Assessment of toxicant and carcinogen concentrations in electronic cigarette liquid and aerosol

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Introduction

Characterization of electronic cigarette (e-cig or ENDS) emissions is important to inform users about the toxicants to which they may be exposed.

Objective

To determine the concentrations of several toxicants in emissions of an ENDS used in an ongoing clinical trial on smoking cessation (ESTxENDS*):

- volatile organic compounds (VOCs)
- aldehydes
- tobacco-specific nitrosamines (TSNAs)
- and metals (their source was also investigated)

Methods

The selected ENDS was Innokin Endura T20-S device equipped with Innokin Prism-S coil (0.8 Ω). E-liquids were "Alfaliquids" (Gaïatrend) with six flavors.

ENDS aerosols were generated with a vaping machine (Figure 1) that was developed in our laboratory according to CORESTA recommended method n°81.[1]

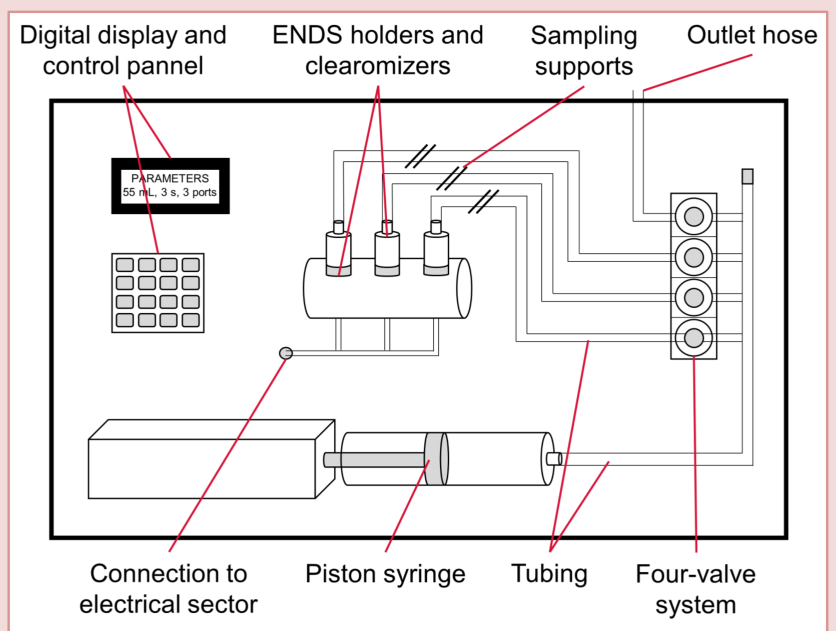

Figure 1 – Schematic view of the vaping machine

Table 1 lists the selected compounds and the analytical methods used.

An elemental analysis was also performed on different components of an ENDS coil (Figure 2) by scanning electron microscope equipped with an energy dispersive X-ray spectrometer and a backscattered electron detector.

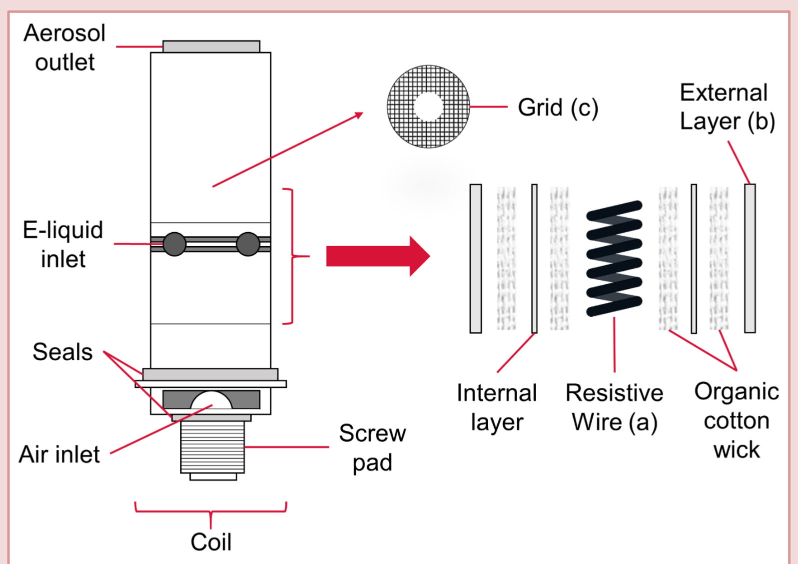

Figure 2 – Description of the ENDS coil composition

Table 1 – List of selected compounds with their number per chemical family (volatile organic compounds (VOCs), aldehydes, tobacco-specific nitrosamines (TSNAs), and metals), summary of the collection methods (including type of sampling support), and analytical instrument. Metals are represented by chemical symbols in order of atomic number.

Family	Compounds	Collection methods	Instruments
VOCs (n=7)	1,3-butadiene, acrylamide, acrylonitrile, benzene, isoprene, naphthalene, toluene	Cryogenic trap (-70°C, impingers with methanol)	Gas chromatography – mass spectrometry (GC-MS)
Aldehydes (n=5)	acetaldehyde, acrolein, crotonaldehyde, formaldehyde, propanal	DNPH derivatization (impingers)	Liquid chromatography – UV detection (HPLC-UV)
TSNAs (n=4)	NAB, NAT, NNK, NNN [1]	Cryogenic trap (-70°C, plastic centrifuge tubes)	Liquid chromatography – mass spectrometry (LC-MS)
Metals (n=20)	Be, Al, V, Cr, Mn, Fe, Co, Ni, Cu, Zn, As, Se, Mo, Pd, Ag, Cd, Sn, Sb, Pt, and Pb	Cryogenic trap (-70°C, plastic centrifuge tubes)	Inductively coupled plasma mass spectrometry (ICP-MS)

[1]N-nitrosoanabasine (NAB), N-nitrosoanatabine (NAT), 4-(methylnitrosamino)-1-(3-bipyridyl)-1-butanone (NNK), and N-nitrosonornicotine (NNN).

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Results

These compounds were detected in ENDS emissions:

- VOCs – none of the selected
- Aldehydes – formaldehyde and acetaldehyde (Table 2)
- TSNAs – none of the selected
- Metals – Zn, Cu, Pb, Al, Ni, and Fe (Table 3)

Figure 3 presents the elemental composition of an ENDS coil.

Table 2 – Concentrations of formaldehyde and acetaldehyde in ENDS aerosols of six flavored e-liquids, expressed in micrograms per gram e-liquid (µg/g e-liq) as mean with standard deviation (nine replicates per flavor).

Flavors	Formaldehyde (µg/g e-liq)	Acetaldehyde (µg/g e-liq)	Comparaison to tobacco smoke[2]
Tobacco (FR-M)	9.2 (2.3)	6.5 (1.4) [1]	●
Tobacco (FR4)	3.6 (0.5) [1]	<LOQ	●
Fresh mint	3.1 (1.2) [1]	<LOQ	●
Red fruits	8.2 (3.8) [1]	<LOQ	●
Raspberry	<LOQ	<LOQ	●
Green apple	12.1 (2.1)	6.9 (1.3)	●

[1]One or more replicates were below limit of quantification (<LOQ) of 0.05 µg/mL (corresponding to ~5 µg/g e-liq);[2]20 cig/day
Results expressed in ng/puff can be calculated considering that one puff consumed about 9.22 ± 0.66 mg of e-liquid.

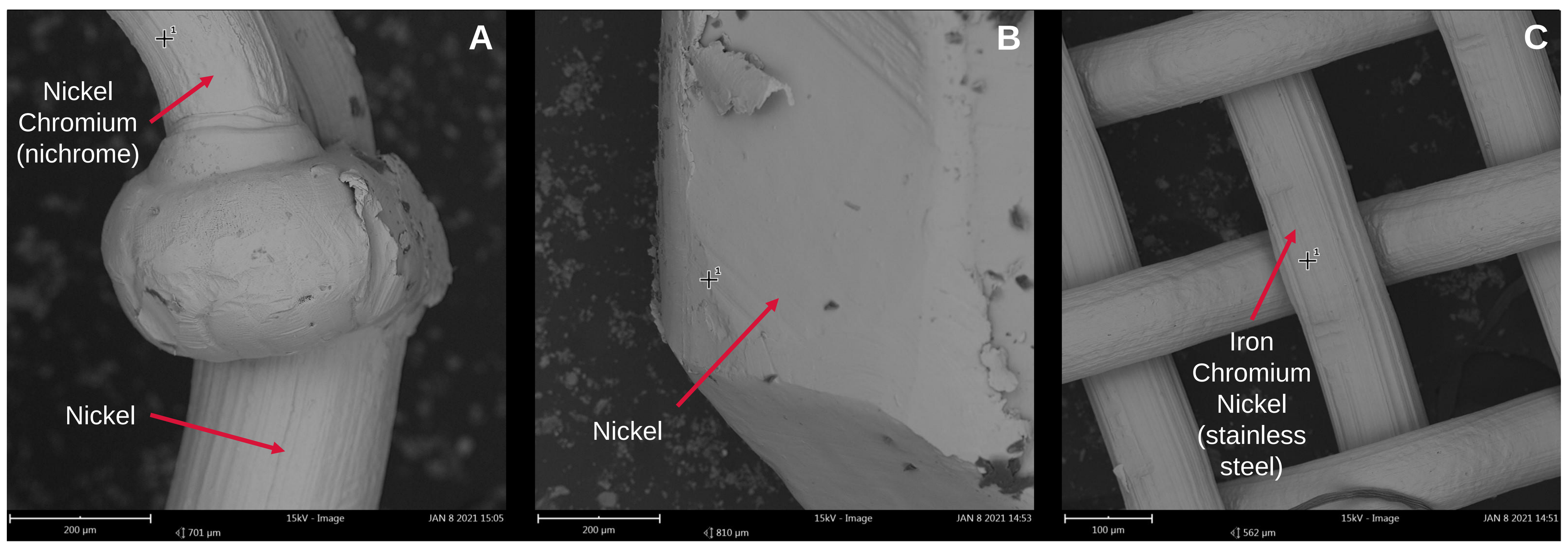

Figure 3 – Backscattered electron images of resistive wire (A), external layer (B), and grid (C) and elemental composition

Table 3 – Metal concentrations in e-liquids and ENDS aerosols, expressed in nanograms per gram e-liquid (ng/g e-liq) as mean with standard deviation. We analysed all six flavored e-liquids and nine replicates for aerosols (one flavor only). Metals are classified by decreasing aerosol metal concentrations.

Metals	E-liquid (ng/g e-liq)	Aerosol (ng/g e-liq)	Comparaison to tobacco smoke[3]
Zinc (Zn)	15.1 (16.9) [1]	797 (272)	● (green)
Copper (Cu)	7.66 (6.58)	640 (348)	● (orange)
Lead (Pb)	1.06 (1.32)	265 (99.0)	● (orange)
Aluminum (Al)	<LOQ [2]	191 (78.7)	● (green)
Nickel (Ni)	2.72 (2.10)	166 (44.3)	● (orange)
Iron (Fe)	8.78 (10.5)	161 (89.0)	● (green)

[1]Five replicates were below limit of quantification (LOQ) of 1 ng/mL for zinc; [2]LOQ for aluminum was 5 ng/mL;[3]20 cig/day.
Metals with concentrations below 10 ng/g e-liq in e-liquid and aerosol were not included in the table. Results expressed in ng/puff can be calculated considering that one puff consumed about 8.87 ± 0.09 mg of e-liquid.

Conclusion

The tested ENDS did not emit significant concentrations of the selected VOCs, TSNAs, and aldehydes. We found several metals in ENDS aerosol and showed that they did not originate from the e-liquids, but from the metallic components of the device. Smokers would still benefit from switching to ENDS, but it is essential to better control the quality of materials used in the manufacture of these devices.

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Reference: [1]Cooperation Center for Scientific Research Relative to Tobacco (CORESTA): Recommended Method n°81. Routine Analytical Machine for E-Cigarette Aerosol Generation and Collection – Definitions and Standard Conditions; (2015). Available at: https://www.coresta.org/sites/default/files/technical_documents/main/CRM_81.pdf (accessed August 2021)

Image source: ENDS pictures originated from Innokin.fr (INNOKIN France) and have been modified.