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Through the Looking Glass:
Abuse of the Evolving Electronic Cigarette and the Impact of Vaping Ethanol in the Evaluation of Impairment

FINAL REPORT

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Statement of Problem

The Evolving E-cigarette and E-liquid Formulations

This modern e-cigarette, patented in 2003, evolved into four generations as defined by the United States Centers for Disease Control and Prevention (CDC) (1). First generation e-cigarettes physically resemble combustion cigarettes and are typically disposable. Second generation became reusable, refillable devices, and the third generation, or "mods", had configurable settings for temperature, power, and device components. The first three generations of e-cigarettes became progressively larger as they became more complicated (1–3). The fourth generation, "pod mods", were simple, compact, and discreet. Marketed as impervious to tampering, many disposable "pods" were easy to open, enabling them to be refilled or modified to vape other e-liquids, pharmacologically active substances, and/or other additives (1, 4, 5). A subset of devices evolved from the customizable 3rd generation specifically designed to be a more cost effective, efficient way to vape drugs other than nicotine (DOTN) via e-liquids, waxes, dabs, crystals, and plant material. The rebuildable dripping atomizer, referred to as an "RDA", enabled a person to drip an e-liquid or place a substance directly through the mouthpiece onto the coil. This practice enabled users to put a smaller amount of a drug into a small volume of e-liquid for direct application to a coil, as opposed to a larger amount of that drug into an e-liquid to be added to the tank. After the rebuildable dripping atomizer, a menagerie of cups, coils, and rigs became available to vape drugs other than nicotine in multiple forms (2, 6).

In May 2016, the FDA promulgated regulations to govern e-liquids, yet product approval deadlines were slated for May 2020, marking a significant 4-year delay in required compliance (US Food and Drug Administration, 2020b). A flavoring ban instituted in January 2020 was an

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attempt to thwart adolescent usage, but only governed pod-based products (8). Chemicals used in e-liquid formulations were not dictated or restricted by the FDA's regulatory language.

The Complication of E-Cigs with Ethanol

E-liquids have been demonstrated to contain ethanol in a range of concentrations, from 0.7 to 206 mg/mL, with nearly 4% of the samples contained ethanol concentrations greater than 100 mg/mL (9). Limited studies regarding the impact of inhaled ethanol are in the published literature. The impact of e-cigarette use to preliminary breath test (PBT) and evidentiary breath test (EBT) were not defined. Interfering substances are defined for the EBTs (10, 11). However, the sticky nature of the e-liquid due to the major components, propylene glycol (PG) and vegetable glycerin (VG), may interfere with the breath test devices, creating false positives and false negatives. At issue was the "wait" or "observation" period before administering a breath test or the value of truncating the BAC result.

After observing driving behavior, a law enforcement officer gathers a multitude of subjective data points to determine an assessment of impairment. Since the inhalation of ethanol bypasses first pass metabolism, acute effects from inhaling ethanol may be felt by the person. Additionally, elements of the Standardized Field Sobriety Tests (SFST) could be observable. Inhaling ethanol, even at low concentrations, could impact horizontal gaze nystagmus, the walk and turn, and the one-legged stand. Therefore, an evaluation to determine any impact to the SFST from vaping ethanol is important to support the confidence of the officer's determination.

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Major Accomplishments: Project Goals and Results

Aim 1. Characterization of continuously evolving design, use, and abuse of electronic cigarettes and the adulteration and/or production of products to be used in the devices

The efficacy of new devices were assessed with methods already published for screening, confirmation, and quantitation with HS-GC-FID, DART-MS, GC-MS, and LC-MS. The research team evaluated the efficacy of vaping the DOTN using a trapping system previously developed and validated. E-liquids will also be evaluated for DOTNs using screening, confirmation, and quantitation protocols.

Evaluation of e-cigarettes and e-liquids

E-cigarette devices from local schools were confiscated by school resource officers, teachers, and administrators in middle and high schools in two school systems in Central Virginia. They were collected in two different 4-month periods, one pre-dating the ban on flavoring chemicals and the other after the ban was announced to take immediate effect. They were submitted to the lab for device evaluation and e-liquid analysis. The data showed that fewer JUUL products were confiscated after the flavoring ban, but an increase in other disposable pod-based products was observed. In the deconstruction of the devices, it became evident that some of the inexpensive products were prone to burning the wicking material (Figure 1). Despite the ban on fruit-flavored e-liquids, these were the predominant flavor profile confiscated (Table 1). Synthetic cooling chemicals emerged in the 2nd set of e-cigarettes, as the FDA also announced they would be considering banning menthol in combustible cigarettes. Impurities and degradation products were identified in some products, which could be attributed to age of product and/or quality of

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the product. Most devices were products typically sold from convenience stores, as opposed to from more high-end products sold in "vape shops".

Solvents and Other Chemicals in E-liquids

Ethanol

Headspace GC-FID was used to evaluate aerosolized ethanol in a simulated 4 second puff from an e-cigarette (9). Dose capture was conducted using a previously validated and published method using a KangerTech AeroTank device (12). Particle size distribution of the aerosols with ethanol containing eliquids was measured using a previously validated method (13) with a cascade impactor. E-liquids were prepared with a 50:50 VG:PG vehicle with 5% and 20% ethanol by volume. As the ethanol concentration in e-liquids increased, the dose of ethanol in the aerosol increased (Figure 2). Mean mass diameter of the particles in the ethanol demonstrate that ethanol in the aerosol will reach the aveoli for drug deposition (Figure 3).

GBL

JUUL products were purchased from online and physical shops to assess the presence of GB. GBL was consistently found in Virginia Tobacco flavor of JUULs and was absent in the other flavors. GBL was also found in the condensation aerosol, demonstrating that the chemical can reach alveoli for absorption. GBL was determined to be in concentrations (average of 370 ppm) well above the documented uses for flavoring chemicals in food products (10-20 ppm)(14).

Other Chemicals

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Evaluation of chemical constituent history since 2014 has demonstrated that many products are

manufactured with complex chemical profiles, with additions of preservatives, solvents, and

"enhancers". The enhancers can be considered menthol as an unlabeled ingredient in nicotine

products and olivetol in cannabis products. Online forums discuss the value of olivetol as a

natural agent which can reduce "harsh highs" from vaping concentrated THC products. A

method to quantitate Vitamin E and Vitamin E acetate was developed. Of the 241 e-liquid

products analyzed, 350 chemical compounds identified since 2016. Of those, approximately 50%

are known irritants, health hazards, or acutely toxic (15).

Drugs Other than Nicotine Use Survey

A survey was deployed via RedCap to assess e-cigarette users for what drugs other than nicotine

they had or do vape. The survey was deployed on Reddit, CraigsList, Facebook, and Instagram.

E-cig users had to be U.S. residents, at least18 years old, and vaped in the last 30 days. Of the

157 surveys started, 35 were completed, 45 were partially completed, and 75 were started by

ineligible participants. Users were an average age of 27 and predominantly white heterosexual

men with a reported income less than $25,000. The most frequent DOTN used in e-cigs is delta-9

tetrahydrocannabinol (71%), followed by cannabidiol (49%), "other cannabinoids" (27%), and

amphetamine (7%). Ethanol, herbal products, kratom, caffeine, vitamins, sexual stimulants,

opioids, ketamine, and steroids were also reported. Other DOTNs reported in free response were

DMT, phenylpiracetam, melatonin, Xanax, chamomile, and skullcap.

Eutectic Mixtures

The survey data demonstrated the adulteration or modification an e-liquid with a DOTN. It is reasonable to consider that the e-liquid already contains nicotine. The addition of a diluent to the nicotine e-liquid creates a eutectic mixture, reducing the melting point of the mixture to below the melting points of the individual drugs. E-liquids were made in-house using a 1:1 PG:VG base mixture. Drug free, 12 mg/mL methadone, 12 mg/mL of nicotine, and a 1:1 methadone:nicotine e-liquids were used to generate aerosols and were captured using a Cooperation Centre for Scientific Research Relative to Tobacco (CORESTA) method. They were analyzed by GC-MS. The dose of nicotine and methadone increased in the aerosol from the 1:1 methadone:nicotine e-liquid compared to the aerosol from the single drug e-liquids (Figure 4) (16).

Aim 2: Evaluate the impact of vaping ethanol on the preliminary breath test, the evidentiary breath test, and the standardized field sobriety test.

Under IRB#HM20015064, thirteen healthy daily (for longer than 3 months) e-cigarette users completed this study. They were aged 21–65, recruited via advertisements and word of mouth. Participants were required to test negative for all drugs and alcohol at the in-person screening visit and prior to each session. After an in-person screening visit, participants completed four, Latin-square ordered, ~3.5-hour sessions at Virginia Commonwealth University's (VCU) Center for the Study of Tobacco Products. Sessions were separated by a minimum of 48 hours and differed by liquid ethanol concentration (0% ethanol or 20% ethanol; no nicotine, Kai's Virgin Vapor; Vista, CA) as well as the number of puffs participants were asked to take (1 4-second puff or 10 4-second puffs). Participants were instructed to abstain from food for two hours prior to each session.

Each session began with a 90-minute waiting period. Then, subjective effects questionnaires were administered: the Biphasic Alcohol Effects Scale and the Subjective High Assessment Scale. Next, a baseline Standardized Field Sobriety Test (horizontal gaze nystagmus, walk-and-turn, one-legged stand) was conducted by a trained and certified, plain-clothed Richmond Police Department (RPD) or VCU police officer). The horizontal and vertical gaze nystagmus test was conducted with the DAX device (Ocular Data Systems; Pasadena, CA). Next, a preliminary breath test (PBT;Intoxilyzer 800, CMI Inc, Owensboro, KY) and evidentiary breath test (EBT; Intox EC/IR II, provided by the Virginia Department of Forensic Science) were conducted by a trained RPD or VCU police officer. Next, participants were asked to use the ENDS device (Kangertech Subox Mini C set to 30 W) for that session (taking either one 4-second puff, or ten 4-second puffs). Immediately after vaping, the PBT was administered again, as well as the EBT. Then, the SFST and the subjective effects questionnaires were administered again. Throughout the rest of the session, the PBT and EBT were administered at several timepoints (Figure 5). Custom-designed hardware and software (eTop; American University of Beirut, Lebanon) with mouthpieces manufactured to fit the SUBOX Mini C was used to measure puff number, duration, volume, inter puff interval, and flow rate.

Timepoint 2, representing the PBT that was administered immediately following vaping in any session, demonstrated the PBT had a measurable result. Only e-liquids with 20% ethanol provided indicated measurable ethanol in the PBT, and the 10 puff regimen resulted in more measurable ethanol immediately after vaping (Figure 6). The EBT had no measurable ethanol result at any vaping regimen. SFST results did not demonstrate any impact to vaping ethanol.

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Subjective effects indicated that some people may feel some acute effects from vaping ethanol, but it is not predictable.

The data demonstrates that PG and VG did not interfere with the PBT or EBT. The standard observation period of 15-20 minutes that police officers observe during a roadside impairment evaluation is sufficient for ethanol to reabsorb across mucosal membranes. Other industries and organizations that use the PBT to assess ethanol consumption must observe an observation period or risk false positive results.

IMPACT

E-liquids were submitted to the laboratory, unsolicited, from people claiming to have experienced unanticipated and adverse events after vaping e-liquids or taking oils which purportedly contained CBD. They were evaluated by direct analysis in real time time-of-flight mass spectrometry (DART TOF MS) and gas chromatography mass spectrometry (GC-MS). Samples for the GC-MS analysis were diluted 1:10 with methanol. Unknowns were confirmed through the NIST, SWGDRUG, and Cayman Chemical databases. Many products have been found to contain synthetic cannabinoids (Figure 7) (17).

In July of 2019, the epidemic known as E-cigarette or Vaping Product Use-Associated Lung Injury (EVALI) begin to spread nationwide. Therefore, as having one of the oldest "databases" of e-liquid compositions acquired through untargeted analyses, the team spent significant time combing through data and spectra that has been generated since 2014 to create a comprehensive table of chemicals to be shared with the CDC and the Association for Public Health Laboratories

(APHL). This work was published to highlight the potential issues with using chemicals with known toxicity to lung tissue under the pretense of being GRAS for e-liquid formulations (15).

We are using a device called DAX in our clinical study to record nystagmus. This device is used by some law enforcement agencies to support their conclusion in court. Several police departments have indicated interest in the equipment after seeing its utility.

The team has been called to testify to several sub-committees in the Virginia General Assembly about products emerging in the gray and black markets in Virginia. Dr. Peace has also testified to the FDA twice, in addition to the work conducted with them regarding the EVALI cases. Additionally, Dr. Peace speaks to a wide variety of groups, from parents and teachers to officers, substance use treatment providers, and legislators to support their efforts to develop evidence-based policies and legislation.

DISSEMINATION

Publications

1. **Peace MR**, Smith ME, Poklis JL. The Analysis of Commercially Available Natural Products Recommended for use in Electronic Cigarettes. Rapid Communications in Mass Spectrometry. 2020;34(11):e8771. doi:10.1002/rcm.8771

2. Mulder HA, Stewart JB, Blue I, Krakowiak R, Patterson J, Karin K, Royals J, Dupont A, , Forsythe K, Poklis JL, Poklis A, Butler S, Turner JBM, **Peace MR.** Characterization of E-cigarette coil temperature and toxic metal analysis by Infrared Temperature Sensing and Scanning Electron Microscopy- Energy Dispersive X-Ray. Inhalation Toxicology 2020;32 (13-14)447-455. DOI: 10.1080/08958378.2020.1840678

3. Holt AK, Poklis JL, Cobb CO, **Peace MR.** *The Identification of Gamma-butyrolactone in JUUL Liquids.* Journal of Analytical Toxicology. Accepted, Advanced article. https://doi.org/10.1093/jat/bkab067

4. Holt, AK, Poklis JL, **Peace MR.** *A Retrospective Analysis of the Chemical Constituents in Regulated and Unregulated E-cigarette Liquids.* Frontiers in Chemistry, October 2021. https://doi.org/10.3389/fchem.2021.752342

5. Reveil L, Halquist M, Poklis JL, **Peace MR.** *A determination of the aerosolization efficiency of drugs of abuse in a eutectic mixture with nicotine in electronic cigarettes.* Drug Testing and Analysis, July 18, 2022. https://doi.org/10.1002/dta.3343

6. Holt AK, Poklis, JL, **Peace MR.** *The History, Evolution, and Practice of Cannabis and E-cigarette Industries Highlight Necessary Public Health and Public Safety Considerations.* Accepted. Journal of Safety Research

7. Holt AK, Poklis JL, **Peace MR.** *Δ8-THC, THC-O Acetates and CBD-di-O Acetate: Emerging Synthetic Cannabinoids Found in Commercially Sold Plant Material and Gummy Edibles.* Journal of Analytical Toxicology, 2022, bkac036, https://doi.org/10.1093/jat/bkac036.

Scientific Conferences

1. Baird TR (presenter), **Peace MR**, Negus SS, Evaluation of the Abuse Potential of Methcathinone Using Intracranial Self-Stimulation in Rats. Accepted. Poster presentation at Society of Forensic Toxicologists, San Antonio, 2019.
2. Butler SN (presenter), Poklis JL, **Peace MR**. Simple, Rapid, and Accessible Detection of Ethanol in E-liquids by Fuel Cell BrAC Test. Poster presentation at Society of Forensic Toxicologists, San Antonio, 2019.
3. Connolly G (presenter), Somerville R, Mulder HA, Poklis JL, Wolf CE, Robertson L, Blank ML, Hoek J, **Peace MR**. Characterization of Nicotine, Glycols, and Ethanol in New Zealand E-liquids: Evidence of Ongoing Global Quality Control Issues. Poster presentation at Society of Forensic Toxicologists, San Antonio, 2019.
4. Poklis JL, Mulder HA, Butler SN, Miller SA, Friedrich A, **Peace MR** (presenter). Victims of the Consumer-driven Demands for the unregulated cannabis and hemp industries – Case studies of poisonings. Platform presentation at Society of Forensic Toxicologists, San Antonio, 2019.
5. Poklis JL, Edinboro L, Mulder HA, Butler SN, Miller SA, **Peace MR** (presenter). A Voice in the Wilderness: Unexpected Drugs Found in Unregulated Cannabidiol E-liquids. Accepted: The International Association of Forensic Toxicologists, Birmingham, UK, 2019.
6. Poklis JL (presenter), Gholap V, **Peace MR**, Wolf CE, Willams GR, Halquist MS. Blue Lotus Flower (Nymphea caerulea) in an Electronic Cigarette. Society for Research on Nicotine and Tobacco (SRNT), New Orleans, LA, March 2020.
7. Sales ER (presenter), Poklis JL, Turner JBM, **Peace MR.** Vaping in the fourth generation: A comparison of Nicotine Dose Capture in Different Forms of Concentrated Substances. Accepted. American Academy of Forensic Sciences, February 2020.
8. Holt AK (presenter), Poklis JL, **Peace MR**. A 4-Year Systematic Analysis of Commercial E-liquids: The Evolution of G.R.A.S. to Inhaled Toxins. Poster. 50th Annual Meeting, Society of Forensic Toxicologist, Online SOFTember. Sept 8th, 2020.
9. Poklis JL (presenter) , Gholap V, Smith ME, **Peace MR**, Wolf CE, Williams GR, Halquist MS. Identification of Apomorphine and Nuciferine in an Herbal E-liquid, Extracted Resin and Electronic Cigarette Aerosols. Poster. 50th Annual Meeting, Society of Forensic Toxicologist, Online SOFTember. Sept 8th, 2020.
10. Wieczorek B (presenter), Holt AK, Poklis JL, McGee Turner JB, **Peace MR**. The Structural Similarities and Differences between a Variety of Electronic Cigarette Pods and Devices Contributing to the Possibility of Manipulation by Users. Poster. 50th Annual Meeting, Society of Forensic Toxicologist, Online SOFTember. Sept 8th, 2020.
11. Sales ER (presenter), Mulder HA, Poklis JL, McGee Turner JB, **Peace MR**. Ethanol bioavailability demonstrated by dose and particle size analysis of aerosols generated using ethanol-containing e-

liquids. Platform. 50th Annual Meeting, Society of Forensic Toxicologist, Online SOFTember. Sept 10th, 2020.

12. Holt AK (presenter), Adreance MA, Poklis JL, Eversole AN, Cobb CO, Eissenberg TE, **Peace MR**. Vaping in Schools: Analysis of Confiscated Vaping Devices from a Public-School System in Central Virginia. Platform. 50th Annual Meeting, Society of Forensic Toxicologist, Online SOFTember. Sept 30th, 2020.

13. Sales ER (presenter), Poklis JL, **Peace MR.** Analysis of ethanol aerosolized in an e-cigarette by HS GC-FID and an assessment of particle size distribution. Platform Presentation. Society of Forensic Toxicologist, Annual Meeting, Nashville TN, 2021

14. Reveil L (presenter), Poklis JL, **Peace MR.** A determination of the aerosolization efficiency of drugs of abuse in a eutectic mixture with nicotine in e-cigarettes. Platform Presentation. Society of Forensic Toxicologist, Annual Meeting, Nashville TN, 2021

15. Holt AL, Poklis JL, **Peace MR.** The Impact of Vaping Drugs Other Than Nicotine: From SFST to Workplace Drug Testing to Accidental Poisonings. International Association of Chemical Testing, Tucson AZ 2022

16. Reveil L (presenter), Poklis JL, **Peace MR.** A determination of the aerosolization efficiency of drugs of abuse in a eutectic mixture with nicotine in e-cigarettes. Platform Presentation. Midwestern Association for Therapeutic Drug Monitoring and Toxicology, Annual Meeting, Kalamazoo, MI, 2022

Workshops and Webinars

o **Prosecuting Attorneys Association of Michigan,** July 2019.
o **Idaho Drug Recognition Expert Annual Re-training,** July 2019.
o **University of Virginia Health System,** August 2019.
o **Area Health Education Center (AHEC)-Greensboro, NC.** October 2019 **Conference: "Head in the Clouds – Prevention and Treatment Strategies for Electronic Cigarette Use in Teens and Young Adults".**
o **American College of Medical Toxicologists Workshop.** December 2019. **Criminal Poisoning & Drug Facilitated Sexual Assault: Forensics, Legal, and Medical Aspects.**
o **New England Association of Forensic Sciences Workshop.** November 2019. **"Analytical Approaches for Screening and Confirming Herbal and Synthetic Drugs in Multiple Matrices"**
o **Virginia Nurses Association Conference, Danville, VA.** October 2019. Conference: "Smoke and Mirrors – Risks in Pulmonary Health
o **Saudi Arabia, King Abdullah University, Medical Campus. December 2019.**
o **Consortium for Cannabidiol Science and Safety, June 2020.**
o **Medical College of Wisconsin, Grand Rounds,** May 2020.
o **PittCon NIJ Symposium, Chicago IL,** March 2020.
o **Society of Human Resource Managers, December 2020. Continuing Education Webinar.**
o **Virginia Nurses Association Conference, Danville, VA.** December 2020.
o **Marathon County, Wisconsin, Marijuana & Youth AOD Partnership,** August 2020.
o **Northwestern Alcohol Conference, June 2021** – Keynote Speaker and Workshop Chair
o **National Association of Drug Diversion Experts,** June 2021

o **Shimadzu Webinar** January 2021
o **National Academy of Sciences Transportation Research Board,** February 2021.
o **National Alliance of Health Care Purchasers** March 2021
o **Richmond Police Academy, June 2021.**

- o **London Toxicology Group. June 2022**(Virtual)
- o **American Society of Mass Spectrometry, Shimadzu Breakfast Workshop,** June 2022
- o **New Jersey Drug Recognition Expert Association.** June 2022
- o **University of Wisconsin, Toxicology Grand Rounds,** May 2022.
- o **Midwestern Association for Therapeutic Drug Monitoring and Toxicology,** April 2022
- o **American Academy of Forensic Sciences,** February 2022
  Faculty: Workshop: Unseen Threats

Popular Media, Books, News

- Discover Magazine, Is CBD a Cure-All?, #6 science news story of 2019, December 2019
- AARP, What is CBD and Does It Work? September 2019
- Mens' Health, Vaping Cannabis, The 9 Biggest Lies in Wellness, December 2019
- New York Times, Ads Pitching CBD as a Cure-All are Everywhere, July 2019
- Time Magazine, the state of CBD, Interview Conducted, July 2019
- Newsy Interview, CBD Poisonings Reach Highest Level Yet, Here's Why, July 2019
- Health and Cannabinoid News Sites
  - o Synthetic Cannabinoids Invade CBD Industry, June 2019
  - o FDA Receives Substantial Response to Information Request on CBD, June 2019
- CNN, Interview for Sanjay Gupta's Series on Cannabis in America, "Weed 5"Aired October 2019
- SAMHSA Technical Expert Panel published "Reducing Vaping Among Youth ad Young Adults". Work was completed in first half of 2020.
- ToxPod, May 2020, Vaping with Michelle Peace.
- Consumer Reports. January 2020. *Is it Safe to Vape CBD*
- Innovations in Forensic Examination of Seized Drugs and Forensic Toxicology, February 2021 VIDEO

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REFERENCES

1. E-Cigarette, or Vaping, Products Visual Dictionary.
    https://www.cdc.gov/tobacco/basic_information/e-cigarettes/pdfs/ecigarette-or-
    vaping-products-visual-dictionary-508.pdf (19 May 2020).

2. Poklis, J.L., Mulder, H.A., Halquist, M.S., Wolf, C.E., Poklis, A. and Peace, M.R. (2017)
    The Blue Lotus Flower (Nymphea caerulea) Resin Used in a New Type of Electronic
    Cigarette, the Re-Buildable Dripping Atomizer. *Journal of psychoactive drugs*, **49**,
    175–181.

3. Williams, M. and Talbot, P. (2019) Design Features in Multiple Generations of Electronic
    Cigarette Atomizers. *International Journal of Environmental Research and Public
    Health*, **16**. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC6720609/ (6 October
    2020).

4. Fadus, M.C., Smith, T.T. and Squeglia, L.M. (2019) The rise of e-cigarettes, pod mod
    devices, and JUUL among youth: Factors influencing use, health implications, and
    downstream effects. *Drug and alcohol dependence*, **201**, 85–93.

5. Spindle, T.R. and Eissenberg, T. (2018) Pod Mod Electronic Cigarettes—An Emerging
    Threat to Public Health. *JAMA Network Open*, **1**, e183518–e183518.

6. Harrell, P.T. and Eissenberg, T. (2018) Automated dripping devices for vapers: RDTA's,
    bottomfeeders, squonk mods, and dripboxes. *Tobacco control*, **27**, 480–482.

7. Enforcement Priorities for Electronic Nicotine Delivery Systems (ENDS) and Other
    Deemed Products on the Market Without Premarket Authorization (Revised):
    Guidance for Industry.

8. Yingst, J.M., Bordner, C.R., Hobkirk, A.L., Hoglen, B., Allen, S.I., Krebs, N.M., et al.
    (2021) Response to Flavored Cartridge/Pod-Based Product Ban among Adult JUUL
    Users: "You Get Nicotine However You Can Get It". *International Journal of
    Environmental Research and Public Health*, **18**, 207.

9. Poklis, J.L., Wolf, C.E. and Peace, M.R. (2017) Ethanol Concentration in 56 Refillable
    Electronic Cigarettes Liquid Formulations Determined by Headspace Gas
    Chromatography with Flame Ionization Detector (HS-GC-FID). *Drug testing and
    analysis*, **9**, 1637–1640.

10. Watterson, J.H. (2009) Assessment of Response of the Intoxilyzer® 8000C to Volatiles
    of Forensic Relevance In Vitro, Part I: Acetone, Isopropanol, and Methanol. *Journal
    of Analytical Toxicology*, **33**, 9.

11. Jones, A.W. and Andersson, L. (2008) Determination of ethanol in breath for legal
    purposes using a five-filter infrared analyzer: studies on response to volatile
    interfering substances. *Journal of Breath Research*, **2**, 026006.

12. Peace, M.R., Mulder, H.A., Baird, T.R., Butler, K.E., Friedrich, A.K., Stone, J.W., et al. (2018) Evaluation of Nicotine and the Components of e-Liquids Generated from e-Cigarette Aerosols. *Journal of Analytical Toxicology*, **42**, 537–543.

13. Mulder, H.A., Patterson, J.L., Halquist, M.S., Kosmider, L., Turner, J.B.M., Poklis, J.L., et al. (2019) The Effect of Electronic Cigarette User Modifications and E-liquid Adulteration on the Particle Size Profile of an Aerosolized Product. *Scientific Reports*, **9**. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC6629610/ (21 May 2020).

14. Holt, A.K., Poklis, J.L., Cobb, C.O. and Peace, M.R. (2021) Identification of Gamma-Butyrolactone in JUUL Liquids. *Journal of Analytical Toxicology*, **45**, 892–900.

15. Holt, A.K., Poklis, J.L. and Peace, M.R. (2021) A Retrospective Analysis of Chemical Constituents in Regulated and Unregulated E-Cigarette Liquids. *Frontiers in Chemistry*, **9**, 854.

16. Reveil, L., Pearcy, A.C., Povlick, J., Poklis, J.L., Halquist, M.S. and Peace, M.R. A determination of the aerosolization efficiency of drugs of abuse in a eutectic mixture with nicotine in electronic cigarettes. *Drug Testing and Analysis*, **n/a**. http://onlinelibrary.wiley.com/doi/abs/10.1002/dta.3343 (6 August 2022).

17. Holt, A.K., Karin, K.N., Butler, S.N., Ferreira, A.R., Krotulski, A.J., Poklis, J.L., et al. Cannabinoid-based vaping products and supplement formulations reported by consumers to precipitate adverse effects. *Drug Testing and Analysis*, **n/a**. http://onlinelibrary.wiley.com/doi/abs/10.1002/dta.3253 (29 May 2022).

Figures and Tables

Figure 1. Disassembly of used pod-based e-cigarette devices.

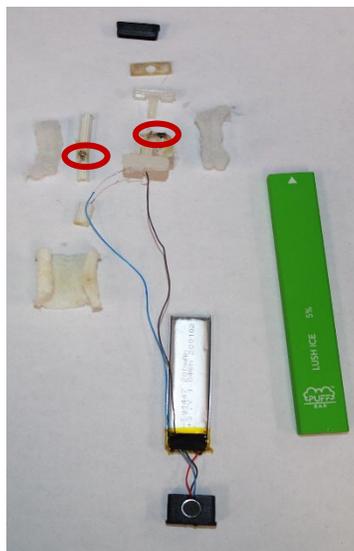Puff Bar pod-based e-cig device showing burning of wick and insulator (red circles).

Table 1. Chemical Constituents of Confiscated Vaping Products

Composition of Submitted E-liquids		Submission 1 N=75	Submission 2 N=75
Drug	Nicotine	100%	100%
	CBD	1%	0%
Flavor Profile	Fruity	55%	47%
	Menthol	3%	16%
	Mint	1%	1%
	Minty + Fruity	0%	12%
	Tobacco	1%	1%
	Unknown/Other	40%	23%
Organic acid	Benzoic acid	40%	56%
	Lactic acid	3%	3%
	Both	53%	41%
	None	4%	0%
Degradation products	Minor tobacco alkaloids	23%	21%
	Nicotine metabolites	43%	52%
	Flavorant-PG adducts	53%	28%
Additives	Caffeine	1%	0%
	Synthetic cooling agent	7%	59%
	Menthol	91%	79%

% increased in 2nd period   % decreased in 2nd period

This resource was prepared by the author(s) using Federal funds provided by the U.S. Department of Justice. Opinions or points of view expressed are those of the author(s) and do not necessarily reflect the official position or policies of the U.S. Department of Justice.

Figure 2. Ethanol dose capture from condensation aerosol.
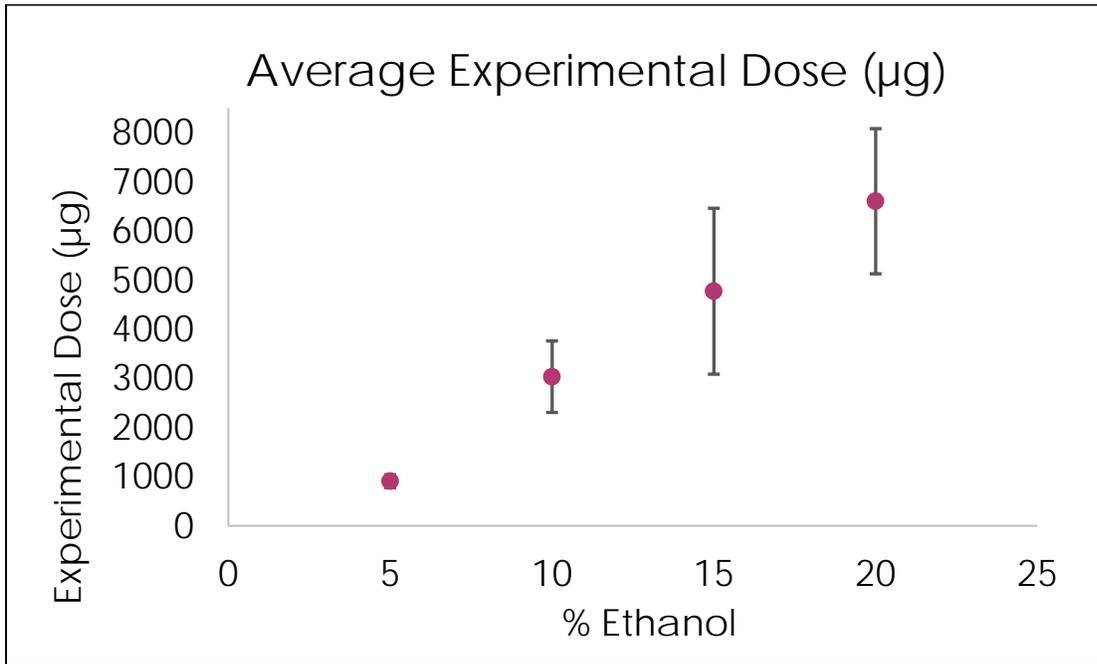
Figure 3. Particle size evaluation of condensation aerosol from e-liquid containing 20% ethanol.
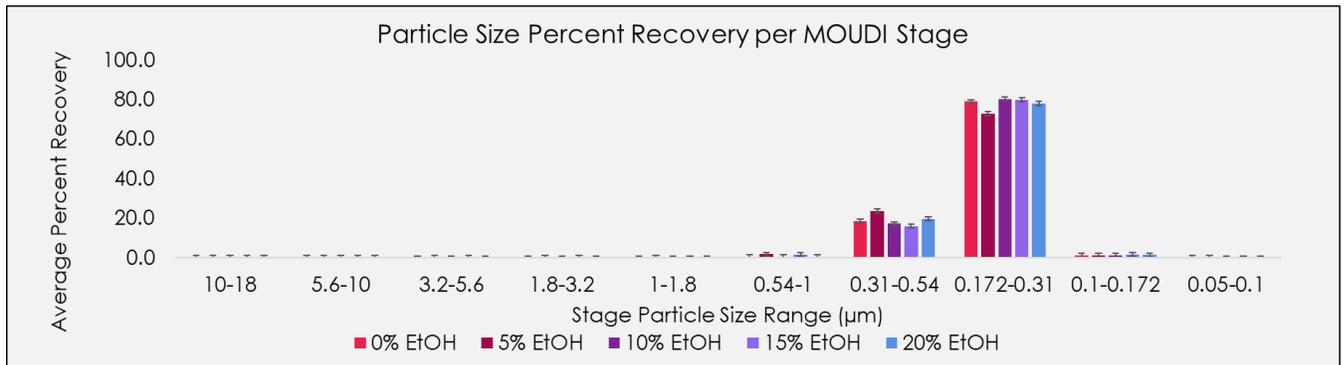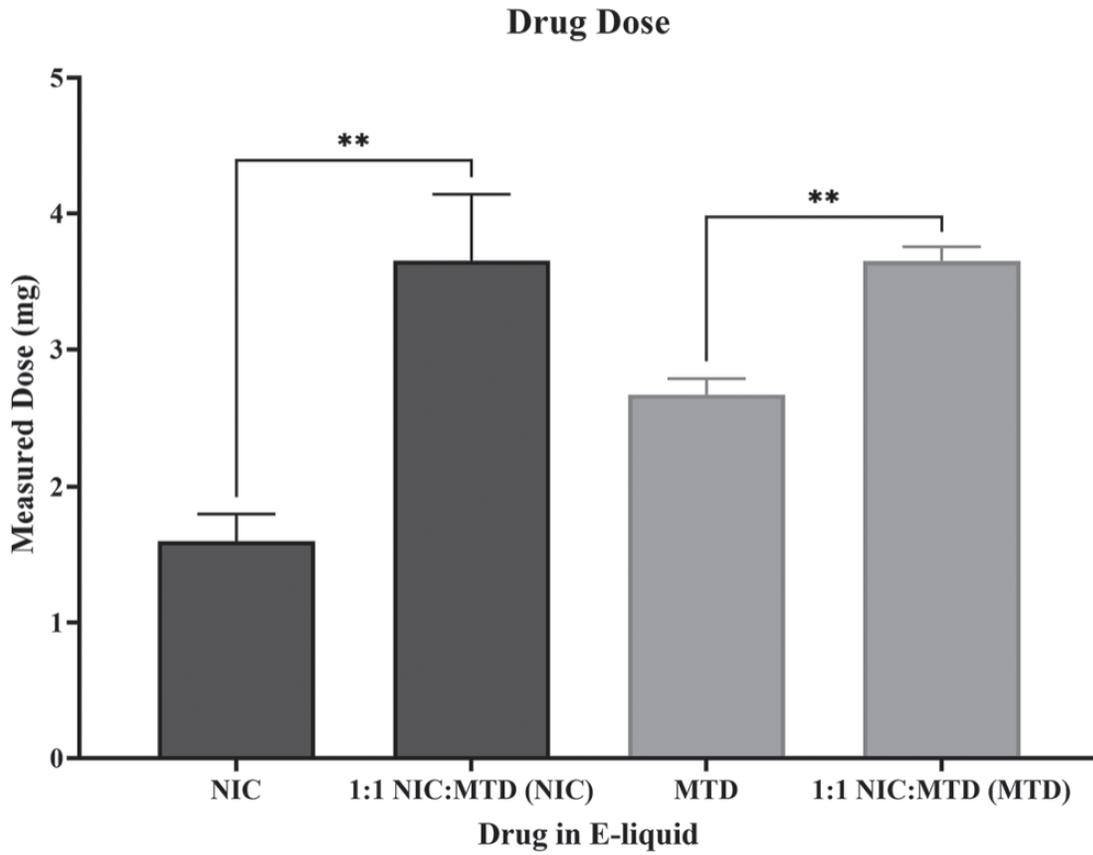
Figure 5. Experimental design to determine impact of vaping ethanol on the preliminary and evidentiary breath tests and the standardized field sobriety test
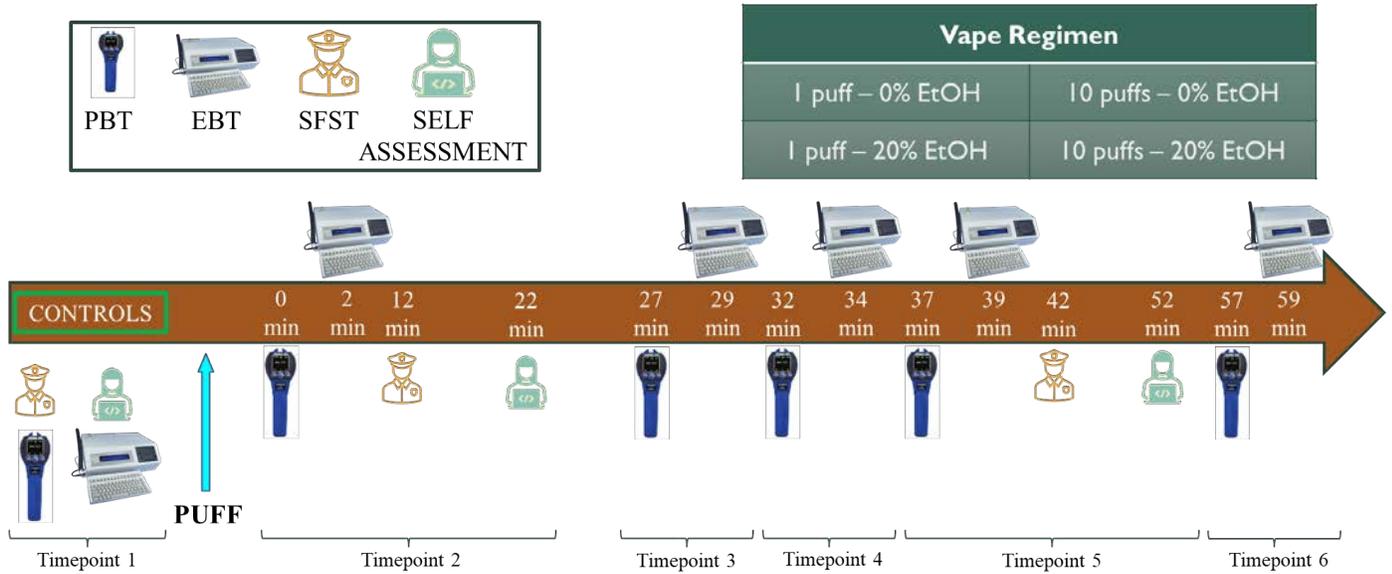

Figure 6. Preliminary breath test results after vaping 0% or 20% ethanol.
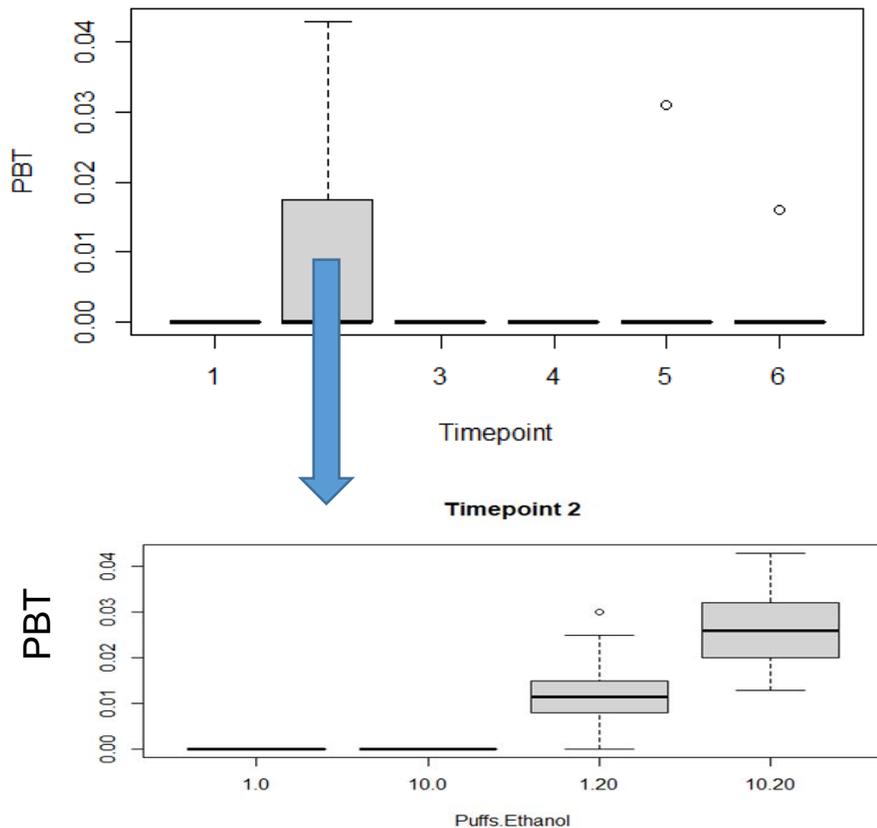
Figure 7. Adulteration of CBD products with synthetic cannabinoids

Top figure is direct analysis in real time by time-of-flight mass spectrometry. Bottom figure is GC-MS analysis of same product, with insert confirmation from Cayman Chemical reference library. Analyte was determined to be MEP-FUBINACA.