Solid particle investigation in the mainstream smoke of 3R4F reference cigarettes and the mainstream aerosol of Tobacco Heating System THS 2.2

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Introduction and Objective

An aerosol is a mixture of liquid droplets and potentially fine solid particles suspended within a gas whereas smoke is a visible suspension of combustion-related particles in air, typically emitted from a burning substance. PMI's heat-not-burn Tobacco Heating System 2.2 (THS 2.2) uses an electronically controlled heating mechanism to precisely heat specially designed tobacco sticks at operating temperatures well below combustion (J. P. Schaller et al.). As a result, the aerosol generated during the use of THS 2.2 contains significantly lower levels of harmful and potentially harmful constituents compared with cigarette smoke and is free of combustion-related particles.

The objective of the current work was to evaluate if combustion-related particles were released in the mainstream aerosol from the heat-not-burn product THS 2.2 in comparison to the smoke produced from a reference cigarette. For this purpose, a methodology using a Dekati commercial thermo-denuder operating at 300°C and associated with chemical characterization was developed and validated.

Methods, Equipment & Validation

The aerosol generated from the use of THS 2.2 or the mainstream smoke released from reference cigarette (3R4F) reach the entrance of the thermo-denuder maintained at 300°C (see Figure 1) :

1) The aerosol is heated and transported to a gas stripper section used to remove the gas vapor phase from evaporated droplets
2) The thermo-denuder treated aerosol was measured with a Condensation Particle Counter 3775 (CPC) and an Aerodynamic Particle Sizer 3321 (APS) or trapped in an impactor (T. Jalanti and P. Henchoz) for chemical characterization

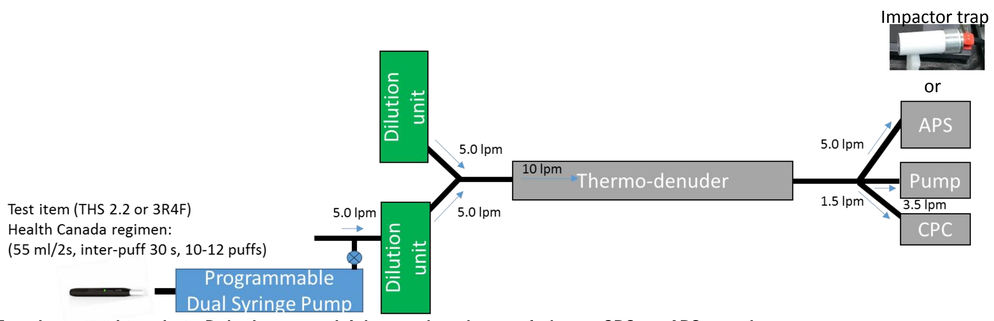

Figure 1: Experiment design using a Dekati commercial thermo-denuder coupled to an CPC, an APS or an impactor trap

The thermo-denuder was validated on three aspects (P. Pratte et al., submitted):

- Wall losses obtained based on penetration measurements for model aerosols (dry NaCl and SiO_2 particles) (Figure 2)
- Droplets' removal efficiency from penetration measurements of model liquid aerosols (glycerin/water/propylene glycol mixtures) (Figure 3)
- Liquid coating removal efficiency using glycerin-coated NaCl particles (Figure 4)

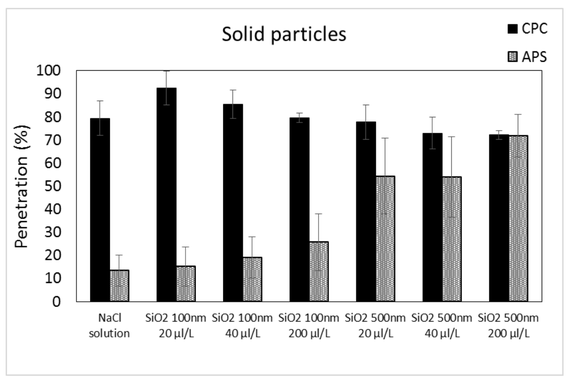

Figure 2: Aerosol penetration for SiO_2 and NaCl particles using CPC and APS instruments

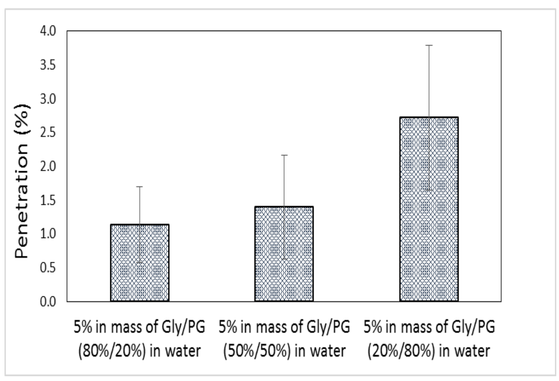

Figure 3: Penetration measured from tested nebulized liquid formulations using a CPC positioned downstream the thermo-denuder operated at 300°C

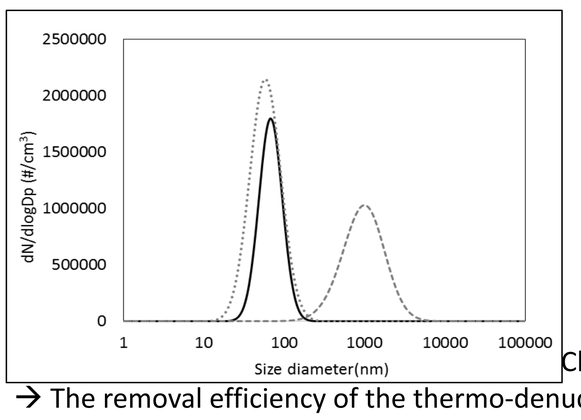

Figure 4: Coating removal experiments. The black lognormal-fitted curve corresponds to the measured size distribution of NaCl seeds (at 30°C). The dashed and the dotted lognormal-fitted curves represent the size distribution of glycerin-coated NaCl particles after they passage in the thermo-denuder when the temperature was set at 30 and 300°C, respectively

Cl particles (wall losses 20.6%)

→ The removal efficiency of the thermo-denuder was 3.7%

→ The thermo-denuder was shown to remove efficiently liquid coatings from NaCl particles in the submicron range

→ Based on the findings, the related Limit Of Detection (LOD) and Lower Limit Of Quantification (LLOQ) were calculated: LOD = 3.7%, LLOQ = 11.1 %

Applications

The thermo-denuder was used to remove droplets from mainstream cigarette smoke and the aerosol produced from THS 2.2. The penetration values measured with the CPC were compared with the LOD and LLOQ to determine whether combustion-related particles or high boiling point droplets could have been detected or/and quantified.

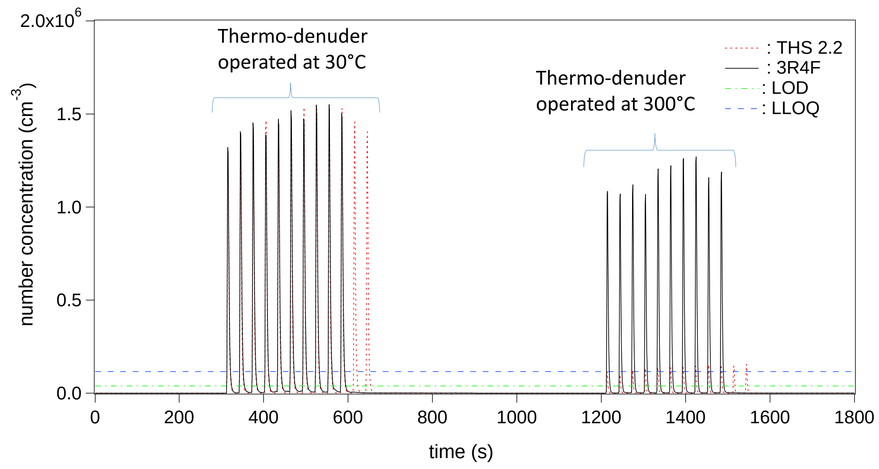

Figure 5: Particle number concentration measured at the outlet of the thermo-denuder operating at 30°C (left) and at 300°C (right). 3R4F mainstream smoke (black curve) and THS 2.2 aerosol (red-dashed curve) were generated using Health Canada regimen (55ml/2s, inter-puff 30 s, 12 puffs for THS 2.2 and 10 puffs for 3R4F). One test item was used for both conditions (30°C & 300°C)

→ The penetration for the thermo-denuder treated 3R4F mainstream smoke was found to be far above the LLOQ

→ The penetration for the thermo-denuder treated THS 2.2 aerosol was overlapping wit the LLOQ considering the experimental uncertainty

In a previous study (P. Pratte et al.), the CPC/APS were replaced by an impactor trap followed by Scanning Electron Microscope (SEM) and Electron Diffusive X-ray (EDX) analyses to characterize the chemical nature of collected solid particles (Figure 6)

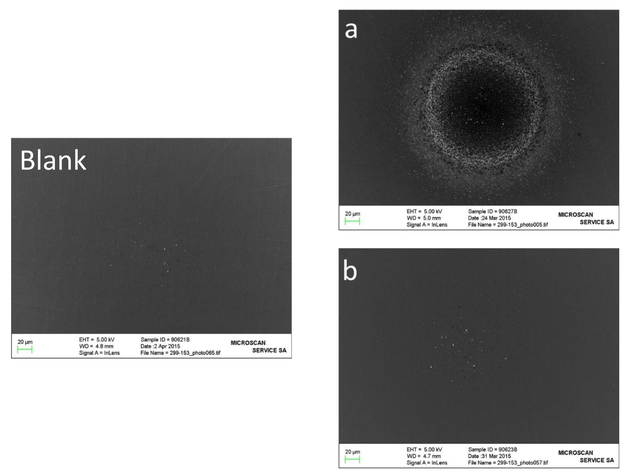

Figure 6: Pictures showing accumulated submicron particles from the thermo-denuder treated mainstream of a) 3R4F smoke and b) THS 2.2 aerosol. SEM/EDX analyses were performed by Microscan Service SA (Rue de la Blancherie 17, 1022 Chavannes-près-Renens, Suisse)

→ <u>3R4F experiments</u>:
- ~ 10^{12} particles per 3R4F, attributed to combustion-related solid particles/high boiling point droplets
- The combustion-related particles' Count Median Diameter was found to be approximately 75 nm
- Mainly carbon-based solid matter with oxygenated species was found

→ <u>THS 2.2 experiments:</u>
- Compared to the blank, no additional particles were observed

Conclusions

- According to SEM/EDX analyses, carbon-based solid particles were released and transferred in the mainstream smoke of 3R4F owing to combustion and resulting in a count median diameter of 75 nm
- The methodology allowed to determine (number-based) that 3R4F smoke consist of ~ 60% of combustion-related particles or/and high boiling point droplets
- From SEM/EDX analyses no combustion-related solid particles were observed in the mainstream aerosol produced from THS 2.2
- The slight particle concentration detected for THS 2.2 aerosol is attributed to a potential matrix effect or remaining high boiling point droplets at the outlet of thermo-denuder
- In light of the above, it can be concluded that combustion is not taking place in THS 2.2 and that no smoke is generated
- This methodology could be used for any other applications such diesel or biomass burning for indoor/outdoor air quality

References

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