An Assessment of Nicotine Levels on Office Surfaces Before and After Use of Electronic Cigarettes

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1. Introduction

- It has been reported that environmental tobacco smoke (*i.e*. exhaled tobacco smoke + smoke from a smouldering tobacco product) may become sorbed onto surfaces in areas where people have smoked conventional cigarettes, and subsequently re-emitted over time [1].
- It has been suggested that nicotine in smoke deposits almost entirely 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) [2].
- This scenario has been termed "third-hand smoke". Some researchers have suggested that this may present a potential health hazard to bystanders [1,2].
- Electronic cigarettes (e-cigarettes) represent a rapidly-emerging product category that holds promise as a conventional tobacco cigarette alternative.
- 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 in the exhaled aerosol.
- Although numerous studies have demonstrated that exhaled e-cigarette aerosols contain negligible amounts of nicotine (reviewed in [3]), there is currently a debate as to whether e-cigarette use results in the deposition of nicotine on surfaces resulting in a risk of so-called "third-hand exposure".
- As there have been some publications on this topic, we wanted to (i) explore whether nicotine is deposited on the walls and desk in a small office following use of a typical closed and open system e-cigarette by experienced users and (ii) assess the subsequent potential formation of TSNAs.

2. Setting, Sampling and Analysis

Products

Two experiments were conducted using two different commercial products: (i) blu™ PLUS closed system e-cigarette [containing replaceable cartridges pre-filled by manufacturer] and (ii) blu™ PRO open system [refilled by the consumer] both containing 1.8% nicotine classic tobacco flavour e-liquid.

Setting

Both experiments were conducted in a UK office of dimensions 4.20 x 2.95 x 3.05 m^3 (surface, 12.4 m^2; volume, 37.8 m^3). The office was under natural ventilation conditions (*i.e*. no air conditioning and all windows/doors were kept closed during the study); the average measured ventilation rate was 0.7 air changes per hour. The temperature and relative humidity in the office over the course of the studies were in the ranges 17–24 °C and 28–45%, respectively.

E-cigarette aerosol was generated by three experienced e-cigarette users who used the products *ad libitum* over the course of 135 min in the office (*Figure 1*).

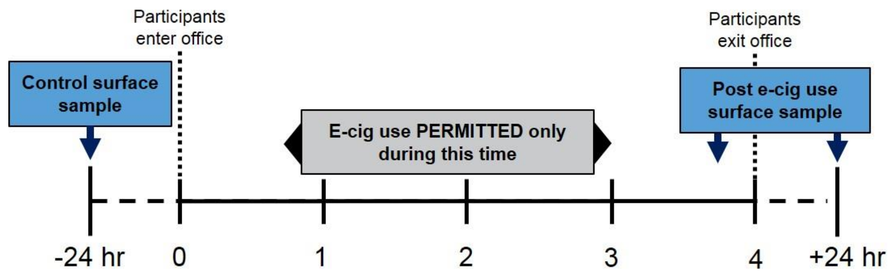

Figure 1. Timeline illustrating when participants entered and exited the office, when e-cigarettes were used and sampling times.

Surface Sample Collection

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. Before each experiment, all surfaces were rigorously cleaned with methanol.

Wipe samples were taken as described by Quintana et al. (2013) [4] using KimWipes. Metal templates with a 30 x 30 cm^2 opening area were attached to each surface. The area inside the template was wiped in a zig-zag pattern from left to right, right to left and then top to bottom, bottom to top twice. Two replicate samples were taken at each time point from each surface. After sampling, the wipe tissues were wrapped in aluminium foil and packed and sealed in polyethylene bags until sample analysis.

Sample Analysis: Nicotine and TSNAs

Wipe tissues were extracted for 3 hr with 60 mL methanol solution spiked with d4-nicotine as an internal standard. Nicotine was analysed by GC-MS. For this, an aliquot of 20 mL of the extraction solution was evaporated, residues reconstituted in methanol and the filtered extracts transferred into auto sampler vials for analysis on a Thermo Scientific TRACE gas chromatograph with a single-quadrupole mass spectrometer. The chromatographic separations were carried out using a Restek Rtx-35 column (30 m*0.25 mm i.D.; 1 µm film). Helium (constant flow: 1 mL/ min) was used as carrier gas. Oven temperature started at 50 °C and after 2 min was increased by 10 °C/min up to 250 °C. The final temperature was held for 15 min. The mass spectrometer operated in the selective ion monitoring (SIM) mode. For nicotine quantification, *m/z* 161 was used. Identification was performed by retention time and specific compound mass.

Results were calculated as nicotine deposited on surface area of 1 m^2 (µg/m^2).

NNK (a general marker for TSNAs) was analysed by LC-MS/MS from an evaporated aliquot of the extraction solution. The residues were dissolved in 50% methanol and the filtered extracts were transferred into auto sampler vials. Analysis was conducted using an Agilent 1290 liquid chromatograph coupled with an API 6500 triple quadrupole mass spectrometer with positive electrospray ionization from AB Sciex. A Pnenomenex Gemini C18 column (3 µm, C18, 110 Å, 150*4.6 mm) was used for LC separation. Analysis was carried out using a gradient elution, in which the mobile phase composition of 50% (water/methanol with 0.1 % formic acid) was held for 4 min, changed to 10% in 1 min, maintained between 5-6 min and then changed to the initial composition between 7-11 min. The flow rate was 0.6 ml/min. For quantifying, the multiple reaction monitoring (MRM) transition the $[M^+H^+]$ of NNK at *m/z* 208 → 122 and d4-NNK at 212 → 126 were assayed. The *m/z* 208.1 → 78.9 transition was used as qualitative ion pair.

Results were calculated as NNK on surface area of 1 m^2 (ng/m^2); limit of detection, 77.8 ng/m^2.

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

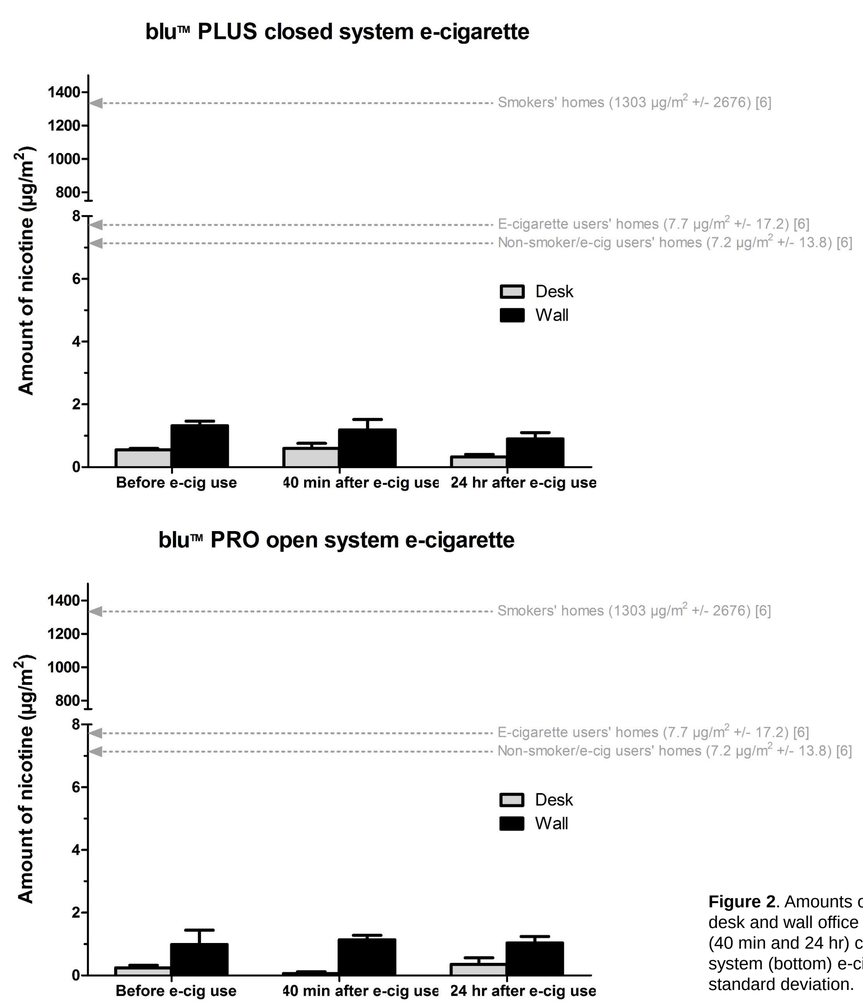

Figure 2. Amounts of nicotine detected on the desk and wall office surfaces before and after (40 min and 24 hr) closed (top) and open system (bottom) e-cigarette use. Bars show standard deviation.

- During the vaping period, users collectively took 322 puffs for the closed system product and 339 for the open system product, as determined by video recording of the experiments.
- Samples taken prior to e-cigarette use indicated the presence of trace levels of nicotine. This was unsurprising, as nicotine has been reported to be widely occurring in the build environment [5,6].
- There was no measurable increase in the levels of nicotine detected on the surfaces 40 min or 24 hr after use of both the closed and open system e-cigarettes. The average concentration of nicotine detected on the walls and desk during each test phase for both e-cigarette products was <1.5 µg/m^2. As nicotine is not evenly distributed on the surfaces tested, it is not possible to interpret any differences in values smaller than the standard deviation.
- During each test phase for both e-cigarette products, there was no detectable levels of NNK on the surfaces analysed; all samples were below the limit of detection.

4. Conclusions

- Using the closed or open system e-cigarette products tested in this study did not lead to a measurable increase in nicotine levels on the surfaces analysed. This is consistent with previous reports that e-cigarette users exhale negligible levels of nicotine into ambient air which may be attributable to the high retention rate of nicotine in the user's body [7]. Moreover, NNK (a general marker for TSNAs) could not be detected on the surfaces analysed at each test phase.
- 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].
- Interestingly, when Goniewicz and Lee (2014) released machine generated e-cigarette aerosols into an exposure chamber, an increase in the amount of nicotine deposited on various surfaces was detected [8]. This is to be expected since there is 0% nicotine retention and 100% release of nicotine to the ambient air. It is therefore questionable to compare results from machine generated aerosol released into a room with aerosol generated from human subjects when assessing so-called "third-hand exposures" to e-cigarette emissions.
- Under the conditions of this study, our results indicate that there is little evidence of nicotine deposition on surfaces from use of the e-cigarettes tested and is unlikely to pose an issue to bystanders.
- The results presented here relate to a typical closed and open (tank) system e-cigarette and may not be generally applicable to other products such as Advanced Personal Vaporizers ('MODs') due to potential differences in vaping behaviour, aerosol properties and technologies. Further research with different product types in different settings with different volunteer groups is planned.

References, Declaration of Interests & Acknowledgments

[1] Matt GE et al., (2011) Thirdhand Tobacco Smoke: Emerging Evidence and Arguments for a Multidisciplinary research Agenda. *Enviro Heal Persp* 199(9): 1218-1226.
[2] Sleiman M et al., (2010) Formation of carcinogens indoors by surface-mediated reactions of nicotine with nitrous acid, leading to potential thirdhand smoke hazards. *PNAS*. 107(15): 6576-81.
[3] McNeill A et al., (2015) E-cigarettes: An evidence update. Public Health England report: 2015.
[4] Quintana PJ et al., (2013) Wipe sampling for nicotine as a marker of thirdhand tobacco smoke contamination on surfaces in homes, cars, and hotels. *Nicotine Tob Res*. 15:1555–1563.
[5] Rickert WS (1999) Background paper: Environmental tobacco smoke: properties, measurement techniques and applications. International Consultation on Environmental Tobacco Smoke and Child Health. *World Health Organization*.
[6] Bush D and Goniewicz ML (2015) A pilot study on nicotine residues in houses of electronic cigarette users, tobacco smokers, and non-users of nicotine-containing products. *Int J Drug Policy.* 26(6): 609-11.
[7] O'Connell G et al., (2015) An Experimental Method to Determine the Concentration of Nicotine in Exhaled Breath and its Retention Rate Following Use of an Electronic Cigarette. *J Environ Anal Chem*. 2(161): 1-6.
[8] Goniewicz ML and Lee L (2014) Electronic cigarettes are a source of thirdhand exposure to nicotine. *Nicotine Tob Res.* 17(2): 256-8.

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