Cooperation Centre for Scientific Research Relative to Tobacco

CORESTA Guide N° 22

Technical Guide for the Selection of Appropriate Intense Vaping Regimes for E-Vapour Devices

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E-Vapour Sub-Group

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for E-Vapour Devices

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1. INTRODUCTION

It is likely that regulators will be interested in evaluation of e-vapour devices using intense usage scenarios. Indeed, the U.S. Food and Drug Administration published guidance for Industry titled ‘Premarket Tobacco Product Applications for Electronic Nicotine Delivery Systems’ in May 2016. Lines 1021 – 1024 of this draft guidance states:

“Evaluating new tobacco products under a range of conditions, including both non-intense (e.g., lower levels of exposure and lower volumes of aerosol generated) and intense (e.g., higher levels of exposure and higher volumes of aerosol generated), enables FDA to understand the likely range of delivery of emissions.”

As such, CORESTA has prepared the following guidance document on the selection of appropriate intense vaping regimes.

1.1 Purpose

CORESTA Recommended Method N° 81 was published in 2015; this laid out the essential requirements found necessary for the generation and collection of e-vapour aerosol for analytical testing purposes, and may be regarded as reflecting non-intense use (lower volumes of aerosol/lower exposure). The regime has since been further adopted by research laboratories for *in-vitro* testing purposes. The purpose of this document is to provide guidance on which criteria should be considered when defining the required device and aerosol generation/collection system settings for intense use. Intense use can be regarded as the conditions which will result in higher levels of aerosol generation under normal use conditions (higher volumes of aerosol/higher exposure).

1.2 Outline

E-vapour devices cover a wide variety of products, ranging from simple airflow activated e-vapour devices to large button-activated refillable devices with a number of mechanisms by which the user can adjust the device settings to control their vaping experience. Despite the diversity of these devices, the basic mechanism of aerosol generation is by electrical heating of a wick material saturated with an e-liquid and activation via generation of an airflow by user inhalation and/or button activation.

The amount of aerosol generated can be affected by a number of factors, including product design (for example, e-liquid volume, voltage, heating element temperature, wick material), user’s vaping topography and device settings.

Due to the diversity of designs and product types, consumer use behavior may vary markedly; if topography data for the device under study is available, it is recommended to use this as a basis for determining intense usage scenarios.

If device-specific topography data is not available, the data presented in Section 3 (Topographical data) may be used in conjunction with the guidance in Section 2 (Parameters affecting aerosol delivery) to design an intense vaping regimen to generate higher aerosol levels for analytical chemical or biological assessment.

2. PARAMETERS AFFECTING AEROSOL DELIVERY

It is important to note that the below parameters are not independent of each other, and need to be regarded collectively when determining intense usage.

2.1 Puff duration

The primary factor impacting the amount of aerosol generated is the amount of time for which the heating element is activated (Wilkinson et al, 2016; Margham et al 2016). As long as the heating element remains supplied with e-liquid, the amount of aerosol generated will increase proportionally to the heating time. Puff duration can be influenced by consumer preference, puff volume, and any automatic cutoffs installed in the device to limit the duration of activation.

2.2 Puff volume

Puff volume has less effect on the amount of aerosol generated in comparison to cigarettes. Studies have shown higher puff volumes both increasing (Bao et al, 2016) and decreasing (Margham et al, 2016) the amount of aerosol generated. Additionally, in puff-activated devices a certain minimum airflow velocity (a function of puff volume over puff duration) is required for activation. The airflow velocity required for activation may vary depending on device design (Williams and Talbot, 2011).

2.3 Puff frequency

Unlike conventional cigarettes, the frequency of puffing has limited bearing on the amount of aerosol generated, as the device is dormant between puffing. Increasing the puff frequency may marginally increase aerosol generation per puff with all other factors remaining constant, as the temperature of the heating element and wick remains elevated (Margham et al, 2016).

2.4 Puff profile

Under current device constraints, a square-shaped profile is recommended. A certain minimum airflow velocity is required for device activation in puff-activated devices. With a bell-shaped profile, airflow velocity will be insufficient for activation at the beginning and end of the puff. By using a square puff profile where the airflow is constant, maximum aerosol generation may be assured.

2.5 Puff number

Increasing the number of puffs taken during a test run will correspondingly increase the amount of aerosol generated and collected. It is important not to exceed the total capacity of the Cambridge Filter Pad for aerosol absorption during the test run. This has been reported to be up to 850 mg on a 44 mm pad (Miller et al, 2016). It is also important to ensure that the puff number does not exceed the ability of the device to generate additional aerosol (for example, past the point of exhaustion of the liquid reservoir).

2.6 Battery charge status

Devices may contain either rechargeable or non-rechargeable batteries. Depending on device design these may either deliver a constant voltage to the heating element during use, or supply a maximum set current at full charge which then slowly declines during use until the battery is discharged to its set cutoff voltage.

As the amount of aerosol generated will be greatest when maximum voltage is delivered to the heating element (Gillman et al, 2015), it is recommended that batteries are fully charged before use. Additionally, as battery capacity and performance will deteriorate on repeated use fresh batteries should be used.

2.7 Heating element or atomizer age

During prolonged use, heating elements may become coated with e-liquid residue and decline in performance due to thermal stress, affecting aerosol generation. For this reason, it is recommended that a new heating element is used for aerosol generation.

2.8 Voltage setting

Devices may have controllable voltage delivery to the heating element. As voltage is increased, the amount of aerosol generated will similarly increase (Gillman et al, 2015).

2.9 Ventilation setting

Devices may have mechanical features to increase or decrease the amount of air that is mixed with the generated aerosol. As ventilation is increased, the concentration of the aerosol will decrease with all other factors remaining constant; as such, higher aerosol generation may be observed at the minimum ventilation setting. However, it should be understood that modifying the ventilation will also change the device pressure drop and thus, the vaping behavior of the user.

2.10 Device orientation

Depending on device design, devices may require an orientation other than horizontal to facilitate efficient wicking of the e-liquid. Device orientation is referred to in CRM81 which states "*A specific orientation of the product during testing is not specified within this method. Different products or analytical methods may require a product orientation other than horizontal. This information should be taken into account in the machine design*". Therefore, careful consideration of device type and performance needs to be assessed and understood prior to design of any (standard or intense) regimen.

In addition, AFNOR XP D90-300-3 July 2016 (Electronic cigarettes and e-liquids Part 3: requirements and test methods for emissions -) provides a specified vaping angle of 45±5 degrees downwards (or justification for an alternative tilt angle) devices during testing.

Device and instrument settings which would be unrepresentative of typical consumer behaviour should be avoided; for example, extreme puff durations, activation of button-activated devices without airflow and use of devices with minimal e-liquid levels. These usage scenarios may result in dry wicking and subsequent generation of thermal degradation by-products, which would be experienced by the user as an unpleasant flavour. It has been reported that consumption by the user under these circumstances will be self-limiting (Farsalinos et al, 2015b).

3. TOPOGRAPHICAL STUDIES

Topography data from recent studies are summarized in Table 1. The critical parameters assessed in these include puff duration, puff interval and puff volume.

Table 1: Summary of publications reporting e-vapour vaping topography data (Mean ± SD)

Reference	Device type	Conditions		Participant number	Measure	Puffs/ Day	Puffs/Session	Puff duration	Puff interval	Puff volume	Flow rate
Norton et al., 2014	Cig-a-like	Lab	ad-lib	18	CressMicro	NR	8.7 ± 1.6	3.0 ± 1.6 s	29.6 ± 11.7 s	118.2 ± 13.3 mL	NR
Lee et al., 2015	Cig-a-like	Lab	ad-lib	20	CressMicro	NR	Initial: 19.3 ± 2.5 1 week: 23.7 ± 2.4 2 weeks: 21.3 ± 2.4	Initial use: 2.2 ± 0.45 s 1 week: 3.1 ± 1.4 s 2 weeks: 2.9 ± 0.9 s	Initial use: 19.2 ± 12.1 s 1 week: 15.2 ± 9.9 s 2 weeks: 22.1 ± 22.0 s	Initial use: 64.0 ± 21.6 ml 1 week: 66.5 ± 16.7 ml 2 weeks: 63.3 ± 23.4 ml	Initial use: 30.6 ± 10.3 ml/s 1 week: 25.1 ± 8.1 ml/s 2 weeks: 24.8 ± 8.6 ml/s
Robinson et al., 2015	Cig-a-like	Natural	ad-lib	21	wireless personal use monitor	225 ± 59	15 ± 25 (from 3 to 117)	3.5 ± 1.8 s (from 0.7 to 6.9 s)	42.7 ± 12.1 s (from 10 to 150 s)	133 ± 90 mL 9 to 388 mL	37 ± 16 mL/s (from 23 to 102 mL/s)
Behar et al., 2015.	Cig-a-like	Lab	ad-lib 10 min, 15 min break ad-lib 10 min	20	CressMicro	NR	Blu: 33 ± 8 V2: 31 ± 8	Blu: 2.75 ± 0.96 s V2: 2.54 ± 1.04 s	Blu: 16.9 ± 8.2 s V2: 18.9 ± 7.3 s	Blu: 56 ± 22 mL V2: 45 ± 22 mL	Blu: 21 ± 6 mL/s V2: 18 ± 6 mL/s
Strasser et al., 2016	Cig-a-like	Lab	ad-lib 10 min (2 sessions : day 5& 10)	28	Video	NR	Day 5: 16.1 ± 11.9 Day 10: 13.2 ± 9.4	Day 5: 2.0 ± 0.7 s Day 10: 2.1 ± 0.7 s	Day 5: 11.2 ± 5.2 s Day 10: 11.2 ± 5.2 s	NR	NR
Robinson et al., 2016	Cig-a-like	Natural		20	wireless personal use monitor	78± 162 (14 to 275)	NR	2.0 ± 0.6 s (from 1 to 3 s)	NR	65.4 ± 24.8 mL (24 to 114 mL)	30.4 ± 9.2 mL/s (19 to 60 mL/s)

Reference	Device type	Conditions		Participant number	Measure	Puffs/ Day	Puffs/Session	Puff duration	Puff interval	Puff volume	Flow rate
Farsalinos et al., 2013	Tank	Lab	ad-lib	80	Digital camera	NR	E-CIG: 43 ± 8	EC: 4.2 ± 0.7 s SM-S: 2.1 ± 0.4 s SM-E: 2.3 ± 0.5 s	NR	NR	NR
Spindle et al., 2015	Tank	Lab	Control	12	Non commercial Instrument	NR	10 (control)	4.2 ± 1.1 s	30 s (control)	101.4 ± 50 mL	24.2 ± 10.7 mL/s
Dautzenberg and Bricard, 2015	Tank	Natural	ad-lib	185	Smartphone connected	163 ± 138	NR	Isolated puff: 4.6 ± 2.2 s 2-5 puffs: 4.1 ± 1.9 s 6-15 puffs: 3.7 ± 1.8 s >15 puffs: 3.2 ± 1.6 s Mean: 3.8 ± 1.9 s	2-5 puffs: 19.3 ± 15.1 s 6-15 puffs: 16.8 ± 13.2 s >15 puffs: 13.7 ± 11.5 s Mean: 16.6 ± 13.5 s	NR	NR
Spindle et al., 2016	tank	Lab	2 sessions 10 puffs / 30s ad-lib 90 min	29	Non commercial Instrument	NR	Control: 10.0 ± 0.1 ad-lib: 62.6 ± 32.3	Control: *4.5 ± 1.6 s* ad-lib: 5.3 ± 2.2 s	Control 25.2 ± 1.6 s ad-lib: 102.8 ± 63.1 s	Control: 124.6 ± 89.2 mL ad-lib: 148.5 ± 119.6 mL	Control: 27.8 ± 19.5 mL/s ad-lib: 27.5 ± 22.6 mL/s
Ramôa et al., 2015	Tank with different nicotine (0, 8, 18 or 36 mg/mL).	Lab	Control 10 puffs/30s (2 sessions 12h – 48h)	16	Non commercial Instrument	NR	10 (control)	Session 1&2 5.6 ± 2.1 s (0 nic) 5.8 ± 2.2 s (8 nic) 5.2 ± 1.8 s (18 nic) 4.1 ± 1.5 (36 nic)	30 s (control)	Session 1&2 196 ± 214.9 mL (0 nic) 193.2 ± 152.1 mL (8 nic) 119.5 ± 66.4 mL (18 nic) 81.4 ± 41.9 mL (36 nic)	Session 1&2 33.4 ± 32.3 mL/s (0 nic) 31.1 ± 21.2 mL/s (8 nic) 23.0 ± 10.5 mL/s (18 nic) 20.0 ± 7.7 mL/s (36 nic)
Farsalinos et al., 2015	Mod	Lab	Control	47	E-cig connected	NR	Vapers: 89 ± 14 Smokers: 86 ± 7	Vapers: 3.5 ± 0.2 s Smokers: 2.3 ± 0.2 s	NR	NR	NR
Cunningham et al., 2016	Cig-a-like Tank	Lab	ad-lib (1 session)	64 55	SA7 modified	NR	21.1 ± 14.9 16.1 ± 8.0	2.0 ± 0.7 s 2.2 ± 0.9 s	23.2 ± 10.6 s 29.3 ± 19.2 s	52.2 ± 21.6 mL 83.0 ± 44.3 mL	39.0 ± 10.3 mL/s 60.6 ± 19.8 mL/s

Reference	Device type	Conditions		Participant number	Measure	Puffs/ Day	Puffs/Session	Puff duration	Puff interval	Puff volume	Flow rate
Hua et al., 2013	NR	Natural	no	9	No topography instrument used	NR	NR	4.3 ± 1.5 s	NR	NR	NR
St Helen et al., 2016	all types	Lab	ad-lib	Tank n=8 Cig-a-like n=2 Mod n=3	Video	NR	Tank: 80.2 ± 35.3 Cig-a-like: 35 ± 35.2 Mod : 38 ± 30.8	Tank e-cig: 3.2 ± 1.4 s Cig-a-like: 5.2 ± 1.9 s Mod: 3.2 ± 0.7 s	Tank: 80.7 ± 51.3 s Cig-a-like: 319 ± 332 s Mod: 82 ± 81 s	NR	NR

*NR = Not Reported

The literature also suggests that those that vape for a shorter series of puffs (i.e. 2-5 puffs), have longer puff durations compared to those taking a larger series (>15 puffs). The inter-puff interval is also impacted by series and duration of puffs (Dautzenberg & Bricard, 2015).

4. TECHNICAL LIMITATIONS OF AEROSOL GENERATION INSTRUMENTS

Aerosol should be generated using a collection system capable of meeting the requirements described in CRM 81 using a pre-set puff volume and puff duration. Current commercially available instruments for aerosol generation and collection have the following general limitations:

- Puff volume: maximum 150-210 mL
- Puff duration: maximum 9.9 s
- Puff frequency: minimum 10 s

Additional limitations exist for extremes of puff duration and puff frequency; for example, with a 9.9 s puff duration a puff frequency of 10 s will not be possible. Additionally, at extended puff durations and decreased puff frequency the number of ports available for use will be decreased on some instruments.

Instruments designed for cigarette smoking may be adapted for use as e-vapour aerosol generators; however, it should be noted that these are more limited in terms of puff duration and lack features such as button pushers or angled vaping heads. In order to accurately align activation with puffing for button activated devices, an instrument equipped with an integrated button pusher should be used.

5. SUMMARY

The amount of aerosol generated can be affected by a number of factors, including product design, vaping topography and device settings. In selecting an appropriate aerosol generation regime for intense use, the parameters described in section 4 should be adjusted appropriately taking into account the topography data for the device or type of device in question if available (Table 1).

Device and instrument settings should result in higher aerosol generation under normal expected human usage than that observed for non-intense use; it should be understood that the parameters are not independent and the settings should be based on representative intense human usage rather than the maximum extremes of each individual parameter.

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