

INDOOR AIR CHEMISTRY - An exploratory study on e-cigarettes shows no negative impact on indoor air quality

Catherine Goujon, [Maya Mitova](#), Nicolas Mottier, Emmanuel Rouget, Manuel Tharin, Serge Maeder

PMI R&D, Philip Morris Products S.A., Quai Jeanrenaud 5, 2000 Neuchatel, Switzerland (part of Philip Morris International group of companies)

Introduction and Objectives

Electronic Vapor products (commonly referred as electronic cigarettes, e-cigarettes) do not produce sidestream aerosol and the only source of aerosol constituents in the indoor environment is the aerosol exhaled by the user.

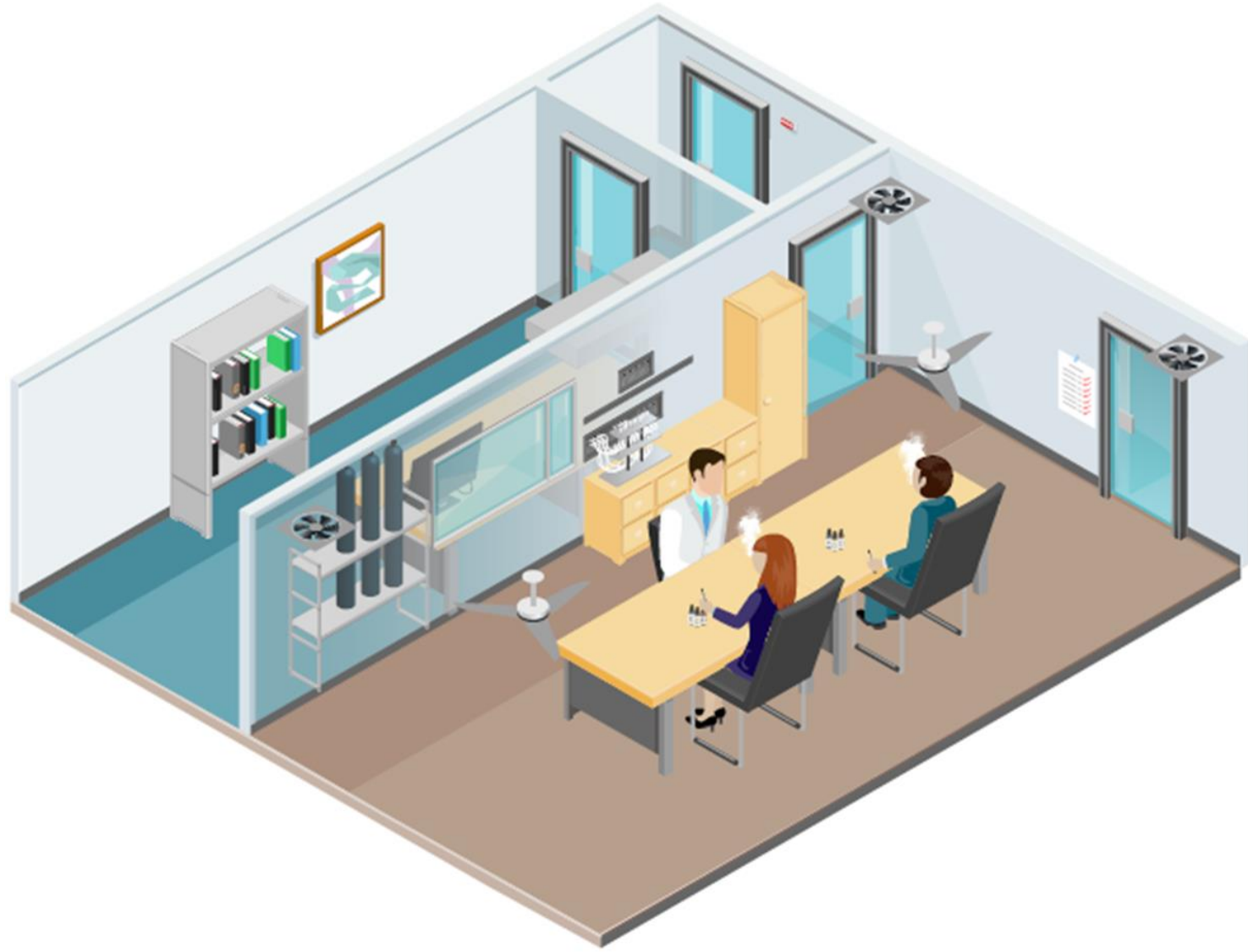
The goal of this exploratory study was the assessment of the impact on Indoor Air Quality (IAQ) of the aerosol produced by a representative selection of rechargeable and refillable tobacco-flavored e-cigarettes in an environmental controlled room. The Indoor Air Chemistries (IAC) of e-cigarettes were compared to the IAC of background air.

Brand name	Type	Nicotine content in e-liquid [mg/mL]	Nicotine content in mainstream aerosol [µg/puff] **
Solaris KS	Rechargeable	20	30.6
Nicolites	Rechargeable	16	48.6
Vivid	Refillable	18	70.5

** : CORESTA smoking regime: 55 mL puff volume for 3 sec, square shape puffing profile, 30 sec between puffs, group of 50 puffs, to achieve a constant delivery with battery recharging every 50 puffs

Study Design and Methods

- Environmental conditions set according to EN 15251:2007. The selected ventilation rate (87 m³/h, 1.2 air changes/h) corresponds to a normal level of expectation and should be used for new buildings and renovations (Residential category II)
- Assessment of eight airborne constituents
 - ETS markers: RSP gravimetric, 3-ethenylpyridine, nicotine
 - Indoor Air Quality markers: Total Volatile Organic Compounds (TVOC) as toluene equivalent, carbonyls (acetaldehyde, formaldehyde)
 - Specific analytes (aerosol formers): glycerin, propylene glycol
- Methods adapted from existing international standards to reach required selectivity and sensitivity (Mottier et al, 2016)
- Four hours collection, five trapping systems.
- Panelists: non-smokers for background, adult e-cigarette and dual users for vaping sessions
- 2 vapers, vaping per panelist (1.5 e-cigs/person/h): each 40 min for 10 min without restraint during vaping
- 3 vaping sessions/h
- Products: Solaris KS, Nicolites, Vivid, Background (BKG)
- Three repetitions of each session performed on three separate weeks.



RSP
(ISO15593:2001)
Gravimetry
µ-balance



Nicotine
3-Ethenylpyridine
(ISO18145:2003)
GC-El-MS



Carbonyls
(ISO16000-3:2011)
LC-APCI(neg)-MS/MS



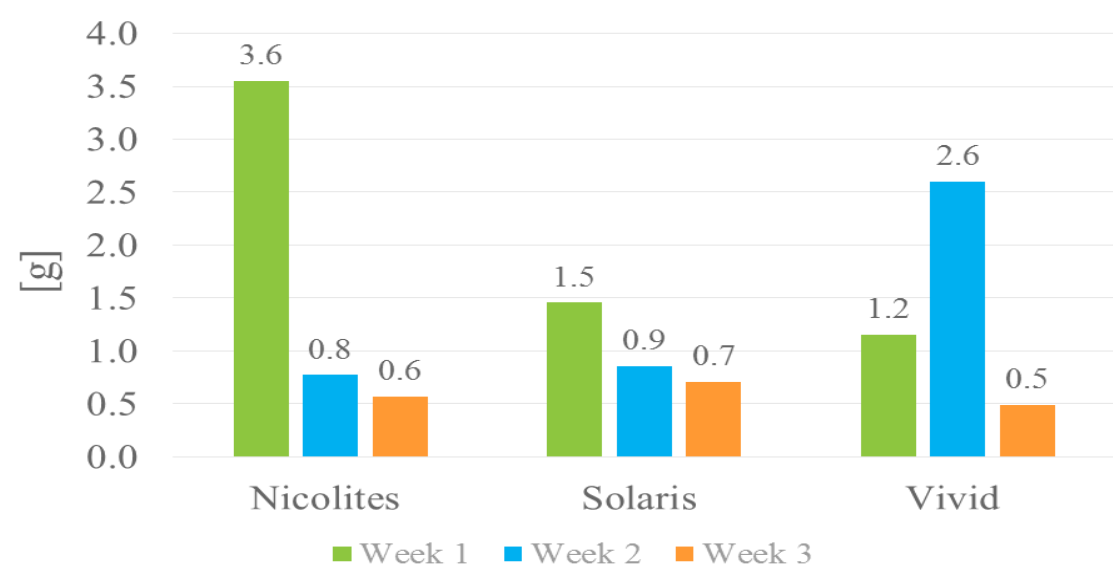
Aerosol Formers
GC-MS



TVOCs
(ISO16000-6:2011
ISO16017-1:2000)
TD-GC-FID/MS

Results and Discussion

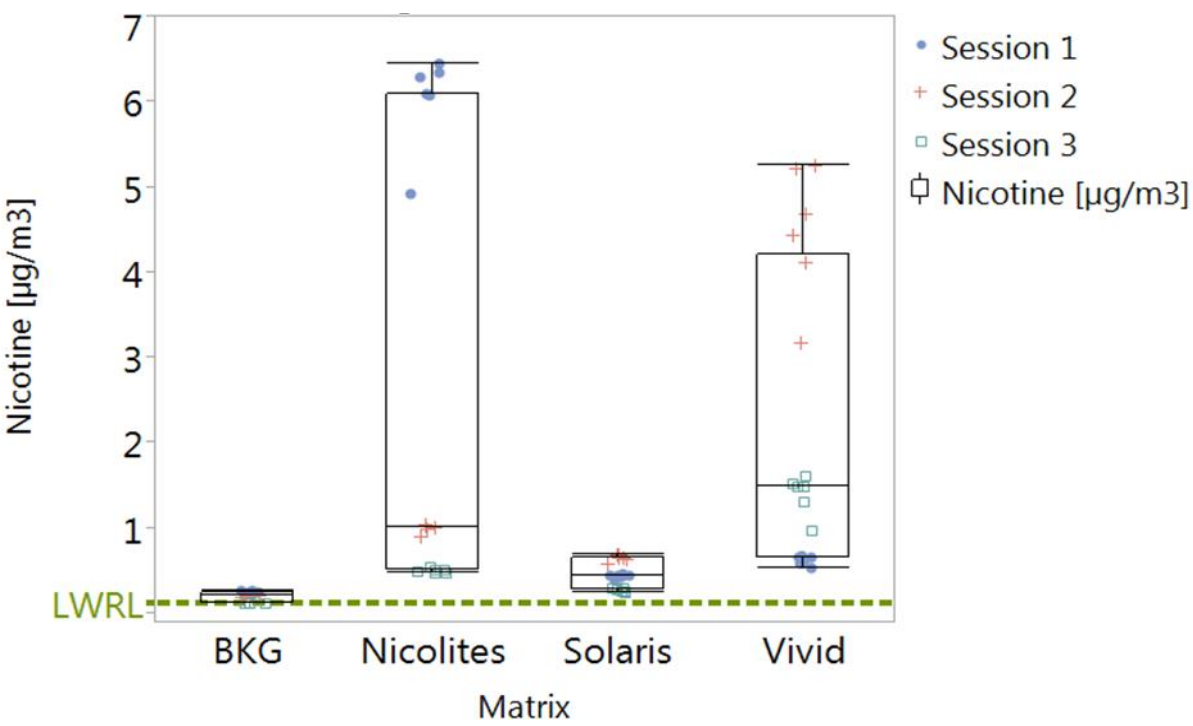
Consumption of e-liquid



Large differences between the consumed e-liquids during the sessions were measured and were explained by the different vaping behaviour of panellists
Normalized values showed a factor up to 6 for e-liquid consumption.
E-liquid consumed influenced indoor air concentrations for the major e-liquid constituents (Aerosol Formers, nicotine)

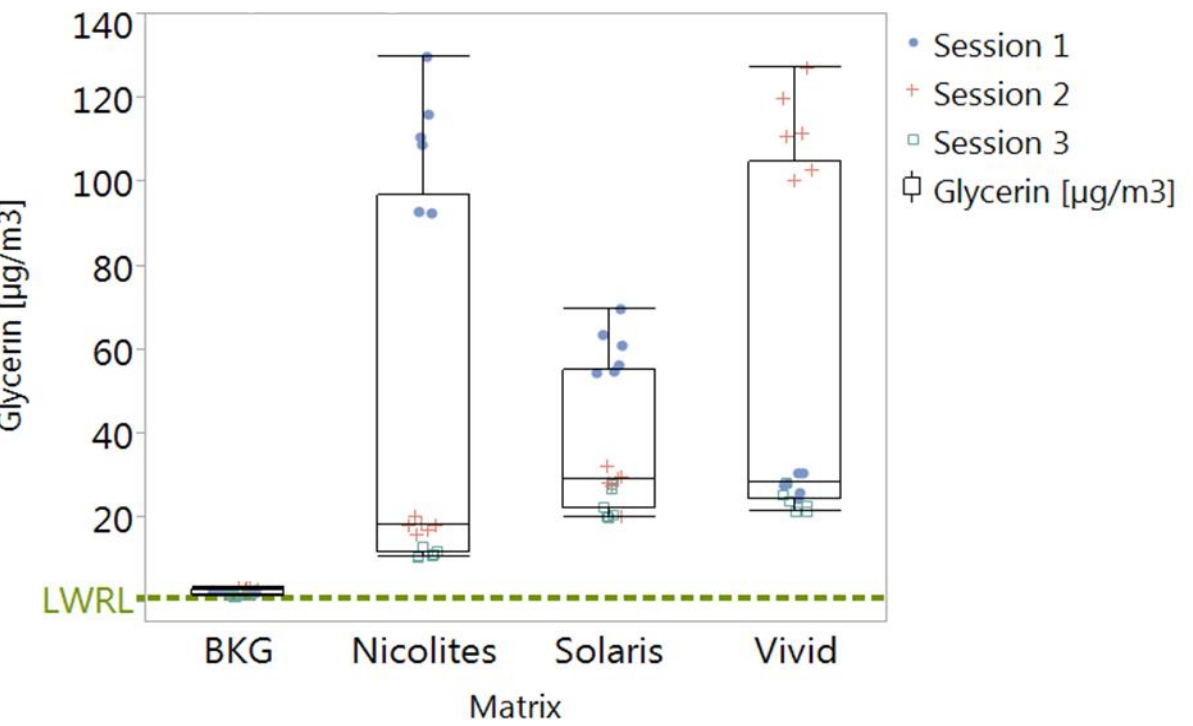
Indoor Air Concentrations

Nicotine



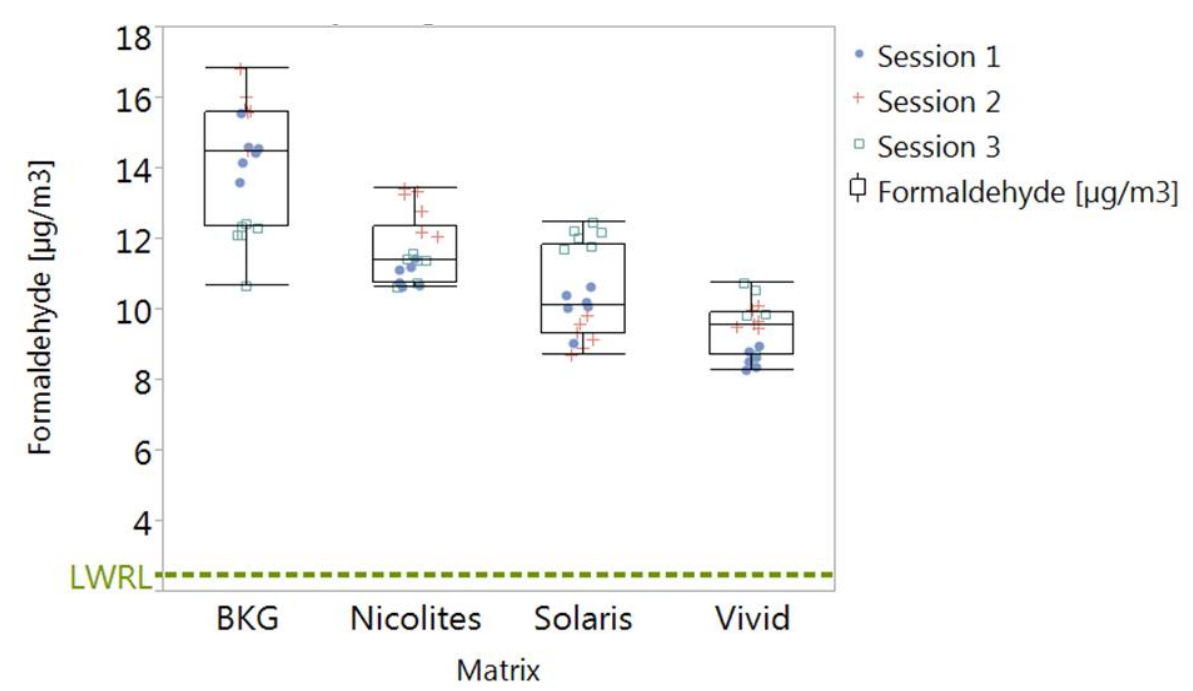
Statistical increase of nicotine above background levels when using e-cigarettes. Concentrations strongly influenced by vaping behavior.
Median levels of nicotine are at least two orders of magnitude lower than EU indicative occupational exposure limit of 500 µg/m³ (Commission Directive 2006/15/EC)

Aerosol Formers: Glycerin



Statistical increase of glycerin above background levels when using e-cigarettes. Concentrations correlated with e-liquid consumption.
Median levels of glycerin are at least two orders of magnitude lower than guideline levels of 10 000 µg/m³ (ACGIH, 2001)

Carbonyls: Formaldehyde



No statistical increase of formaldehyde above background levels when using e-cigarettes. Same observation was done for acetaldehyde.
The measured medians for formaldehyde were ranking between 9.6 and 11.4 µg/m³ and the ones for acetaldehyde were ranking between 5.1 and 8.7 µg/m³ in e-cigarette environmental aerosols.

Analytes levels obtained for environmental aerosols of e-cigarettes

Analyte	Solaris KS adjusted * (-) **	Nicolites adjusted * (-) **	Vivid adjusted * (-) **
RSP gravimetric [µg/ m ³]	-	-	-
3-Ethenylpyridine [µg/ m ³]	-	-	-
Nicotine [µg/ m ³]	0.221 (0.0761-0.411)	0.791 (0.305-5.57)	1.28 (0.444-3.67)
Glycerin [µg/ m ³]	26.5 (21.2-52.1)	15.6 (9.78-90.3)	25.7 (22.0-99.8)
Propylene glycol [µg/ m ³]	20.7 (13.0-24.0)	204 (90.1-1381)	143 (34.7-503)
Acetaldehyde [µg/ m ³]	-	-	-
Formaldehyde [µg/ m ³]	-	-	-
TVOC[µg/ m ³](toluene equivalent)	-	-	-

*Analytes levels (median and first and third quartile, 25th and 75th percentile) obtained for e-cigarettes environmental aerosols after background subtraction.
** the value for e-cigarettes is equivalent to the background value "-".

The non-parametric Kruskal-Wallis method was applied for the global assessment of the impact of each e-cigarette (Solaris KS, Nicolites and Vivid) on the indoor levels of the analytes when compared to the background concentrations with panellists present in the room.

The evaluation of the results showed that the concentrations in background and environmental aerosol of tested e-cigarettes could be considered as equivalent for five of the analytes - RSP-gravimetric, 3-ethenylpyridine, acetaldehyde, formaldehyde and TVOC expressed as toluene equivalent.

Nicotine, glycerin and propylene glycol levels were higher in indoor air compared to background levels in all studied brands. The measured median levels for these compounds in indoor air following e-cigarettes use were considerably lower than the few guideline values that exist for these compounds. Indeed the guideline levels are at least 50 times above the maximum median levels for all tested brands and well over 100 times above the maximum median levels in most cases.

Guideline levels

- nicotine: 500 µg/m³ (Commission Directive 2006/15/EC)
- glycerin: 10 000 µg/m³ (ACGIH, 2001)
- propylene glycol: 10 000 µg/m³ (AIHA, 2011)

Conclusions

Under the simulated 'residential category II' environmental condition, the concentrations of five of the eight analytes (RSP-gravimetric, 3-ethenylpyridine, acetaldehyde, formaldehyde and TVOC expressed as toluene equivalent) in the environmental aerosol of Solaris KS, Nicolites and Vivid were similar to the background levels. The levels of nicotine, glycerin and propylene glycol were increased above background, however they were at least 50 times below the few guideline values that exist for these compounds.

In summary, under the simulated 'residential category II' environmental condition and on the measured indoor air quality parameters, no negative impact on the overall indoor air quality was observed when using e-cigarettes in an indoor environment.

References

- American Conference of Governmental Industrial Hygienist (ACGIH, 2001). Documentation of Threshold Limit Values and Biological Exposure Indices for Glycerin Mist. 6th edition, 705-706
- American Industrial Hygiene Association (AIHA, 2011). Workplace Environmental Exposure Level Guide for Propylene Glycol
- Commission Directive 2006/15/EC, 7 February 2006 establishing a second list of indicative occupational exposure limit values in implementation of Council Directive 98/24/EC and amending Directives 91/322/EEC and 2000/39/EC
- Nicolas Mottier, Manuel Tharin, Camille Cluse, Jean-René Crudo, María Gómez Lueso, Catherine G. Goujon-Ginglinger, Anne Jaquier, Maya I. Mitova, Emmanuel G.R. Rouget, Mathieu Schaller, Jennifer Solioz., Validation of selected analytical methods using accuracy profiles to assess the impact of a Tobacco Heating System on indoor air quality, Talanta 2016, 158, 165-178
- ABBREVIATIONS:IAC: Indoor Air Chemistry, TVOC: Total Volatile Organic Compounds, BKG: background, EC: European Commission, EU: European Union; RSP: Respirable Suspended Particles

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Competing Financial Interest

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