Assessing particulate matter emissions from conventional cigarettes and heated tobacco products

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In quantifying solid particle emissions from Internal Combustion Engines, a spectrum of methodologies has been advanced for distinguishing solid particles from volatile and semi-volatile compounds. Previous research [1] introduced a novel Volatile Particle Removal (VPR) system, incorporating an advanced Catalytic Stripper (CS) capable of oxidising volatile hydrocarbons and sequestering sulfur species. This system underwent adaptation and optimisation to facilitate the assessment of whether solid particles are present in the emissions from combustible conventional cigarettes (CCs) and heated tobacco products, specifically the IQOS products developed by Philip Morris International.

The study analysed particulate matter emissions generated by reference (1R6F) conventional cigarettes and IQOS products (ILUMA and DUO) using a Programmable Single Syringe Pump (PSSP), comparing scenarios with and without the VPR system. Particle number concentration was monitored using a Condensation Particle Counter (CPC), while particle size distributions were determined with a Scanning Mobility Particle Sizer (SMPS) and an Engine Exhaust Particle Sizer (EEPS). Inline compositional analysis of the emitted particulates was also performed with a Time-of-Flight Aerosol Chemical Speciation Monitor (ToF-ACSM).

The VPR system was used to eliminate volatile particulate matter exhibited remarkable efficiency i.e. tetracontane and glycerine particles were removed at rates exceeding 99.990% and 99.999%, respectively. The penetration efficiency of solid particles was also evaluated using monodisperse and polydisperse particles. Average penetration rates exceeded 80% for particles larger than 10 nm, with penetration for 10 nm particles surpassing 50%. Notably, penetration efficiency appeared invariant for particles larger than 20 nm.

It was observed that aerosol generated by IQOS devices markedly surpassed conventional cigarettes in terms of reduced particle emissions. The total (solid or droplets) particle number emitted per unit (stick or cigarette) was significantly higher for CCs compared to IQOS by four orders of magnitude. The IQOS devices emitted larger particulate matter (droplets), predominantly in the range from 100 to 150 nm, in contrast to the majority of CC particles, which ranged from 30 to 100 nm, with an additional peak around 250 nm. Particulate matter emissions from both sources predominantly consisted of volatile species. The VPR system with IQOS products almost eliminated particle counts of the particulate matter in the IQOS emissions. The downstream of the VPR emissions from CCs remained significantly high, verifying the existence of solid particles in the CCs case. Particle sizing for those solid particles revealed two distinct peaks: an initial peak at 10 nm for nuclei-mode particles and a second peak at 100 nm, indicative of aggregated particles.

Significant disparities were also identified in the composition of particulate matter emitted from IQOS products and conventional cigarettes. Without the VPR, concentrations of organic compounds were comparably high across all tests, exhibiting similar magnitudes. However, CC emissions contained organic compounds with lower oxygen content compared to those from IQOS products. Sulphate concentrations in CC smoke were an order of magnitude higher than in IQOS emissions. Additionally, CC smoke exhibited a notably higher prevalence of nitrates, approximately three times that in IQOS emissions, and chloride concentrations in CC smoke were about 30 times greater than in IQOS emissions. In the presence of the VPR, concentrations of these compounds in IQOS emissions were negligible, well below the instrument's detection limit. For CCs, even post-catalytic stripping, certain organic compounds and chlorides persisted.

In conclusion, this study's detailed analysis of particulate matter revealed that emissions from IQOS consist of volatile particulate matter (droplets), whereas conventional cigarette (CC) emissions contain both volatile and solid particles. The data showed no indication of soot particles in IQOS emissions, unlike cigarette smoke, which contains a high concentration of soot particles.

[1] A. D. Melas, V. Koidi, D. Deloglou, E. Daskalos, D. Zarvalis, E. Papaioannou & A. G. Konstandopoulos, *Aerosol Science and Technology*, **2020**, *54:6*, 704-717, DOI: 10.1080/02786826.2020.1718061