# Exploring the side effects of vaping (electronic cigarette)

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**Abstract**

The last decade, there has been a significant increase trend towards the use of electronic cigarettes (e-cigarettes), especially among young people. Different concentrations of propylene glycol (PG) or glycerin (VG), flavorings and nicotine are mixed in plastic cartridges and commercially offered or privately produced by the vaporists. During vaping, a mixture of air and vapors is inhaled to the lungs. Since smoke is not burned but vaporized (heated), less chemicals are emitted. The expired air of vaporists was analyzed by Solid Phase Micro Extraction - Gas Chromatography/Mass Spectrometry (SPME-GC/MS) and the emitted volatile organic compounds (VOCs) were compared with that of healthy and smoke individuals. The levels of VOCs emitted after vaping appeared to be lower compared to that of conventional smoking (from combustible cigarettes). Nevertheless, specific VOCs associated with e-liquid flavors were detected (e.g. 1,2-ethanediol diacetate, ethyl acetate, D-limonene, acetic acid-phenyl ester, 1-butanol 3-methyl-acetate and benzyl alcohol) along with PG. The wide range of available flavors and their purity along with the heated temperature are important parameters affecting the evolution of VOCs. Therefore, the potential health, safety and environmental effects of vaping are examined and discussed.

**Keywords:** e-cigarette, SPME-GC/MS, VOCs, human breath.

## Introduction

Over the last decade, e-cigarettes that emulate smoke with a smoke-free technique appears increasingly on the market in Western countries. By 2025, the global e-cigarette market is expected to reach over $50 billion. The main constituents of e-liquids are flavors (commercially available 7700 flavors) [1] and usually nicotine, which are dissolved in propylene glycol (PG) and/or glycerol (VG) [2-4]. E-cigarette can contain harmful and/or potentially harmful substances, including nicotine, heavy metals, VOCs (Volatile Organic Compounds such as acetaldehyde, acrolein, formaldehyde), and probably some cancer-causing agents [5]. The worldwide rise of vaping has attracted the interest of scientists because of their related health and environmental effects.

According to various studies in literature, e-cigarette is still not considered a safe product because [3, 6]: (a) Propylene glycol can cause respiratory irritation and may increase the risk of asthma, (b) Glycerol can cause lipid pneumonia when inhaled, (c) Nicotine is addictive. Rechargeable cartridges with high nicotine content are potentially life-threatening, especially for children, (d) Some aerosols contain carcinogens substances, (e) The possible effects of the use of e-cigarettes on health are not yet all known.

Although e-cigarettes still contain some dangerous and carcinogenic substances for humans, VOCs emitted by vaporists appear to be in smaller quantities than in conventional cigarettes. In the present study, a holistic approach of vaping side effects is explored and discussed.

## Material and Methods

Volunteers were asked to blow calmly in 1 L Tedlar bags (Supelco, USA). The bags were previously cleaned with pure nitrogen flows and heated at 100 $^{o}$C for more than 24 hours to remove residual contaminants. The VOCs of exhaled breath were collected in tedlar bags (Fig. 1) and extracted by Solid Phase Microextraction (SPME) for 30 min (75μm CAR/PDMS, Supelco). The VOCs were then analysed by Gas Chromatography/Mass Spectrometry (GC/MS 7890B/5977B, Agilent Technologies) in splitless mode.

**Fig. 1** Extraction of SPME fiber into a Tedlar bag.

Desorption time of SPME was for 1 minute at 280 $^{o}$C in the GC injector. VOCs were separated using a SPB$^{TM}$-624 capillary column (60m × 0.25mm × 1.4 µm film thickness, Supelco) working with helium constant flow (1.7 mL/min). The column temperature program was: 35 °C for 5 min, increase at a rate of 4 °C/min to 180 °C and 180 °C for 20 min. The MS worked in full SCAN mode, in the scan range of 35–350 amu. The scan rate was set at 2.3 scan per second. The temperature of the ion source, quadrupole and transfer line was 230 °C, 150 °C and 250 °C, respectively. The electron impact ionization was at 70 eV.

Chromatographic peaks were identified with the help of NIST11 mass spectral library and confirmed by comparing the retention times with the retention times obtained from a standard mixture consisting of 60 VOCs (EPA 524 VOC Mix A).

## Results and Discussion

The exhaled air consists of (a) Inorganic gases: ~78% nitrogen, 14%-17% oxygen, ~4% carbon dioxide, 0.96% argon, 0.5-2 ppm ammonia, some ppm of hydrogen, 0-6 ppm carbon monoxide, (b) Organic volatiles: less than 1 ppm acetone, isoprene, methanol, ethanol, hundreds of other VOCs in the lower ppb levels and (c) Humidity: 5.0-6.3% water vapor [7, 8].

A representative SPME-GC/MS chromatogram of the exhaled air from a healthy person is shown in Fig. 2.

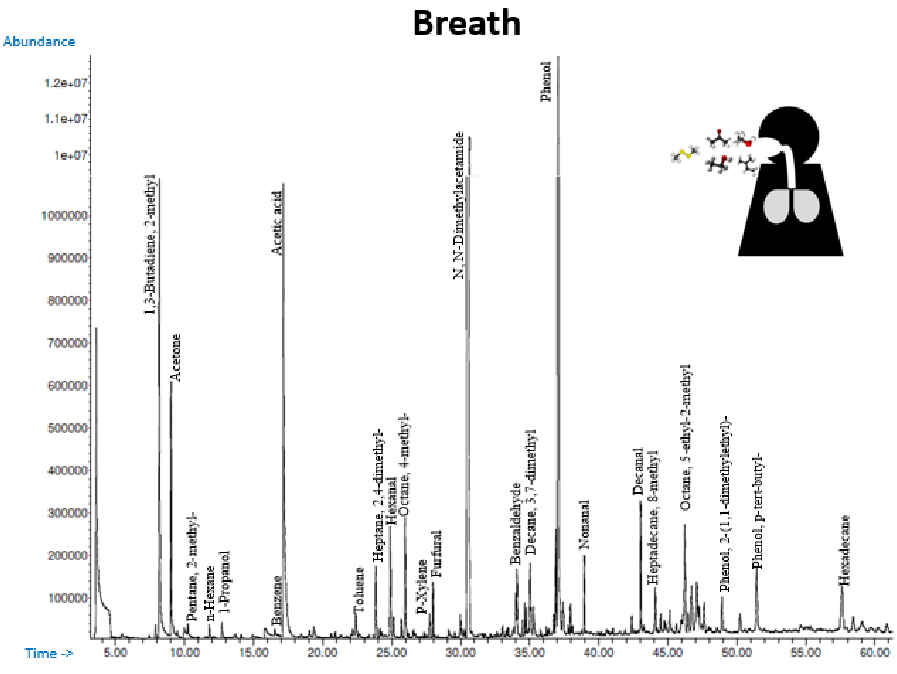


**Fig. 2** Chromatogram of exhaled air sample of a healthy person.

Hundreds of endogenous VOCs are internally produced as a function of human metabolism. At the same time, many others enter the human body through food, medication and exposure (exogenous VOCs). Table 1, presents some compounds that were identified in the breath of a healthy-non smoker individual, with SPME-GC/MS.

**Table 1.** Indicative VOCs in the breath of a healthy-non smoker individual.

| Retention Time ($R_t$) | VOCs |
|---|---|
| 8.179 | 1,3-Butadiene, 2-methyl |
| 9.017 | Acetone |
| 10,234 | Pentane, 2-methyl- |
| 11,524 | 1-Pentene, 2-methyl- |
| 11,782 | n-Hexane |
| 12,691 | 1-Propanol |
| 14,088 | 2-Butanone |
| 17,154 | Acetic acid |
| 21,745 | Acetoin |
| 23.844 | Heptane, 2,4-dimethyl |
| 24.883 | Hexanal |
| 25.972 | Octane, 4-methyl- |
| 30,506 | N,N-Dimethylacetamide (from Tedlar bag) |
| 37,067 | Phenol (from Tedlar bag) |
| 43,027 | Decanal |

In general, substances emitted during smoking and exist in tobacco are divided into [9]: (a) Nicotine and its derivatives, (b) Tobacco-specific nitrosamines (TSNAs), (c) VOCs (e.g. Benzene), (d) Polycyclic aromatic hydrocarbons (PAHs – e.g. pyrene), (e) Inorganic elements (e.g. cadmium), (f) Solid and liquid airborne particles, many of which are hazardous (Particulate Matter) and (g) Carbon monoxide.

A representative chromatogram of the exhaled air from a smoker is shown in Fig. 3. Table 2, shows a number of compounds that were found in the breath of a smoker individual.

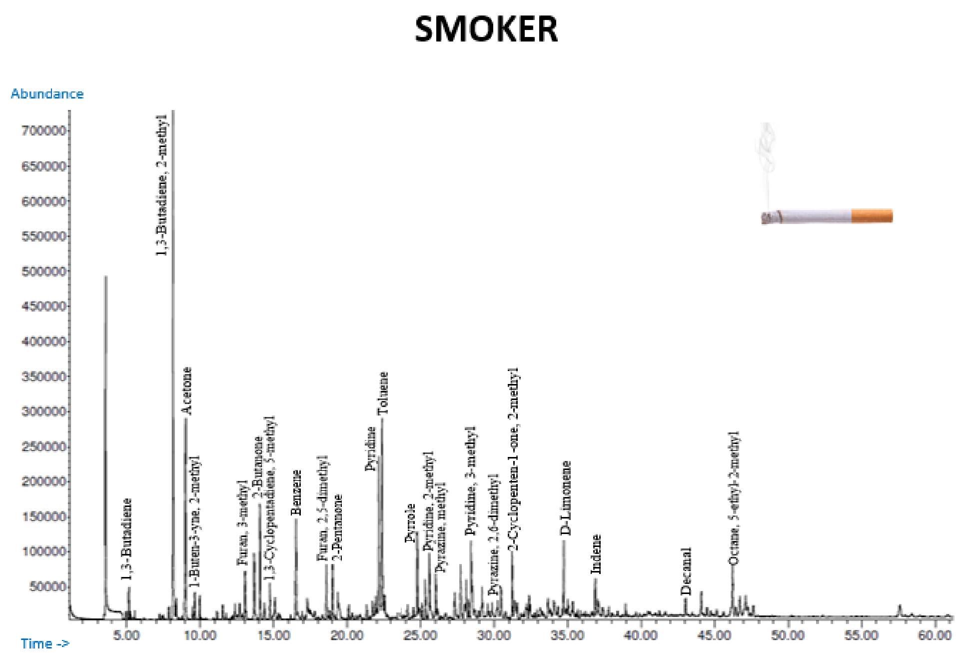


**Fig. 3** Chromatogram of exhaled air sample of a smoker.

**Table 2.** Indicative VOCs determined in the breath of a smoker individual.

| $R_t$ | VOCs |
|---|---|
| 14,367 | Propanenitrile |
| 16,523 | Benzene |
| 16,645 | Isobutyronitrile |
| 17,798 | 2-Butenenitrile |
| 18,329 | Furan, 2-ethyl |
| 18,601 | Furan, 2,5-dimethyl- |
| 21,337 | Pyrazine |
| 22,146 | Pyridine |
| 22,383 | Toluene |
| 24,775 | Pyrrole |
| 25,592 | Pyridine, 2-methyl- |
| 27,984 | Furfural |
| 29,195 | Styrene |
| 34,832 | Benzofuran |
| 36,609 | 2,4-Dimethylfuran |

E-cigarette fluids vary widely in respect to the PG to VG ratio. This ratio determines the amount of steam that the user prefers to produce. High PG ratios produce less vapor and greater sense of inhalation. High VG ratios produce a vapor mass that is denser, bulkier and has less sensation in the neck and mouth [10].

The volatile substances emitted by an e-cigarette user were compared in relation to a smoker and a healthy person. E-cigarette aerosol (Fig. 4) contains significantly less VOCs than the aerosol from conventional cigarettes.

The SPME-GC/MS analyses applied to e-cigarette users revealed that the aerosol from e-cigarettes consists of specific VOCs associated to the flavors of the e-liquids. When smokers' and vaporists' breath were compared with that of healthy-non smoker persons, there was a high increase in the amount and number of the exhaled VOCs. Table 3, shows some characteristic compounds that were found in the breath of a vaporist.

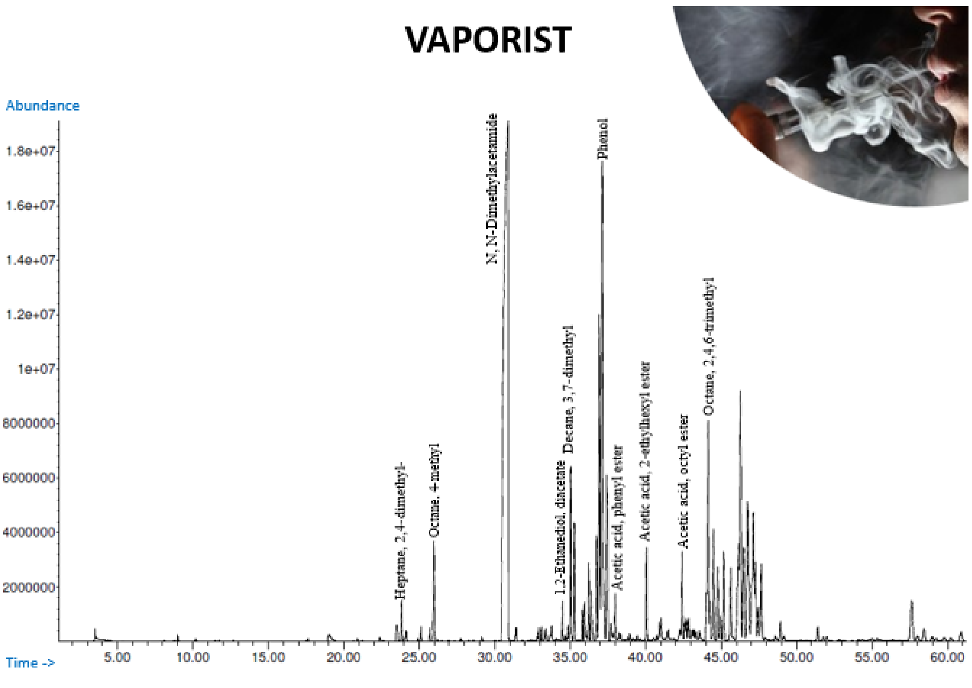


**Fig. 4** Chromatogram of exhaled air sample of a vaporist.

**Table 3.** Indicative VOCs found in the breath of a vaporist.

| $R_t$ | VOCs |
|---|---|
| 11,753 | n-Hexane |
| 12,24 | Methacrolein |
| 12,67 | 1-Propanol |
| 13,057 | Furan, 3-methyl |
| 18,486 | Trichloroethylene |
| 22,39 | Toluene |
| 22,627 | Octane |
| 24,052 | Propanoic acid |
| 28,271 | Butanoic acid |
| 28,586 | Pyridine, 2,6-dimethyl |
| 28,937 | 3-Hexen-1-ol, (E)- |
| 29,131 | o-Xylene |
| 29,983 | Heptanal |
| 34,087 | 5-Hepten-2-one, 6-methyl |
| 34,489 | 1,2-Ethanediol,diacetate |
| 34,653 | Octanal |
| 34,768 | D-Limonene |
| 35,799 | 1,2-Propanediol, diacetate |
| 37,705 | 1-Octanol |
| 37,984 | Acetic acid, phenyl ester |

Another issue of concern, is the wide range of commercial flavors, their purity and the heating temperature; the latter, changes according to the e-cigarette device (Fig. 5).

**Fig. 5** The four main categories of e-cigarettes.

An e-liquid (e.g. strawberry flavor), is not just a single compound but a complex mixture of VOCs (as shown in Fig. 6). Other known commercial flavors are that of biscuits, watermelon, pineapple, whiskey, cappuccino, hazelnut, etc.; this list is endless.

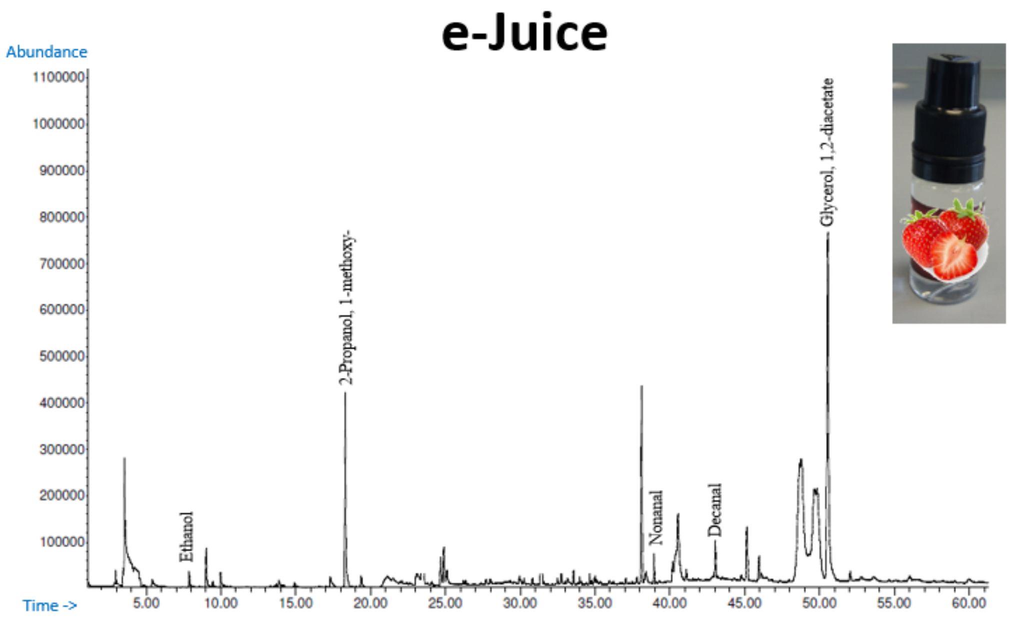


**Fig. 6** Chromatogram of e-juice (strawberry).

The chemical composition of the aerosol may be different from the liquid, since the use of the electronic cigarette requires the heating of the liquid and under these conditions, due to various chemical reactions, new compounds may be formed. According to the literature, the main compounds produced are shown in Fig. 7.

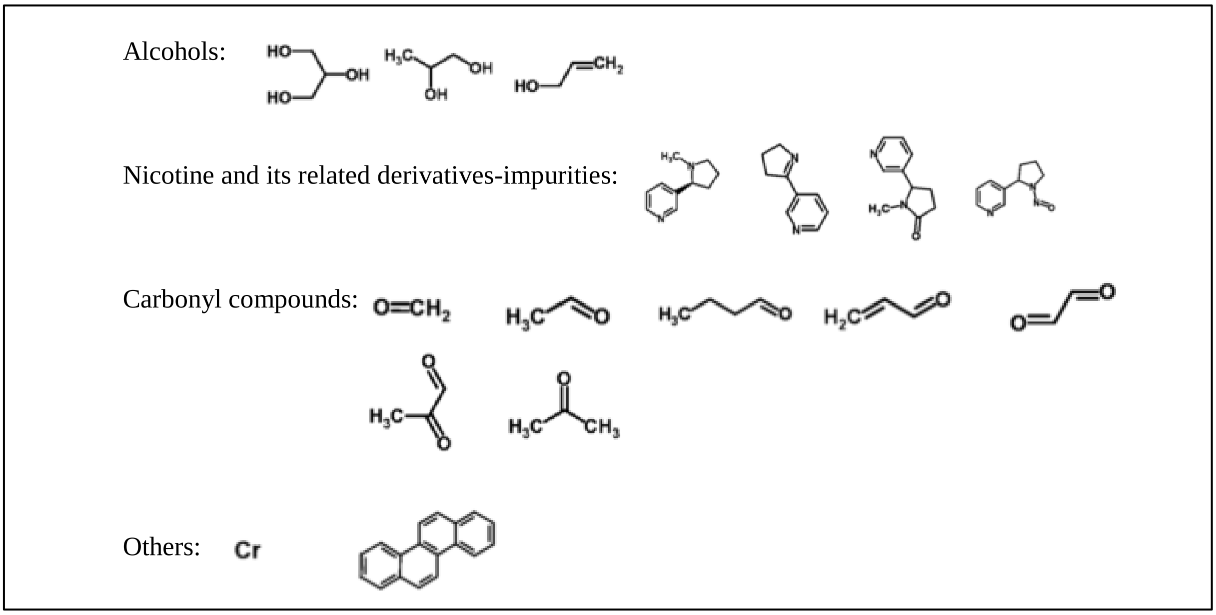


**Fig. 7** Emissions from electronic cigarette [11].

Another issue of major concern is the appropriate disposing of “vape” cartridges and lithium ion batteries. E-cigarettes leftovers are increasing and probably require hazardous waste management.

That is why further research is needed to solve the questions that exist in relation to the widespread use of e-cigarettes.

## Conclusions

E-cigarettes emerge as a hot trend in modern society. The analysis of VOCs in the exhaled breath of vaporists was performed using the SPME-GC/MS method. Specific chemical moieties associated with the e-cigarette were detected and discriminated from the breath of smokers and non-smokers individuals. Long term epidemiological and toxicological studies are required to fully explore the potential health, safety and environmental effects of e-cigarette usage.

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