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Assessing Exhaust Gas Exposure in Real Driving Conditions with a Portable Air-Liquid Interface Chamber

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Responding to the outdoor air pollution being one of the gravest environmental and health hazards, mobile source emissions have been subject to scrutiny and emissions reduction efforts through increased efficiency, improved fuels, engine design, combustion control, exhaust aftertreatment, and traffic management. Assessment of the effects of various improvements on human health has been extended from basic laboratory measurements to testing under real-world (real-driving) conditions and to more health relevant metrics than, for example, total particulate mass.

Exposure of cell cultures at air-liquid interface (ALI), mimicking i.e. human lung surface, is believed to be one of the most realistic means to model toxicity of complex mixtures of pollutants on human health. While a number of ALI exposure systems have been developed, the complexity of the close cooperation of “emissions source” and toxicology groups and of the instrumentation are among the limiting factors of ALI use. This work combines these two approaches into portable, on-board ALI exposure chamber, capable of operating in a moving vehicle, delivering its exhaust to living cell cultures.

Cell cultures grown on commercially available 6 mm Transwell inserts are positioned in a compact, airtight exposure box, where the sample is evenly distributed across eight wells of a standard 24-well plate at 25 cm³/min per insert. In a 40x35x45 cm inner dimensions incubator, sample and control air, conditioned to 5% CO_2, 37°C and >85% humidity, are drawn through 2-4 exposure boxes. Characterization with silver nanoparticles revealed 50% particle losses at 15 nm and deposition rate of approximately 1.5% at both 10 and 21 nm mean diameter. The system has undergone an extensive field validation, including 4 h of exposure and 2 h transport in a vehicle each day for 5 days, 5-day operation outside in vans and tents at -7 to +32°C.

In the PAREMPI project, the ALI exposure chamber has been mounted on an instrumented trailer used to measure emissions from two heavy-duty diesel trucks. Diluted exhaust produced during operation of the truck on public road in Finland in winter conditions was supplied to an advanced in vitro human airway epithelium MucilAir™ (Epithelix), a reconstituted, fully differentiated, and functional human respiratory tissue derived from primary cells, capable of long-term culture at the air-liquid interface, recognised as one of the closest representations of human lung tissue available for in vitro studies.

This is the first known use of ALI exposure chamber as a portable on-board system (PEMS). In other experiments within the project, the exposure chamber was sampling exhaust from light-duty vehicles of different types and emissions standards, operating on different fuels.

The portable exposure chamber, along with a field-deployable auxiliary mobile base including a small laminar flow box, additional incubator and freezer, can be easily used to study the toxicity of various emissions, effluents and polluted air, aiming for a more relevant toxicity measure than chemical composition alone.

The presentation will focus on the ALI exposure chamber design, with results of toxicological assays being presented at a later time.

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