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中国烟草总公司
郑州烟草研究院

Key parameters affecting the release of aldehydes in e-cigarette aerosols

FAN Meijuan

Zhengzhou Tobacco Research Institute of CNTC

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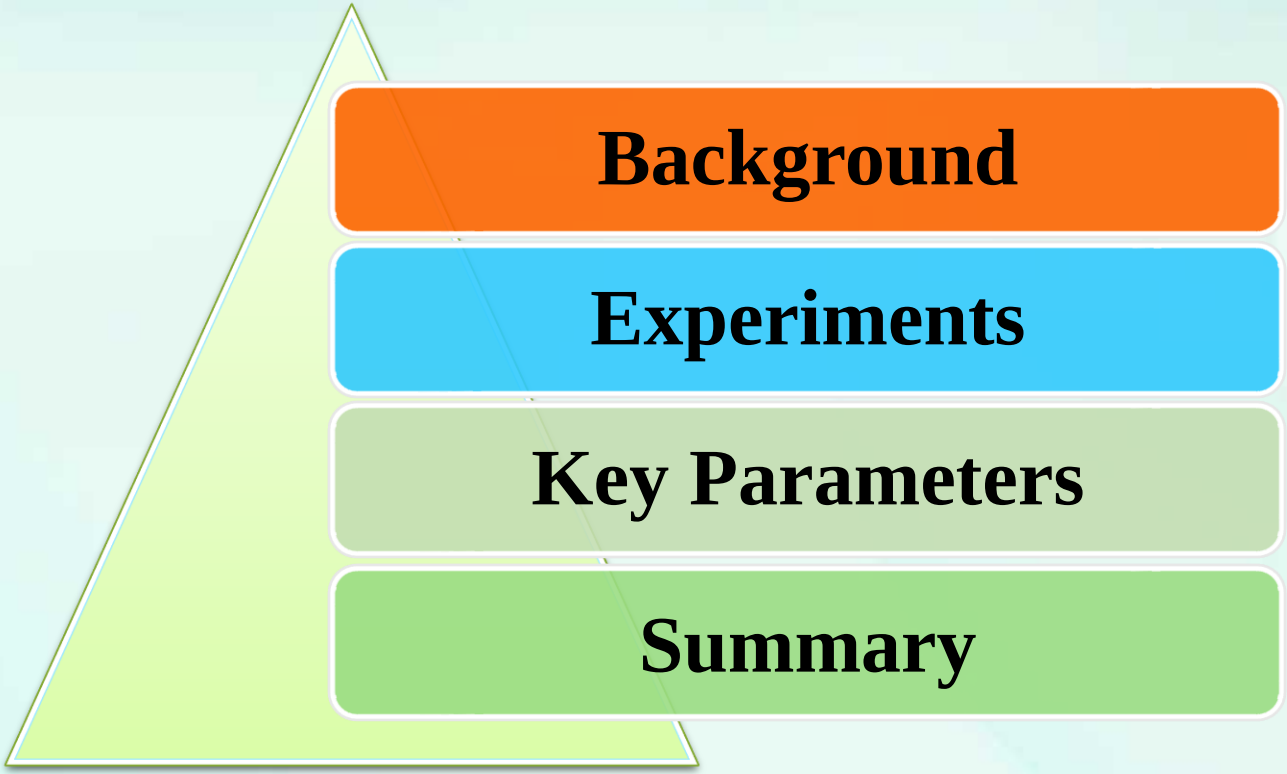
Outline



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Background

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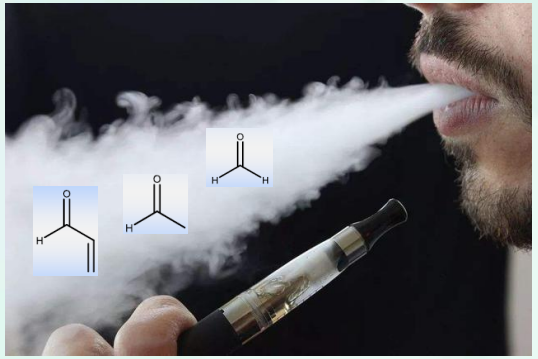
Aldehydes in e-cigarette aerosols



- **Formaldehyde** is a Group 1 human carcinogen as classified IARC
- **Acetaldehyde** is regarded as a Group 2B possible human carcinogen
- **Acrolein** is toxic, is a strong irritant for the skin, eyes, etc.

Requirements

- **US FDA** recommends consider formaldehyde, acetaldehyde and acrolein in aerosols (Premarket Tobacco Product Applications for Electronic Nicotine Delivery Systems)
- **Afnor XP D 90-300-3** recommends target values for formaldehyde (200), acetaldehyde (3200) and acrolein (16 μg/200Puffs)
- **BSI PAS 54115** monitor formaldehyde, acetaldehyde and acrolein in aerosols

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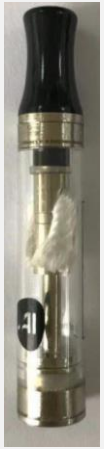
Experiments

- **Key Parameters**

E-liquid

- moisture content
- V_{PG}: V_{GLY}
- nicotine content

E-cig device



- power output

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Experiments

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Sample

- Refillable e-cigs
- Basic solution（PAS 54115）：78 % v/v propylene glycol (PG), 18 % v/v glycerol(GLY), 2 % v/v purified water, and 2 % v/v nicotine
- Vaping condition（ISO 20768:2018）：Puff duration 3 s, Puff volume 55 mL, Puff frequency 30 s. Puff number 50

Methods

- Determination of formaldehyde, acetaldehyde and acrolein in aerosol of e-cigs
- Study on vaporization temperature of e-cigs

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Key Parameters—moisture content

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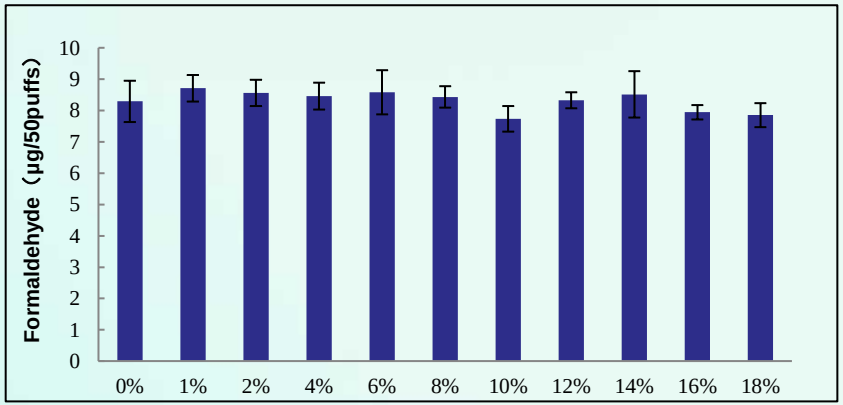
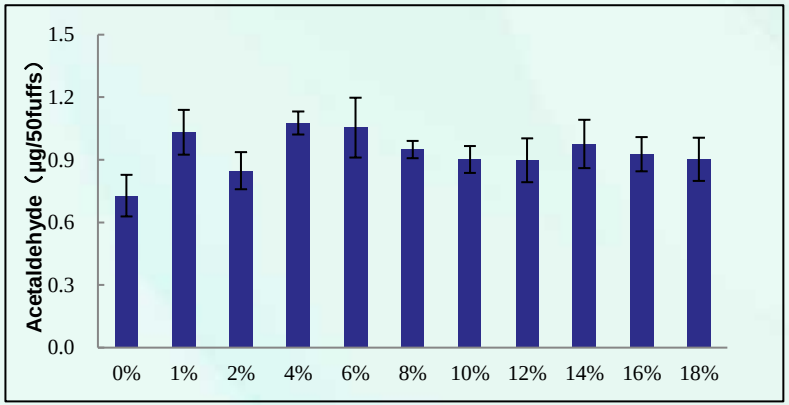
- **moisture content**
  - **0、1 %、 2 %、 4 %、 6 % 、8 %、10 %、12 %、14 %、16 % and 18 %（V_{PG}:V_{GLY}:V_{NIC}=78:18:2）**
  - **formaldehyde：7.74~8.72 μg/50 puffs，acetaldehyde：0.85~1.08 μg/50 puffs，acrolein: ND**
  - **moisture content have little effect**





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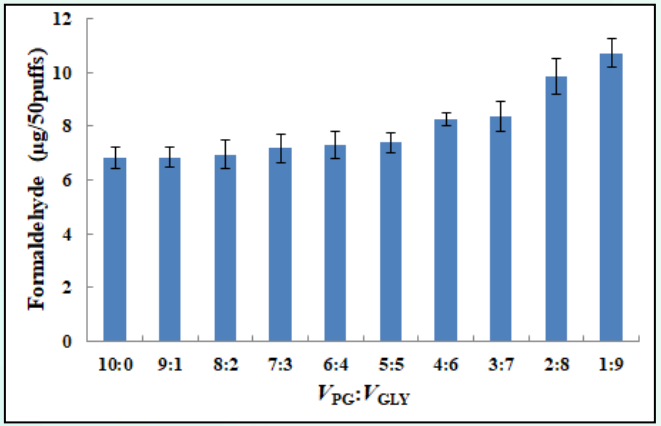
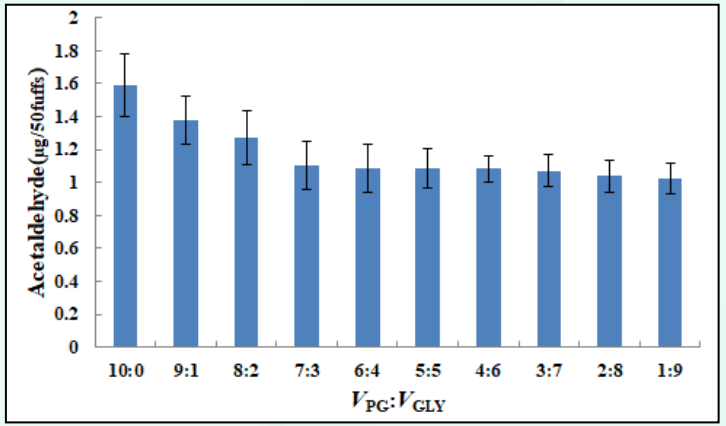
Key Parameters—V_{PG}:V_{GLY}

- V_{PG}:V_{GLY}
  - 10:0、9:1、8:2、7:3、6:4、5:5、4:6、3:7、2:8、1:9 (V_{water}:V_{NIC}=2:2)
  - formaldehyde：6.83~10.73 μg/50 puffs，acetaldehyde：1.03~1.59 μg/50 puffs
  - With the increase of GLY, the generation of formaldehyde increased, and acetaldehyde decreased





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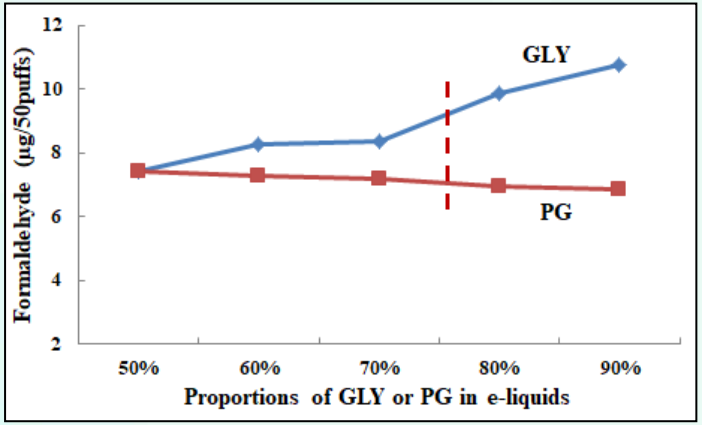
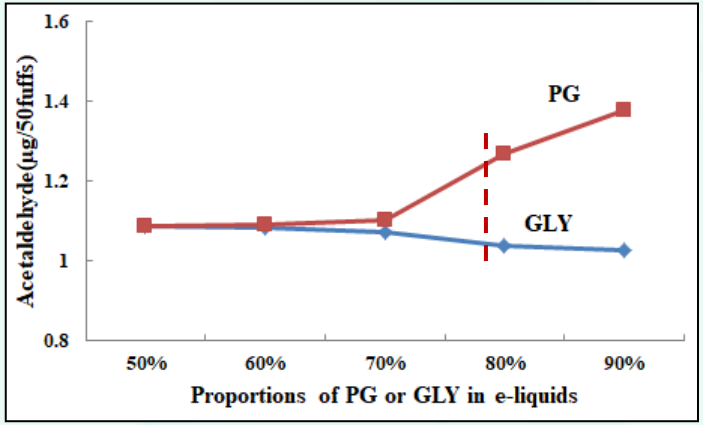
Key Parameters—V_{PG}:V_{GLY}

- V_{PG}:V_{GLY}





- At same proportion, GLY generate more formaldehyde than PG
- C-C bond cleavage in the C3 molecule
- $13C_3$-GLY study: formaldehyde derived primarily from GLY

- At same proportion, PG generate more acetaldehyde than GLY
- C2-C3 bond cleavage
- $13C_3$-PG study: acetaldehyde derived primarily from PG

Wang P. PLoS ONE 12(1):e0169811.
Melvin M. CORESTA 2018.

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Key Parameters—V_{PG}:V_{GLY}

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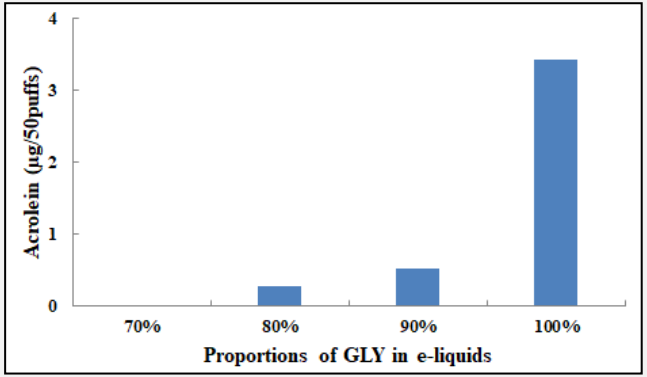
Pure GLY

- Unlike PG, GLY produced most amount of formaldehyde, acetaldehyde and acrolein, 103.59, 16.35 and 3.42 μg/50 puffs
- Viscosity of GLY (243 mPa·s) is much higher than PG (56 mPa·s), GLY cannot reach the coil timely, lead to "dry burn"
- For 50 puffs, e-liquids contain PG consumed 0.18 g, pure GLY only consumed 0.016 g

Source of acrolein



- When the proportion of GLY was 80 %, acrolein became detectable, with the increase of GLY, the release levels grew fast, from 0.26 to 3.42 μg/50 puffs.
- Acrolein mainly resulted from the thermal decomposition of GLY

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Key Parameters—nicotine content

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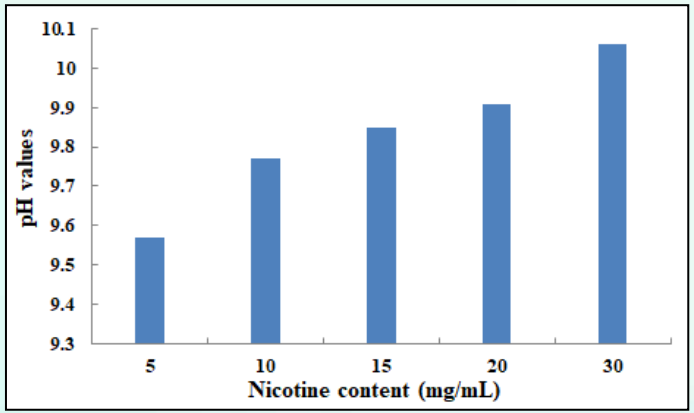
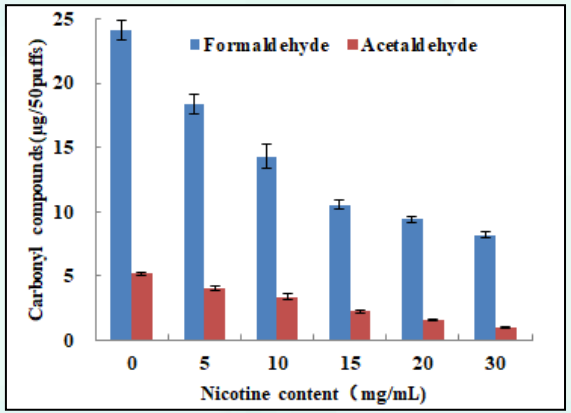
- **Nicotine contents**
  - 0、5、10、15、20、30 mg/mL（V_{PG}:V_{GLY}:V_{water}=78:18:2）
  - higher total nicotine contents yielded higher pH values
  - The yields of formaldehyde and acetaldehyde decreased with the increase of nicotine contents
  - Hydrogen ion catalyzed dehydration of PG and GLY. And, higher pH values yielded lower formaldehyde and acetaldehyde





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Key Parameters—power output

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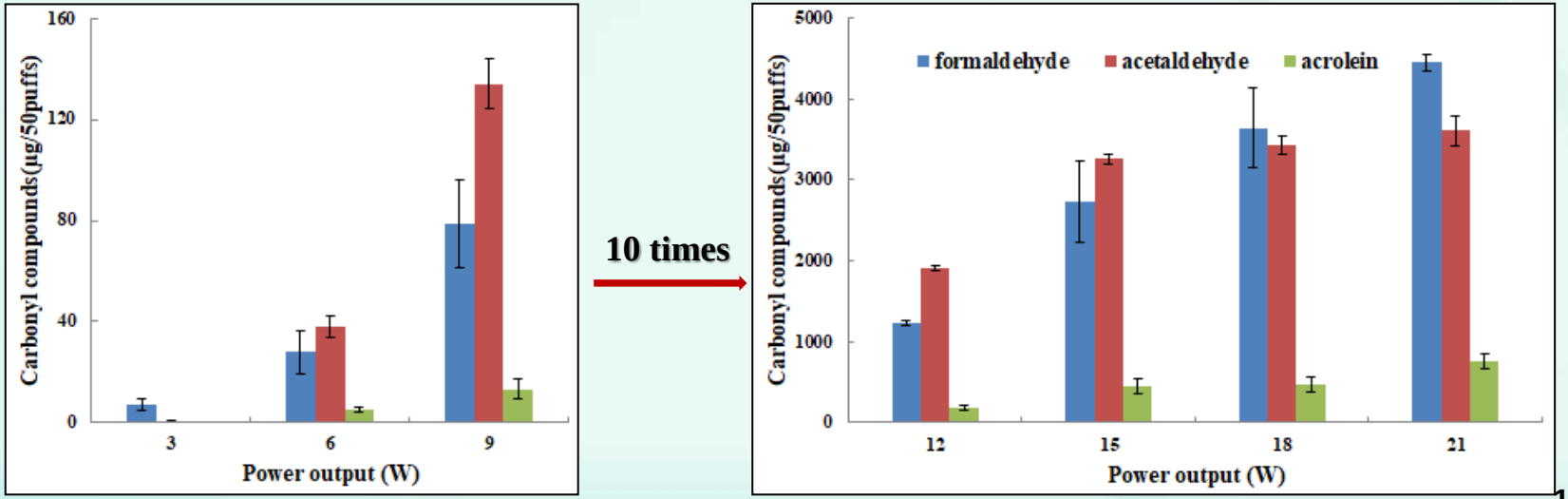
- **Power output**
  - **Coil resistance:3 Ω**
  - **By adjusting applied voltage, power output: 3、6、9、12、15、18、21 W**
  - **At 3 W， only formaldehyde and acetaldehyde were detected; Raise to 6 W, acrolein was also detected. The emission levels of aldehydes show a sharp rise at 12 W**



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Key Parameters—power output

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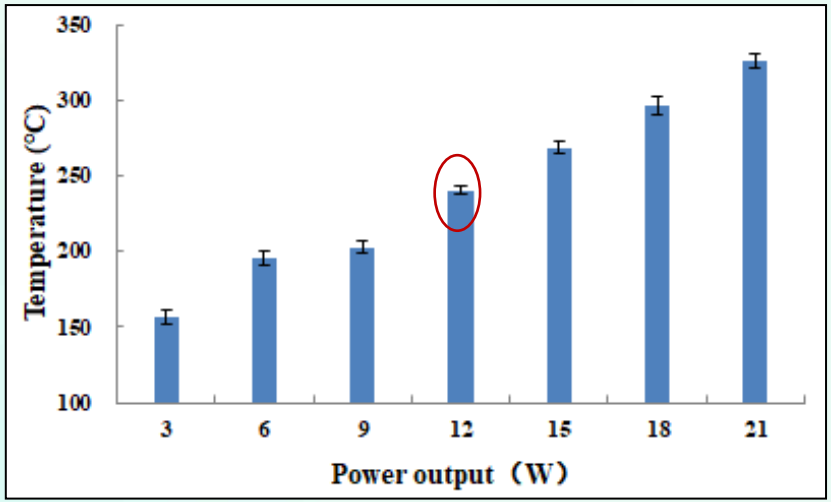
Effect of power on temperature



- Temperature of heating coil show increase with increase of power output, reached 340 ℃ at 21 W
- At 3~9 W, the temperature of heating coil was low, the e-liquid can reach the coil timely
- At 12 W, the temperature of heating coil (250 ℃) was higher than the boiling point of PG (187 ℃), vaporization rate of e-liquid was increased, e-liquid cannot reach the coil timely, lead to "dry burn"

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Summary

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Sources of aldehydes

- **Formaldehyde derived primarily from GLY**
- **Acetaldehyde derived primarily from PG**
- **Acrolein mainly resulted from the thermal decomposition of GLY**

Key parameters

- **Moisture content have little effect**
- **With the increase of GLY, the generation of formaldehyde , and acetaldehyde**
- **With the increase of nicotine contents, the yields of formaldehyde and acetaldehyde**
- **With the  of power output, the levels of aldehydes . At 12 W, the aldehydes release show a sharp rise**

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Thanks for your attention!

Email: fanmj@aliyun.com

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