



CANNABIS - WHITEPAPER COLLECTION

Dilution of cannabinoid (THC) aerosols for subsequent chemical analysis

CERULEAN

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Introduction

Vaping cannabis oils for medical and recreational purposes is becoming increasingly prevalent in the USA. This demands a duty of care of the manufacturer and regulator to ensure that the products are fit for use and as far as reasonably practicable, harm free. Already state regulators are demanding screening of oils and in some cases aerosols for metals and other toxicants.^{i,ii}

The composition of the aerosol produced by such cannabis oil vaping devices (predominantly containing the lipid (-)-trans-delta-9-tetrahydrocannabinol which is commonly referred to as THC) is of acute interest when establishing the possible harm that might be imparted to a user.

Understanding the delivery of therapeutics or toxins in the aerosol phase of a vaping device first requires that the vaping device generates an aerosol that can be analysed. Moreover, it is important when generating an aerosol in the laboratory that this is not only generated in a standard and reproducible manner but also is representative, as far as possible, of the same aerosol when generated under “real world” conditions. This demands that the test laboratory develops methodologies that do not introduce experimental artefacts that can confound interpretation. For example, overheating a vaping liquid can result in decomposition of the liquid into highly toxic carbonyls.ⁱⁱⁱ

Cannabis cartridges for vaporisation are often prefilled with concentrated oils and require a coil heater and power source for heating of the liquid to form an aerosol. This introduces an important variable in the understanding of how a user of cannabis might be exposed to toxicants. The base cannabis oil may be analysed for metals or other toxicants but the transport to the aerosol phase may alter the dose of toxicants to the user. Moreover, it is known, from the analogous nicotine vaping systems, that there is sometimes leaching of metals or other chemicals from the device cartridge itself which must be factored into any judgement on dose of toxicants^{iv}. It is therefore necessary to experimentally determine the actual dosage of toxicants in the aerosol formed when a cartridge loaded with cannabis oil is heated and “vaped”.

Forming an aerosol should not normally prove a major hurdle for the careful experimenter, however, cannabis oils tend to be highly viscous when undiluted and this presents problems in first volatilising the oil and secondly in depletion of the oil at the heating coil.

This may be partly overcome by increasing the heating power of the coil but this risks localised overheating, thermal decomposition and consequent production of toxins that would not normally be formed.

For examining aerosol emissions from an electronic nicotine delivery system (ENDS), it is usual to employ a specialist puffing machine^v. This has a precise, programable “puff engine” that can produce a puff of set volume, duration and interval, a capture system which can be a physical trap in the form of a glass fibre filter or chemical trap such as a solvent filled impinger.

The shape of the puff profile, or how the volume is swept, is a square wave to ensure a constant flow during puffing at a level greater than the flow trigger point of flow activated ENDS, shapes used in cigarette smoking such as a bell profile are not suitable.

There has been much work conducted on the frequency and duration of draw for conventional cigarettes and ENDS and the WHO TobLabNet recommends puffing every 30 seconds with a 55ml volume for standard conditions.^{vi}

As a starting point for cannabis oil emissions from a vaping device using conditions analogous to those used for ENDS seems prudent especially as the electronic systems at least can be considered as near identical. These conditions would be a 55ml puff of 3 seconds duration with a square shaped profile (figure 1) every 30 seconds. These puffs would continue for the duration of the experiment.

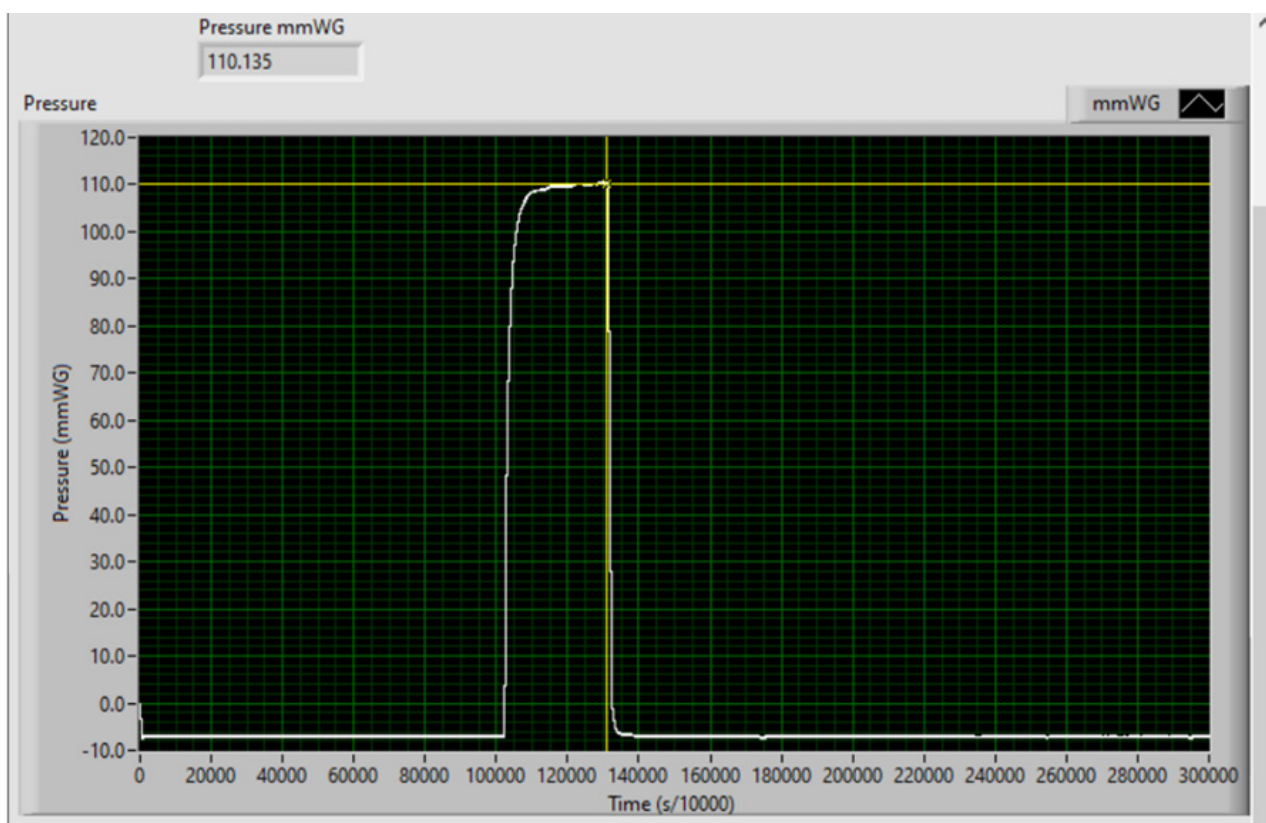


Figure 1: Pressure drop trace as captured by a pressure drop transducer and logging system in line with GoSelect cannabis vaping system / CET11 vaping machine. The slight peak distortion on the start of the profile is due to the high pressure drop of the device before the coil begins heating the cannabis oil

The capturing of the aerosol generated could be considered to be very similar to ENDS aerosols so similar mechanisms for the physical trapping could be deployed – a glass fibre pad specified to capture 99.9% of all particles with a diameter of 0.3 micrometres or greater in a chemically inert holder is routinely used.

A practical problem remains. The delivery of aerosol for vapes containing concentrated cannabis oils can be very low on a puff-by-puff basis. Moreover, the liquid tends to “set” and cause a very high resistance to flow which further diminishes the delivery until no aerosol is generated. It almost goes without saying that for an analytical laboratory this is not acceptable as the fast generation of representative aerosol captured for analysis is key to efficiency within the laboratory.

It has been noted that lower total cannabinoid vapes seem to enter the vapour phase more readily when vaped so it was postulated that by diluting cannabis oil with a suitable organic solvent it would be possible to facilitate aerosol formation in a vaping device.

Experimental

The sequence of experiments were performed using the Cerulean CET11 aerosol generation machine. The CET11 aerosol generation machine was manufactured and supplied by Cerulean, Rockingham Drive, Milton Keynes, United Kingdom and consists of a programmable puff engine with a maximum sweep volume of 70ml based around a stepper driven controlled precision aluminium bore syringe.

The samples used for test were the GoSelect vaping system with a cartridge that was filled with cannabis oil diluted with IPA (propan-2-ol) creating mixtures of 50%, 60%, 70%, 80% and 90% cannabis oil in IPA. The cartridges were filled using a small syringe that was loaded with the THC/IPA mix and then heated to approximately 50°C to mitigate the high viscosity of the oil. When testing each unit was fitted with a freshly charged battery pack.

The GoSelect devices were connected to the primary capture pad via a short length of silicone tubing (figure 2) and the primary capture pad was “backed” by a second pad to catch any breakthrough of aerosol (figure 3).

Puffing on the cartridges used a puff of 3 second duration, volume 55ml with a square shaped profile. Puffs were taken on a 30 second cycle. For the vaping experiment the device was angled at 30° to the horizontal to mimic user typical use patterns.

The device under test was activated by flow and was fitted with an ovoid shaped mouthpiece. This was connected to the CFH labyrinth seals, a set of thin silicone seals that allow a seal to be formed gently around test products with cylindrical symmetry, via a short length of silicone tubing that pushed into the CFH seal.

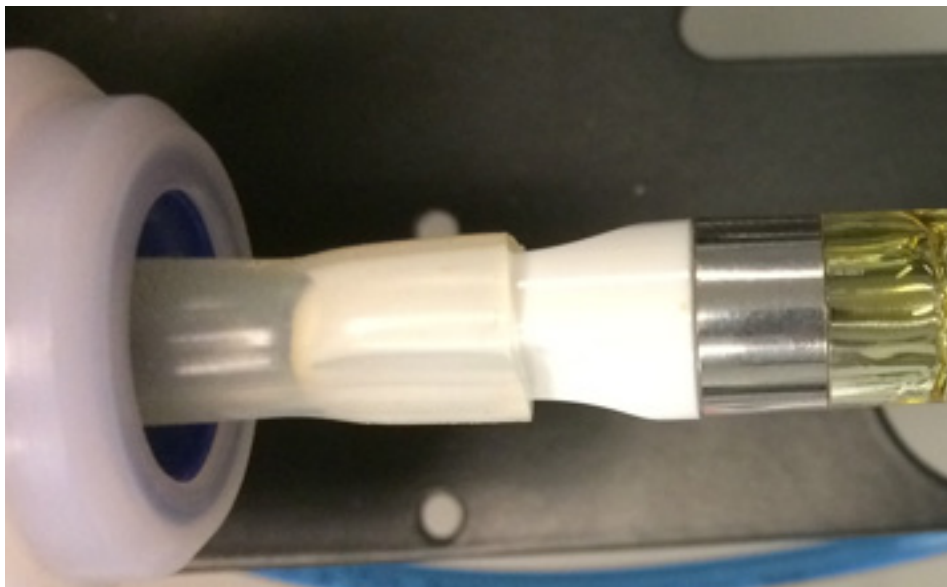


Figure 2: Connection between GoSelect cartridge and labyrinth seals (blue) of the Cambridge Filter Holder which contains the glass fibre pad for collection.

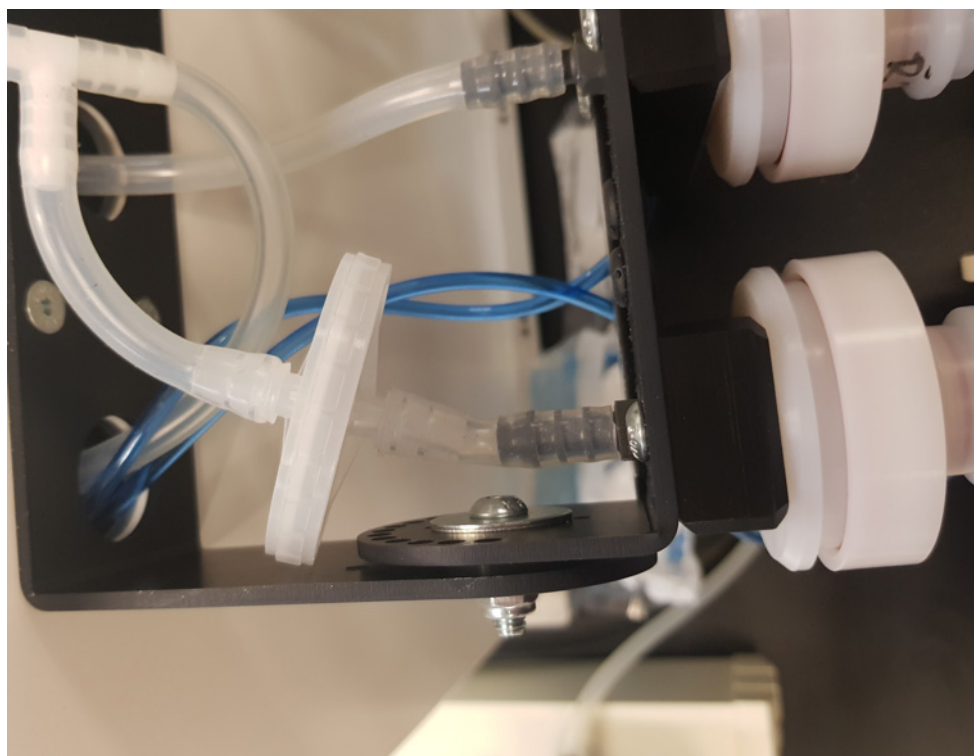


Figure 3: Cambridge Filter holder (bottom of image) backed by a secondary filter trap as used in the experiments

A Baratron transducer was placed in the circuit beyond the secondary capture pad to allow measurement of the pressure drop / flow in the puffing circuit during puffing. This had a two-fold purpose; firstly, to observe any puff shape distortion through increased pressure drop due to resistance to flow in either the capture system or device and secondly to ensure that pressure drop was not rising and so restricting flow. Typical pressure drops between 110mmWG and 120mmWG were observed throughout the experiments.

A 0.1mg resolution balance was used for mass balance calculations.

The experimental protocol required that the device was weighed before and after puffing as were the capped Cambridge Filter Holder and secondary filter trap.

Results

The experiment encountered some technical difficulties mainly with battery life and the planned 70 puffs per cartridge was not always achieved. Some dilutions had fewer puffs taken and in one instance more. In all cases the cartridges were not exhausted.

Experiments were terminated when the monitored pressure drop fell below a 100mmWG or rose above 150mmWG as at that point it was clear from observing the flow indicator light on the GoSelect battery that the puff was not being consistently drawn.

Figures 4 through 6 show the pressure drop measurements for a properly activating GoSelect cartridge, a cartridge that is partially leaking or unable to create aerosol due to an exhausted battery, and the final image shows the increased pressure drop due to blockages in the flow path or solidification of cannabis oil.

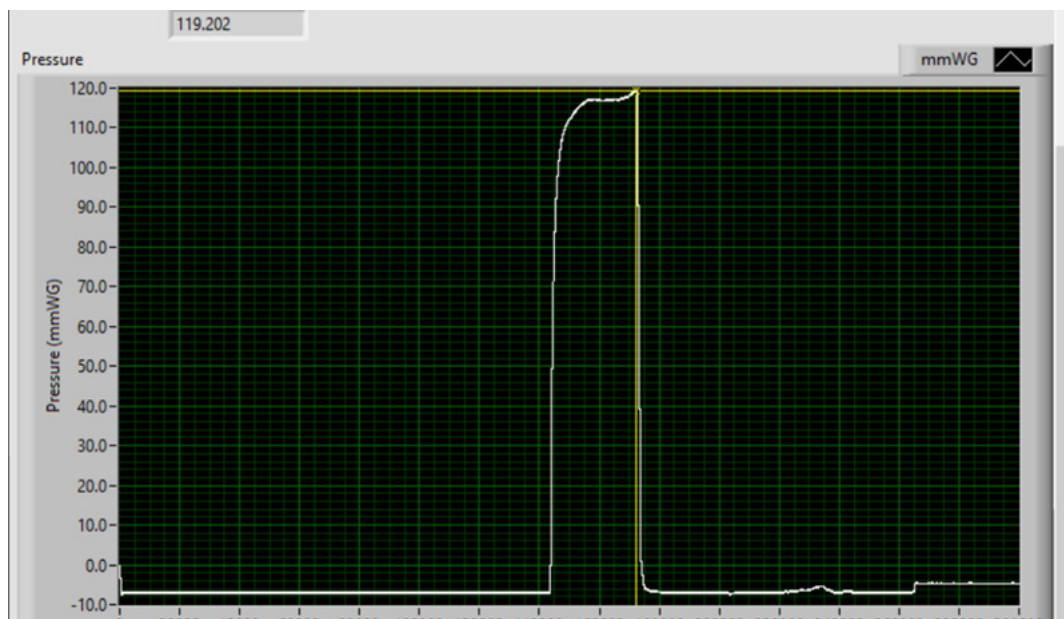


Figure 4: Pressure drop trace for GoSelect cartridge behaving normally during a 55ml, 3 second puff square profile

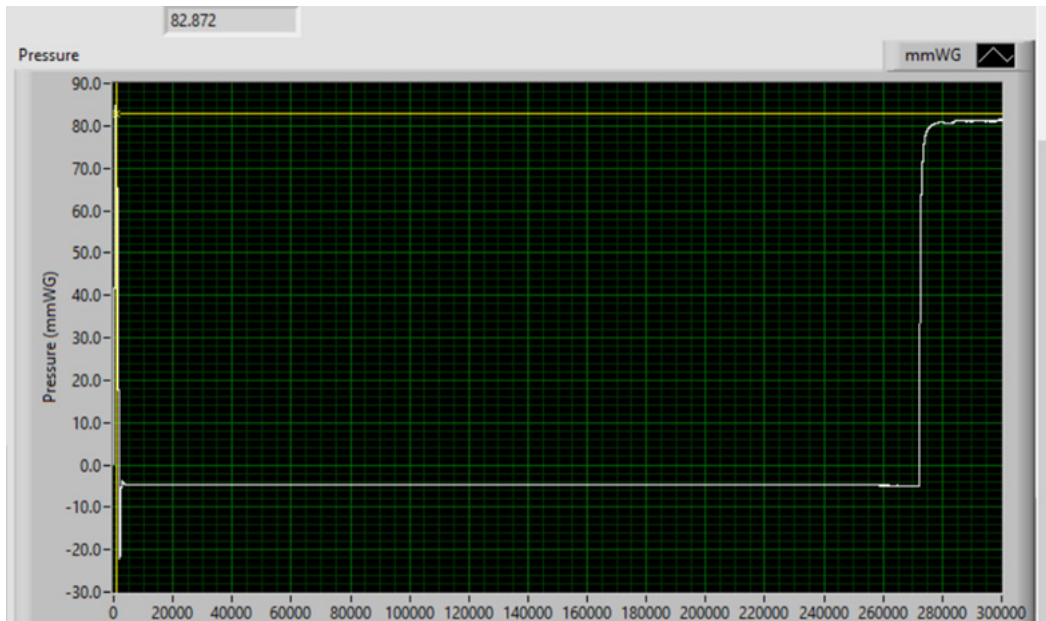


Figure 5: Pressure drop trace for GoSelect cartridge with air leak in system or low battery power - note maximum pressure drop of 82mmWg

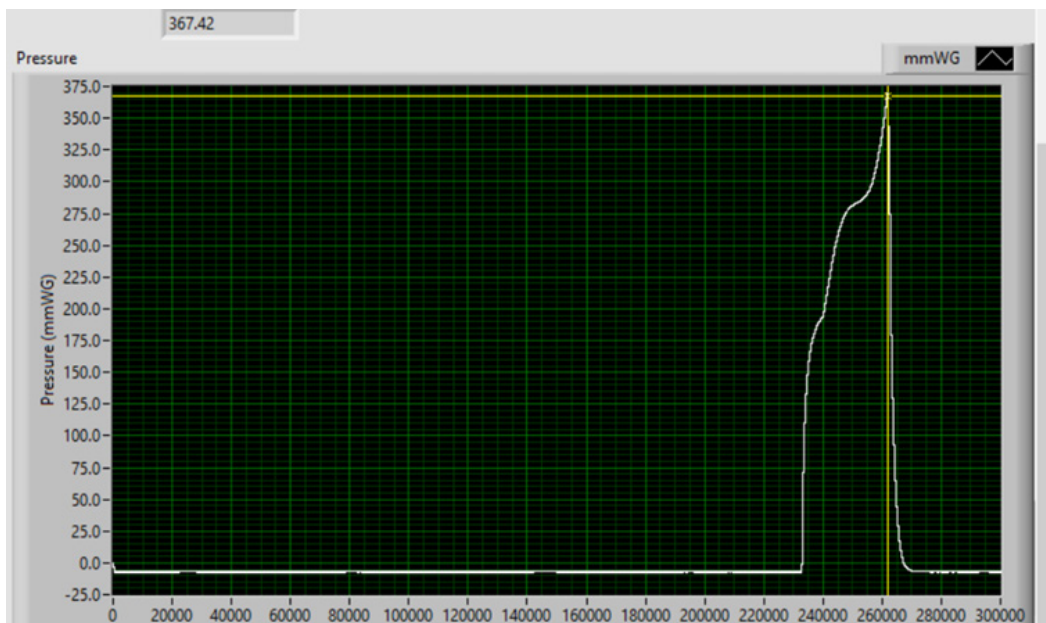


Figure 6: Pressure drop profile of GoSelect cartridge with blockage or solidifying cannabis oil. Note distortion of profile and pressure drop exceeding 360mmWg

The delivery (loss in mass from the cartridge), and the mass of aerosol captured on the first capture pad are detailed for the various dilutions in table 1.

The first capture pad when removed from the holder was observed to have an even coating of the yellow cannabis oil whilst the secondary pad showed little or no discolouration (figures 7 and 8). There was no measurable increase in weight of the second pad.

Dilution method for successfully creating cannabinoid (THC) aerosols for subsequent chemical analysis.

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Mix THC:IPA	Puffs	Mass lost from cartridge / (g)	Weight gain pad 1	Mass discrepancy (g)	% captured on pad	% lost / unaccounted
50/50	70	-0.0839	0.0462	-0.0377	55%	45%
60/40	100	-0.1393	0.0738	-0.0655	53%	47%
70/30	70	-0.2776	0.1909	-0.0867	69%	31%
80/20	60	-0.0371	0.0298	-0.0073	80%	20%
90/10	40	-0.0159	0.0149	-0.0010	94%	6%

Table 1: mass lost by cartridge and gained by primary capture pad for GoSelect cartridges loaded with different cannabis oil/IPA mixtures

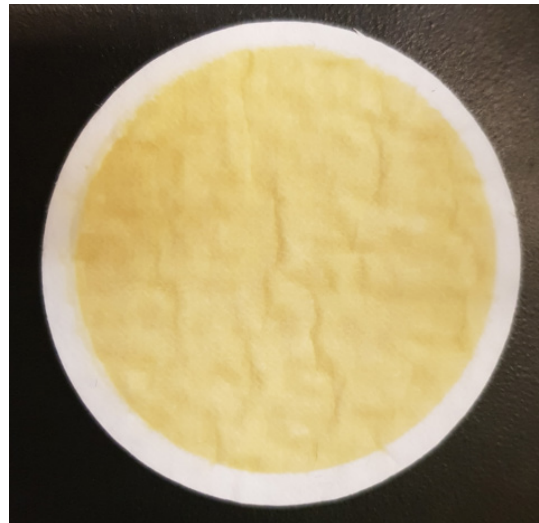


Figure 7: discoloured primary pad after puffing diluted cannabis oil

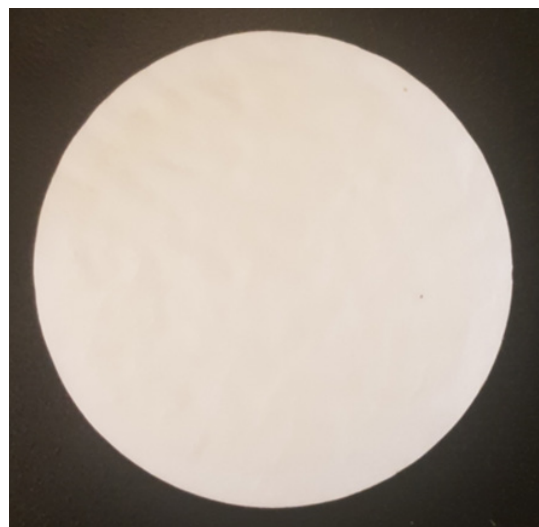


Figure 8: secondary capture pad showing no discoloration after puffing

Discussion

Plotting the percentage of recovered mass and not recovered mass against proportion of cannabis oil in the mix shows that the percentage of mass captured/lost closely follows the degree of dilution (Figure 9). It is a strong possibility that the mass that has not been captured by the primary capture pad is the solvent added to the oil that was intended to reduce viscosity.

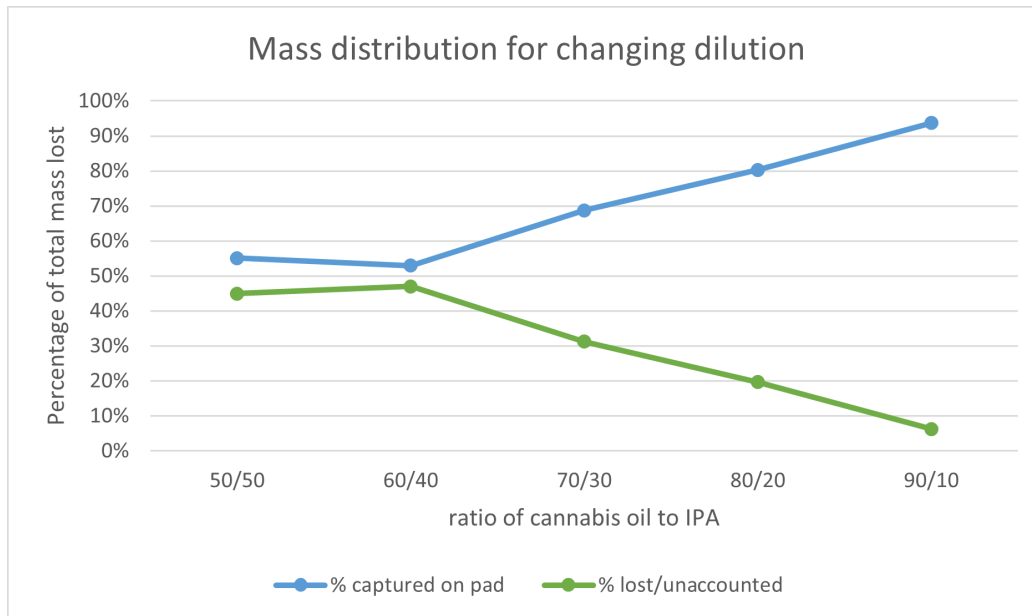


Figure 9: plot of percentage recovered mass and unrecovered mass for differing dilutions of cannabis oil with IPA

If we also examine the delivery, the aerosol mass that leaves the cartridge to the aerosol phase, on a per puff basis (Table 2 and Figure 10) we can see that the delivery increases markedly to 30% dilution and then drops away, as does the captured mass of aerosol.¹

Mix THC:IPA	delivery per puff/mg	CFH capture per puff/mg
50/50	1.199	0.660
60/40	1.393	0.738
70/30	3.966	2.727
80/20	0.618	0.497
90/10	0.398	0.373

Table 2: per puff delivery and recovery for various dilutions of cannabis oil

¹ The mass captured as a proportion for the 10% diluted oil is greater but the absolute mass captured is significantly greater

Dilution method for successfully creating cannabinoid (THC) aerosols for subsequent chemical analysis.

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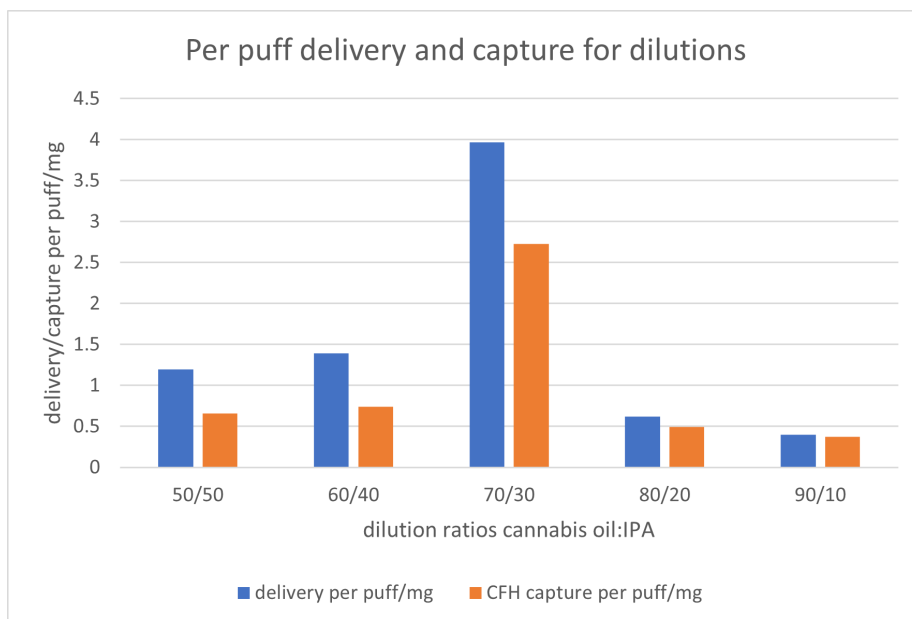


Figure 10: Per puff delivery and recovery for various dilutions of cannabis oil with IPA

The dilution of the cannabis oil with IPA improves the ability of the cartridge coil to volatilise the liquid compared to an undiluted oil. The amount of mass lost to the system seems to be directly correlated to the degree of dilution. However, there seems to be a “sweet spot” for dilution which maximises the ability of the cartridge to deliver aerosol mass, 30% dilution.

This ability to “help” the oil into the aerosol phase could be quite valuable when considering experiments where we might wish to capture aerosol mass in alternate trapping systems such as liquid filled impingers or where we need to transport aerosol to in vitro or in vivo systems for advanced inhalation toxicology studies. That the experimenter can choose a dilution that maximises the mass delivered by puff would enable experiments to be shortened in duration.

The solvent chosen was an arbitrary one with no assessment of the toxicological impact of using IPA as a diluent, other more suitable solvents could easily be identified and tested.



Conclusions

Dilution of cannabis oils with an organic solvent offers a means of reducing viscosity in the oil and an improved transfer of the oil to the aerosol phase when vaping.

The level of dilution with organic solvent changes the transfer rate from cartridge to aerosol with a mix of 70% cannabis oil to 30% IPA (propan-2-ol) giving the best transfer.

Capture of the subsequent aerosol by a glass fibre pad is possible, the amount of aerosol captured as a proportion of the aerosol generated follows the dilution i.e., 50% of aerosol is captured for a 50% dilution, 80% of aerosol is captured where there is 80% cannabis oil with a 20% dilution. It is proposed that the missing mass (uncaptured) is essentially the diluent, which appears may pass directly through the pad or be evaporated.

Using a dilution method may not always be possible in practice due to design constraints of the cartridge (if a fixed unit) but it offers a means of creating a consistent aerosol for toxicological studies of cannabis vaping liquids and devices.

ⁱ *Regulated Marijuana testing programme: Sampling and testing program, Colorado Code Regulations 212-3-4-115, 4499), May 20, 2021*

ⁱⁱ *Heavy Metals Testing, Bureau of Cannabis Control, California Code of Regulations Title 16 Division 42, 5723, 2018, 1-120*

ⁱⁱⁱ *Zelinkova, Z; Wenzl, T; Influence of battery power settings on carbonyl emissions from electronic cigarettes" Tob. Induc. Dis.; 2020; 18; 77 1-5*

^{iv} *Gray, N; Halstead, M; Valentin-Blasini, L; Watson, C; Pappas, R.S; "Toxic metals in liquid and aerosol form from pod-like electronic cigarettes"; J.Anal.Tox 2020, 00; 1-7*

^v *ISO20768:2018 Vapour products- Routine analytical vaping machine – Definitions and standard conditions*

^{vi} *WHO TobLabNet SOP1 – standard operating procedure for intense smoking of cigarettes*

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CERULEAN AROUND THE WORLD



● Tobacco Companies ● Coesia Companies

Cerulean UK

Head Office
T: +44 1908 233833
E: info@cerulean.com

Cerulean India

Coesia India Pvt Ltd.
T: +91 80 4157 3445
E: info@cerulean.com

Cerulean USA

GD USA Inc t/a Cerulean
T: +1 804-601-3204
E: info@cerulean.com

Cerulean China

Cerulean Shanghai Co Ltd.
T: +86 21 6125 3288
E: info@cerulean.com

Cerulean Singapore

c/o Molins Far East Pte Ltd.
T: +65 6289 3788
E: mfe@molins.com



Cerulean
Rockingham Drive,
Linford Wood East
Milton Keynes
MK14 6LY UK

T: +44 (0) 1908 233833
F: +44 (0) 1908 235333
E: info@cerulean.com
W: www.cerulean.com