Assessment of nicotine in the ambient air before, during and after the use of e-cigarettes in an office

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1. Introduction

E-cigarettes and related products are gaining acceptance with consumers as alternatives to traditional tobacco products. Consequently, there is a growing interest from regulators and public health organisations on whether the aerosol exhaled from such products has implications for the quality of air breathed by bystanders.

There is currently an absence of robust scientific evidence on the impact of exhaled aerosol on indoor air quality in everyday environments, like homes and offices. Nonetheless, there are calls, including by some by government bodies, to prohibit the use of e-cigarettes in workplaces and enclosed public spaces. For example, WHO recently suggested e-cigarette use indoors should be banned as it "increases exposure of non-smokers and bystanders to nicotine and a number of toxicants" in the ambient air [1].

The aim of this study was to perform an assessment of indoor air quality by analysing the airborne concentrations of nicotine, propylene glycol and glycerol (the major components of e-liquids) before, during and after use of e-cigarettes in 'real-life' conditions. As there are no general indoor air quality guidelines or standards for nicotine, propylene glycol or glycerol, a comparison of the findings to UK workplace exposure limits (WELs) is made to provide an indication of potential bystander air quality [2].

2. Study design

To assess indoor air quality within a real-life environment, a meeting was conducted in a small office with five volunteers (three experienced, regular e-cigarette users [non-cigarette smokers] and two non-users) who had given informed consent. Smoking or vaping had not occurred in the room previously and was under natural ventilation (i.e. no air conditioning and windows are doors were kept closed during the study). The air exchange rate of the office was confirmed using a standard tracer gas method as described [3]. The internal volume of the room was 38 m^3 and was furnished with a central table and five chairs, with an ancillary table for detection apparatus. A schematic representation of the office layout, the two independent sampling locations and the positions of the e-cigarette users and non-users is shown in **Figure 1**.

To investigate potential changes in indoor air quality, the ambient air was analysed before, during and after a 165 min vaping session. Sampling times are shown in **Figure 2**.

During the vaping session, three of the five participants used Puritane™ 16 mg disposable e-cigarettes (Fontem Ventures) purchased over-the-counter from a range UK outlets. Products were consumed *ad libitum* (i.e. with no restrictions how to consume the product); the other two participants did not use the product during the meeting. Sufficient products were available in the event of exhaustion or product failure.

The study was conducted by a leading independent UK accredited laboratory with recognised expertise in air quality measurements and analyses for Imperial Tobacco.

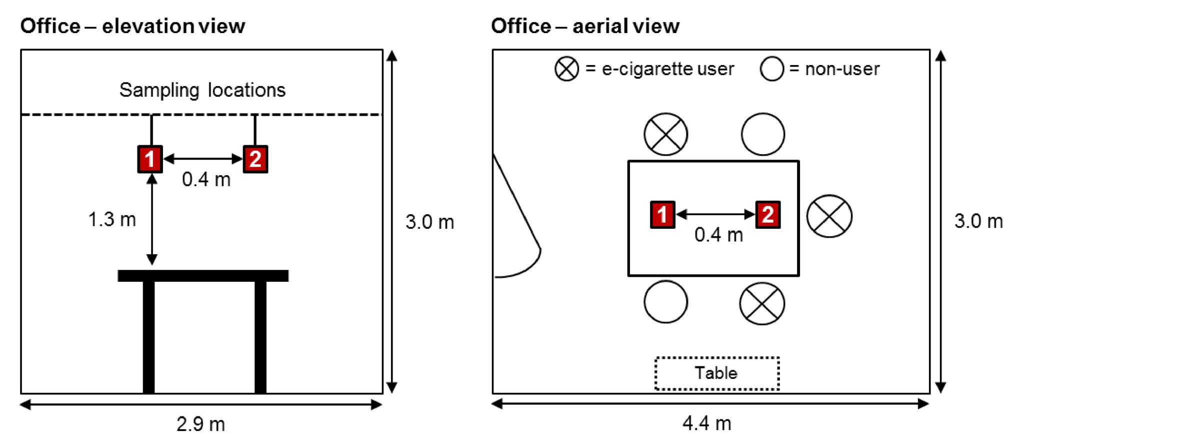

Figure 1 The layout of the office, the sampling locations and the positions of the e-cigarette users and non-users during the meeting.

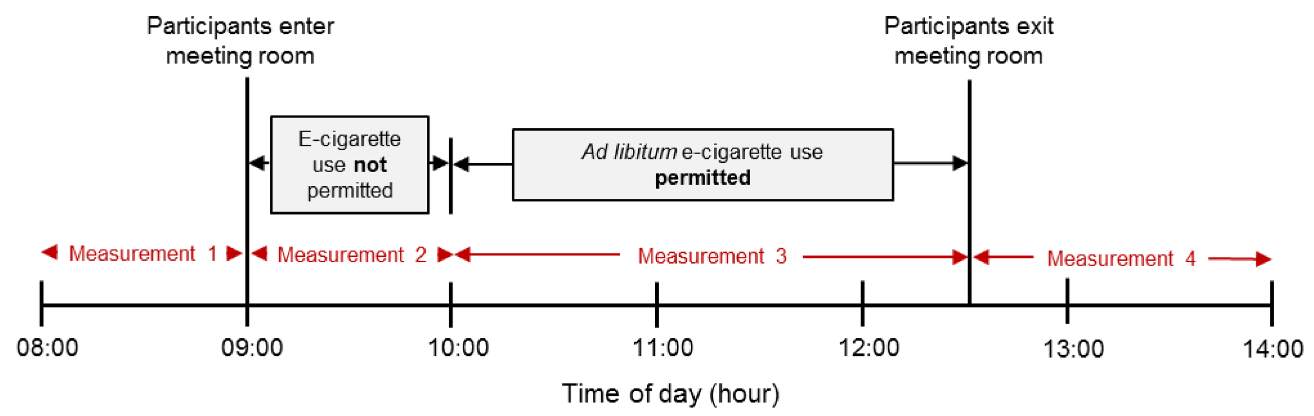

Figure 2 Timeline showing when participants entered and exited the office, when e-cigarette use was and was not permitted and the sampling times.

3. Analytical methods

Nicotine

Airborne concentrations of nicotine were measured using gas chromatography with nitrogen-phosphorous detector following active sampling on XAD-4 sorption tubes at a rate of 1000 mL/min for 60 to 165 minutes, as required. The limit of detection (LOD) of nicotine in air ranged from 7 to 25 μg/m^3 according to volume of air sampled e.g. during the 165 min vaping session the LOD was 7 μg/m^3.

Propylene glycol

Indoor air samples were collected by active sampling with a constant flow of 150 mL/min with Tenax as adsorbent and analysed by thermal desorption and gas chromatography using a flame ionisation detector according to the standard method ISO 16000-6. The LOD was 1 μg/m^3 using a sample volume of 24 L.

Glycerol

Airborne concentrations of glycerol were measured using gas chromatography following active sampling on XAD-7 sorption tubes at a rate of 1000 mL/min for 60 minutes (as recommended). The LOD of glycerol in air was in the range 150 to 350 μg/m^3.

4. Summary of findings

The average puff rate over the three e-cigarette users during the 165 min vaping session was 3.2 puffs per minute. This level of product use may have been influenced by the no-vaping restriction during the first hour. The measured room ventilation rate showed a low level of natural ventilation for the size of the office and number of occupants, with an average air exchange rate of 0.8 air changes per hour. The Chartered Institute of Building Services Engineers (CIBSE) state typical office spaces should have at least 1.0 air change per hour [4]. Given the puffing frequency and this air exchange rate, it is likely that findings in this study may be an overestimate.

Table 1 summarises the results for airborne concentrations of nicotine, propylene glycol and glycerol before, during and after the vaping session. As would be anticipated, the concentration of propylene glycol in the indoor ambient air, the major constituent of the e-liquid, was higher during the vaping session relative to the background and no vaping control period but remained within the WEL set for this chemical. Following cessation of vaping, there was a substantial decrease in the concentration of propylene glycol in the indoor ambient air. By contrast, there was no measurable increase in the airborne concentration of nicotine during use of the Puritane™ 16 mg disposable e-cigarette in the office space.

Due to the relatively large limit of detection for glycerol (150 to 350 μg/m^3), glycerol was not detected in any of the samples taken, with the results being < 250 μg/m^3 for the vaping samples. A more sensitive method for detection and quantification of glycerol in air needs to be identified for use in future studies of this type.

Table 1 Analysis of nicotine, propylene glycol and glycerol in indoor ambient air before, during and after a vaping session (average from the two sampling locations).

Chemical	Background (before participants enter room) [μg/m³]	Room occupied (NO VAPING) [μg/m³]	Room occupied (VAPING PERMITTED) [μg/m³]	Room unoccupied (after participants leave room) [μg/m³]	Workplace exposure limit (8 h mean) [μg/m³]	Comments
	Measurement 1	Measurement 2	Measurement 3	Measurement 4		
Nicotine	< LOD	< LOD	< LOD	< LOD	500	No measurable increase during vaping relative to background and no vaping control; below the WEL
Propylene glycol	< LOD	< LOD	204	10.2	474000 (total vapour and particulates)	Increase during vaping relative to background and no vaping control period; substantial decrease with cessation of vaping; below the WEL
Glycerol	< LOD	< LOD	< LOD	< LOD	10000	Glycerol not detected in any sample; due to large limit of detection, a more sensitive analytical method is required

5. Conclusions & future work

The results presented here relate to the Puritane™ 16 mg disposable e-cigarette product only; it is conceivable that results may vary with different types of e-vapour device (e.g. tank system) and compositions of e-liquid. Equally, air flow conditions, room size, number of e-cigarette users and consumption topography (i.e. mouth 'puffer' or 'inhaler') are likely to affect indoor air quality in any further work. In future work, analytical techniques may be refined further to provide greater precision.

There was no measureable increase in the concentration of nicotine in the indoor ambient air during vaping. To explore this finding further, we aim to determine:

- the quantity of nicotine retained by the e-cigarette user (i.e. the fraction not exhaled into the ambient air); and
- whether any potential nicotine in the exhaled aerosol is deposited to various surfaces.

During the use of the Puritane™ 16 mg disposable e-cigarette in a small office space, the concentration of propylene glycol measured in the office air, and therefore breathed by bystanders, was significantly lower than the UK workplace exposure limit set for this chemical. Exposure of bystanders to indoor ambient air following exhalation of this chemical at the levels seen in this study within the e-cigarette aerosol would not be anticipated to cause health problems, a conclusion in agreement with [5].

This experimental design may be employed to evaluate the indoor ambient air quality assessment of other chemicals or particulates and to test the predictions from our air quality model, presented previously [6].

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