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The Portable Exhaust Toxicity System Concept: Compact Air-liquid Interface Exposure System for Dynamic Engine Operation

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Background:

- Exposure to traffic & mobile machinery emissions associated with adverse health effects.
- Traditional metrics (total particle mass, total number of non-volatile particles) are only surrogates and do not necessarily reflect health risks (i.e., substantial risks from volatile fraction and sub-23-nm particles not covered by PN standard).
- Synergistic (and anti-synergistic) effects make it difficult to assess health risks from chemical composition.
- Direct exposure of various cellular models at air-liquid interface (mimicking the working surface of human lungs) at realistic doses believed to provide the most relevant approach. (Steiner S, Heeb NV, Czerwinski J, Comte P. et al., Test-methods on the test-bench: a comparison of complete exhaust and exhaust particle extracts for genotoxicity/mutagenicity assessment. Environ. Sci. Technol. 2014;48:5237-44.)
- Typical test conditions in published studies: constant dilution (typically 10:1), laboratory conditions. (Why not use CVS, a full-flow dilution tunnel, as for regulated pollutants? Semi-volatiles are associated with large part of toxic effects, and deposition and reentrainment concerns apply. Engineers, how often do you clean the CVS?)
- Measurement during real-world operation (not restricted to "real driving emissions" as defined in the EU legislation, but the *real* 'real driving emissions') often provides a more realistic assessment than laboratory tests.

Goal: To develop an air-liquid interface exposure system capable of operating on the road.

Concept presented here (still work in progress):

A) Sampling: Directly from exhaust pipe (tailpipe or fitting before/within/after aftertreatment)

B) Dilution: Adapt from online measurement or proportional gravimetric sampling devices (proportional sampler for lower dilution ratios and rotating disc diluter for higher dilution ratios used here)

C) Conditioning: Add CO_2 to reach 5 % CO_2 within the sample, heat to 37 °C, humidify to 85-95 % (membrane humidifiers directly fed with water)

D) Exposure: Flow brought to enclosures, within which it is divided into eight symmetrical paths to standardized "inserts" or "wells" with membranes with cellular models. Deposition occurs by natural diffusion.

Preliminary results:

- Exhaust source: Gasoline direct injection engine operated on an engine dynamometer
- Test sequence: cold-start and warm-start WLTC (World Harmonized Light Vehicle Test Cycle)
- Different cellular models (BEAS-2B, 3D lung model MucilAir™) tested
- All models survived five-day exposure (two test sequences per day)
- Cells transported in a car between testing facility and toxicological laboratory each day (2 x approx. 1 hour "road time", equivalent to the test sequence)
- Particle losses on the membrane humidifier in low tens of percent

Discussion:

- System tested in laboratory so far but all components either are road-ready (i.e., rotating disc diluter), have a road-ready equivalent (proportional sampler), or can be fabricated as road-ready (i.e., insulated heated enclosure to maintain 37 °C).
- It is anticipated that an exposure system size, power consumption and complexity will be analogous to a higher-end online on-board monitoring instrument (i.e., FTIR).
- On-road & field testing, in addition to being more realistic in mimicking everyday operation, overcomes one of the major hurdles in exhaust toxicity studies – the distance and transport of cellular cultures between toxicological laboratory and test facility.
- Direct applicability to other sources (home heating appliances, industrial nanoaerosols, …)