

# Selected harmful or potentially harmful constituent yields in the aerosol of commercial closed electronic systems

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The research described in this presentation was sponsored by Philip Morris International.



# OBJECTIVES

- Analyze the aerosol emissions from various closed system electronic cigarettes from different markets, under a range of standardized test conditions
- Compare against the emissions of the reference cigarette 3R4F
- Test product robustness under different puffing regimes



# Closed System E-Cigarettes





# Study Design

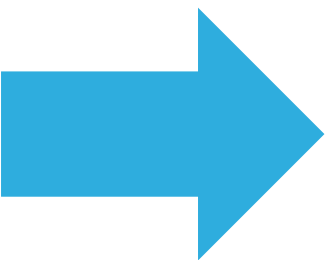


# Study Design

- Sampled 21 different e-cigarettes between the years 2015 – 2018, from the United Kingdom, and Canada
- Yields obtained under the ISO 20768:2018 (similar to CRM 81) puffing regime (**55ml** volume - **3s** duration - **30s** interval)
- Alternative vaping regimes
- Puffs collected up to the depletion of the e-liquid

# Study Design

- Analyzed by an independent ISO 17025 accredited lab
- Minimum 3 replicates each with new device to assess device-to-device variability



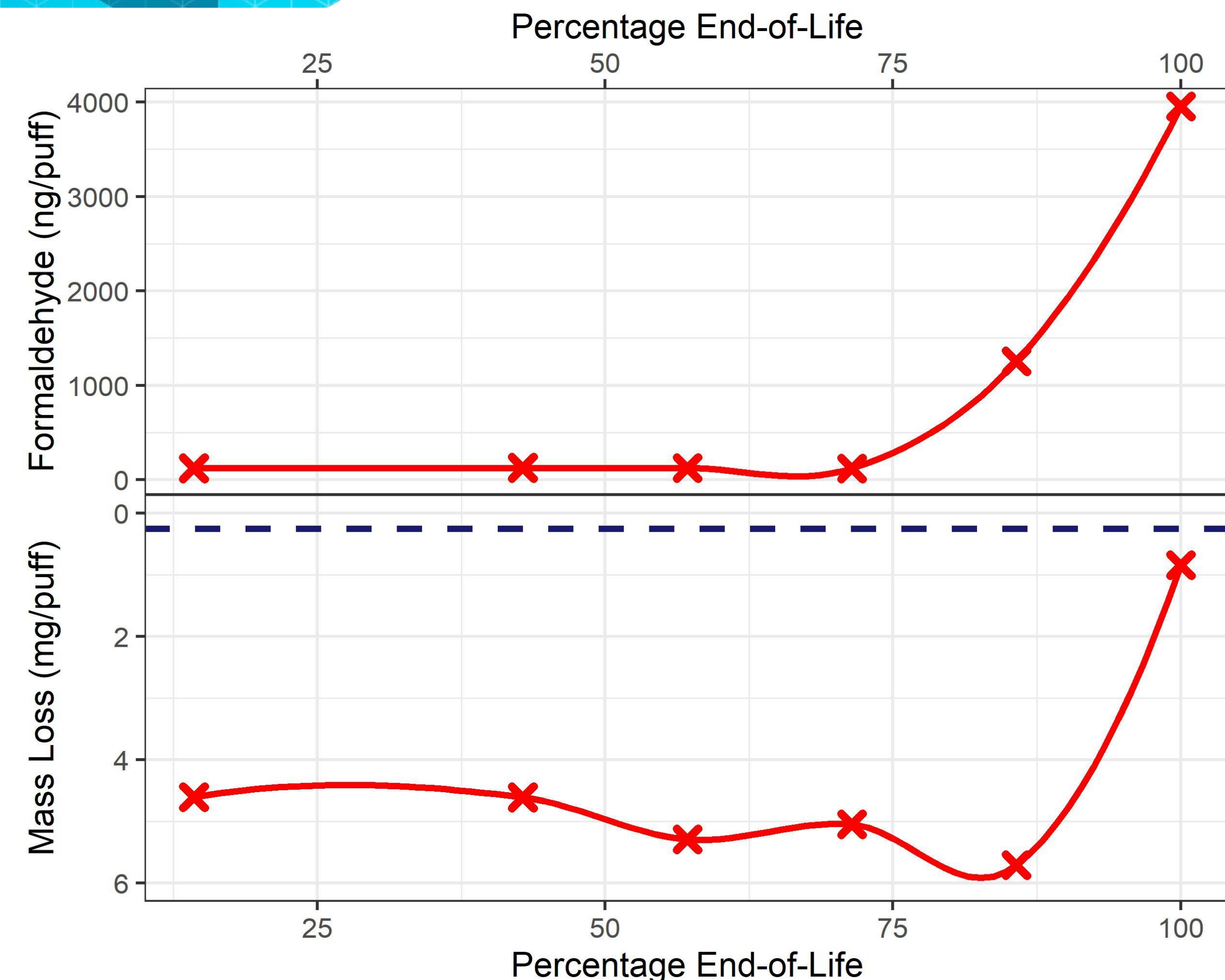
Focus on this presentation: data for carbonyl compounds formaldehyde, acetaldehyde, and acrolein, which are quantifiable in most products sampled



# Concept of End-of-Life (EoL)



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- Aerosol collected per blocks of 50 puffs
- End-of-Life when the aerosol generation ends (device turns off or ACM < 12.5 mg per 50 puffs)\*
- Products ranged from 200 to 1550 puffs until liquid depletion (1750 for different regimes)





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# Testing Design

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# Method of Comparison in Aerosol Emissions

Average emissions from e-cigarettes (from first to last puff)  
**VS**  
3R4F cigarette levels

- ✓ On puff basis for standard regime

$$\frac{\text{Formaldehyde (ng/collection)}}{\text{Number of Puffs}}$$

- ✓ On concentration basis for different regimes (100 cm<sup>3</sup>)

$$\frac{\text{Formaldehyde (ng/collection)}}{\text{Number of Puffs}} \times \frac{100}{\text{Puff Volume (100 cm}^3\text{)}}$$



# General Statistics

## Average Yield, and Global Life-time Average Yield

$$AY_{wj} = \frac{\sum_{i=1}^r y_{ij}}{r}$$

$$LAY^I = \frac{\sum_{j=1}^{pb} AY_{wj}}{pb}$$

## Device-to-Device Variability

$$\bar{S}_{btwLAY}^I = \sqrt{\frac{\sum_{i=1}^r (LAY_i - LAY^{II})^2}{r - 1}}$$

	1 (1-50)	2 (51-100)	3 (101-150)	$j$	...	$pb$	Row Statistics
1					...		$LAY_{1.}$
2							$LAY_{2.}$
3							$LAY_{3.}$
$i$				$y_{ij}$			$LAY_{i.}$
...							...
$r$							$LAY_{r.}$
Column Statistics	$AY_{w.1}$	$AY_{w.2}$	$AY_{w.3}$	$AY_{w.j}$	...	$AY_{w.pb}$	$LAY^{II}$ $LAY^I$





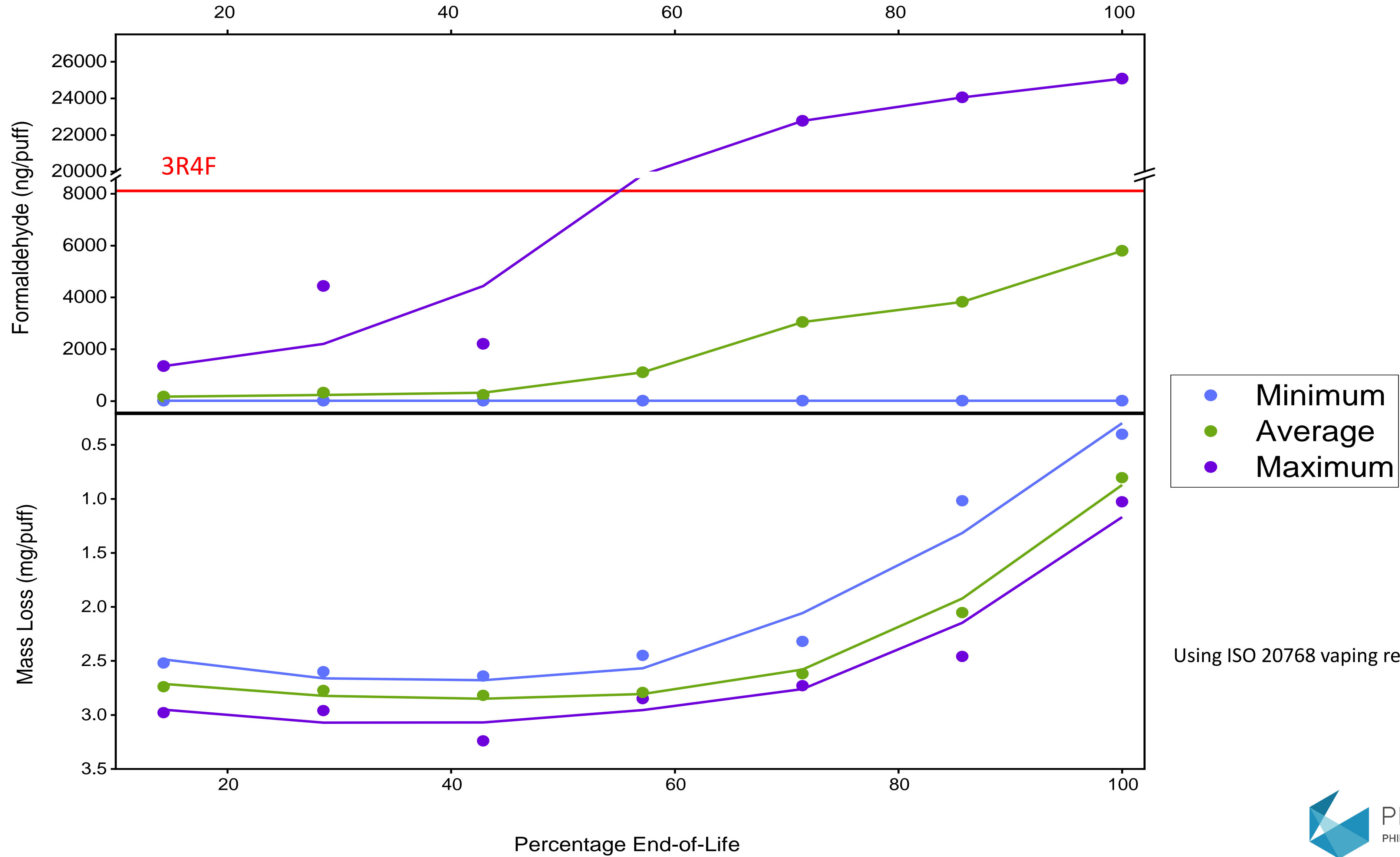
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# Results

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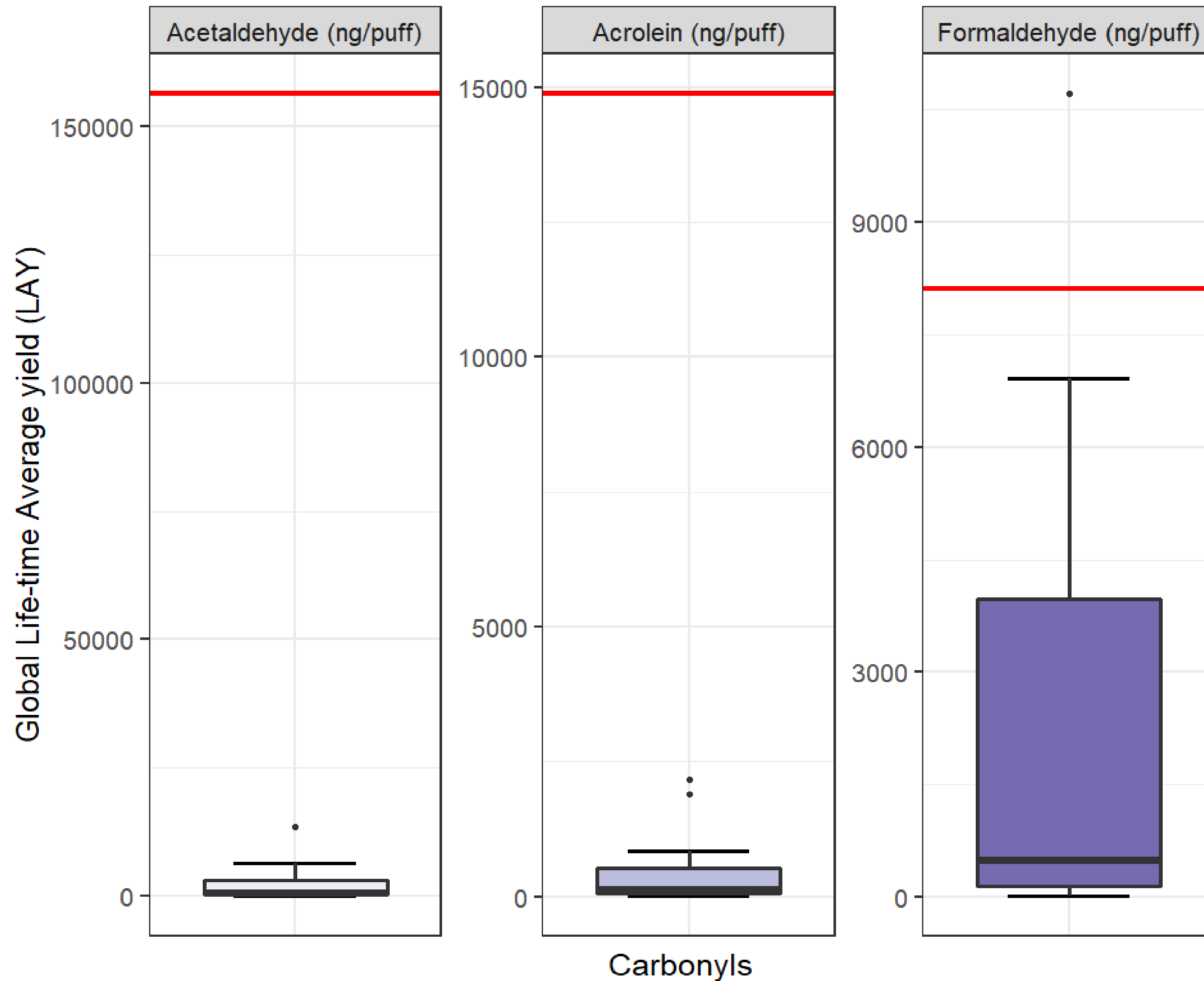


# Closed System Emissions up to EoL





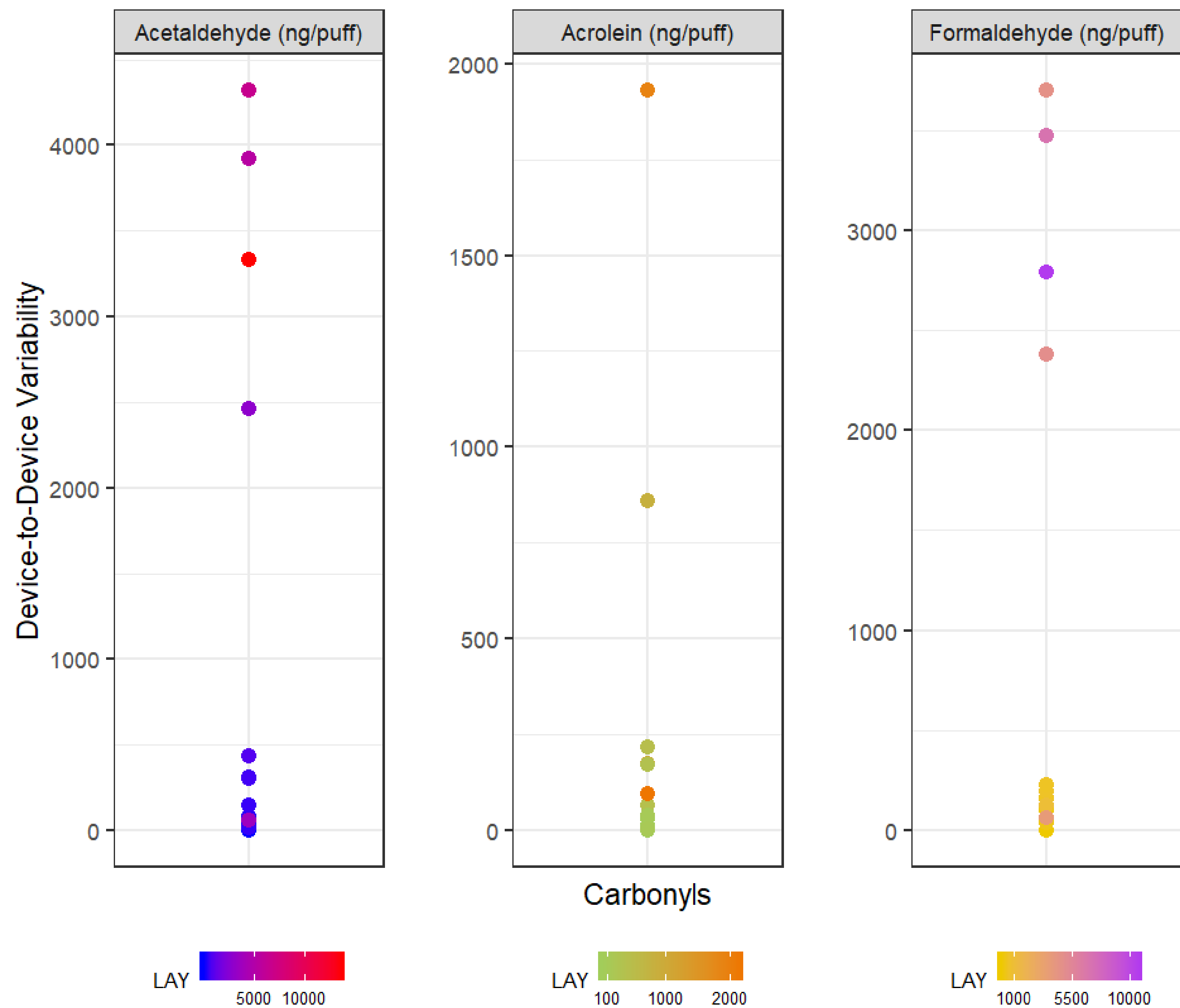
# Global Lifetime Average Yield:



- Three carbonyls on average lower than 3R4F
- Large variability in formaldehyde between products
- One product with formaldehyde emissions higher than 3R4F



# Device-to-device Variability





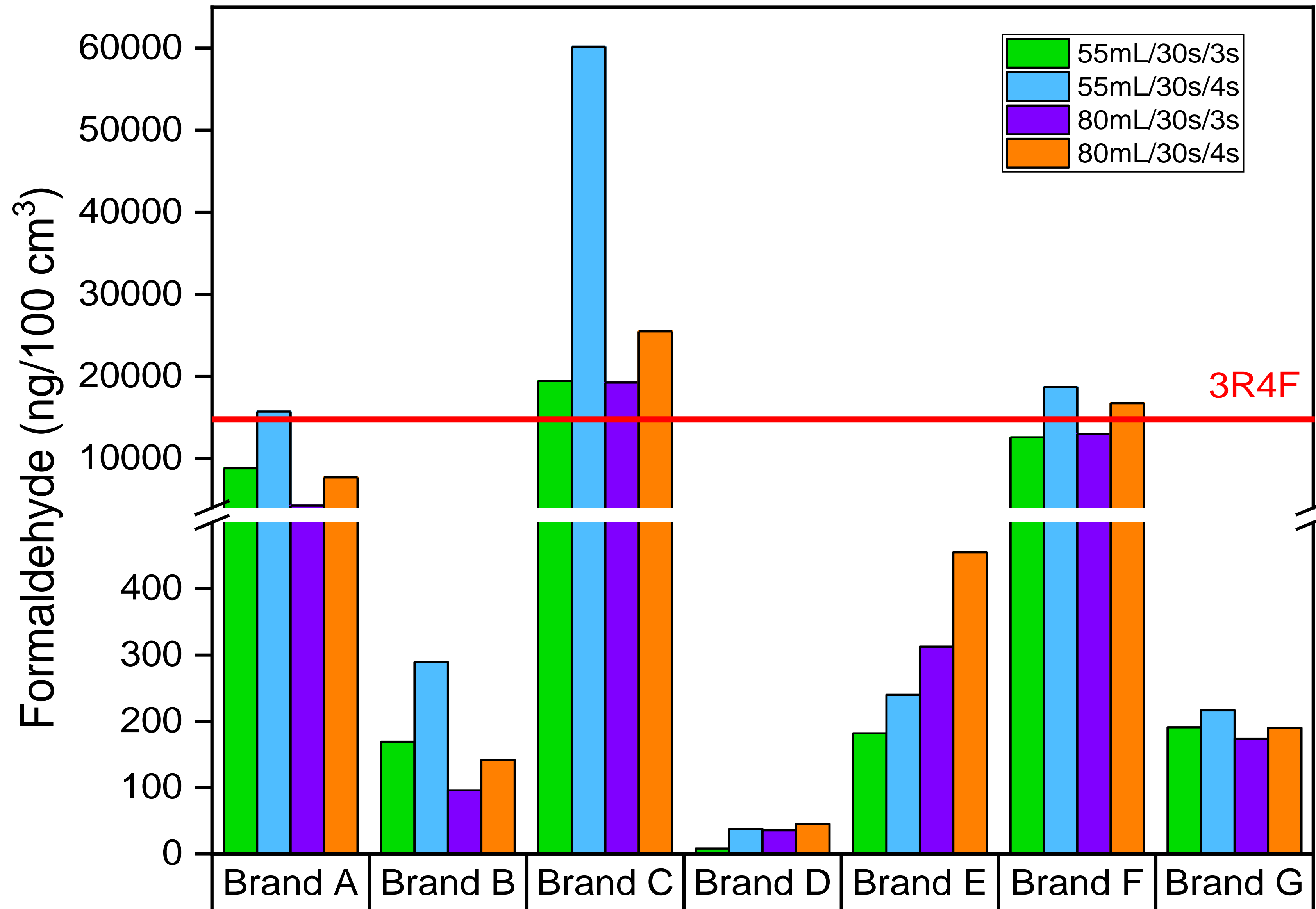
# Product Robustness

Increasing puff duration and/or puff volume

Puffing Volume	Puffing Duration	Inter-puff Interval
55 (ml)	3 (s)	30 (s)
55 (ml)	4 (s)	30 (s)
80 (ml)	3 (s)	30 (s)
80 (ml)	4 (s)	30 (s)



# Product Robustness





## Conclusions

- It is important to analyze closed systems until full liquid depletion
- Generally, the products showed lower emission levels of acetaldehyde, formaldehyde, and acrolein, than 3R4F
- Formaldehyde in the aerosol had a large variability between products and is therefore a good marker of product performance
- Not all products demonstrated the same robustness against minor changes in vaping regimes



Thank you