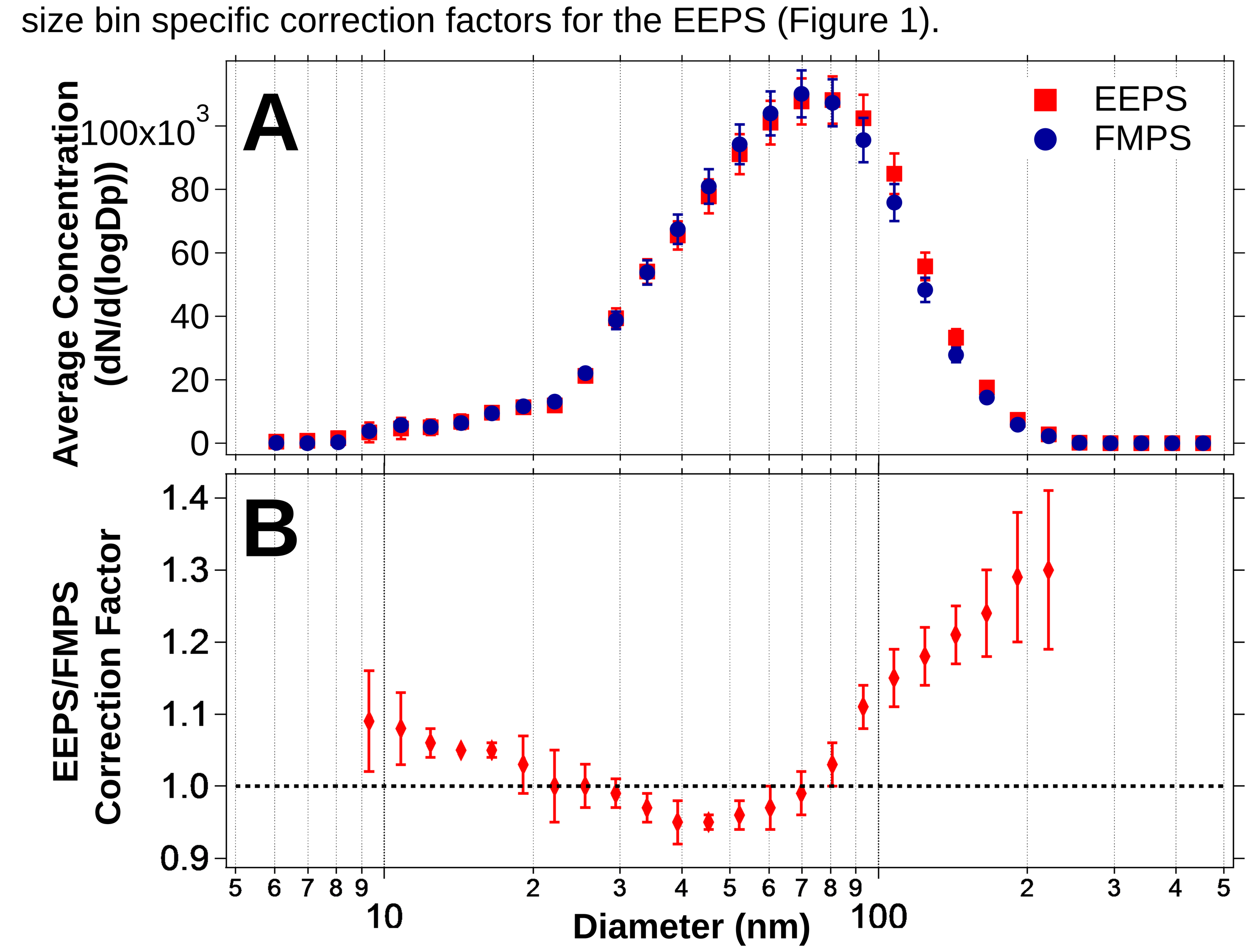


Figure 1A: Average distribution for the EEPS and FMPS at a dilution ratio of 118
Figure 1B: EEPS/FMPS correction factors with a 95% confidence interval

Correction factors are approximately 1.0 in the size bins with the largest number concentration (22-80 nm). Size bins with the smallest number concentration were associated with larger confidence intervals.

DPF Collection Efficiency

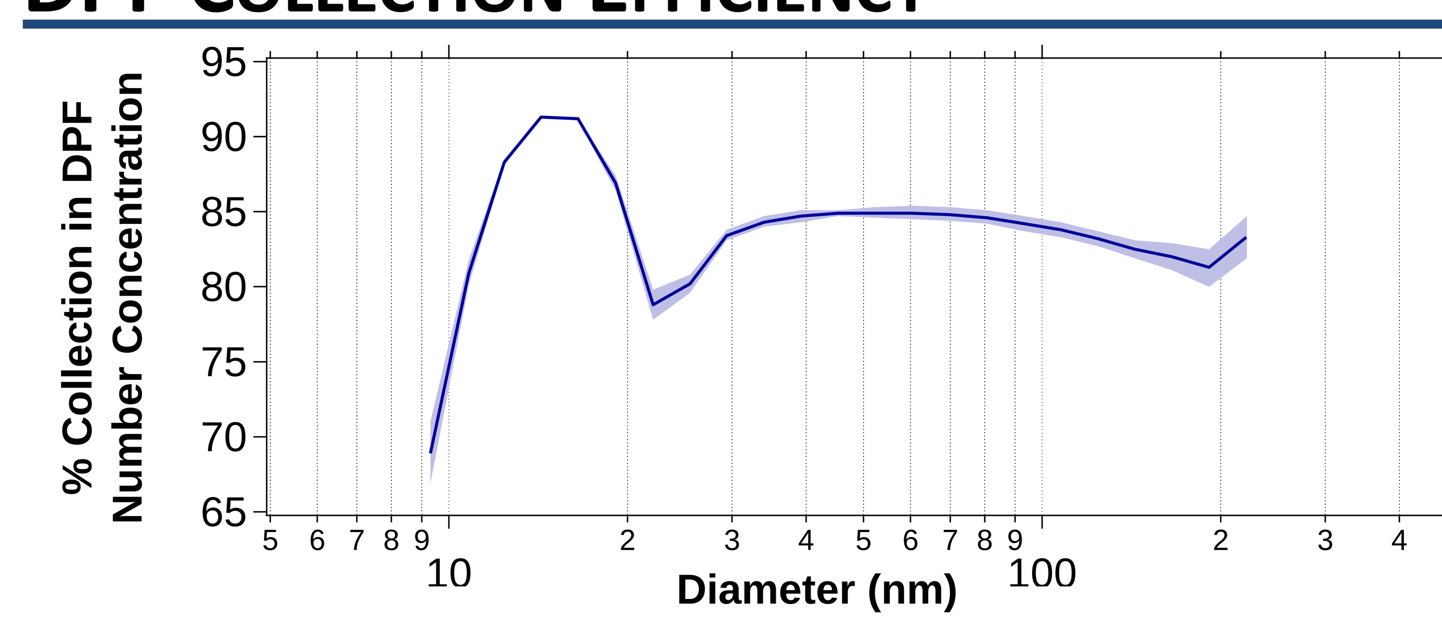


Figure 2: Calculated DPF collection efficiency of the DPF. Shading represents confidence interval from correction factors.

The impact of correction factor on the calculated DPF collection efficiency is estimated with 95% confidence to be ≤ 4 %. Higher collection efficiency was observed in the <22 nm size fraction, potentially due to losses in volatiles downstream of the DPF or particle losses in the dilution systems.

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