



CANNABIS - WHITEPAPER COLLECTION

Electrostatic Precipitator use for capture of cannabinoid (THC) aerosols

CERULEAN

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Introduction

Screening for metals in legal cannabis products, including vaping liquids, is required by multiple state legislaturesⁱ ⁱⁱ. Colorado, in particular, the metals content in the aerosol phase, including mercury, arsenic, cadmium, and lead, is required to be measured.

The driving force in part for the determination of metals in cannabinoids (predominantly containing the lipid (-)-trans-delta-9-tetrahydrocannabinol which is commonly referred to as THC) is the known ability of Cannabis sativa plants to remediate metals from soilsⁱⁱⁱ. Cannabis is so effective in phytoremediation within the environment that hemp (a non-psychoactive variety of cannabis) has been used as a tool in the bioremediation of metal contaminated soils^{iv}. The role of cannabis as a hyperaccumulator for various trace metals leads to concerns for high concentrations of toxic metals in any aerosol or smoke stream^v.

Commercially available cartridges may contain a variety of high cannabinoid mixtures. Terpenes can be added to the oils for flavouring as well as diluents that modify the viscosity of the concentrated oils which are typically of exceptionally high viscosity when undiluted^{vi}. The oils can vary in weight percentage of cannabinoids from 40% to over 90%, the higher the concentration of cannabinoids apparently the higher the viscosity of the liquid. The balance of the mixture is likely to contain plant derived terpenoids^{vii} ^{viii} and diluents such as MCT (medium chain triglyceride) oil, triethyl citrate, propylene glycol, vegetable glycerine etc.

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 metals. The base cannabis oil may be analysed for metals but the transport to the aerosol phase may alter the dose of metals to the user. Moreover, it is known, from the analogous nicotine vaping systems, that there is sometimes leaching of metals from the device cartridge itself which has to be factored into any judgement on dose of toxic metals^{ix}. It is therefore necessary to experimentally determine the actual dosage of metals in the aerosol formed when a cartridge loaded with cannabis oil is heated and “vaped”.

Vaping cannabis oil with a high cannabinoid content can prove challenging due to the high viscosity of the oil and the tendency for localised heating not to be sufficiently strong to deliver consistent aerosol. This can in part be mitigated by preheating the cartridge to reduce viscosity or by increasing the vaping liquid temperatures. It is of note that a survey of nicotine cartridge heating showed liquid temperatures of between 135°C and 334°C^x and for comparison the PAX labs vaporiser 3 device (PAX labs, San Francisco, California) App controls the liquid temperature in the device between 430°F and 790°F (221°C to 421°C). It is possible that liquid temperature could influence metal transfer to the aerosol.

A typical capture method in cigarette smoke metals analysis is the use of an electrostatic precipitator of the Cottrell type where the smoke particles are negatively charged using a high voltage electrode and then these charged particles are drawn to a grounded plate and so precipitating onto a quartz glass tube. Efficiencies of capture reach 98% when compared to physical traps. This method is used to prevent spurious background effects from liquid or physical trapping systems which may produce trace quantities of the elements being studied and so compromise the LOD/LOQ.

When used for nicotine ENDS the recovery rate of electrostatic precipitation is reported to be much more variable, from less than 15% to greater than 80% depending on the relative proportions of propylene glycol, vegetable glycerine and water in the liquid. The polarity of the liquid seems to be significant in the efficiency of capture and non-polar liquids have poor capture efficiency by this method. This could be a significant problem when it is considered that THC also is broadly a non-polar liquid/aerosol.

It has been proposed that the low efficiency within an electrostatic precipitator is because the aerosol formed is not immediately condensed to liquid droplet form when leaving the device and so needs time to condense^{xi}.

An experiment was conducted to establish the usefulness and limitations of using an electrostatic precipitator for cannabinoid aerosol capture using commercially available prefilled THC cartridges.

Experimental

The experiments were performed using the Cerulean CETI1 aerosol generation machine. The CETI1 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 electrostatic precipitator (EP) ETS100 was also supplied by Cerulean, Rockingham Drive, Milton Keynes, United Kingdom and consisted of a high voltage electrode (20kV) within a quartz tube surrounded by an earthed element. Aerosol could flow through the EP, see schematic figure 1

Use of an Electrostatic Precipitator for the capture of cannabinoid (THC) aerosols.

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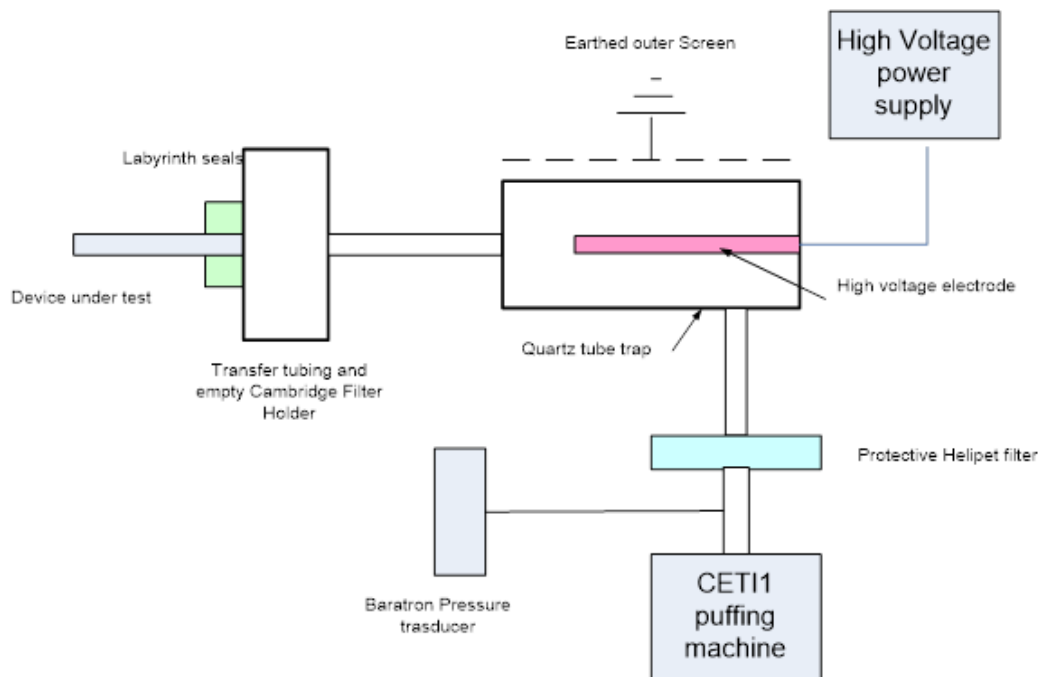


Figure 1: experimental schematic for electrostatic trapping experiments

The samples used for test were the GoSelect Purple Punch cartridge (84.1% total cannabinoids 0.3g) and the GoSelect Berry Gelato cartridge (92.1% total cannabinoids, 1.0g). Each unit was fitted with a freshly charged battery pack (figure 2).



Figure 2: Typical GoSelect Vaping system with cannabis oil in cartridge.

Puffing on the product 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.

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.

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 was the capped electrostatic precipitator tube and for the Berry Gelato tests the protective filter and the “interface” components were also weighed.

Results

The products selected for test were able to deliver a good aerosol stream without further treatment – higher cannabinoid content cartridges were often found to need some preheating to obtain a sufficiently low viscosity to support continuous vaping.

The experimental arrangement allowed viewing of the aerosol within the EP and figures 3, 4 and 5 show the aerosol entering the trap and the dispersion at +10 seconds and +30 seconds from entry. In a tobacco smoke trap the smoke would clear almost instantly whilst in the case of the GoSelect aerosols the inside of the trap cleared slowly, and it is debatable if the trap cleared completely before the next puff was taken on a 30 second cycle.

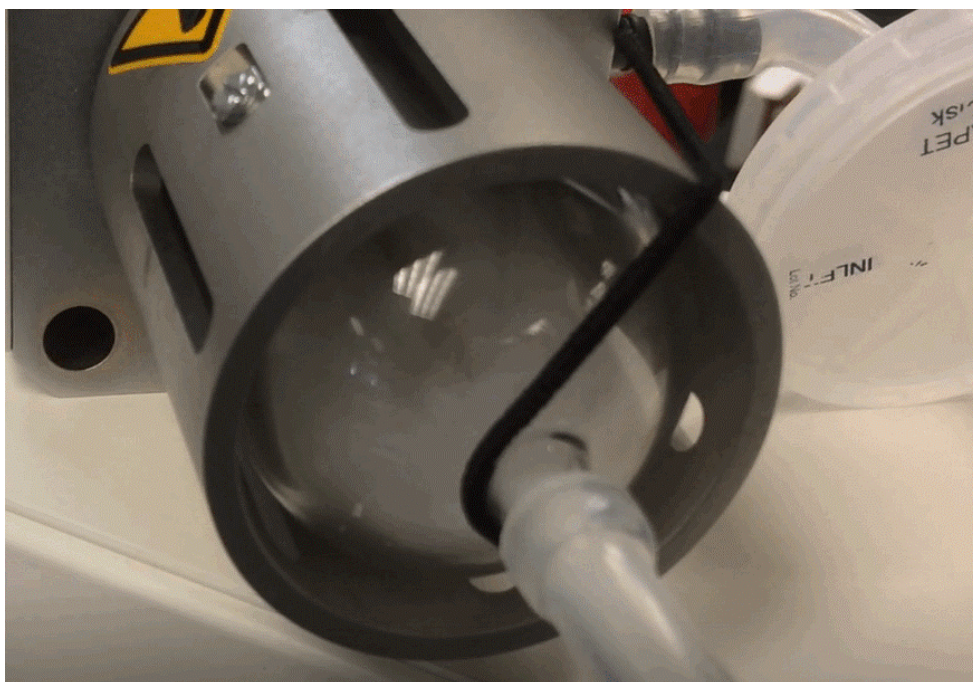


Figure 3: Inside of the Electrostatic precipitator trap at the end of a puff, time zero. The inner electrode is totally obscured by the cannabis aerosol. Device was GoSelect Purple Punch 84.1% total cannabinoids 0.3g cartridge

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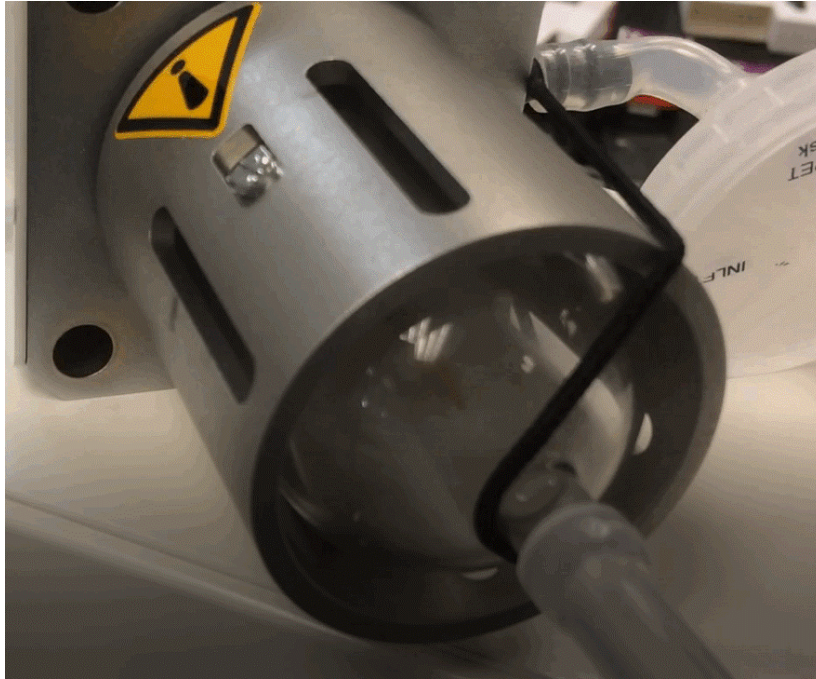


Figure 4: Image of inside of the Electrostatic Precipitator trap 10 seconds after entry of aerosol. Note that the trap is beginning to partially clear, yet the internal electrode remains obscured. For a tobacco smoke product, the trap after 10 seconds would be expected to be fully cleared.

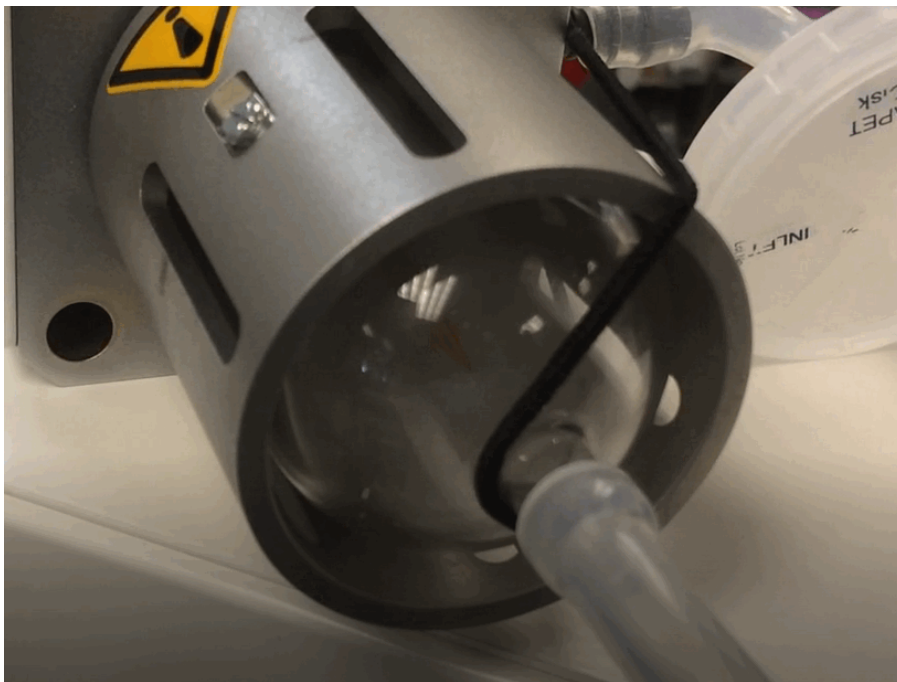


Figure 5: Inside of electrostatic precipitator 30 seconds after puff. The electrode is starting to emerge from the obscuring aerosol, but some aerosol remains. This will be drawn through the trap as the next puff is drawn and will not be captured.

Weighing of various components of the experimental arrangement allowed an assessment of where in the system it was possible to capture aerosol for analysis. The initial tests with the GoSelect Purple Punch vaporiser only examined the difference between the loss in liquid from the cartridge and the capture by the electrostatic trap. It was quickly established that there was a significant discrepancy between the mass captured and the mass lost from the cartridge so a repeat experiment with the GoSelect Berry Gelato cartridge included measurement of the protective filter mass gain and the aerosol deposited in the transfer arrangement.

The mass balance results are shown in table 1

	Berry Gelato puff: 0-30	Berry Gelato puff: 31-60	Purple Punch puff: 0-100
% Total Cannabinoids	92.10%		84.10%
Mass loss from cartridge / g	0.1484	0.1110	0.0800
Mass gained by EP trap / g	0.0433	0.0268	0.0322
Mass gained by transfer tubing / g	0.0125	0.0061	
Mass gained by protective filter / g	0.0450		
Mass imbalance (unaccounted mass) / g	0.0476		
Delivery per puff/mg	4.95	3.70	0.80
EP recovery per puff/mg	1.443	0.8933	0.322
EP recovery efficiency	29%	24%	40%
Max recovery transfer tube and EP	1.86	1.10	
Max recovery rate	38%	30%	

Table 1: delivered mass of THC from two devices using 55/3/30

Throughout the experiment the pressure drop of the devices was measured using the Baratron device. The initial pressure drop measured on the cartridge was 130mmWG and this was held throughout the experiment. This is of some interest as a pressure drop below 100mmWG tends to indicate a leak between cartridge and CETI1 machine (or for that matter within the system) and a pressure drop increasing towards 500mmWG indicates significant resistance to draw such as might occur through a blocked filter or extra high viscosity in the cannabis oil or even the oil solidifying.

On dismantling of the EP trap, it can be clearly seen that a thick, sticky deposit of cannabinoid aerosol has been captured. See figure 6



Figure 6: Deposit of cannabinoid oil inside of the Electrostatic trap after 60 puffs of Berry Gelato vapour. Experimental conditions 55/3/30 and 20kV on electrode.

Discussion

The efficiency of capture of the THC aerosol by the electrostatic trap is less than would be expected for cigarette smoke and within the bounds expected for other nicotine ENDS. A simple observation is that the first 30 puff block for the Berry Gelato device delivered more aerosol than the second 30 puff block, this could be a consequence of the high viscosity of the liquid not allowing the cannabis oil to “flow” to the coil, an effect noted elsewhere. Partial external heating of the liquid may be a means of providing greater uniformity of delivery through an experiment.

It is notable that the empty Cambridge Filter holder and tube used for connection between the electrostatic precipitator and the device under test was a significant point where aerosol could condense and an improved experimental fixture, with the EP trap connecting directly to the device under test could increase the recovery rate for the experimental arrangement.

The figures 3 through 5 show that the aerosol has not fully cleared before another puff is taken, extending the interval between puffs to 60 seconds may increase recovery rate. There is a potential trade off. At 30 second puff interval there is a slight internal heating effect for the cannabis oils which will aid transport of the liquid to the coil. Extending the puff cycle to 60 seconds will eliminate this heating effect and therefore the transport to the coil may not be as good and an alternate means of reducing the cannabis oil viscosity would be needed.

It is perhaps of note that the lower cannabinoid content oil (Purple Punch) had a higher trapping efficiency than the higher cannabinoid content oil (Berry Gelato). There was no indication on the packaging of the liquid product as to the makeup of the 15.9% of non-cannabinoid content of the oil and it is possible that this unknown content is instrumental in improving recovery rates, a more polar solvent or diluent would improve the trapping efficiency.

An improvement to the methodology that would increase recovery rates would be to minimise the distance between device and trap, lengthen the interval between puffs, and externally heat the cartridge to promote oil mobility to the coil. It may be also advantageous to add some 10% of a polar solvent such as IPA (Propan-2-ol) to the cannabis oil to promote capture although in practice with sealed systems this may not be possible.

Even with the flaws in the methodology and the low recovery rate it is possible to estimate the amount of puffing that would be required to collect enough sample for digestion and analysis using ICPMS. The capture rate of between 0.3mg and 1.4mg in the EP trap or an approximate 30% to 40% trapping efficiency would give good guidance for the number of puffs that need to be taken to allow an analytically significant sample to be taken.

Conclusions

The use of an electrostatic precipitator (EP) for capture of cannabis aerosol for metals analysis is clearly not as efficient as for cigarette smoke and is comparable to the method as applied to nicotine ENDS devices. This is not an ideal situation and alternate methods could be developed for capture. These also have drawbacks, especially in the case of the CDC method where the extraction of THC oils from a long narrow tube is somewhat challenging.^{xi}

A ballpark estimate of recovery of between 30% to 40% gives the laboratory a guide to the amount of puffing from a device that would be needed to allow digestion and analysis by ICPMS for critical metals analysis.

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 Cittero, S; Santagostino, A; Fumagalli, P; Prato, N; Ranalli, P; Syorbati, S; "Heavy metal tolerance and accumulation of Cd, Cr and Ni by Cannabis Sativa L" Plant Soil, 2003, 256, 243-252

iv Charbowski, E; "Hemp 'eats' Chernobyl waste, offers hope for Hanford" Central Oregon Green pages 1998

v Girdhar, M; Sharma, N.R; Rehman, H; Kumar, A; Mohan A; Biotech 4 (6) 579-589 2014

vi Meelan-Atrash, J; Strngin, R.M; "Pine rosin identified as a toxic cannabis adulterant". Forensic Sci.Int 2020, 312, 110301

vii Azakan, Z; "Cannabis, a complex plant; Different compounds and different effects on individuals" Ther .Ad. Psychopharmacol. 2012 2, 214-254

viii Varlet, V; Concha-Lozano, N; Berthet, A; Plateel, G; Favrat, B; De Cesare, M; Lauer, E; Augburger, M; Thomas, A; Giroud, C; "Drug vaping applied to cannabis; Is 'cannavaping' a therapeutic alternative to marijuana?" Sci. Rep. 2016, 6, 25599

ix 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

x Chen, W; Wang, P; Ito, K; Fowles, J; Schusterman, D; Jaques, P.A; Kumagai, K; "Measurements of heating coil temperature for e-cigarettes with "top-coil" clearomiser"; PLoS One , 2018 13 No e0195925

xi Mallampati, S.R.; McDaniel, C; Wise, A.R; "Strategies for nonpolar aerosol collection and heavy metals analysis of inhaled cannabis products" ACS Omega, 2021, 6, 26, 17126-17135

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