

Cannabis vaporisation: Understanding products, devices and risks

Caroline A. MacCallum¹  | Lindsay A. Lo² | Carly A. Pistawka³ |
April Christiansen⁴ | Michael Boivin⁵

¹Department of Medicine, Faculty of Medicine, University of British Columbia, Vancouver, Canada

²Department of Public Health Science, Dalla Lana School of Public Health, University of Toronto, Toronto, Canada

³Faculty of Science, University of British Columbia, Vancouver, Canada

⁴Six Degrees Medical, Vancouver, Canada

⁵CommPharm Consulting, Barrie, Canada

Correspondence

Caroline A. MacCallum, 317—2194 Health Sciences Mall, Vancouver, BC V6T 1Z3, Canada.

Email: info@dracarolinemaccallum.com

Abstract

Issues: Vaporisation is a common method of cannabis administration. Inconsistent terminology and jargon regarding vaporisation has led to confusion. The increasing public interest and access to cannabis, combined with possible safety concerns associated with certain cannabis vaping products, warrants improved consumer and public and health care professional knowledge.

Approach: To improve this knowledge, we conducted a review of the common terminology, regulatory status, products and device types related to cannabis vaporisation.

Key Findings: Cannabis vaporisation devices can be separated into nine types. While vaporisation reduces respiratory risks associated with cannabis combustion, not all vaping products and device types carry the same level of safety. Metered dose inhalers and dried product vaporisers present the lowest safety risk due to a lower risk of toxin exposure and the use of lower tetrahydrocannabinol potency products.

Implications: As both vaping and cannabis use increase in popularity, focusing on accurate health education will help facilitate health promotion to encourage lower risk use. The current lack of understanding on risk differences between types of cannabis vaporisation is a missed opportunity for harm reduction. Increased opportunities for public health and health care professional education on different cannabis vaporisation devices and associated risks are warranted. Improvements to health warning labelling may also be beneficial.

Conclusion: Not all cannabis vaporisation devices and products carry the same level of risk. A better understanding of risk differentiation is needed among consumers and health professionals. Continued research, policy development and health education can lead to safer cannabis vaporisation.

KEYWORDS

cannabis, cannabis concentrates, vaping, vaporisation, e-cigarette, health education

This is an open access article under the terms of the [Creative Commons Attribution-NonCommercial](https://creativecommons.org/licenses/by-nc/4.0/) License, which permits use, distribution and reproduction in any medium, provided the original work is properly cited and is not used for commercial purposes.

© 2023 The Authors. *Drug and Alcohol Review* published by John Wiley & Sons Australia, Ltd on behalf of Australasian Professional Society on Alcohol and other Drugs.

1 | INTRODUCTION

Vaporisation is becoming an increasingly common method of cannabis administration. However, there is a general lack of understanding on the differences between various vaporisation devices at both a consumer and public health/health care professional level [1]. This has important implications for facilitating the safe use of cannabis. The rapid expansion of available products, coupled with jargon and inconsistent terminology regarding different products and devices, has made it difficult to gain an adequate level of knowledge. Different cannabis vaporisation devices carry different levels of risk. However, it is not uncommon that cannabis consumers, medical or recreational, assume an equivalent level of safety between all cannabis vaporisation devices. Many public health and health care providers agree that they do not possess a high level of confidence or competence in addressing vaporisation and e-cigarette use [1]. The nuances between cannabis and nicotine vaporisation adds another layer of complexity. To our knowledge there has been no literature published providing a comprehensive review of vaporisation devices specific to cannabis that also discusses risk differentiation. Such information is important to encourage lower risk behaviours and is central to public health aims in harm reduction.

The aim of this manuscript is to provide a practical review of key information on cannabis vaporisation including regulation status, medical versus recreational use, product types and device types. This review was developed through a combination of expert clinical opinion, reviewing common questions in medical education sessions conducted by the authors, and reviewing the available literature. Information on vaporisation product and device types were gathered from both peer-reviewed and grey literature. Google scholar and PubMed were searched for relevant articles. Peer-reviewed research already known to authors and included in accredited medical education programmes was also reviewed. Given the limited available research on this topic, grey literature such as news articles, blog posts or educational resources on reputable cannabis sites were also reviewed. Collaborative discussions among the authors, based on available literature and expert clinical opinion, were then carried out to reach consensus for review content.

2 | KEY CONCEPTS OF CANNABIS VAPORISATION

2.1 | Smoking versus vaporisation

Expanded access to cannabis has led to the production of many cannabis vaporisation products [2]. Smoking and

vaporising cannabis are both inhalation methods of cannabis exposure, which have a quick onset of action and a shorter duration compared to oral ingestion [3]. Smoking cannabis utilises high temperatures ($\sim 600^{\circ}\text{C}$ – 900°C) leading to combustion and the inhalation of carbon monoxide and other toxins (e.g., benzene, toluene, tar, ammonia) [4, 5]. In contrast, vaporisation heats materials to a lower temperature ($\sim 160^{\circ}\text{C}$ – 230°C) which creates a vapour that has significantly reduced levels of these toxins [6–8]. Due to this, many people consider cannabis vaporisation to be a safer alternative to smoking.

2.2 | Regulation versus non-regulation

Regulated cannabis products are significantly safer than unregulated products [9, 10]. Regulated products must uphold strict guidelines and pass standardised testing to ensure products remain free or within acceptable levels for human consumption of contaminants, pesticides, microorganisms, diluents or fillers, as well as being accurately labelled [9, 11]. This can be more complicated in a country like the United States, where cannabis is not regulated federally, as it is in Canada. Inconsistent standards and protocols for testing, even within regulated markets, adds further complexity to the issue. There is a great need for unified federal regulation to ensure consistent and trustworthy testing of cannabis products.

Unregulated products can pose a health risk due to the lack of standardised laboratory testing to ensure the final product meets safety standards. This was seen with the emergence of e-cigarette and vaping-associated lung illness (EVALI), which, in the United States, was associated with the use of black-market electronic THC vaping products and nicotine products [12]. It is important to note that the health risk was due to the fillers that contained THC within these devices, rather than THC itself. In Canada, however, where cannabis is regulated federally, no cases of EVALI were linked to cannabis vaporisation products. As such, the regulation status of a product contributes to the potential risk of using these devices. More research into creating internationally recognised standards for testing is needed.

2.3 | Medical versus non-medical use

Medical versus non-medical cannabis use may carry different risks. This is due to different intentions of use, products and doses being used [13, 14]. Under the care of a health care provider, medical cannabis patients can receive monitoring and education on product safety. Without health care provider support, an individual using cannabis for non-medical reasons may be unaware

of different product types and associated risks, and may be more inclined to purchase products from unregulated sources. It is important to note that some people may be using cannabis for medical purposes without health care provider support. These individuals may have cannabis use patterns more similar to recreational populations [14, 15]. Thus, this population may also benefit from health promotion education on safe vaporisation tactics.

3 | DIFFERENCES IN HEALTH RISKS OF CANNABIS VAPORISATION PRODUCTS

Facilitating lower risk use of substances is a key harm reduction strategy that also fundamentally aligns with health promotion goals in public and community health [16]. Accurate and accessible information is critical to accomplishing these goals and underpins the following information on cannabis vaporisation products and devices. There are three main cannabis forms used in cannabis vaping devices (Figure 1): cannabis flower, 'E-liquid' and solid cannabis concentrates. E-liquids are liquid form cannabis concentrates that include any liquid used in vaporisers which converts the liquid into an aerosol by the vaporisation device [17]. These liquids commonly contain propylene glycol and vegetable glycerin in various concentrations, high concentrated cannabis

extracts and varying terpene profiles [17]. High THC E-liquid are most commonly sold in these devices, while also available with CBD, Delta-8 THC and synthetic cannabinoids. E-liquids are held and stored in cartridges or pods, which can either be refillable or single-use. Finally, there are solid cannabis concentrates (e.g., wax, shatter, live resin), which are condensed accumulations of the plant's trichomes. E-liquids and solid cannabis concentrates commonly contain very high concentrations of THC (40–95%), often exceeding 80% THC [9, 18–21]. Solid cannabis concentrates tend to be higher concentrated in THC (>90% THC) than E-liquids [22, 23], with both being significantly higher compared to dried cannabis flower (usually <30%) [24–26]. This is important to note as the majority of adverse events associated with cannabis use are THC-dose dependent [27].

It should be noted that E-liquids are commonly referred to as 'cannabis oils' or 'vape oils' amongst consumers, in advertisements and in the literature [28]. We recommend defining 'cannabis oils' as a distinct product form that is meant for ingestion, not inhalation, which contains cannabinoids suspended in a carrier oil (e.g., medium chain triglycerides oil, grape seed oil, olive oil, sunflower oil) [28]. In a true 'cannabis oil' the carrier oil makes it too viscous to undergo the vaporisation process correctly. Inhalation can occur if thinning agents are used. As such, we suggest defining 'E-liquids' as cannabis products that have cannabinoids suspended in a carrier



FIGURE 1 Cannabis vaping products used in various vaping devices. A = metered dose inhalers; B = desktop vaporiser; C = portable vaporiser; D = thermal extraction device; E = first generation disposable cannabis e-cigarettes; F = second generation cannabis e-cigarettes with prefilled or refillable cartridges; G = third generation tanks or mods; H = fourth generation pod mods; I = dab pen; J = dab rig. 1 = metered dose cartridge; 2 = dried cannabis flower; 3 = 510-thread cartridge with e-liquid; 4 = e-liquid refill bottle; 5 = pod cartridge with e-liquid; 6 = wax; 7 = shatter; 8 = budder. *Some devices in categories B, C and D can also take E-liquid and solid cannabis concentrate products.

oil, but with the addition of thinning agents that make it suitable for inhalation [28]. Common thinning agents used in E-liquids include propylene glycol, vegetable glycerin, polyethylene glycol 400 (PEG 400) and medium chain triglycerides [29]. Flavouring agents were commonly added to electronic cigarettes to appeal to younger users [30]. These flavourings are largely an unrecognised potential hazard when they become ultrafine aerosol that penetrate deeply into the lungs [30]. Although these flavourings are commonly viewed as safe for oral consumption, the risks associated with inhalation has not been fully elucidated [30]. Patients should be advised to avoid cannabis inhalation products containing these flavouring agents.

The main safety concern related to cannabis vaporisation products are toxins and contaminants. As cannabis is a plant, it may be contaminated with microorganisms (e.g., pathogenic bacteria, yeasts and moulds) [9, 31]. In an attempt to control microorganisms, pesticides are sometimes used, which can also become a contaminant [32]. E-liquid and cannabis extracts may contain other chemicals introduced through the extraction process, including naphtha, ethanol, butane and petroleum ether, which may be harmful to health [33, 34]. Formulations that use propylene glycol and vegetable glycerin as propellants can form formaldehyde, a group 1 carcinogen, when exposed to heat [33, 34]. Additionally, vitamin E acetate, a component found in many unregulated E-liquid vaping products, has been associated with EVALI [12]. There is a great need for federal regulation of cannabis products that enacts strict testing and quality assurance guidelines. This will help ensure products do not contain toxins or contaminants at levels unsafe for human exposure by inhalation.

4 | DIFFERENCES IN HEALTH RISKS OF CANNABIS VAPORISATION DEVICES

There is no official consensus on exact terminology and definitions regarding cannabis vaporisation devices (see Table A1 for a glossary of terms). Vaporisation devices heat cannabis products to temperatures that avoid combustion and produce a vapour instead of smoke [4, 6, 35]. It is important to note, however, that some vaporisation devices (e.g., e-cigarettes) do not actually produce a vapour, which is a substance in gas phase, and instead produce an aerosol, which is a suspension of particles or liquid droplets in air or another gas [17]. In a real-world context, however, devices that produce both a true vapour and aerosol are referred to as vaporisers. This is of note because cannabinoids are not soluble in water, thus aerosolised cannabis requires solubilisers which can irritate the respiratory tract [36]. It is important to

emphasise the use of regulated cannabis products and devices is key in mitigating the risk of ill-health effects, particularly regarding lung health.

From a health promotion and harm reduction standpoint, if individuals are going to inhale cannabis, dried cannabis flower vaporisers are preferred for several reasons. There may be a lower risk of negative impacts on lung health compared to smoking or vaporising e-liquids or concentrate [6, 35]. Additionally, given the risk of adverse events associated with higher THC dosing, the potency and maximum dose of cannabinoids delivered by devices is important to consider. In this respect, the vaporisation of regulated dried cannabis products may also be preferable, as the potency of most regulated cannabis flower is <30% THC, compared to cannabis concentrates which commonly range from 70% to 90% THC. The difference between cannabis vaping devices are outlined in Table 1 and the subsequent sections.


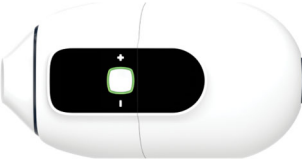

4.1 | Metered dose inhalers

Metered dose inhalers are another device type to inhale cannabis with. Currently, no vaporisation devices can deliver cannabinoids at a set dose with standard pharmaceutical parameters. Metered dose inhalers seek to address this issue by providing a high-precision dose inhaler, which is designed to precisely aerosolised multiple doses of granulated raw cannabis plant [37, 38]. These devices are not a true 'vaporiser' as they produce aerosol, however, it is important to be aware of them, as many devices commonly considered to be vaporisers also produce aerosol. Safety data supports no adverse lung effects and fewer adverse events, such as impairment, compared to other methods of consumption (e.g., smoking, vaporisation) [37, 38]. This is likely due to the low and accurate dosing provided by metered dose inhalers. Some devices also log the inhalation process via software, making it ideal for medical cannabis use as dosing can be monitored and treatment regimens adjusted as needed. This device type is not as easily accessible compared to other devices and is not available through non-medical streams.

4.2 | Desktop and C. portable vaporisers

Cannabis vaporisers most commonly use dried cannabis flower. However, some are also compatible with E-liquids or other solid cannabis concentrates such as dab wax (devices specific to dabbing are discussed in sections I and J) and E-liquids. Vaporisers can either be tabletop/desktop versions (Figure 1B) or portable versions (Figure 1C). Both types have temperature control

TABLE 1 Types and features of cannabis vaping devices.

Device	Product type used	Average THC potency of product	Vapour or aerosol	Temperature control	Pre-filled	Refillable	Rechargeable	Pros ^a	Cons ^a
A. Metered dose inhalers  	Granulated raw cannabis	<10% THC	Aerosol	No	Varies	Varies	Varies	<ul style="list-style-type: none"> Provides a consistent, accurate dose. Standardised manufacturing. Lower potential for overconsumption. 	<ul style="list-style-type: none"> Limited availability
	B. Desktop vaporisers 	Dried flower, E-liquid, solid cannabis concentrate	<30% THC	Vapour	Yes	No	Yes	Yes	<ul style="list-style-type: none"> Powerful. Convection, conduction or hybrid options. Temperature settings. Available with a three-in-one input (dried cannabis flower, E-liquids and solid cannabis concentrates).

(Continues)

TABLE 1 (Continued)









Device	Product type used	Average THC potency of product	Vapour or aerosol	Temperature control	Pre-filled	Refillable	Rechargeable	Pros ^a	Cons ^a
C. Portable vaporisers 	Dried flower, E-liquid, solid cannabis concentrates	<30% THC	Vapour	Yes	No	Yes	Yes	<ul style="list-style-type: none"> Use dried flower. Available with a three-in-one input (dried cannabis flower, E-liquids and solid cannabis concentrates). Convection, conduction or hybrid options. Temperature settings. Small, portable. 	<ul style="list-style-type: none"> Dried flower requires grinding beforehand. Requires regular cleaning.
D. Thermal Extraction Devices 	Dried flower, E-liquid, Solid cannabis concentrates	Varies	Vapour	No	No	Yes	N/A	<ul style="list-style-type: none"> Does not require charging or electricity. Product versatility. Portable. 	<ul style="list-style-type: none"> Requires external heating source (e.g., butane torch). No evidence confirming that combustion does not occur. No charging required.
E. First generation disposable cannabis E-cigarettes 	E-liquid containing cannabis extracts	70–85% THC	Aerosol	No	Yes	No	No	<ul style="list-style-type: none"> Inexpensive. Discreet. Small, portable. User friendly. 	<ul style="list-style-type: none"> Single use. No temperature settings. Low power.
F. Second generation cannabis E-cigarettes with prefilled or refillable cartridges 	E-liquid containing cannabis extracts	70–85% THC	Aerosol	Both, depends on model	Yes	Yes	Yes	<ul style="list-style-type: none"> User friendly. Small, portable. Discreet. Refillable. Cartridges are mostly universal. Rechargeable. 	<ul style="list-style-type: none"> Potential leaking

TABLE 1 (Continued)

Device	Product type used	Average THC potency of product	Vapour or aerosol	Temperature control	Pre-filled	Refillable	Rechargeable	Pros ^a	Cons ^a
G. Third generation tanks or mods 	E-liquid containing cannabis extracts	70–85% THC	Aerosol	Both, depends on model	No	Yes	Yes	<ul style="list-style-type: none"> • Replaceable and personalised components. • Bigger battery. • More power. • Portable. 	<ul style="list-style-type: none"> • Steep learning curve. • Larger size. • Can leak. • Expensive to purchase.
H. Fourth generation pod mods 	E-liquid containing cannabis extracts	70–85% THC	Aerosol	Both, depends on model	No	Yes	Yes	<ul style="list-style-type: none"> • Prefilled cartridges are leakproof. • Closed or open system. • Low maintenance. 	<ul style="list-style-type: none"> • Cartridges must be compatible to the device and manufacturer
I. Dab pens 	Solid cannabis concentrates	70–90% THC	Aerosol	Yes	No	Yes	Yes	<ul style="list-style-type: none"> • Portable. • Product versatility. • Less odour. 	<ul style="list-style-type: none"> • Requires regular cleaning. • High THC concentration. • Larger battery required.
J. Dab rigs 	Solid cannabis concentrates	70–90% THC	Aerosol	Rarely	No	Yes	N/A	<ul style="list-style-type: none"> • Does not require charging or electricity. • Product versatility. 	<ul style="list-style-type: none"> • Require external heating source. • No temperature control. • Requires regular cleaning. • Large size (not very portable). • High THC concentration. • Requires coordination.

^aPoints listed in the pros and cons columns reflect information relevant to both safety, as well as common views of consumers so healthcare professionals can understand why an individual may or may not choose a device.

and are refillable and rechargeable. Depending on the individual vaporiser, cannabis is heated through either convection or conduction (see Table A1 for definitions). Convection vaporisers usually allow for more even and accurately controlled temperature. Due to their size, desktop vaporisers have a larger chamber and subsequently can hold more dried flower or oil, and also produce more vapour. This will dictate the dose of cannabis consumed in one inhalation session. The loading process for dried cannabis flower requires grinding it, loading it into the chamber, and allowing the device to heat the flower and create vapour. Emptying the used product from the chamber is required after each vaporisation session. Vaporisers also may require additional cleaning of the filter screen and mouthpiece. Vaporisers may have temperature control settings, which will impact the potency of inhaled cannabis. Vaporisers are also more discrete compared to smoking as they produce less odour, which is generally desirable to consumers.

4.3 | Thermal extraction devices

Thermal extraction devices, or TEDs, are becoming increasingly common for vaporisation of dried flower, E-liquid and solid cannabis concentrates [39]. These devices are battery-free and use an external heat source, such as a butane torch or induction heater [39, 40]. As such, TEDs are small and portable. Similar to some dried flower vaporisers (see Section B), vapour is produced via conduction heating [40, 41]. Due to the external heating mechanism, however, TEDs are not fully temperature controlled. The DynaVap, for example, states that it only needs to be heated to 330–337°F for use, and makes a click sound upon reaching 350°F [42]. Although these devices can be used effectively at this temperature to avoid combustion [39, 42], there is no mechanism to avoid reaching combustion temperatures. As such, a noted limitation of these devices is knowledge of heating time, as overheating can lead to combustion, especially when learning to use [41, 42]. At this time, there is a lack of evidence confirming the absence of combustion in regular use of TEDs.

4.4 | First generation disposable e-cigarettes

The original disposable e-cigarettes are considered to be ‘1st generation vaporizers’ [17]. Despite being designated as vaporisers, they produce an aerosol upon heating cannabis E-liquid. Based heavily on e-cigarettes for nicotine, these devices were originally designed to mimic the look and feel of combustible cigarettes. Many newer disposable e-cigarettes mimic the appearance of nicotine disposables. First

generation e-cigarettes are closed system devices. These devices are neither rechargeable or refillable and are disposed upon running out of E-liquid or charge. They also do not allow for temperature control. The E-liquid inside the cartridge contains cannabis concentrates, usually a THC isolate, and are not recommended for medical use. E-liquid may also contain alternative cannabinoids, such as cannabidiol, in addition to flavouring [20, 43]. They are marketed and likely viewed by consumers as being affordable, discrete and convenient in shape and size, contributing to their continued popularity. While there are regulated disposable cannabis e-cigarettes available in most markets, there are also many unregulated ones. The use of unregulated THC vaping products is a significant public health concern and has been linked to cases of EVALI [12].

4.5 | Second generation e-cigarettes with prefilled or refillable cartridges

Second generation e-cigarettes resemble first generation e-cigarettes but are reusable, as the cartridges can be replaced and the battery can be re-charged (often via USB) [17]. Similar to first generation vaporisers, they produce an aerosol upon heating e-liquid. These devices contain cartridges that are either refillable or prefilled. Most cartridges are 510-threaded, meaning they can be screwed off and on devices with a 510-compatible battery in the battery pen. Cartridges for these e-cigarettes contain e-liquid, which can be either regulated or unregulated and are purchased separately from the device. Second generation e-cigarettes have more features than disposable first-generation vaporisers, such as buttons or switches to change temperature and puff length. Similar to first generation disposable e-cigarettes, second generation e-cigarettes continue to be popular due to their discrete, convenient shape and size. The cartridges tend to be more expensive compared to disposable e-cigarettes, but the reusability of the device may contribute to the popularity of the second generation model. The risk of inhaling contaminants or toxins if using unregulated cartridges remains a significant public health concern for this device as well. To date, no cases of lung health problems have been reported with regulated second generation e-cigarettes, but there remains a lack of safety studies.

4.6 | Third generation tanks or mods

Tanks and mods are considered to be third generation vaporisers [17]. Similar to earlier generation vaporisers, they produce an aerosol upon heating e-liquid. They are rechargeable, refillable and temperature-controlled vaping devices created to be used many times. These devices are

considered to be the most versatile as they are modifiable by users based on their preferences. One modifiable aspect of tanks or mods includes battery size, which affects battery life, size and overall power. Unlike cartridge-based products, tanks are used. Different volumes of tanks impact the volume of e-liquid storage, in addition to size. Some of these devices are modifiable. A common modification is a Sub-Ohm tank, which contains low coils in order to create a large aerosol cloud, and stronger delivery of the substance being used. Because of their modification capabilities, tanks and mods are considered to be less user friendly, with a steeper learning curve and higher maintenance requirement. These devices are not recommended for medical use and usually are not sold in medical streams. As these devices take e-liquid, the same risks to health are present if individuals purchase e-liquid from non-regulated sources. The sale of regulated cannabis containing e-liquid that is not already contained in cartridges is less common, thus there may be a higher risk of obtaining product required for this device type from unregulated sources.

4.7 | Fourth generation pod mods

Pod mods, or 'pods' are rechargeable, re-fillable, and usually temperature-controlled vaping devices that contain a liquid pod cartridge [17]. Pods can either be 'open', where the pod cartridges are refillable, or 'closed' pre-filled cartridges that can be popped in and out of the device. Because of this, closed pod mods require less maintenance and do not involve manual refilling. Similar to earlier generation vaporisers, they produce an aerosol upon heating e-liquid. Compared to second generation e-cigarettes, pod cartridges snap into place rather than twist in. Unlike many other vaping device products, pod cartridges must be compatible with the device being used and are not modifiable. Thus, many pod mods have proprietary pods that must be bought with the device. Pod mods can vary in size and shape, and their battery is more powerful than an e-cigarette, but smaller and weaker than a bulky mod or tank. Pod mods are rechargeable, generally inexpensive, and can be found in both unregulated and regulated markets. When purchasing e-liquid for open pod mod systems, or cartridges for closed pod mod systems, it is important to review the ingredients and THC content and ensure it is coming from a regulated producer.

4.8 | Dab pens

Dab pens, or wax pens, are portable vaping devices for concentrates, or a 'portable dab rig' [17]. Similar to dab rigs, combustion is possible if temperatures become too

high, although this is probably less likely for dab pens due to battery operated temperature control. Dabs' or concentrates such as shatter, wax, honeycomb, budder or amber are added directly on the heating coil. As the melted wax interacts with the heating coil, the contents are aerosolised for inhalation. Dab pens may be chosen for their decreased odour, potency or versatility in products for use. Similar to a vaporiser and dab rig, the refillable chamber requires regular cleaning after each use. The higher temperatures required to vapourise concentrates involves a larger battery than vape pens, resulting in a slightly larger size. Similar to dab rigs, the high levels of THC and potential contaminants in cannabis concentrates make dab pens not suitable for medical use. From a public health standpoint, the vaping of highly concentrated cannabis products in any form should be dissuaded for both non-medical and medical use.

4.9 | Dab rigs

A dab rig is a tabletop device, where concentrates are added to a heated surface, aerosolised and filtered through water prior to inhalation [17]. Solid cannabis concentrates require a higher temperature for vaporisation (200°C to 400°C) compared to other e-liquid or dried flower vaporisers [44]. When using the correct temperature, dabbing is considered a form of vaporisation due to the lack of combustion. However, if temperatures become too high, combustion can occur. This may be more likely if external heat sources such as a blowtorch are used to heat the surface. Dabs use solid cannabis concentrates such as wax which are some of the most highly concentrated cannabis products. Thus, the potential dose of THC tends to be the highest for dabbing

TABLE 2 Key practice considerations for cannabis vaporisation.

Product-related

- The use of regulated, third party tested vaping cannabis products is a key factor in vaporisation safety.
- The three main types of vaping cannabis products are:
 - Dried cannabis flower
 - the safest and preferred vaporisation product.
 - E-liquid, which carries a health risk of EVALI if from unregulated sources.
 - Solid cannabis concentrates, which are not recommended due to high THC potency.
 - E-liquids and cannabis extracts may contain toxins such as formaldehyde or vitamin E acetate due to product formulations, especially in unregulated products.
 - E-liquids and cannabis extracts often contain highly concentrated THC (up to 90%), increasing the risk of adverse events (e.g., impairment, substance misuse).

amongst all the cannabis vaporisation devices, increasing the risk of adverse events or dependence. Further, dab cannabis products are less commonly available through regulated streams of purchase. Thus, some individuals may purchase products online or through unregulated storefronts. Compared to its portable counterpart (see above), dab rigs do not require electricity and are more powerful. Comparatively, dab rigs require more cleaning after use, are easily breakable, require an external heating source and are considered harder to learn to use than other vaping methods. From a health standpoint, because of the high THC concentration utilised, and potentially high concentration of contaminants, if unregulated, dab rigs are not recommended for non-medical or medical use.

5 | PRACTICAL IMPLICATIONS AND FUTURE DIRECTIONS

We have presented information on different cannabis vaporisation products and devices that can be utilised. It is important that consumers and public health/health care professionals are aware of the benefits and risks of these individual devices. As both vaping and cannabis use increase in popularity, focusing on accurate health education will help facilitate lower risk use. To date, health messaging on vaporisation has largely been negative, potentially missing opportunities to reduce harm. Key implications for practice are outlined in Table 2.

Going forward, greater education for public health and healthcare professionals on cannabis vaporisation is needed. For example, professional bodies that provide continuing medical education should invest in increased educational opportunities with detailed information on cannabis vaporisation that recognises the health risk for different product devices. By improving competency, public health/health care professionals can better engage in educating and promoting behaviours to reduce harm related to cannabis vaporisation at both an individual and policy level. Increased education campaigns and better standards for health risk labelling of different cannabis products and devices should be invested in. The ease of access to high THC potency cannabis products coupled with a lack of education surrounding different vaping products and devices is concerning.

Low and high THC potency products are displayed side-by-side in dispensaries with little information available on risk differentiation. This is similar for dried cannabis flower vapes and cannabis concentrate vapes. Greater efforts should be taken to inform the public about the health risks from certain cannabis products and devices in order to facilitate informed decision

making. For example, the potential risk of inhaling formaldehyde from vaporisers that use E-liquid is not well known. Further, as concerns over increased rates of problematic cannabis use in the general population grow, efforts to encourage the use of lower THC potent products should be taken. We believe better standards for health warning signs based on cannabis product and device type are needed.

6 | LIMITATIONS

The current literature base on this topic was not robust enough to conduct a systematic review. As such, the authors applied a narrative approach [45] to synthesise key findings from the literature and evidence in cannabis vaporisation, and specifically to provide a synopsis of the issues and challenges regarding the use of vaporisation technology in clinical practice. The approach was guided by the experience and expertise of the authors, not by a systematic search process or by a rigorous inclusion/exclusion procedure. As such, this review and its findings may not be reproducible, and the citations that are selected are subject to the authors' bias [46, 47]. To mitigate some bias, this review is collaborative in nature and incorporates input from multiple domains of expertise, including family medicine, internal medicine, public health and pharmacy. Regardless, given the nature of a narrative review and the limited literature base, the findings and recommendations in this review are weak in strength.

7 | CONCLUSION

The rapid increase in popularity of vaporisation, lack of standards and multiple devices has led to confusion for both consumers and health care providers. In order to convey appropriate and accurate health messaging, health care providers need to understand these differences and their safety considerations in order to provide information to their patients/the public. Each vaporisation device is different, thus requiring an understanding of their regulation status, general use patterns, compatible product type, advantages and disadvantages. More cannabis-related education targeting a wide range of health care providers (e.g., physicians, nurses, pharmacists, social workers) is warranted to enhance provider expertise in discussing this topic with patients. Adjustments to health warning labelling that are specific to different cannabis vaping devices and product types may be warranted. There is a significant need for more primary, high-quality research on this

topic to allow for stronger conclusions and recommendations to be made.

AUTHOR CONTRIBUTIONS

Each author certifies that their contribution to this work meets the standards of the International Committee of Medical Journal Editors.

ACKNOWLEDGEMENTS

The authors state no acknowledgements for the present work.

CONFLICT OF INTEREST STATEMENT

The production of manuscript was not supported by any funding. Caroline A. MacCallum is the Medical Director of Greenleaf Medical Clinic and Chief Medical Officer for Translational Life Sciences. She is an advisor to PreveCeutical, Pinnacle Care, Africana, EO Care, Andira Medicine, Active Patch Technologies, Syqe Medical, and Dosist. She was previously on the Board of Directors for The Green Organic Dutchman. Additionally, she has provided medical consultation and/or received support for industry sponsored continuing medical education from: Aleafia, Aurora, Canopy, Tilray, Emerald Health. MB has received financial support as a speaker and consultant for CHE activities from Teva, Pfizer, Novo Nordisk, Khiron, Tilray, mdBriefcase, J&J, Abbvie, Ascensia, Astra Zeneca, Biosynt, and Emergent BioSolutions. Lindsay A. Lo, Carly A. Pistawka, and April Christiansen report no conflicts of interest.

ORCID

Caroline A. MacCallum  <https://orcid.org/0000-0002-7889-3959>

REFERENCES

1. Metcalf M, Rossie K, Stokes K, Tanner B. Health care professionals' clinical skills to address vaping and e-cigarette use by patients: Needs and interest questionnaire study. *JMIR Form Res.* 2022;6:e32242.
2. Goodman S, Wadsworth E, Leos-Toro C, Hammond D. Prevalence and forms of cannabis use in legal vs. illegal recreational cannabis markets. *Int J Drug Policy.* 2020;76:102658.
3. Huestis MA. Human cannabinoid pharmacokinetics. *Chem Biodivers.* 2007;4:1770–804.
4. Fehr KO, Kalant H. Analysis of cannabis smoke obtained under different combustion conditions. *Can J Physiol Pharmacol.* 1972;50:761–7.
5. Tashkin DP. Effects of marijuana smoking on the lung. *Ann Am Thorac Soc.* 2013;10:239–47.
6. Abrams DI, Vizoso HP, Shade SB, Jay C, Kelly ME, Benowitz NL. Vaporization as a smokeless cannabis delivery system: a pilot study. *Clin Pharmacol Ther.* 2007;82:572–8.
7. Moir D, Rickert WS, Levasseur G, Larose Y, Maertens R, White P, et al. A comparison of mainstream and sidestream marijuana and tobacco cigarette smoke produced under two machine smoking conditions. *Chem Res Toxicol.* 2008;21:494–502.
8. Pomahacova B, Van der Kooy F, Verpoorte R. Cannabis smoke condensate III: the cannabinoid content of vaporised Cannabis sativa. *Inhal Toxicol.* 2009;21:1108–12.
9. MacCallum CA, Lo LA, Pistawka CA, Boivin M. A clinical framework for evaluating cannabis product quality and safety. *Cannabis Cannabinoid Res.* 2022;8:567–74.
10. Vandrey R, Raber J, Raber M, Douglass B, Miller C, Bonn-Miller MO. Cannabinoid dose and label accuracy in edible medical cannabis products. *JAMA.* 2015;313:2491–3.
11. Public Health Agency of Canada. Mandatory cannabis testing for pesticide active ingredients—Requirements [Internet]. 2018 [cited 23 January 2023]. Available from: <https://www.canada.ca/en/public-health/services/publications/drugs-health-products/cannabis-testing-pesticide-requirements.html>
12. Layden JE, Ghinai I, Pray I, Kimball A, Layer M, Tenforde M, et al. Pulmonary illness related to e-cigarette use in Illinois and Wisconsin—preliminary report. *N Engl J Med.* 2020;382:903–16.
13. MacCallum CA, Lo LA, Pistawka CA, Christiansen A, Boivin M, Snider-Adler M. A clinical framework for assessing cannabis-related impairment risk. *Front Psych.* 2022;13:883517.
14. Turna J, Balodis I, Munn C, Van Ameringen M, Busse J, MacKillop J. Overlapping patterns of recreational and medical cannabis use in a large community sample of cannabis users. *Compr Psychiatry.* 2020;102:152188.
15. Lo LA, MacCallum CA, Yau JC, Barr AM. Differences in those who prefer smoking cannabis to other consumption forms for mental health: what can be learned to promote safer methods of consumption? *J Addict Dis.* 2023;41:258–62.
16. Stancliff S, Phillips BW, Maghsoudi N, Joseph H. Harm reduction: front line public health. *J Addict Dis.* 2015;34:206–19.
17. Centers for Disease Control and Prevention. E-Cigarette, or Vaping, Products Visual Dictionary. 2021.
18. Canadian Centre on Substance Use and Addiction. Talking pot with youth [Internet]. 2019 [cited 13 July 2019]. Available from: https://www.ccsa.ca/sites/default/files/2019-03/CCSA-Cannabis-Communication-Guide-2018-en_0.pdf
19. Cinnamon Bidwell L, YorkWilliams SL, Mueller RL, Bryan AD, Hutchison KE. Exploring cannabis concentrates on the legal market: user profiles, product strength, and health-related outcomes. *Addict Behav Rep.* 2018;8:102–6.
20. Guo W, Vrdoljak G, Liao VC, Moezzi B. Major constituents of cannabis vape oil liquid, vapor and aerosol in California vape oil cartridge samples. *Front Chem.* 2021;9:694905.
21. Meier MH, Docherty M, Leischow SJ, Grimm KJ, Pardini D. Cannabis concentrate use in adolescents. *Pediatrics.* 2019;144:e20190338.
22. Bidwell LC, Martin-Willett R, Karoly HC. Advancing the science on cannabis concentrates and behavioural health. *Drug Alcohol Rev.* 2021;40:900–13.
23. Schmidt E. Cannabis Concentrates 101: A Guide to Terms, Usage, Potency, and Testing [Internet]. Sun City Center, FL: ACS Laboratory; 2023. Available from: <https://www.acslab.com/retail/cannabis-concentrates-guide>

24. National Institute on Drug Abuse. Cannabis Potency Data | National Institute on Drug Abuse (NIDA) [Internet]. 2022 [cited 28 October 2023]. Available from: <https://nida.nih.gov/research/research-data-measures-resources/cannabis-potency-data>
25. Canada H. About cannabis [Internet]. 2018 [cited 28 October 2023]. Available from: <https://www.canada.ca/en/health-canada/services/drugs-medication/cannabis/about.html>
26. Smart R, Caulkins JP, Kilmer B, Davenport S, Midgette G. Variation in cannabis potency and prices in a newly legal market: evidence from 30 million cannabis sales in Washington state. *Addiction*. 2017;112:2167–77.
27. Ashton CH. Adverse effects of cannabis and cannabinoids. *Br J Anaesth*. 1999;83:637–49.
28. Ashton L. Differences between CBD oil and CBD vape juice e-liquid [Internet]. CFAH 2021 [cited 6 October 2023]. Available from: <https://cfah.org/cbd-oil-vs-vape-juice/>
29. Troutt WD, DiDonato MD. Carbonyl compounds produced by vaporizing cannabis oil thinning agents. *J Altern Complement Med*. 2017;23:879–84.
30. Barrington-Trimis JL, Samet JM, McConnell R. Flavorings in electronic cigarettes: an unrecognized respiratory health hazard? *JAMA*. 2014;312:2493–4.
31. Sarma ND, Waye A, ElSohly MA, Brown PN, Elzinga S, Johnson HE, et al. Cannabis inflorescence for medical purposes: USP considerations for quality attributes. *J Nat Prod*. 2020;83:1334–51.
32. Craven CB, Birjandi AP, Simons B, Jiang P, Li XF. Determination of eighty-two pesticides and application to screening pesticides in cannabis growing facilities. *J Environ Sci (China)*. 2021;104:11–6.
33. Jensen RP, Luo W, Pankow JF, Strongin RM, Peyton DH. Hidden formaldehyde in e-cigarette aerosols. *N Engl J Med*. 2015;372:392–4.
34. Russo EB. Current therapeutic cannabis controversies and clinical trial design issues. *Front Pharmacol*. 2016;7:309.
35. Earleywine M, Barnwell SS. Decreased respiratory symptoms in cannabis users who vaporize. *Harm Reduct J*. 2007;4:11.
36. Hazekamp A, Ruhaak R, Zuurman L, van Gerven J, Verpoorte R. Evaluation of a vaporizing device (Volcano®) for the pulmonary administration of tetrahydrocannabinol. *J Pharm Sci*. 2006;95:1308–17.
37. Almog S, Aharon-Peretz J, Vulfsons S, Ogintz M, Abalia H, Lupo T, et al. The pharmacokinetics, efficacy, and safety of a novel selective-dose cannabis inhaler in patients with chronic pain: a randomized, double-blinded, placebo-controlled trial. *Eur J Pain*. 2020;24:1505–16.
38. Palylyk-Colwell E, Farrah K. Metered-dose inhalers for medical cannabis use. *Can J Health Technol*. 2022;2:1–29.
39. Morgan J, Gschwend G, Houston M, Jones A, Kelso C. Vaping preferences of individuals who vaporise dry herb cannabis, cannabis liquids and cannabis concentrates. *Drug Alcohol Depend*. 2022;240:109632.
40. Danklin B. The Best Dry Herb Portable Vaporizers for 2023—Vaporizer Wizard [Internet]. 2023 [cited 28 October 2023]. Available from: <https://www.vaporizerwizard.com/best-portable-vaporizers/>
41. City Vaporizer. DynaVap M [Internet]. 2023 [cited 28 October 2023]. Available from: <https://cityvaporizer.com/product/dynavap-m-2021/>
42. DynaVap. DynaVap. 2023 [cited 28 October 2023]. Thermal Extraction vs. Other Smoking Methods. Available from: <https://www.dynavap.com/en-ca/blogs/news/thermal-extraction-vs-other-smoking-methods>
43. Civileto CW, Hutchison J. Electronic vaping delivery of cannabis and nicotine. *StatPearls* [Internet]. Treasure Island (FL): StatPearls Publishing; 2023 [cited 28 November 2023]. Available from: <http://www.ncbi.nlm.nih.gov/books/NBK545160/>
44. Meehan-Atrash J, Luo W, Strongin RM. Toxicant formation in dabbing: The Terpene Story. *ACS Omega*. 2017;2:6112–7.
45. Turin T, Ahmed S, Vaska M. Conducting a literature review in health research: basics of the approach, typology and methodology. *J NHFB*. 2016;5:44–51.
46. Sukhera J. Narrative reviews in medical education: Key steps for researchers. *J Grad Med Educ*. 2022;14:418–9.
47. Sullivan GM. Why are medical education literature reviews so hard to do? *J Grad Med Educ*. 2018;10:481–5.
48. Leafly. Cannabis glossary. n.d. Leafly Retrieved 17 February 2023. Available from: <https://www.leafly.ca/learn/cannabis-glossary>
49. O'Driscoll A. Anatomy of a vape pen. Leafly. 2020. Available from: <https://www.leafly.ca/news/cannabis-101/vape-pen-anatomy>

How to cite this article: MacCallum CA, Lo LA, Pistawka CA, Christiansen A, Boivin M. Cannabis vaporisation: Understanding products, devices and risks. *Drug Alcohol Rev*. 2023. <https://doi.org/10.1111/dar.13800>

APPENDIX

TABLE A1 Terms and definitions related to cannabis vaporisation.

Term	Definition
General	
Aerosol	A suspension of small solid and/or liquid particles dispersed in air or another gas.
Concentrate	A highly potent, concentrated substance, made from the cannabis plant that contain large amounts of cannabinoids and terpenes.
Conduction	The transfer of heat between two objects that are in direct contact (e.g., direct contact between dried flower and a heating plate). A method to produce vapour. https://ibn.idsi.md/vizualizare_articol/75018
Convection	The process of transferring heat, by passing heated air over a material, such as cannabis flower or oil. This is an indirect heating method.
Dabbing	A process of inhaling cannabis concentrates that have been aerosolised on a hot surface ('nail'). May also refer to the inhalation of cannabis concentrates using a dab pen or vaporiser.
Extract	A type of concentrate produced using a solvent.
EVALI	E-cigarette or vaping use-associated lung injury. An acute respiratory illness, and/or lung damage, associated with using e-cigarette and vaping products. Previously known as VAPI (vaping-associated pulmonary illness), VALI.
Formaldehyde	A highly toxic gas that is produced during the evaporation of mixed propylene glycol and glycerin. Formaldehyde is a group 1 carcinogen.
Group 1 carcinogen	Category of compounds that are carcinogenic to humans. Group 1 carcinogens have enough strong evidence to state a causal role between the compound and cancer in humans.
Propylene glycol	A common base fluid in e-liquid when combined with vegetable glycerin. Propylene glycol is a synthetic food additive.
Solubiliser	A substance that increases the solubility of another substance.
Vapour	A substance in the gas phase, which can also be found in liquid and solid states.
Vapourise	To convert into vapour, to evaporate and convert to the gas phase.
Vegetable glycerin	A common base fluid in e-liquid when combined with propylene glycol. A clear, viscous liquid made from coconut, palm and soy oils. May also be referred to as 'glycerol'.
Vitamin E acetate	A synthetic form of vitamin E that is often used as a food additive, or a thickening agent in e-liquid. Inhalation of vitamin E acetate is strongly associated with EVALI.
Device components	
510-thread	A type of thread connection between a vape cartridge and battery. In a 510 thread, the connector is 5 mm long, and is comprised of 10 threads.
Cart/cartridge	A pre-filled or refillable glass cartridge that contains the e-liquid.
Chamber	The compartment that holds dried cannabis in a portable or desktop vaporiser. Also commonly referred to as an 'oven'.
Closed system	A vaping device that uses compatible cartridges that are prefilled and disposable.
Open system	A vaping device that uses a chamber or tank that can be refilled by the user.
Pod	A prefilled or refillable pod cartridge for a pod mod.
Sub-Ohm	A type of tank that contains low resistance coils in order to create a large aerosol cloud with a stronger substance delivery.
Tank	1. The component of pod mods that stores the e-liquid. 2. Synonym for Mod (see 'Mod').
Product type	
Cannabis flower	The dried and cured flower bud from the female cannabis plant. Cannabis flowers are hairy, sticky and contain trichomes, cannabinoids and terpenes.

(Continues)

TABLE A1 (Continued)

Term	Definition
Cannabinoid	Chemical compounds found in cannabis (phytocannabinoids) or within the human body (endocannabinoids). There are over 100 known cannabinoids, of which THC and CBD are the most well known.
Solid cannabis concentrate	A collection of highly potent, concentrated mass of cannabinoids (primarily THC) that have been extracted from the cannabis plant. Concentrate types, such as shatter, budder, wax and crumble, are classified based on the production method and final consistency.
E-liquid	Liquid that is aerosolised by an e-cigarette or vaping device.
Isolate	A cannabis extract that has been refined into a crystalline or powder product that contains a pure cannabinoid (e.g., THC or CBD).
Device types	
1st gen	See 'disposable e-cigarette'.
2nd gen	A second-generation e-cigarette that uses a prefilled or refillable cartridge, and is rechargeable. Also called a 'personal vaporiser'.
3rd gen	See 'Mod'.
4th gen	See 'Pod mod'.
Bong	A water pipe, usually made from glass, that is used to vapourise and cool cannabis or other substances.
Cigalike	See 'disposable e-cigarette'.
Dab pen	A handheld electronic device that is used for vaporisation and inhalation of cannabis concentrates. Also known as a wax pen.
Dab rig	A water pipe that filters cannabis vapour using water as a way to inhale cannabis concentrates.
Desktop vaporiser	Large, stationary vaporiser that uses a direct power source. Desktop vaporisers are often compatible with dried flower, cannabis oil and wax.
Disposable e-cigarette	A first-generation vaping device that is single use and disposed upon finishing the e-liquid or losing charge. Also known as 'cigalikes'.
E-cigarette	A battery-operated electronic device used to inhale vapour that resembles a cigarette.
Metered dose inhaler	An aerosol-generating device that can provide precise and consistent doses for inhalation.
Mod	A modifiable, rechargeable vaping device. The components, including the atomiser, tank, mouthpiece, battery and coils—can be interchanged. Also referred to as 'Tanks' or a 3rd generation vaping device.
Pod/pod mod	A fourth-generation vaping device that uses compatible prefilled or refillable 'pod' cartridges and is rechargeable.
Portable vaporiser	A portable electronic vaporiser that aerosolises dried flower, oil and/or wax.
Vaporiser	A device that either produces a true vapour or an aerosol.

Note: References gathered from [17, 48, 49].