Dynamic properties of exhaled e-cigarette aerosol vs. conventional cigarette smoke

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Electronic cigarettes (e-cigarettes) are gaining acceptance with consumers as an alternative to conventional combustible cigarettes. Both regulators and public health organisations are beginning to examine whether particles exhaled following the use of such products have potential implications for bystanders in workplaces and enclosed public spaces. E-cigarettes do not contain tobacco, do not require combustion and do not generate side-stream smoke. There is limited data available on the properties of exhaled e-cigarette particles and how they differ from those released during the smoking of a conventional cigarette. To that end, we aimed to investigate the spatial and temporal variations of exhaled particles following the use of an e-cigarette and the smoking of a conventional cigarette in a chamber under controlled environmental conditions.

An exposure chamber with controllable ventilation rates was used with a bystander simulated using a "dummy", whose surface was heated in the range 31-34°C, similar to the temperature of the surface of the human body. A human volunteer vaped an e-cigarette or smoked a conventional cigarette according to a set puffing regime, at three different distances from the bystander, and under three different ventilation rates. Three volunteers participated in the study and were experienced e-cigarette users. Airborne particles were measured using a fast mobility particle sizer (FMPS), an electrical low pressure impactor (ELPI), and a scanning mobility particle sizer (SMPS) at the bystander's position. With these analytical techniques, the particle concentration, size distribution and decay rates at the bystander's position were assessed.

During the use of the e-cigarette, a very fast change in the particle concentration was observed both in time and space. In the worst case scenario (shortest distance between the vaper and the bystander, minimal room ventilation), the increase of the particle concentration was observed 5 seconds after each puff, reaching a concentration of 10^6 #/cm^3. The airborne particle concentration rapidly returned to background levels <1000 #/cm^3 after 5 seconds, irrespective of the number of puffs taken, while the peak particle size shrank from 100-150 nm to 20-30 nm during this period (Figure 1). This is in stark contrast to the conventional cigarette. The duration of the particle concentration increase following a single puff was similar to that of the e-cigarette. However, the particle concentration at the bystander's position increased up to 50000 #/cm^3 with successive puffs, i.e. ~ 50 times higher than with the e-cigarette. The particle concentration returned to background levels after 30-45 minutes and was dependent upon the exposure chamber ventilation rate. Regarding size, particles released during one puff on the conventional cigarette were in the range 200-300 nm, and shrank to 80-100 nm within a few seconds (Figure 1). Interestingly, this particle size was unchanged until their removal after 30-45 minutes.

The rapid removal of e-cigarette particles from the bystander's position and thus the indoor air suggests that exhaled e-cigarette particles are mainly liquid droplets which evaporate very rapidly. This is in contrast to the tobacco combustion particles, that are released when smoking a conventional cigarette and that remain suspended in the ambient air for some time. This study shows clear and substantial differences between exhaled e-cigarette liquid droplets and conventional cigarette smoke particles.

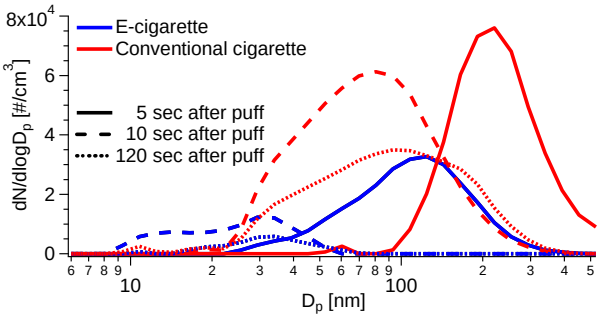

Figure 1. Particle number size distributions measured 5 seconds (solid lines), 10 seconds (long dashed lines), and 120 seconds (short dashed lines) after a puff with an e-cigarette (in blue) and a conventional cigarette (in red).

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