Document Title:	**Chasing the Electronic Cigarette Dragon: Characterizing the Evolution and Impact of Design and Content**
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Document Number:	**252921**
Date Received:	**May 2019**
Award Number:	**2016-DN-BX-0150**

"Chasing the Electronic Cigarette Dragon: Characterizing the Evolution and Impact of Design and Content"

Final Report

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National Institute of Justice
Research and Development in Forensic Science for Criminal Justice Purposes
Grants Number: 2016-DN-BX-0150
Grant Period: January – December 2017
Approved Extension: June 30, 2018
DUNS Number: 10-530-0446
EIN: 54-6001758
Reporting Period: 01.01.2017 – June 30, 2018

Submission Date: September 20, 2018

Andrea J. Publow, MFA, CRA
Director of Sponsored Programs- Government/NonProfit Support

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Statement of Problem

Electronic cigarettes (e-cigarettes or e-cigs), known as "personal vaporizers" (PV) by avid users or electronic nicotine delivery devices (ENDS) by industry, have experienced a significant increase in popularity for those seeking an alternative to smoking traditional tobacco products. These products are comprised of a battery-powered atomizer and a cartridge filled with a pharmaceutical (nicotine), flavorants, and water dissolved in glycerol products. E-cigarette devices are manufactured with a spectrum of opportunities to personalize usage: from off-the-shelf non-customizable devices to a variety of options such as self-wrapping of the element, packing homemade wicks, self-preparation of the liquid nicotine refill, and wattage adjustors to administer a desired drug dosage.

Google searches have resulted in a plethora of drug forums, blogs, and YouTube videos that provide accounts of adulterating the glycerol-based liquids used in the devices to deliver drugs such as tetrahydrocannabinol, methamphetamine, fentanyl, and synthetic cannabinoids. The forums also discuss in detail how to manipulate e-cigs themselves for more efficient delivery of certain illicit drugs. The industry has evolved quickly in the last 2 years to produce devices that facilitate aerosolization of "dry" non-glycerol-based formulations – items such as plant materials, crystalline formulations, and powders.

As e-cig devices and the associated pharmaceutical products evolve, it is imperative to track their development and know how they are being promulgated. It is critical to understand how their use contributes to issues related to criminal justice and public safety concerns such as the distribution of illicit substances, toxicological episodes, and postmortem investigations. While several research initiatives around the world have concentrated on the nicotine-focused use of e-cigarettes, to this investigator's knowledge, the research supported by the National Institute of Justice is the only effort focused and committed to understanding their more nefarious uses and outcomes. While in the process, this research group has begun to produce significant work from a single early e-cigarette model that will be important for the tobacco products community. Even with the progress already made, the research has only really just begun to understand how electronic cigarettes are used and contribute to criminal justice concerns, with significant concerns that the devices have quickly evolved. This proposal aims to characterize how electronic cigarettes have and continue to evolve, investigate how the newest models impact drug delivery compared to what is now the base model currently under investigation, and investigate what "illicit" pharmaceutical products are developed and promulgated, and how they are successfully distributed. From a toxicological perspective, drug delivery as a function of power in electronic cigarettes needs to be fully characterized, particularly if drug bioavailability is dependent on both drug chemistry and device manipulation. Therefore, this research group evaluated the relationship between drug chemistry, heat, power, and aerosolization for understanding bioavailability.

Implications and Impact of Criminal Justice Policy and Practice

This research has provided greater understanding in the court systems nationwide as to the nature of drug usage, abuse, and overdose cases in which electronic cigarettes were used to deliver an illicit drug. Given that one role of the forensic toxicologist is to define and characterize drug usage trends, this publicly funded research posed an important, relevant, and critically timed study to address an identified threat to public health and criminal justice. This research also supported analytical efforts in controlled substances units and the findings and opinions of scientists, medical examiners, death investigators, and forensic toxicologists as they present analytical results.

We have worked with several laboratories and received samples to demonstrate the use of e-cigs as drug paraphernalia. Dr. Peace has prepared expert testimony and provided advice for detectives, crime scene investigators, drug recognition expert law enforcement, controlled substance labs, and forensic toxicology practitioners. We have also been engaged by the U.S. Armed Forces twice to discuss the efficacy of e-cigs, which led to several small research projects. From these discussion and cases, we determined additional funding was warranted to explore several issues with immediate implications.

We have been invited to speak at the Eastern Analytical Research Symposium, the DEA, and to New Zealand as an International Vision Fellow (supported by New Zealand) in the Environmental Science and Research Crown Research Institute (which houses their crime lab). These talks provide evidence that the impact to the criminal justice system continues to unfold.

This research group has provided presentations and a list of publications to the U.S. Food and Drug Administration and to US Department of the Navy. Dr. Peace also met with the Ministry of Health for New Zealand to discuss e-cigarette health implications and the status of products available. This research has been part of describing and characterizing the function of an e-cigarette and contributing to critical decisions in sectors outside of criminal justice, namely the public health sector.

Accomplishments: Project Goals and Results

This study had three main objectives that address the evolution of unregulated electronic cigarette industry and rising concerns of the impact of pharmaceutical misadventures leading to overdoses and deaths. Aim 1 and 2 used methods already developed by the research team from the previous award. The third aim is meant to help the research group develop a model for the analysis of particle size distribution that would be pertinent for the forensic toxicology community in the assessment of intoxications and overdose deaths.

I. **Characterize new models of electronic cigarettes and popular customizations.** The first NIJ funded study developed a model of analysis using the KangerTech AeroTank, 1.8Ω preassembled atomizer/clearomizer with a single contact coil (the wraps

on the coil touch as opposed to being stretched apart). At the time the studies began, this was touted as a popular, moderately customizable device. Since then, a number of devices and modifications have become more popular for the use of illicit or "alternative" pharmaceuticals.

Devices that could be considered for our studies are third and fourth generation e-cigs. Third generation products have adjustable voltages on large rechargeable batteries, have refillable tanks, and the atomizers are completely customizable by the user. Third generation devices are still, largely, traditional in the sense that they have a coil wrapped in contact or non-contact configuration, and component characterization was already conducted in the previous award. Fourth generation e-cigs are predominantly "dripper" devices or non-eliquid devices, which allow for alternative products, such as plant materials and waxes, to be vaped. A number of these products were purchased and include ceramic donuts, quartz bar-coils, and cup devices. One completely metallic device contains two cups advertised to facilitate vaping two types of solid materials simultaneously. The IR probe was rebuilt to evaluate the temperature/heating profiles of these fourth-generation devices.

The Source Orb e-cigarette was packaged with six different atomizers: coil-less, single coil, and double coil, made up of quartz, ceramic, or titanium. The Donut Kandy Pens were equipped with a coil-less ceramic chamber. The Wulf Mod Dome Kit equipped with a dual coil ceramic and the Vaped Vubbler with a single ceramic titanium coil were also evaluated (Figures 1,2,3,4). The temperatures of these coils and cups are significantly lower than the Kanthal and NiChrome coils of traditional second and third generation coils (Figures 5-6). These devices, even those that have coils, are made specifically for waxes and dabs. Coils in these fourth-generation e-cigarettes have a ceramic or glass rod through the coil, which prohibits wicking from a tank. Users are directed to not use these devices for e-liquids. Characterization of new devices is critical to understand the nature of new drug paraphernalia and educate law enforcement to collect such evidence. Additionally, devices may drive or facilitate new drug formulations, which are critical to understand.

II. **Characterize e-liquids purchased over-the-counter or the internet.** Drug forums and vendors were monitored for e-liquids being sold that purportedly contain alternative pharmaceuticals. One clue to assess for adulterated e-liquids is cost. Most nicotine e-liquids range from $5-10. A number of sites selling e-liquids with alternative drugs charge more per bottle, as much as 5-20 times more expensive. Additionally, crime labs and law enforcement agencies were contacted as partners for the analysis of the e-liquids acquired in their jurisdictions. DART-MS was used to screen products, and a trap was used to collect the aerosol for drug quantitation by $LCMS^3$ or GC-MS, as appropriate. SPME was used in the trap to quickly assess whether drugs other than nicotine (DOTNs) were effectively aerosolized.

Nine different e-liquids were purchased online, suspected of having questionable QA/QC in the manufacturing process or containing chemicals intended for a "legal high". For some products, matching resins and powders were purchased and analyzed (Figure 7).

Samples were analyzed by DART-MS. All e-liquids were also evaluated for volatiles by HS-GC-FID, and isopropanol was found in five of the nine e-liquids. A summary of the presumptive analyses is in Table 1.

Four samples were purchased from a retailer who indicated he had four products containing Kratom. Two "Purple Haze" e-liquids labeled 0 and 12 mg and two "King Kratom" e-liquids each containing approximately 5mL of liquid and labeled the same were analyzed. Neither the retailer nor the bottles were clear as to what the quantity referred to (mitragynine, nicotine, plant material, etc.). All samples were determined to contain both nicotine and mitragynine (Figure 8). Quantitation by LC-MS/MS determined the samples had 1.0 (±0.0) μg/mL and 1.7 (±0.1) μg/mL mitragynine in the "0 mg" bottles and 0.3 (±0.0) and 1.2 (±0.1) μg/mL mitragynine in the "12 mg" bottles. Mitragynine was not found in the aerosol by SPME-GC SIM, indicating that the drug was not effectively aerosolized or that it was not effectively extracted by the SPME fiber. There is some evidence that heavy molecular weight drugs may not efficiently aerosolize, therefore requiring further investigation.

THC was successfully aerosolized from a cup-based atomizer, as determined by SPME-GC, proving that these devices are hot enough and effective in aerosolizing drugs. The synthetic cannabinoid 5F-ADB and dextromethorphan were identified in e-liquids purportedly containing only CBD to be consumed for "health benefits" (Figure 9).

III. Develop a model for the characterization of the particle-size distribution in aerosols.

The aerosol generated by e-cigarettes is formed by condensation of heated vapor into droplets and is a stable liquid aerosol, because the droplets do not quickly fall under the influence of gravity. We evaluated the particle sizes of the aerosol generated by an e-cigarette, a KangerTech AeroTank, 1.8 Ω preassembled atomizer with eGo-V2 variable voltage battery was used to determine if the particle size of propylene glycol (PG), vegetable glycerin (VG), the common humectants found in e-liquid formulation, and the drug nicotine, are similar to that of nicotine in "smoked" cigarettes and if the particle size is altered with the change in voltage of the battery used in the e-cigarette. These studies served as a model for performing this type of analysis on other e-liquids labeled or determined to contain other active ingredients or drugs.

For the studies conducted with nicotine, the coil resistance, voltage, and PG to VG ratio were varied. Three 12 mg/mL nicotine e-liquids were created in 50:50 PG:VG, 100% PG, and 100% VG solutions. For the coil resistance study, pre-assembled atomizers with coil resistances at 1.5, 1.8, and 2.2 Ω at 4.3 V were used for all three nicotine formulations. For the voltage study, the voltage was varied at 3.9, 4.3, and 4.7 V at 1.8 Ω for all three nicotine formulations. Methamphetamine and methadone were prepared at 60 mg/mL in 50:50 PG:VG e-liquid formulations and the aerosol was generated at 3.9, 4.3, and 4.7 V at 1.8 Ω resistance.

A 10-stage Micro-orifice Uniform Deposit Impactor (MOUDI) cascade impactor was used to collect aerosol at each stage at a flow rate of 30 ml/min to ensure that particles

reached all 10 stages. Each stage was weighed pre- and post-aerosol to assess glycol deposition. Nicotine was quantitated on each stage by LC-MS/MS. Voltage, resistance, and glycol composition was varied to determine the impact that each variable had on particle size. Experiments were repeated in triplicate.

Important findings from the nicotine model experiment include:

- Glycol deposition and nicotine distribution had the same particle size distribution.
- Majority of the particles' distribution was 0.172-1.0 μm, correlating with deposition in the pulmonary region.
- Mean particle size was 0.3389 ± 0.0090 μm of a 50:50 PG:VG nicotine e-liquid, similar to traditional cigarettes.
- No statistical difference of mean mass aerodynamic diameter (MMAD) particle size distribution exists between different common voltages and coil resistances. PG produced slightly larger aerosolized particles, confirming the user testimony that PG provides a stronger hit in the back of the throat. (Figures 10-11)

Methamphetamine and methadone were prepared at 60 mg/mL in 50:50 PG:VG e-liquid formulations for particle size distribution comparison to the nicotine model. The aerosol was generated at 3.9, 4.3, and 4.7 V at 1.8 Ω resistance, and drugs were quantitated by previously validated methods on the GC-MS. The glycol distributions of methamphetamine and methadone condensation aerosols were determined gravimetrically. Methamphetamine and methadone had similar distributions to the 50:50 PG:VG nicotine distribution at 1.8 Ω. The glycol gravimetric results for methamphetamine and methadone on each stage of the MOUDI resulted in a 95-96% and 85-97% deposition onto the 0.172-0.31 μm stage, respectively (Figure 10). For methamphetamine and methadone glycols, the MMAD were similar in size at 0.330 ± 0.014 μm and 0.3225 ± 0.0024 μm, respectively. Statistical analysis for the glycol distributions of the two drugs in comparison to nicotine glycol distributions determined that the glycol distributions were not statistically different from one another ($P = 0.067$).

The drug distributions of methamphetamine and methadone condensation aerosols were determined via GC-MS. Similar to nicotine, the two drugs followed the same distribution patterns as the glycols (Figure 12). The drug distributions for methamphetamine and methadone on each stage of the MOUDI resulted in a 61-86% and 54-75% deposition onto the 0.172-0.31 μm stage, respectively. Ultra-fine particles were also present in methamphetamine and methadone on the 0.05-0.1 μm stage, similarly to nicotine. The MMAD for methamphetamine and methadone were 0.343 ± 0.016 and 0.357 ± 0.056 μm, and were determined not to be statistically different from the MMAD of nicotine ($P = 0.780$).

Advanced e-cigarette users prefer to modify their products by adjusting the coil resistance and battery power in an attempt to optimize their vaping experience and potentially deliver more drug in the aerosol. This research group assessed the effect of variable voltage and yield of nicotine per puff in a 50:50 PG:VG solution and the KangerTech atomizer at 1.8 Ω resistance and determined that the change in voltage did have an effect on the yield of nicotine per puff. However, it was concluded that the increased dose per

puff with increasing voltage was not practically significant. Therefore, the group decided to explore the impact of voltage, resistance, and e-liquid composition on the development of the aerosol to evaluate user reports that they had better experiences by adjusting these parameters. However, as with nicotine concentration, the change in battery voltage and coil resistance did not significantly affect the particle size distributions of the three e-liquids, which would lead to improved bioavailability. The two variables that had the most effect on the particle size distribution were the glycol composition and the active drug ingredient present in the e-liquid. Again, it is concluded that the difference in particle size distribution observed between the PG:VG ratios and these three drugs is not practically significant in terms of drug absorption from the lung tissue into the bloodstream.

The nicotine containing e-liquid composed of 100% PG produced larger particles in comparison to the 100% VG and 50:50 PG:VG nicotine e-liquids. The larger particle size may contribute to the sensation that e-cig users describe as a "throat hit" in association with e-liquids that have high PG contents. People who use e-cigarettes for smoking cessation have commented that they prefer e-liquids with a high PG content, because of the "throat hit" sensation similar to a traditional tobacco cigarette. In contrast with the 100% PG e-liquid, the 100% VG e-liquid produced aerosol particles that were less than 0.1 μm in size. Aerosol particles that are less than 0.1 μm are referred to as "ultra-fine" particles and are known to result in deep lung deposition. However, with smaller particle size, there is a greater chance of the drug being exhaled before it can be absorbed into the bloodstream. To combat this, some e-liquid manufacturers will print instructions on the bottle labels that instruct the e-cig user to inhale and hold the aerosol for a certain amount of time. This method would increase the amount of pulmonary deposition that would lead to more drug absorption into the blood, thereby increasing the bioavailability of the aerosolized drug.

The nicotine aerosol particles formed by the KangerTech model e-cigarette appear to be similar in size to the particles formed by traditional cigarettes. The nicotine aerosol particles followed the same distribution patterns of 100% VG and 50:50 PG:VG, indicating that VG is the driving force for aerosol particle development. This demonstrates that the e-cigarettes are able to produce small particle sizes leading to deep lung tissue deposition and efficient drug delivery, even when glycol composition is altered.

Methamphetamine and methadone exhibited similar particle size distribution behaviors as nicotine. While it was determined that the difference in the MMAD of the three drugs was not statistically significant, the amount of drug recovered on the particle size stage for 0.172-0.31 μm was greater for methamphetamine and methadone than nicotine, as demonstrated by the 58-82% and 46-64%, and 23-51% drug deposition, respectively, in this range. Methamphetamine smoke has been reported to have less than 1 μm particle size when air in clandestine meth labs was sampled. The methamphetamine aerosol produced in the e-cig system had a MMAD of 0.53 μm in size, indicating that the e-cigarette is capable of creating similar sized drug aerosol particles when smoked. Heroin, an opioid regularly smoked by users, has a reported MMAD range from 2.1-4.1 μm. The MMAD of methadone in this e-cigarette system at 0.64 μm. Therefore, both

methamphetamine and methadone can be effectively absorbed into the bloodstream when an e-cigarette is used as the vehicle for drug administration. The small particle sizes combined with the user's modulation of glycol composition and inhalation techniques (i.e. inhale and hold) can improve the bioavailability of methadone and methamphetamine in e-cigarette systems, thereby increasing the potential for overdose.

Project Findings

1. Fourth generation e-cigarette products have evolved to facilitate the aerosolization of drugs from products that are not liquid. Specifically, they are designed for waxes, dabs, and solid plant material.
2. E-liquids, semi-solids, and solid materials can contain dangerous DOTNs, such as synthetic cannabinoids.
3. There is evidence that any drug that can be made liquid is being experimented with in e-cigs, including natural products considered "legal highs". The preparation of these products is of concern given the finding of isopropanol in several e-liquid preparations.
4. Majority of the particles' distribution for nicotine was 0.172-1.0 μm, correlating with deposition in the pulmonary region.
5. Mean particle size of a nicotine aerosol was 0.3 μm, similar to traditional cigarettes.
6. No statistical difference of MMAD and particle size distribution exists between different common voltages and coil resistances. PG produced slightly larger aerosolized particles, confirming the user testimony that PG provides a stronger hit in the back of the throat.
7. Methamphetamine and methadone e-liquids generate similar particle size distribution to nicotine.

Appendix: Figures and Tables

Figure 1. Source Orb 4 E-cigarette and Atomizers

Figure 2: Donut Kandy Pen E-Cigarette and Coil-less Ceramic Atomizer

Figure 3. Wulf Mod E-Cigarette and the Dual Coil Ceramic Atomizer

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Figure 4: Vaped Vubbler E-Cigarette with a single titanium coil with Ceramic Atomizer

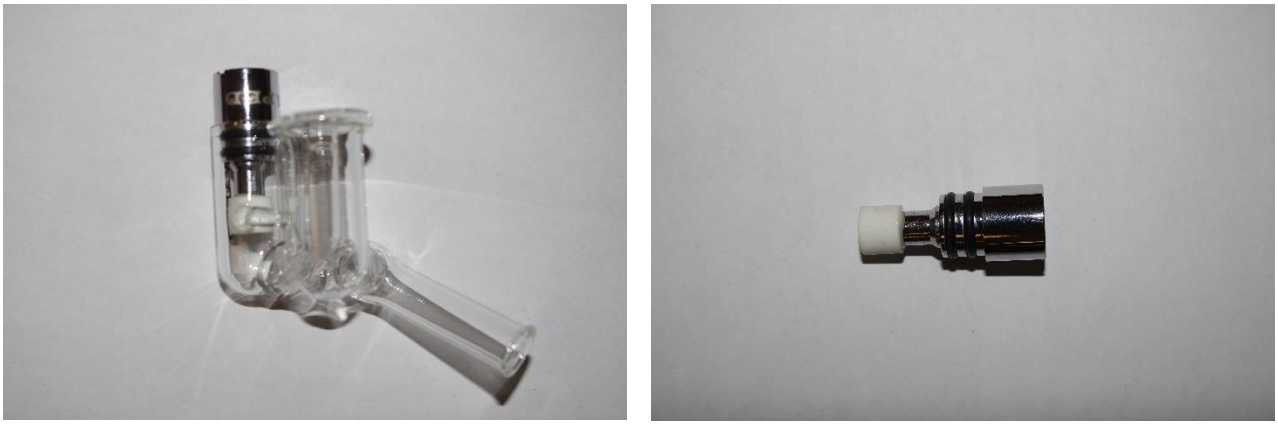

Figure 5: Temperature of Dry Coil-less Cup Atomizers

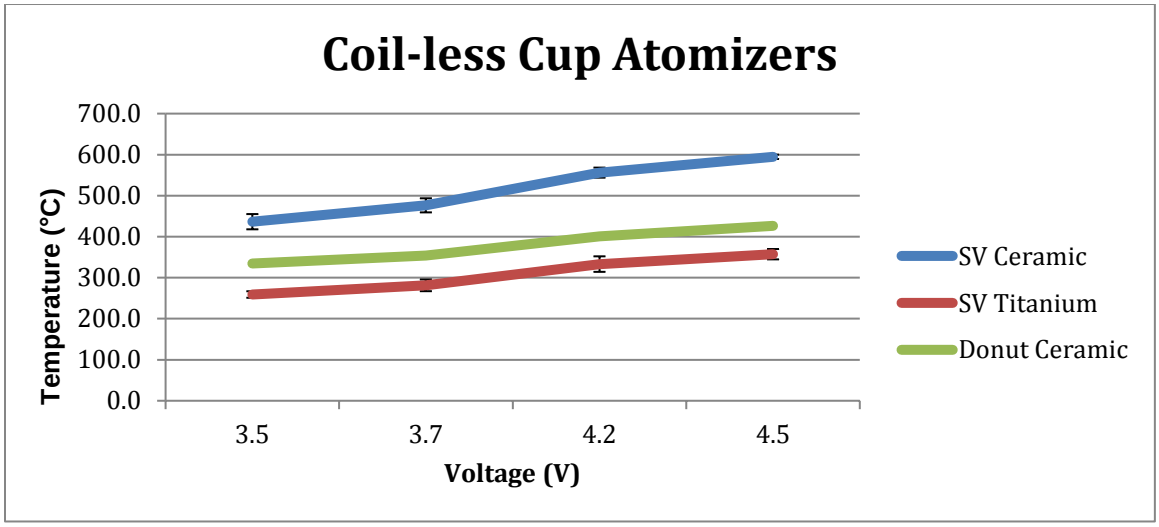

Figure 6: Temperature of Dry Single Coil Atomizers

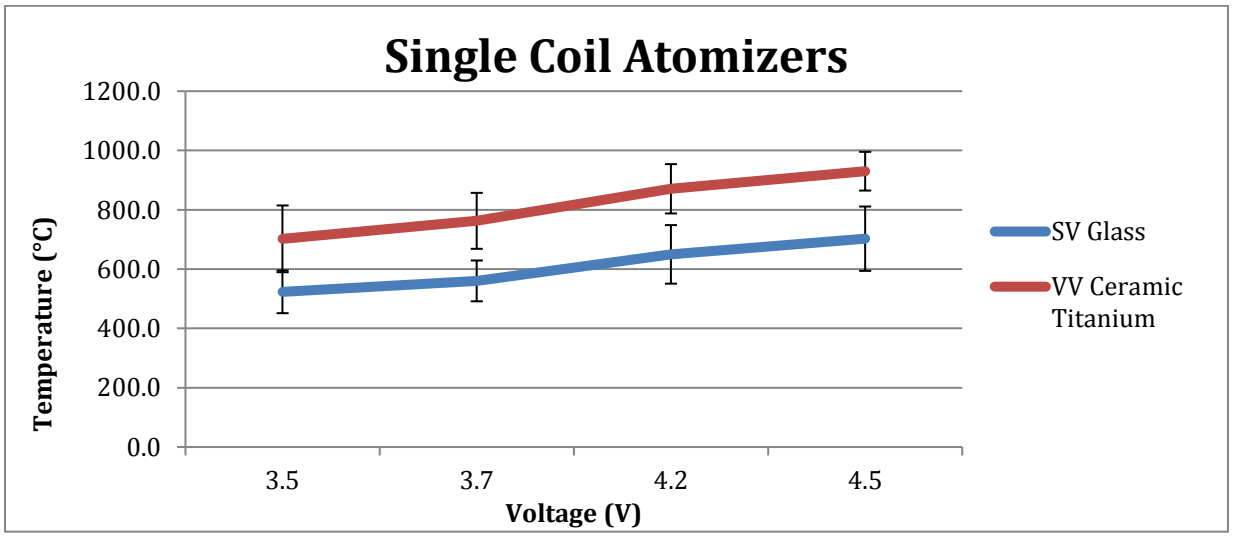

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Figure 7. Presumptive Analysis by DART-MS of Areca Nut E-liquid and Powder

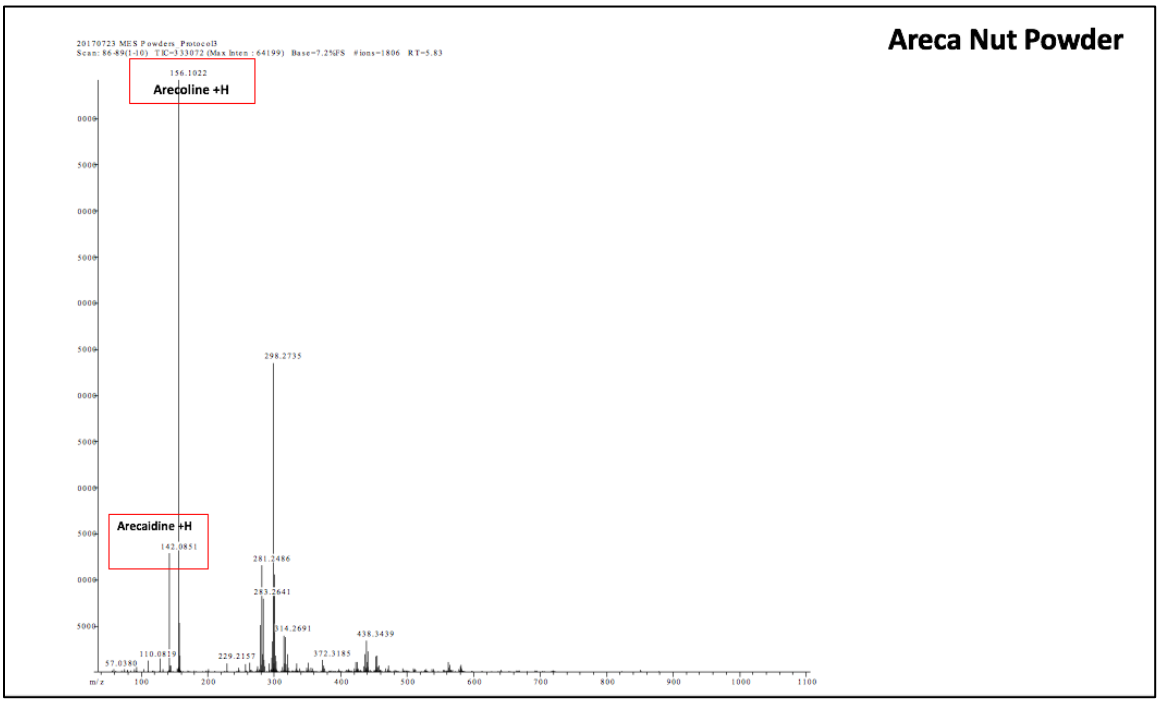

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Figure 8. DART-MS of Purple Haze, "0 mg" E-liquid containing nicotine and mitragynine

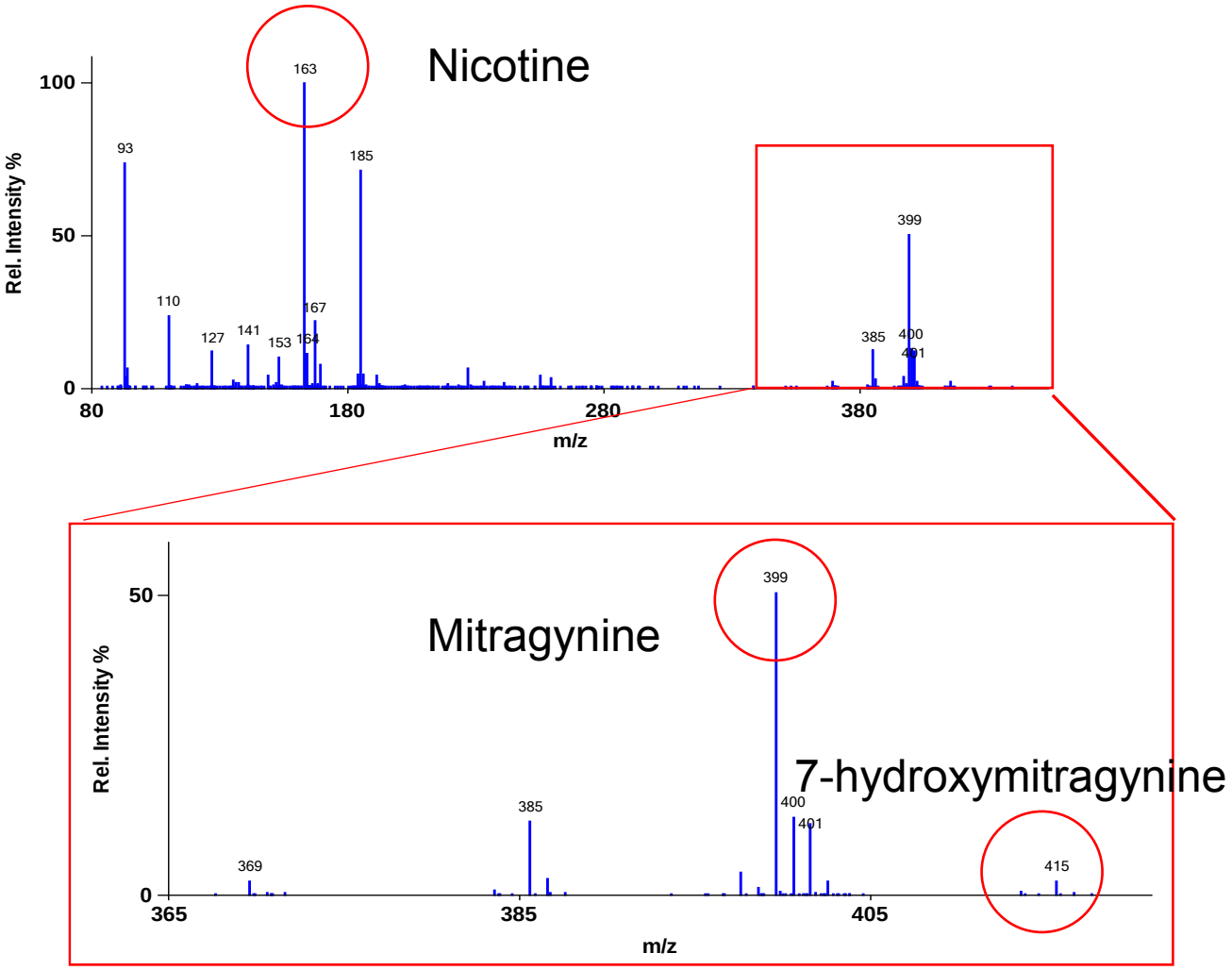

Figure 9. "CBD Only" E-liquids Containing 5F-ADB and Dextromethorphan submitted to the lab (left) and purchased online (right).

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Figure 10: Particle size glycol deposition as a function of glycol composition at 4.3 V and 1.8 Ω

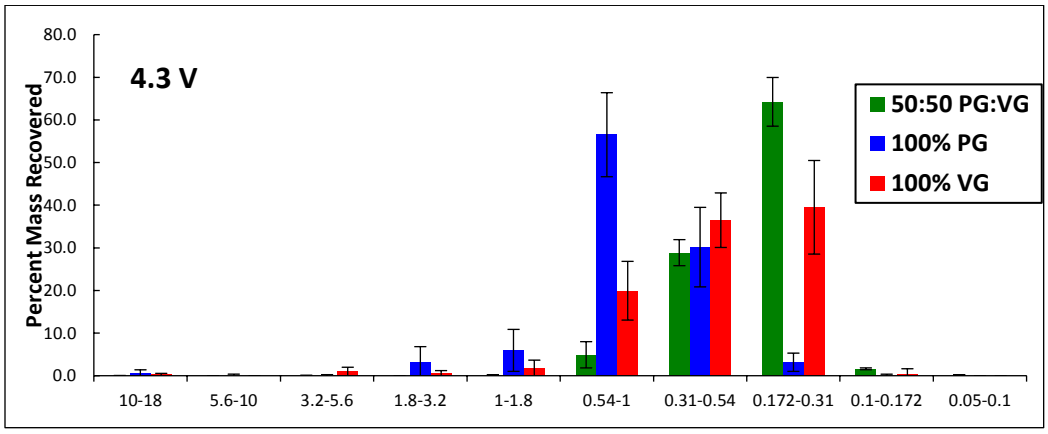

Figure 11. Nicotine particle size distribution as a function of voltage at 50:50 PG:VG and 1.8 Ω

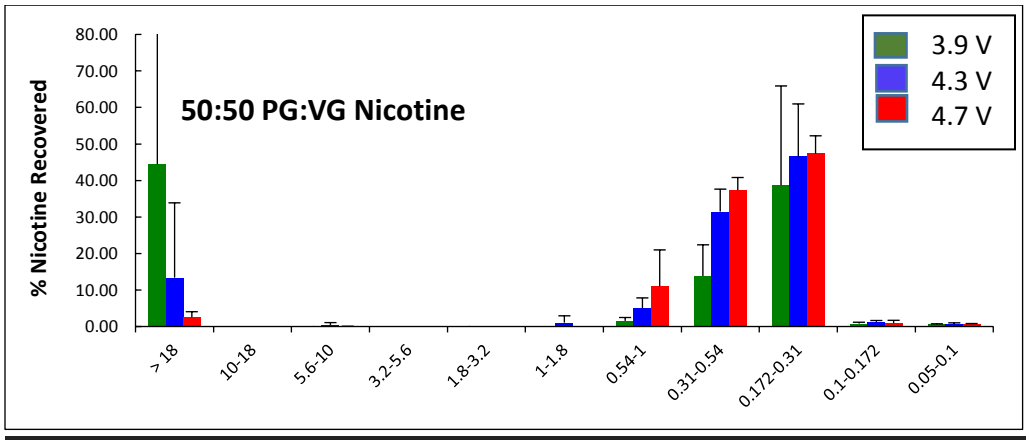

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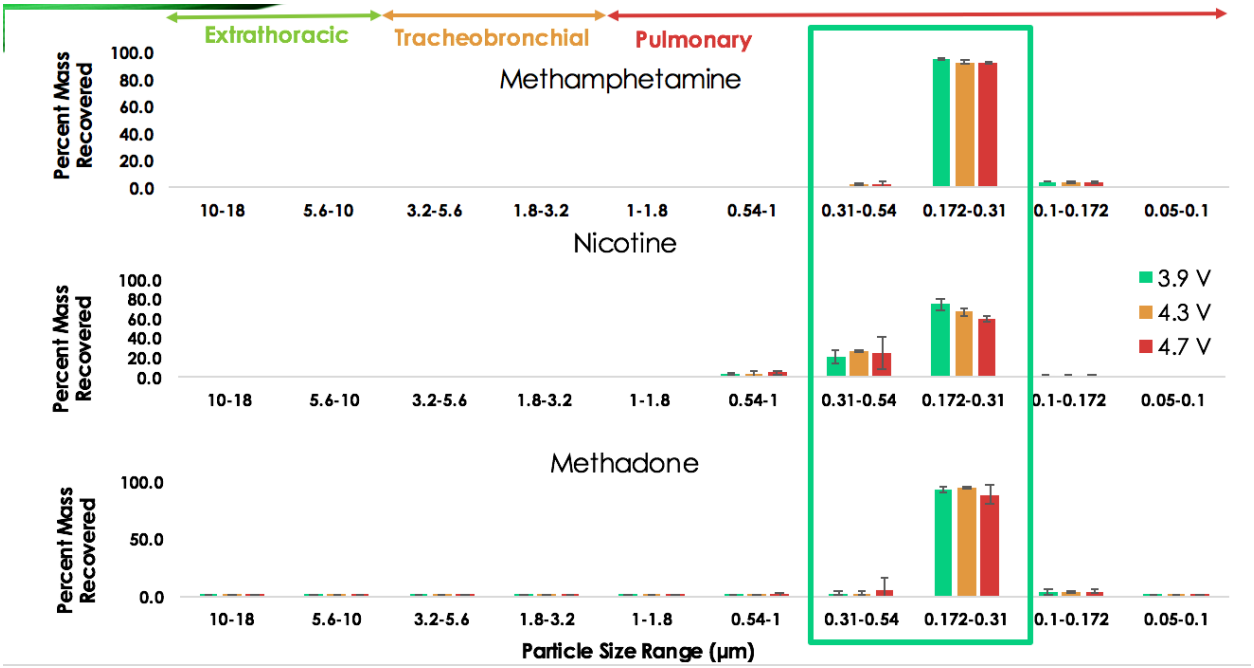
Figure 12. Particle Size Evaluation of Aerosols produced with methamphetamine, methadone, and nicotine by gravimetric analysis (top) and quantitation of drug on each stage (bottom).



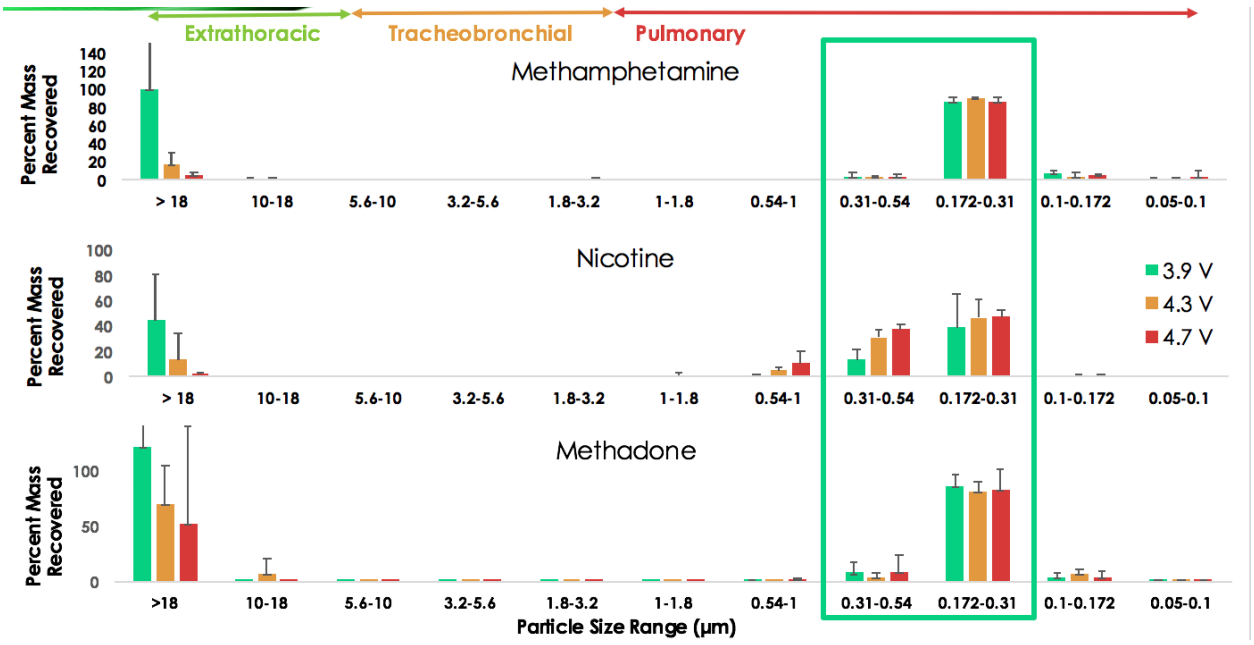


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Table 1: Presumptive Analysis of Pharmacologically Active Compounds Advertised to be in E-liquids and Associated Powders and Resins

Sample	Plant Species	Alkaloid	Vaping Substance	DART-MS [M+H]
African Dream	*Entada rheedii*	Entadamide	E-liquid Resin	√ √
Areca Nut	*Areca catechu*	Arecoline Arecaidine Guvacine	E-liquid Powder	Arecoline : √ Arecaidine: √ Arecoline: √ Arecaidine: √
Bizarro, Klip Dagga, Wild Dagga	*Leonotis nepetifolia* *Leonotis leonurus*	Leonurine	Bizarro e-liquid Klip Dagga e-liquid Klip Dagga resin Wild Dagga resin	ND for all samples
Blue Lotus	*Nymphaea caerulea*	Apomorphine Nuciferine	E-liquid Powder Resin	ND ND Nuciferine: √
Damiana	*Turnera diffusa*	P-cymene B-Sitosterol Arbutin Apigenin 7-glucoside	E-liquid Resin	ND ND
Kra Thum Kok	*Mitragyna javanica*	Mitrajavine 7-hydroxymitragynine	E-liquid:	ND 7-hydroxymitragynine: √
Kra Thum Na	*Mitragyna hirsute*	Mitragynine 7-hydroxymitragynine	E-liquid Powder Resin	ND Powder & Resin Mitragynine: √ 7-hydroxymitragynine: √
Wild Lettuce	*Lactusa virosa*	Coumarin Lactucin	E-liquid Powder	ND Coumarin: √

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Dissemination Products

Presentations – Scientific Papers

1. Mulder HA (presenter), Krokowiak R, Poklis JL, Wolf CE, Halquist M, Poklis A, **Peace MR**. Analysis of Dried Blue Lotus Flower (Mymphea Caerulea) used in an E-Cigarette. Platform Presentation, Southwestern Association of Toxicologists, Wichita KS, April 2017.

2. **Peace MR** (presenter). Chasing the Electronic Cigarette Dragon: Characterizing the Evolution and Impact of Design and Abuse. Platform Presentation, Southwestern Association of Toxicologists, Wichita KS, April 2017.

3. **Peace MR** (presenter), Mulder HA, Krakowiak R, Turner JBM, Halquist MA, Wolf CE, Poklis JL, Poklis A. An Assessment of Drugs Other Than Nicotine (DOTNs) in Electronic Cigarette Products. Poster Presentation, PittCon, Chicago IL, 2017.

4. Patterson JL (presenter), Poklis JL, Hindle M, Turner JBM, Wolf CE, Poklis A, **Peace MR**. Evaluation of the Nicotine Particle Size in an Aerosol Formed by an Electronic Cigarette. Platform Presentation, PittCon, Chicago IL, 2017.

5. Poklis JL, Mulder HA (presenter), Curless B, **Peace MR**. The Unexpected Identification of 5-Fluoro MDMB-PINACA in Commercial Cannabidiol (CBD) "Therapeutic" E-liquids. Poster presentation at PittCon, Orlando FL, 2018.

6. Tomko JT (presenter), Poklis JL, Turner JBM, Wolf CE, **Peace MR**. Assessment of Metals in the Aerosol of Electronic Cigarettes. Platform Presentation at PittCon, Orlando, FL, 2018.

7. Smith ME (presenter), Poklis JL, Turner JBM, Edinboro L, **Peace MR**. Analysis of Commercially Available Natural Vaping Products using Headspace Gas Chromatography and Direct Analysis Real Time Time of Flight Mass Spectrometry (DART-MS). Poster Presentation at PittCon, Orlando, FL, 2018.

8. Mulder HA (presenter), Halquist MS, Poklis A, Poklis JL, Turner J, **Peace MR**. Evaluation of Drugs Other Than Nicotine (DOTNs) in an Aerosol Formed by an Electronic Cigarette. Pittcon Conference & Expo 2017, Orlando FL, March 2018.

9. Royals JM (presenter), Poklis JL, Turner JBM, Wolf CE, **Peace MR**. Ethanol in E-liquids: Concentration in 35 Formulations by Headspace Gas Chromatography with Flame Ionization Detector (HS-GC-FID) and the Impact on the Temperature of the E-Cigarette Coils. Poster Presentation, Society of Forensic Toxicologists, Boca Raton, FL, 2017.

10. Krakowiak R, Poklis JL, Turner JBM, Poklis A, Davis LS, Mulder HA (presenter), **Peace MR**. Quantitation of Aerosolized Methamphetamine from Electronic Cigarettes GC/MS: Does increasing the voltage increase the dose? Poster Presentation, Society of Forensic Toxicologists, Boca Raton, FL, 2017.

11. Joiner RK, Bohidar N, Kirby BF, **Peace MR**, Ward BC (presenter). Rapid field testing of nicotine in e-liquids. Platform Presentation, Society of Forensic Toxicologists, Boca Raton, FL, 2017.

12. Mulder HA (presenter), Poklis JL, Turner JBM, Poklis A, **Peace MR**. Dripping meets Dabbing: Cases Using the Rebuildable Dripper Atomizer to Vape Non-traditional E-liquids and Drugs-Other-Than-Nicotine (DOTNs), Poster Presentation, Society of Forensic Toxicologists, Boca Raton, FL, 2017.

13. Patterson JL, Poklis JL, Halquist M, Hindle M, Turner JBM, Wolf CE, Poklis A, **Peace MR** (presenter). The Effect of Voltage, Resistance, and Glycols Ratio on Glycol and Nicotine Distribution within an Aerosol Generated by an Electronic Cigarette, Poster Presentation, Society of Forensic Toxicologists, Boca Raton, FL, 2017.

14. Grzymkowski J (presenter), Poklis JL, Peace MR. Identification of "Kratom" (Mitragyna speciose) Alkaloids in Commercially Available Products, Poster Presentation, Society of Forensic Toxicologists, Boca Raton, FL, 2017.

Invited Talks, Media Engagements, Miscellaneous

- VICE Interview conducted (published August)
- Interview with *Rolling Stone Magazine* (unpublished)
- Eastern Analytical Symposium. "New Marijuana Products" in a workshop titled "Marijuana: From Research and Use to Abuse", Princeton, NJ, November 2017.
- Mulder HA, Poklis JL, Halquist MS, Turner JBM, Poklis A, **Peace MR** (presenter). Evaluation of Drugs Other Than Nicotine (DOTNs) in an Aerosol Formed by an Electronic Cigarette. Platform Presentation, PittCon, Orlando FL, 2018.
- **Peace MR,** Poklis JL. "Chasing the E-cigarette Dragon: Design Evolution and Impact to Criminal Justice. Drug Enforcement Agency, July 2017.
- New Zealand – International Vision Fellow. Lectures and round table discussions. May 15-June 08, 2018.
    - Ministry of Health – quality of eliquids and products, including manipulation and adulteration.
    - Poison Center – impact of e-cigarette industry to Poison Control Centers in USA as unintentional poisonings and use as vehicles for suicide
    - NZ Police Department – importance of collecting these devices as drug paraphernalia
    - NZ Customs and Border Protection – adulteration and manipulation of devices
    - NZ Crime Lab (toxicology, controlled substances, and trace evidence sections) – description of devices, adulteration, and manipulation. Shared all developed methodologies with all sections so they could develop their own methods for analysis. Consulted one case in which a fog cannon was deployed in a convenience store to stop a robbery and there was concern they could not distinguish the fog cannon trace evidence from e-cigarette vapor on clothing.

Published Manuscripts

1. Poklis JL, Mulder HA, Halquist MS, Wolf CE, Poklis A, Peace MR. The Blue Lotus Flower (Nymphea Caerulea) Resin Used in a New Type of Electronic Cigarette, the Re-buildable Dripping Atomizer. Journal of Psychotropic Drugs (2017). DOI: 10.1080/02791072.2017.1290304

2. Grzymkowski JK, Mulder HA, Peace MR, Poklis JL. Evaluation of Commercially Available "Kratom" (Mitragyna speciose) Products. Submitted to Journal of Herbal Medicines.

3. Peace MR, Mulder HA, Baird TR, Butler KE, Friedrich A, Stone JW, Turner JBM, Poklis JL, Poklis A. Evaluation of Nicotine and the Components of e-Liquids Generated from e-Cigarette Aerosols. Accepted (In Press), Journal of Analytical Toxicology.

Manuscripts in Preparation and Review

1. Mulder HA, Patterson J, Poklis JL, Peace MR. Particle Size Analysis of Aerosols Produced by E-liquids Containing Nicotine, Methamphetamine, and Methadone. Submitted. Toxicology and Applied Pharmacology.

2. Peace MR, Stewart JB, Mulder HA, Dupont A, Royals J, Forsythe K, Poklis JL, Turner JBM. Assessment of Temperature and Metals Loss from Electronic Cigarette Coils with Changing Voltages. In preparation.

3. Krakowiak RI, Poklis JL, Poklis A, Peace MR. The Analysis of E-liquids Containing Methamphetamine Using High Resolution Mass Spectrometry and Gas Chromatography Mass Spectrometry. In preparation.