Cannabis Vape Pens Less Harmful Than Smoking

A Cal NORML Pilot Study

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More Research Needed on Electronic Cannabinoid Delivery Systems (ECDS)

A pilot lab study of cannabis vape pens from California's legal market indicates that they can substantially reduce users' exposure to harmful smoke toxins. The study, sponsored by California NORML, compared the emissions of two different vape pens – a disposable and reusable cartridge model – with pre-roll joints purchased from a San Diego dispensary. The vape pens emitted significantly cleaner emissions than the joint for almost all toxins tested and, unlike the joint, were within EPA safe daily exposure limits for regular users.

"The dangers of vapes have been misrepresented by anti-smoking advocates to suggest their emissions are as hazardous as smoke," says CalNORML director Dale Gieringer, "They are not."

The study's results are similar to those of a second, recently announced, in-house study by the ECDS manufacturer PAX, which reported that PAX vaporizers reduced the presence of harmful toxins by up to 99% compared to joints.[1] Between them, the two studies indicate further room for research on ECDS devices.

Research on ECDS has unfortunately been stifled by federal regulations that prohibit government-approved researchers from testing state-legal cannabis products because they lack DEA approval.[2] Cal NORML's study is the first independent, consumer-sponsored emissions study of store-bought, state-licensed vape pens. The study was conducted in consultation with MayThe5th, an operational consulting company devoted to the development of safer electronic vaporization devices, and performed by NN Analytics, a San Diego laboratory with expertise in nicotine and cannabis vapor testing.

Researchers caution that more studies are needed to determine the performance of other devices in other circumstances. Hundreds of different state-licensed vape devices and concentrates are on the market, none of which are subject to emissions testing requirements. The performance of vapes can be degraded by abnormal conditions such as overheating, clogging, bad batteries, and "dry hits" from poor concentrate flow in the cartridge, which weren't examined in this study.

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[1] One of the PAX devices was an oil vaporizer, the other vaporized natural dry herb. "Reduction of Harmful Combustion Byproducts in Cannabis Aerosol Generated by Controlled Vaporization Compared with Conventional Joint Combustion," by D. Shiokari and R. Rucker, PAX, April 2026. https://cdn.shopify.com/s/files/1/0027/6417/7523/files/PAX_Reduction_of_Harmful_Combustion_Byproducts_Research_Paper_3.pdf?v=1776109966

[2] The recent federal rescheduling order should open the way for state-licensed medical cannabis products to finally become eligible for research.

BACKGROUND

Prior studies have indicated that vaporization can drastically reduce harmful emissions found in tobacco and cannabis smoke.[3] Vaporizers are designed to evaporate a plant's active ingredients - cannabinoids and terpenes in the case of cannabis, nicotine in the case of tobacco - at temperatures below that of burning leaf (~900° C) , where smoke toxins and carcinogens form.

Electronic vape pens heat high potency (~ 80% THC) cannabis concentrates to temperatures around 250 – 600° C - ideally less than 400°C so as to minimize harmful thermal degradation products.[4] Because vape concentrates lack the leafy cellulose hydrocarbons that generate marijuana smoke toxins, they deliver relatively pure active vapor. However, they also contain chemical additives to help them vaporize better, which may pose hazards not found in natural cannabis. In the past, unscrupulous manufacturers used toxic additives that caused an epidemic of fatal EVALI lung disease amongst users of illicit vape pens.[5] Nowadays, licensed manufacturers generally supplement concentrates with terpenes instead. Terpenes are odoriferous and medicinally active compounds found naturally in the cannabis plant. However, terpenes can degrade into noxious byproducts at excessive temperatures and concentrations, a potential risk for electronic vape pens.[6] In addition, concerns have been raised about potential leakage of toxic heavy metals from vape cartridge hardware. [7] Manufacturers have sought to reduce the latter by switching to ceramic and other non-metallic components where possible.

Electronic vape pens should be distinguished from herbal vaporizers, which heat raw cannabis leaf and buds to around 180-220° C, below the point where the

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[3] Report of UK Office for Health Improvement and Disparities, "Nicotine vaping in England: 2022 evidence update" 29 Sep 2022;
D. Gieringer, "Cannabis 'Vaporization': A Promising Strategy for Smoke Harm Reduction," Journal of Cannabis Therapeutics 1 (3-4) 2001;
Maciej L Goniewicz et al, "Levels of selected carcinogens and toxicants in vapour from electronic cigarettes," *Tobacco Control* 6 Mar 2015 doi:10.1136/tobaccocontrol-2012-05085;.
J. Meehan-Atrash et al., "Aerosol Gas-Phase Components from Cannabis E-Cigarettes and Dabbing: Mechanistic Insight and Quantitative Risk Analysis," *ACS Omega* Sept 16, 2019.

[4] M. A. Oar et al., "Thermography of cannabis extract vaporization cartridge heating coils in temperature- and voltage-controlled systems during a simulated human puff," PLOS One 26 Jan 2022

[5] EVALI = Electronic or vaping product use-associated lung injury: See: H Zulfiqar, A. Sankari and O. Rahman, "Vaping-Associated Pulmonary Injury" *Stat Pearls* 25 Jun 2023. "Adult-Use Cannabis Markets Not Associated with Vaping-Related Illness" NORML Release 3 Sept 2020

[6] K Munger, K M Anreise, R Srongin, "Cannabis Concentrate Vaping Chemistry," *Front. Toxicol*. O8 Jun 2025 https://doi.org/10.3389/ftox.2025.1568207 ;
J. Meehan-Attrash, W. Luo and R.. Strongin (2017): "Toxicant Formation in Dabbing: The Terpene Story," *ACS Omega* 2(9). See also X. Tang et al. (2021) "Emissions from Heated Terpenoids Present in Vaporizable Cannabis Concentrates," *Environ. Sci. Technol.* 55.

[7]NORML Release 11 Sep 2025: "Analysis: Vaporizers' Components May Expose Consumers to Heavy Metals." Sumit Gaur and Rupali Agnihotri, "Heavy Metals in Cannabis Vapes and Their Health Implications-A Scoping Review," *Scientific World Journal* 19 Aug 2025 https://pubmed.ncbi.nlm.nih.gov/40874048/

leafy hydrocarbons begin to combust. Previous studies by Cal NORML and others[8] have shown that herbal cannabis vaporizers effectively deliver THC while suppressing smoke toxins. They have accordingly come into use in human medicinal cannabis trials as a safer delivery system for inhaled cannabis. Electronic vape pens raise different safety concerns, since they operate at higher temperatures and use concentrates, not raw plant material. We recommend manufacturers design and label their products with appropriate power or temperature settings to ensure that consumers are not exposed to unwanted levels of harmful pyrolytic constituents.

STUDY DESIGN & RESULTS

This vape pen study was designed to measure emissions of THC and other cannabinoids plus an array of toxic chemicals commonly associated with smoking disease. Researchers conducted a preliminary survey of a half dozen different ECDS devices from California-licensed dispensaries before selecting two popular models for further testing: a disposable "live rosin" pod device with 83% THC, and a standard reusable 510 thread "live rosin" cartridge model with 86% THC. For comparison purposes, a batch of half-gram pre-roll joints with 23% THC was tested. Equal samples of each were inhaled through a puffing machine and tested for cannabinoids and a dozen key toxic emissions , including volatile organic compounds (e.g. benzene), carbonyls (e,g, formaldehyde), and heavy metals (for more information, see ECDSvsPreroll.com).

• **The vapes emitted significantly less toxic emissions per puff than the joint in almost all categories, usually by an order of magnitude or more.** The vape completely suppressed benzene and acrolein, two highly noxious compounds that appeared at levels above safe exposure limits in the joint. Unlike the PAX study, which found minimal traces of formaldehyde in ECDS, only a modest 40%-50% reduction was observed in this study. This may be due to different device temperatures or concentrate ingredients.

• **The vapes varied considerably in the amount of THC delivered per puff:** 3.2 milligrams for the pod versus 5.7 mg for the cart. This was more than the 2.6 mg from the joint, but significantly less than the four-fold potency difference between the vapes and the joint. In practice, vape emissions vary substantially, increasing if temperature rises and dwindling if the device becomes clogged. In joints, potency increases as the joint burns down to the butt.[9] In practice, some users report they don't get as high from vape pens as joints, while others report the

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[8] Gieringer, D, St Laurent, J and Goodrich S, (2004) "Cannabis vaporizer combines efficient delivery of THC with effective suppression of pyrolytic compounds," *J Cannabis Ther* 4:4-27; B. Pomahacova B, Van der Kooy F, and Verpoorte R, (2009) "Cannabis smoke condensate III: The cannabinoid content of vaporised Cannabis sativa," *Inhalation Toxicology* 21(13): 1108-1112; Abrams D. I., Vizoso H. P., Shade S. B., Jay C., Kelly M. E., Benowitz N. L.(2007) "Vaporization as a smokeless cannabis delivery system: a pilot study". *Clin Pharmacol Ther* 2007; 82: 572–8.

[9] Aharon M. Eyal, Danielle Hen-Shoval et al., "Inconsistency in the Composition of the Smoke of a Cannabis Cigarette as Smoking Progresses: Results, Mechanism and Implications." *Cannabis and Cannabinoid Research* 2024-10-01 DOI: 10.1089/can.2023.0123.

opposite. "Dosage delivery can't be gauged accurately from differences in THC potency," comments Gieringer.

More research along these lines is warranted. Some vapes can be adjusted to increase their THC emissions by raising the voltage and temperature, while other devices known as "dab pens" are specifically designed to deliver powerful hits. The vapes in this study were run at a standard power level used in laboratory testing of ECDS devices.[10] In this study, a constant puff stream and temperature were maintained to the extent possible. The cartridge was tested under two different conditions – from a full cart, and from a near-empty cart at 10% fill.

• **The only toxins for which vapes scored worse than joints were the heavy metals nickel and chromium.** Both metals are key components of nichrome wire, which is used for vape heating coils. The joints had higher levels of lead and cadmium, which can be absorbed from the soil. California has heavy metals testing regulations that limit their concentration in cannabis and vape concentrates. However, these tests can't detect metals that leak into the concentrate later during use of the device.

• Devices were evaluated for safety to human health based on EPA exposure standards. Daily exposures to toxins were measured on the assumption that a regular user inhales 22 puffs per day, or about three joints.[11] **The vapes were well within all applicable** EPA/RIC-IRIS[12] **daily exposure limits, while the joint was not**. Heavy metals were far below OSHA, NIOSH and Cal-OSHA occupational exposure limits for both vapes and the joint.[13] However, nickel levels in the cartridge vape approached the exceptionally stringent California OEHHA[14] exposure limits for chronic users. This marginal risk could be avoided by adopting newer nickel-free heating coil technology.

CONCLUSIONS & RECOMMENDATIONS FOR RESEARCH

Our study confirmed that electronic vape pens can provide a safe and effective smoke harm reduction technology for inhaling cannabis. However, many aspects of vape pen technology remain to be investigated. Vape pens have other

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[10] Laboratory-recommended power settings for prefilled cartridges range from 6 to 8 watts depending on cartridge architecture, with 8 watts being selected for the cartridge vape in this experiment. Experiments indicate that in this range liquid-coil interface temperatures of 150-315° C occur, sufficient to generate THC aerosol while remaining below the point where extensive terpene and cannabinoid degradation occurs.

[11] Average usage based on survey of 2,000 vape users by Labstat & the Blinc Group, "Cannabis Puffing Regimes"

[12] US Environmental Protection Agency - Risk Identification and Characterization - Integrated Risk Information System EPA/RIC-IRIS

[13] Heavy metals aren't included in EPA/RIC-IRIS standards. Occupational exposure standards for metals are given by OSHA, Cal-OSHA, and NIOSH: https://www.osha.gov/annotated-pels/table-z-1. All devices tested at 0.1% or less of these limits.

[14] California Office of Environmental Health Hazard Assessment limits are especially stringent, based not on statistical risk to human health, but on the theoretical worst-case scenario of exposure to toxins known to be carcinogenic or mutagenic in animal models.

potential advantages over smoking, including: suppression of second-hand sidestream smoke; avoidance of open flames and ashes; convenience of inhaling modest one- or two-toke doses without having to dispose of a partially burned joint. On the minus sign, disposable vapes, cartridges and batteries present a waste disposal problem; defective batteries can burst into flame; e-cigs can also facilitate furtive cannabis use by youth in schools and make it easier for dependent users to feed their habits.

Our study is intended to provide a framework for further research and development of ASTM-37 manufacturing standards for this badly under-investigated technology. Among the technological issues that need to be investigated are:

- The effects of different, higher temperatures.
- The hazard of "dry hits" from wicks that are underexposed to vape oil.
- The effects of differing concentrate composition and additives.
- Differences in cannabinoid delivery for different devices.
- Improvements in design to reduce residual heavy metals and toxins.
- Effects of second-hand exposure to cannabis vapor.
- Recycling and disposal of cartridges, batteries and e-waste.[15]

Sponsors (Cal NORML, MayThe5th and NN Analytics) call on the industry and public health agencies to support more research on these lines. Vape products are now outselling flower in California,[16] yet virtually all published research to date on inhaled cannabis has focused on smoking, not vaping. "Hopefully, the government's recent rescheduling decision will end obsolete restrictions that have hindered researchers from studying cannabis vape pens that are readily available to millions of U.S. consumers," says Gieringer.

ADDENDA

I. Comparative Toxicity of Emissions: Electronic Cannabis Delivery Systems (ECDS) versus Combustion of Un-Infused Cannabis Pre-Rolls - *available at ECDSvsPreroll.com*

by Arnaud Dumas de Rauly, Founder and Principal Consultant MayThe5th, Chairman of VapeSAFER, Chair of ISO and CEN standards on vaping products.

Comment:

"The core advantage of ECDS is confirmed: a two to three order of magnitude reduction in the screening Hazard Index, putting the overall safety profile unequivocally below the conventional alarm threshold. Public perception often misses the fundamental toxicology here: contrary to popular belief, pre-rolls delivered materially higher per-puff burdens of both formaldehyde and lead than ECDS, and ECDS actually delivers more Δ9-THC per puff, not less, which explains the rapid onset that many patients need when vaping. Over 95% of the Δ9-THC in the source oil arrives intact in the aerosol. The device isn't transforming what you're consuming, it's

[15] Blinc Report, "Transforming-Cannabis-Vaping-into-a-Sustainable-Practice."

[16] MJBIzDaily; "Cannabis Vapes Now Outselling Flowers in California - Thanks to Gen Z" (2026)

preserving it. Now, the residual engineering gap. The high nickel and chromium signal in the cart arm, stemming from common heating elements like nichrome, points to an obvious material science mandate. This is not an insurmountable design flaw; it is a straightforward material selection problem. The data doesn't call for panic; it calls for immediate, results-driven technical optimization and for an industry that stops letting combustion set the benchmark for cannabis inhalation."

II. *LAB REPORT:* Comparative Toxicity of Emissions (ECDS) vs. Combustion of Un-infused Cannabis Pre-rolls - *available at ECDSvsPreroll.com*

By Jake Rubenstein, N.N. Analytics

Comment:

"It has been a pleasure to explore the toxicant exposure of cannabis vaporizer products compared to their combustible counterparts with a consumer organization like CANORML. While NN Analytics' prior investigations on aerosol toxicology and smoke exposure have been heavily focused on tobacco products, we are thankful to be able to use the FDA's recommended list of Harmful or Potentially Harmful Constituents (HPHCs) to address exposure to cannabis smoke and aerosol. NN Analytics is committed to working with toxicological experts and well-established industry partners to establish which toxicants are important to be monitored, as well as to provide industry guidance as to the acceptable threshold limit values (TLVs) of each toxicant by inhalation. We encourage the application of comparator exposure limits, such as the US EPA RFC and (CAL)OSHA databases, for use in the establishment of such limits, for both combusted and aerosolized cannabis products. This hazard index is mission critical to focused work in the comparison of ECDS to combustible products. NN Analytics is committed to broadening the body of work and scope of future needed research regarding these toxicant exposure levels."

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