Indoor Air Quality and Surface Deposition Assessment following Use of an Open System E-Cigarette

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1. Introduction

- Electronic cigarettes (e-cigarettes) represent a rapidly-emerging product category that holds promise as a conventional tobacco cigarette alternative.
- There is a growing interest from regulators and public health organizations on whether the aerosol exhaled from such products has implications on the quality of air breathed by bystanders.
- As e-cigarettes do not contain tobacco and there is no side-stream aerosol generated, the only source of potential bystander exposure would be to nicotine and base components that may be present in the exhaled aerosol.
- It has been suggested that nicotine from cigarette smoke can be deposited on indoor surfaces, where it can be released again to the gas phase or react with ozone, ambient nitrous acid and other atmospheric oxidants producing secondary chemicals, such as tobacco-specific nitrosamines (TSNAs).
- This scenario has been termed "third-hand smoke", and it has been suggested that this may present a potential health hazard to bystanders [1,2].
- Numerous studies have demonstrated that exhaled closed system e-cigarette aerosols contain negligible amounts of nicotine (reviewed in [3]) and there was no measurable increase in the level of nicotine on the surface after cig-a-like e-cigarette use [4].
- To our knowledge, no study assessing the potential impact of exhaled e-cigarette aerosols on indoor air quality and surface deposition following use of open system e-cigarettes has been reported.
- In the present study we aimed to understand the contribution of exhaled aerosols to the pre-existing chemicals in ambient indoor air and the potential deposition of nicotine to indoor surfaces before, during and after unrestricted use of a bluTM open system e-cigarette.

2. Setting, Sampling and Analysis

- 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 and two non-users) who had given informed consent
- Spot sampling for airborne constituents was conducted the day before product use, during room occupation but before vaping started, during the vaping session, after vaping ceased but room was still occupied and the day after product use.
- Surface wipe samples were collected before e-cigarette use was permitted (control period) from the walls and desk flat surface close to the e-cigarette users in the office and then 40 min and 24 hr after e-cigarette use ceased (Figure 1).
- During the vaping session, three of the five participants used the commercial product blu™ PRO open system (Fontem Ventures) containing 1.8% nicotine classic tobacco flavour e-liquid [refilled by the consumer]. Products were consumed ad libitum (i.e. with no restrictions how to consume the product); over the course of 135 min.

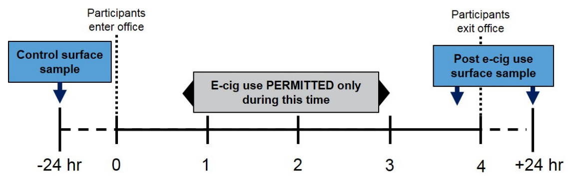

Figure 1. Timeline illustrating experimental setup - when participants entered and exited the office, when e-cigarettes were used and sampling times.
The experiment was conducted in a UK office of dimensions 4.20 x 2.95 x 3.05 m³ (surface, 12.4 m²; volume, 37.8 m³). The office was under natural ventilation conditions and all doors/windows were kept closed during the study. The average measured ventilation rate was 0.7 air changes per hour.

3. No Negative Impact of E-Cigarette Use on Ambient Air Quality

Table 1. Airborne concentrations of the main e-liquid and selected carbonyl compounds and TSNAs during the study.
Results all in µg/m³.
For comparison, the regulatory references for indoor air quality (UK HSE WELs and USA OSHS) are given (all in µg/m³).
Indoor air sampling and analysis were performed according to O'Connell et al. 2015 [5]

Chemical [µg/m³]	Background	Room occupied (no vaping)	Room occupied (vaping)	Room occupied (no vaping)	Room un-occupied	24 hours after vaping	UK - HSE WELs 8-hr TWA	USA - OSHS 8-hr TWA
Nicotine	<7.0	<40.0	<8.0	Not sampled	<8.0	<6.0	500	500
Glycerol	<130.0	<730.0	<610.0	<140.0	Not sampled	<130.0	10,000	5,000
Propylene glycol	<3.0	<3.0	3.5	<3.0	<3.0	<3.0	474,000	-
Acetaldehyde	<10.0	<10.0	11.3	14.0	12.0	<10.0	37,000	360,000
Acrolein	<10.0	<10.0	<10.0	<10.0	<10.0	<10.0	-	250
Formaldehyde	9.0	11.5	15.5	17.0	16.0	13.0	2,500	-
n-Nitrosonornicotine (NNN)	<0.4	Not sampled	<0.4	Not sampled	<0.4	<0.4	-	-
4-Methylnitrosamino-1-(3-pyridyl)-1-butanone (NNK)	<0.4	Not sampled	<0.4	Not sampled	<0.4	<0.4	-	-

- During the vaping period, users collectively took 339 puffs, as determined by video recording.
- There was no measureable increase in nicotine concentrations from the background level during vaping periods. All chemical measured were below the limit of quantification (LOQ), which ranged from 6 to 40 µg/m³. These values are far below the UK HSE WEL as well as the US Occupational Safety and Health Standard of 500 µg/m³.
- As expected, Propylene glycol increased slightly during the vaping period, but remained well below the workplace exposure limit (WEL).
- In this study glycerol levels remained below the LOQ.
- The airborne concentrations of acetaldehyde and formaldehyde showed a small minor increase compared to background levels. this is likley to be due to room occupation and/or a contribution from vaping, as similar levels were detected when the room was unoccupied. Both compounds remained well below the WEL. Acrolein was not detected above limit of quantification at any stage of the experiment.
- There was no measurable increase of in airborne levels of NNN and NNK. All values were below the LOQ.

4. No Increase in Surface Nicotine Levels After E-Cigarette Use

- Samples taken prior to e-cigarette use indicated the presence of trace levels of nicotine. This was unsurprising, as nicotine is reportedly widely present in the environment [6,7].
- There was no measurable increase in the levels of nicotine detected on the surfaces 40min or 24hr after product use. The average concentration of nicotine detected on the walls and desk during each test phase was <1.5 µg/m². As nicotine is not evenly distributed on the surfaces tested, it was therefore no possible to interpret any differences in values smaller than the standard deviation.
- The results reported here support the recent pilot study observations of Bush and Goniewicz (2015) that found no significant difference in the levels of nicotine detected in e-cigarette users' and non-users' homes in real-life settings [6].
- During each test phase, there were no detectable levels of NNK on the surfaces analysed; all samples were below the limit of detection.

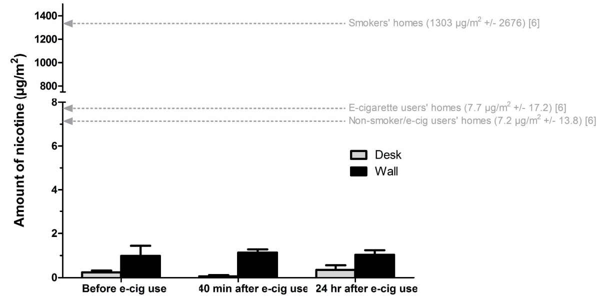

Figure 2. Amount of nicotine detected on the desk and wall office surfaces before and after e-cig use (40 min and 24 hr)
Bars show standard deviation.

5. Conclusions

- Under the conditions of this study, our results indicate that use of the bluTM open system e-cigarette when used ad libitum by three experienced vapers for almost two hours did not negatively impact the indoor ambient air for all chemicals analysed when compared to regulatory indoor air quality guidelines.
- Moreover, the use of the open system e-cigarette in this study did not lead to a measurable increase in nicotine levels or the subsequent formation of TSNAs on the indoor surfaces.
- **Our investigations suggest that the use of the bluTM open system e-cigarette is unlikely to pose exposure issues to bystanders and support the continued use of the product indoors.**
- The results presented here relate to the products which were tested and may not be generally applicable to all other e-cigarettes products such as Advanced Personal Vaporizers ('MODs'). User topographies and technology difference may impact exhaled aerosol characteristics/properties. Further research in these areas will be informative.

References

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Disclosure

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