Determination of Volatile Organic Compounds in E-Cigarette Liquids and Aerosols by GC-MS

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ABSTRACT

In May 2016, the U.S. Food and Drug Administration (FDA) issued the final rule[1] to extend its authority to regulate electronic cigarettes (e-cigarettes) and published the draft guidance Premarket Tobacco Product Application for Electronic Nicotine Delivery Systems.[2] FDA recommends reporting the quantities of designated Harmful and Potentially Harmful Constituents (HPHCs) in e-liquids and aerosols, which include the following volatile organic compounds (VOCs): 1,3-butadiene, isoprene, acrylonitrile, benzene, and toluene. VOCs are found in mainstream cigarette smoke;[3] however, generation of aerosol from an e-cigarette does not involve combustion, for this reason VOCs are not anticipated to be present. This work describes a gas chromatography-mass spectrometry (GC-MS) method for determining these VOCs in e-cigarette liquids and aerosols using a method based on CORESTA Recommended Method No 70.[4]

OBJECTIVE

- Develop and validate a sensitive and selective method for the determination of VOCs in e-liquids and aerosols
- Determine the transfer efficiency of VOCs to the aerosol from fortified reference e-liquids
- Analyze commercial e-liquids and e-cigarette devices covering a range of nicotine concentrations and propylene glycol/glycerin ratios for VOCs

ANALYTICAL METHOD

Parameters	Description
Instrument	Agilent 7890B GC / 5977A MSD
GC Column	RTX-624 30 m x 0.25 mm ID x 1.4 µm df
Oven Program	40 ℃ hold for 6 min, 20 ℃ /min to 235 ℃ hold for 3 min
Injection Volume	1.0 µL
Injection Port Temperature	250 ℃
Injection Mode	Split (100:1)
Flow Rate	1.0 mL/min
Transfer Line Temperature	240 ℃
Source Temperature	230 ℃
Quadrupole Temperature	150 ℃
Run Time	18.8 min

Aerosol Collection and Sample Preparation

25 puffs collected on CFP
(55 mL volume, 5 s duration, 30 s interval, square wave)

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Fritted impinger containing 20 mL methanol (-70 °C)

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Aerosol: Discard CFP; add internal standards to cold impinger solution
E-liquid: Add 0.3 g e-liquid to 10 mL methanol; add internal standards

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Transfer sample to autosampler vial with little to no headspace

CFP = Cambridge filter pad

Validation Matrices: E-liquids and E-cigarettes

Sample ID	Used in E-cig	PG/Gly (%)	Water (%)	Nicotine (%)	VOC Fortification
E-liquid 1	No	50/50	15	2.5	None
E-liquid 2	Yes	50/50	15	0	None
E-liquid 3	Yes	50/50	0	2.5	None
E-liquid 4	No	100/0	15	0	None
E-liquid 5	No	0/100	15	0	None
E-liquid Low	Yes	50/50	15	2.5	Low
E-liquid High	Yes	50/50	2.5	0	High

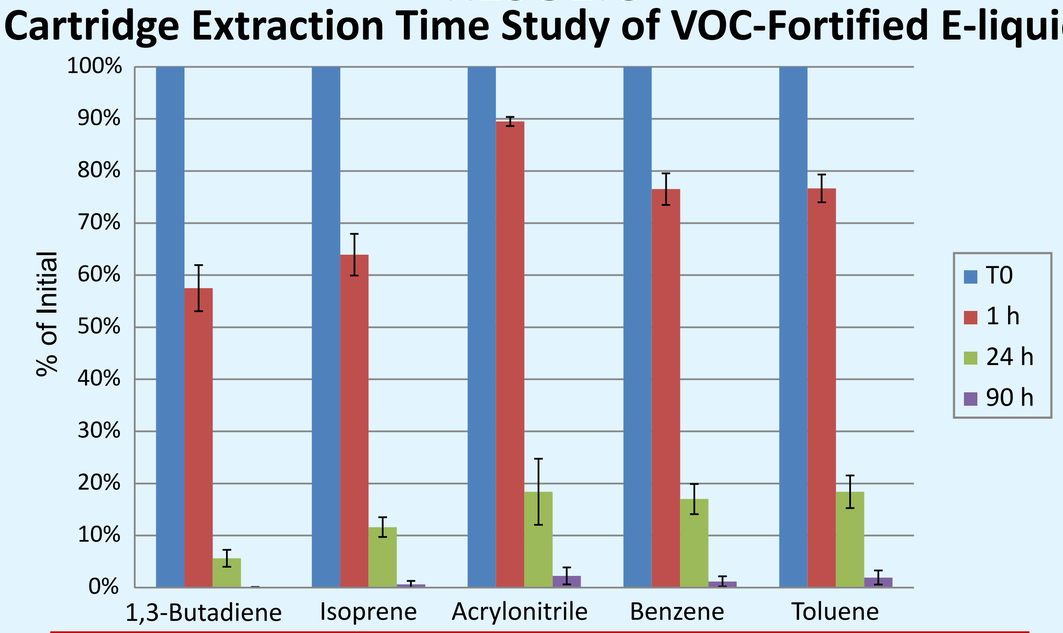
Validation Summary

Parameter		1,3-Butadiene	Isoprene	Acrylonitrile	Benzene	Toluene
Linearity	R^2	≥ 0.999	≥ 0.999	≥ 0.999	≥ 0.999	≥ 0.999
	Range (µg/mL)	0.1 – 4.0	0.5 – 20	0.05 – 2.0	0.1 – 4.0	0.2 – 8.0
Trapping Efficiency	Aerosol (%)	> 99	> 99	> 99	> 99	> 99
E-liquid Low	E-liquid (µg/g)	9.4	48.3	4.84	9.64	19.4
E-liquid High	Aerosol* (µg/g)	45.7	232.4	23.3	46.4	93.2
Recovery	E-liquid (%)	79 – 81	82 – 82	89 – 89	89 – 97	89 – 90
	Aerosol (%)	78	78	80	84	80
3-day Precision	E-liquid (%RSD) (n=6)	≤ 3.6	≤ 3.6	≤ 4.7	≤ 2.1	≤ 1.5
	Aerosol (%RSD) (n=15)	≤ 12.0	≤ 7.9	≤ 1.8	≤ 2.2	≤ 2.5
LOD	E-liquid (µg/g)	0.7	1.7	0.8	0.7	0.7
	Aerosol* (µg/g)	3.2	8.0	4.0	3.2	3.2

*Assume aerosol mass = 0.125 g

RESULTS

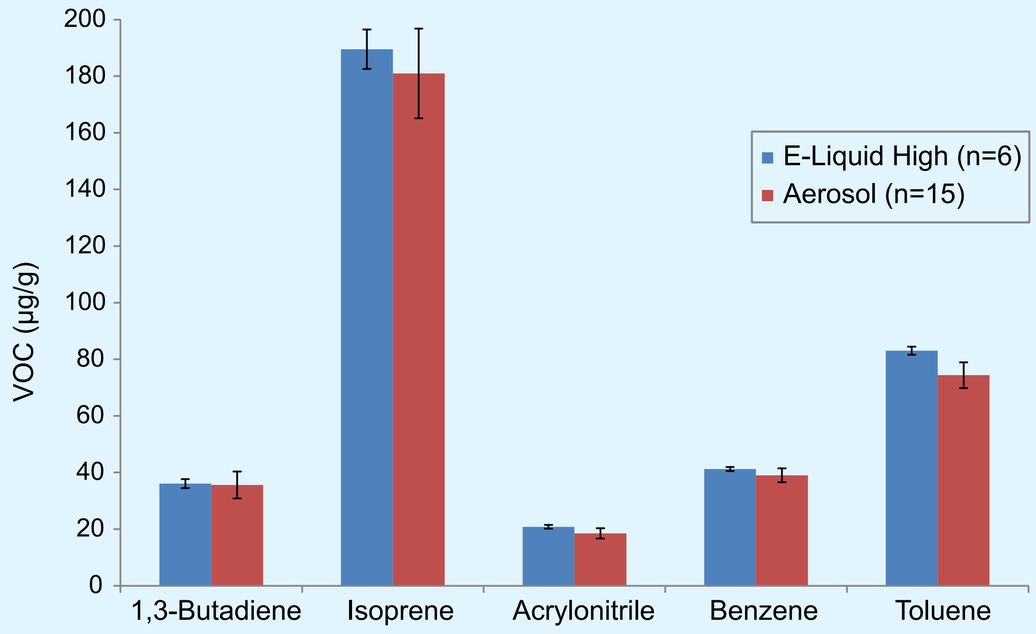
Cartridge Extraction Time Study of VOC-Fortified E-liquid



≥ 98% of VOCs were lost within 90 hours of filling the cartridges

Transfer Efficiency Study

Fortified e-cigarette cartridges were used within 1 hour of filling to minimize losses



≥89% of VOCs were transferred to the aerosol

Survey of Commercial Products

- 13 commercial e-liquids covering a range of nicotine concentrations and propylene glycol/glycerin ratios were analyzed for VOCs. The e-liquids included the following flavor profiles: sweet, fruit, coffee/tea extract, and tobacco.
- The e-liquids and aerosols from 6 top-selling commercial devices including MarkTen® XL Classic and MarkTen® XL Menthol were analyzed for VOCs.

VOCs were not detected in commercial e-liquids or e-cigarette aerosols

SUMMARY

- This method was validated for the quantitative analysis of five VOCs in e-liquids and aerosols.
- Due to the volatility of these analytes, there was essentially complete loss of all the fortified analytes within 3.5 days.
- VOCs were not detected in 13 commercial e-liquids or 6 commercial e-cigarette products.
- These results were anticipated because e-cigarette aerosol formation does not involve combustion of tobacco. VOCs are not stable in e-liquids or cartridges under ambient sample storage and handling conditions.

This poster may be accessed at www.altria.com/ALCS-Science

REFERENCES

1. FDA (2016) Deeming Tobacco Products To Be Subject to the Federal Food, Drug, and Cosmetic Act, as Amended by the Family Smoking Prevention Tobacco Control Act; Restrictions on the Sale and Distribution of Tobacco Products and Required Warning Statements for Tobacco Products. Federal Register Rules and Regulations, 81:28974-29106.
2. FDA (2016) Premarket Tobacco Product Application for Electronic Nicotine Delivery Systems; Draft Guidance for Industry; Agency Information Collection Activities; Proposed Collection; Comment Request. Federal Register Proposed Rules, 81:28781-28783.
3. Liu C, Feng S, van Heemst J, McAdam KG (2010) New insights into the formation of volatile compounds in mainstream cigarette smoke. Analytical and Bioanalytical Chemistry 396:1817-1830.
4. CORESTA (2014) Recommended Method No. 70 Determination of Selected Volatile Organic Compounds in Mainstream Cigarette Smoke by GC-MS.