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GROWING AT HOME: HEALTH AND SAFETY CONCERNS FOR PERSONAL CANNABIS CULTIVATION

PURPOSE

Personal cultivation as described by the proposed *Cannabis Act (2017)*[1] will permit adults to cultivate up to four cannabis plants per household. This provision is intended to both promote equity by facilitating access to legal cannabis, particularly when retail outlets are difficult to access, and to undercut the black market. However, indoor cultivation and processing of cannabis may also introduce or exacerbate certain environmental health risks in the home.

This document identifies health and safety concerns that may be relevant to personal cultivation after legalization – that is, legal home growing and the associated health risks. Although this information may be of relevance to the public at large, the evidence presented here has been synthesized and organized for policy- and decision-makers, environmental and medical health officers, and other public health professionals. This review thus serves as a launching point for considering both wide-scale and regionally oriented preventive actions to mitigate the environmental health risks that may arise from growing at home.

OVERVIEW

Promoting and protecting the health and safety of home growers and their families has thus far received little attention in cannabis legalization debates. Furthermore, many of the policies that have been proposed to mitigate the risks of commercial cannabis (e.g., enforcing safe production practices, requiring child-resistant packaging, and providing informative labelling) may not be applicable to or feasible for cannabis produced or processed at home. Thus, personal cultivation provides an interesting public health challenge, particularly in terms of risks brought into the home, effective communication about those risks, and the limited means that governments have to abate them.

Previous experience with remediating illegal grows has shown that indoor cultivation can be associated with a number of practices intended to optimize growth (e.g., using high-wattage lights) while preventing detection (e.g., bypassing the electrical meter).[2] Although it is hoped that legalization will eliminate the need for practices that incur the greatest risks, inspection professionals in Colorado have reported such practices even in legal home grows.[3] In Canada, medical home growers are required to abide by the relevant building and fire codes, as well as public health and residential tenancy regulations, but are not inspected for compliance. As a result, even licensed medical home growers have in some cases been found to employ practices that compromise their personal safety and/or create a hazardous living environment.[4] Thus, in the absence of public education or other means to promote safe production, it is possible that legislation intended to promote equity and fairness amongst Canadians could create or worsen in-home exposures and risks, leading to adverse health effects.

This document provides a review of the evidence relating to five key environmental health risks anticipated from growing at home: 1) access and accidental poisoning; 2) indoor air quality; 3) inappropriate use of pesticides;[a] 4) electrical and fire hazards; and 5) radiation hazards. These risks may be present during cannabis cultivation, harvesting, and handling, and as a result there may be concomitant existence of each of these types of risks. Multiple intervention tactics may then be required within the same category of risk and

a For the purposes of this paper, we use the regulatory definition of a pesticide, which is any substance used to kill, repel or control any organism that is considered a "pest" (e.g., weeds, insects, fungi, rodents, etc.).

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may differ between the steps. Note that although we draw on learning from illicit cannabis grow-ops,[2] the concerns raised here are those deemed relevant for personal cannabis cultivation as envisioned in the proposed *Cannabis Act (2017)*.[1]

After exploring each of these five key environmental health risks, we identify *policy considerations* relevant to each, highlighting interventions that have been implemented in other legalized jurisdictions and possible policy options that may mitigate some of these risks. In light of the rapidly growing cannabis industry in Canada and elsewhere, we identify *new technology and information resources*, as well as innovations in the field of cannabis cultivation that health care professionals should be aware of when interacting with and advising home growers. Finally, we describe *key public risk messages* linked to each of the identified environmental health concerns. These risk messages should be used in conjunction with other policy interventions, but as presented can provide guidance for public health professionals in their communications with the public.

METHODS

This review was conducted in response to queries from public health practitioners seeking scientific evidence regarding the potential environmental health risks of indoor residential cannabis cultivation, as well as guidance and/or regulations applicable to these or similar contexts.

The source information reviewed here includes peer-reviewed academic studies, as well as grey literature from public health authorities, law enforcement, building inspectors, and fire professionals. Blogs that focus on cannabis-related topics and industry publications were also included insofar as they inform typical practice. Specific attention was paid to jurisdictions that had previously decriminalized or legalized cannabis, in particular Colorado, Washington, Oregon, and California. Literature addressing risks within both illicit and licit (medical) cannabis grows were included. A complete description of the literature search strategy and sources included can be found in ***Appendix A.***

ACCESS AND ACCIDENTAL POISONING

The presence of cannabis plants, products, and waste in the home increases the risk that children, pets, or unaware adults may inadvertently consume cannabis with detrimental effects. In contrast to retail cannabis, which is more likely to be consumed as it is purchased, personal cultivation and the lack of an in-home possession limit mean that households may accumulate significant quantities of cannabis, increasing the overall availability of cannabis in the home. As a result, concerns over uncontrolled access to cannabis and risk of accidental poisoning have prompted some public health and safety organizations to recommend a precautionary ban on personal cultivation.[5,6]

Poison control centre data has been a valuable means to track and understand the impact of increased cannabis availability on cannabis poisoning and its adverse effects. In the US, poison centre and hospital admissions data have been used to understand the serious effects of cannabis intoxication on children (ranging from lethargy and ataxia to tachycardia, hypoventilation, coma, and seizure).[7] Although the form of cannabis ingested was unknown for most cases, data from 91 children revealed that ingestion of cannabis resin (e.g., hashish) was more common than edibles like cookies or candies, and that there were as many cases of intoxication due to ingesting a waste product (unfinished joints) as there were of eating cannabis cookies.[7] This may be because hashish is similar in appearance to chocolate, as speculated by the authors, or it may reflect other factors, such as the use of childproof packaging on commercial edibles and the diligence with which adults store edibles compared to supposedly less appealing products (making them less available), as well as the general curiosity of small children (e.g., putting non-food items in the mouth). Pets may be similarly affected.[8]

Notably, access and poisoning issues are relevant throughout the production process, as pets and children

Cannabis waste products may create access risks if not discarded and processed appropriately.

may be able to gain access to the growing room, the areas of the home where various plant parts are processed (often the kitchen), or to final products in storage or waste materials that have been discarded (in garages, backyard sheds, or garbage and compost bins). This type of access is distinct from concerns arising from poisonings due to **intentional** consumption of final products (e.g., youth accessing their parents' cannabis) and should be treated as such when developing policy interventions.

Policy considerations for access and accidental poisoning

Several studies have shown a clear relationship between decriminalization (or transition toward decriminalization) and the increasing frequency of cannabis poisonings.[9-11] In BC, barriers to accessing cannabis have also decreased considerably in recent years. At the same time, the BC Drug and Poison Information Centre (DPIC, BC Centre for Disease Control) has shown an increase in cannabis exposure calls (all ages) as a proportion of all other exposure calls (from 0.68% in 2013 to 1.20% in 2016).[12] Based on this trend and the increasing accessibility of cannabis, cannabis-related poisonings may further increase after legalization, as they have in other jurisdictions.

Home-grown cannabis and related products are of particular interest because they will not be subject to the safe production, testing, packaging, labelling, and recall requirements that have been established for commercial cannabis.[13,14] Thus, provinces that permit personal cultivation will require additional policies and programs to reduce the likelihood of toxic effects in the home. These may include the following:

- ***Promote safe practices for cannabis plants, products, and waste at home.*** Public education is critical to shaping safe cannabis culture, one component of which is encouraging safe and thoughtful management of cannabis, related products, and waste in the home environment. Further recommendations on public education are provided in the section on *Public Risk Messaging*.
- ***Promote and capacitate poison control centres***. Local poison control centres play an invaluable role in providing immediate, anonymous advice on cannabis poisoning; physicians and emergency departments unfamiliar with cannabis intoxication can also benefit from this resource. Poison control centres could also help connect cannabis users with cessation or treatment resources available in their community through collaboration with established substance abuse and addiction programs.[15]
- ***Surveillance for cannabis poisoning***. Additional data are needed to better understand how and to whom cannabis poisonings occur, both in the home as well as in other settings. In addition to enhancing cannabis-related data collection on the part of poison control centres, it may be useful to require physicians and hospitals to report cannabis intoxication to provincial health agencies, similar to opioid overdose reporting. Such data would allow provincial health agencies to track adverse effects and would provide one means to evaluate the efficacy of policies aimed at controlling harms due to increased cannabis availability (or use).
- ***Making provisions for waste disposal.*** Personal cultivation may increase the amount of cannabis in waste streams. For medical cannabis users, Health Canada previously recommended blending waste material with water, mixing it with cat litter, and disposing of it in the trash. However, depending on the scale of personal production in a community and local policies on organic material in municipal waste, it may be necessary to provide alternative disposal options in line with local recycling and waste procedures. It may also be necessary to consider the implications of chemically processed cannabis in residential waste, as discussed in the *Electrical and Fire Hazards* section below.

INDOOR AIR QUALITY

Perhaps one of the greatest impacts that personal cultivation could have on environmental health relates to its multiple impacts on indoor air quality when grown in occupied spaces. For the purposes of this paper, we will address four key indoor air quality concerns: increased relative humidity, indoor mould, and odour, as well as unsafe levels of carbon monoxide.

Relative humidity is a key determinant of the growth of fungi or mould in the home.[16] Indoor dampness and mould are in turn associated with respiratory conditions, such as asthma, upper respiratory tract symptoms, cough and wheeze, and respiratory infections, among others.[17] To prevent mould growth and subsequent respiratory health issues, as well as costly remediation work and decreases in property values, the American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE)

recommends maintaining relative humidity **below 65%** in occupied spaces.[18]

Cannabis cultivation can elevate the home's relative humidity levels through various means, and can do so significantly. When propagating young clones, for example, growers often use misting or humidifiers to increase relative humidity (sometimes as high as 70%) to support young plants until their root systems become established.[19] Mature cannabis plants also increase indoor humidity by transpiring irrigation water as vapour. It has been estimated that a single mature cannabis plant produces approximately 400 g of water per plant per day,[20] which is roughly equivalent to 5-7 average-sized house plants.[21] Irrigation practices, the use of soil-based vs. hydroponic grow systems, the use of enclosures, the use of fans or additional ventilation, and drying or curing cannabis indoors may also influence moisture burden.

When these cannabis-related moisture contributions are added to other household sources, such as occupants' respiration as well as cooking, dishwashing and bathing,[21] total moisture burden may exceed the home's capacity to ventilate – a concern that may also be relevant to multi-unit dwellings. Ventilation rates are generally low in most climate-controlled, energy-efficient Canadian homes. A modelling exercise based on typical winterized housing stock in three Canadian cities found that as few as 4-10 mature cannabis plants were sufficient to create a moisture issue. Pre-existing moisture problems found in many of the homes would be further exacerbated by cultivating cannabis.[20]

Even when relative humidity levels are not greatly elevated, cannabis cultivation can contribute to ***indoor mould***. Powdery mildew, a common and tenacious pathogen that infests cannabis, can germinate at typical relative humidity levels of 50-70%.[22] Although powdery mildew and most of the other mould and mildew species found on cannabis are not human pathogens,[23] an infested cannabis crop may nevertheless contribute to indoor mould and particulate matter, with potential impacts on respiratory health through allergic sensitivity or irritation.[17] Mouldy plants should be disposed of immediately, and in a way that does not allow unsuitable material to be reprocessed (e.g., the use of waste plant material for hash oil).

Cannabis-related odours derive from a complex mixture of hundreds of volatile compounds (terpenes and terpenoids) that are produced alongside odourless cannabinoids in the resinous secretion of the flower.[24] Thus, odours increase with flowering and may also intensify during drying, curing, and processing as essential oils are volatilized. The combination of volatile compounds expressed varies among species and hybrids and may be subjectively more or less pleasant. To date, there is no evidence to suggest that cannabis odours are specifically detrimental to human health[25]; however, as with any strong odour, it can be argued that odour itself impacts well-being through annoyance, disruption, and stress.[26,27]

Carbon monoxide (CO) is a hazardous by-product of propane- or natural gas-powered carbon dioxide (CO_2) generators or "burners" that are sometimes used to enhance plant growth and increase yield.[28] CO accumulation within the home may also be affected (positively or negatively) by modification of the home's ventilation capacity.[29] Ignition devices also create an explosion hazard in the event of a fire due to the presence of compressed gas. Other hazardous practices include venting furnaces or water heaters directly into the grow room to increase CO_2.[3]

Policy considerations for indoor air quality

A great deal of attention has previously been focused on both the indoor and outdoor air quality concerns related to commercial cannabis facilities, and a number of regulations, technologies, and best practices have been developed to mitigate these issues.[30-33] However, very different approaches are required to address these issues in private homes:

- ***Limit plant numbers.*** Because impacts on indoor air quality scale up with the number of plants, low plant limits should minimize risks for home growers. However, even a few plants may create or exacerbate moisture issues in some homes. Furthermore, Canadian law enforcement has indicated that plant limits under the proposed *Cannabis Act* will be difficult or impossible to enforce, and overgrowth is considered likely.[5] Thus, plant limits alone are insufficient to mitigate the indoor air quality risks of indoor cultivation.
- ***Grow outside of the home.*** Cultivation-related humidity and mould issues can be avoided by growing outside of the home. Several provinces have indicated that they will permit outdoor or open-air growing on private property,[34,35] although this increases the risk of theft and may exacerbate odour issues. A second option is to allow or encourage growth in secure, non-attached structures on the same property, which would also allow for the installation of odour control technology, if necessary.

On the left, four three week old cannabis plant seedlings in plastic pots.
On the right, three fully mature cannabis plants budding under grow lights.

- ***Consider use of indoor air cleaners.*** Although air filtration units are typically limited in their ability to capture mould spores, which tend to settle before they can be entrained and removed,[36] the use of additional ventilation in the grow space (fans, etc.) may create a more turbulent environment in which air filtration could help to reduce airborne spores. However, to date there has been no formal evaluation regarding the efficacy of portable air filtration units or air cleaners in the context of indoor cannabis cultivation.
- ***Implement odour-reducing techniques and technologies.*** Low-cost options that can be implemented without structural alterations include choosing low-odour varieties, storing cannabis in air-tight containers, and using masking agents,[b] deodorizers, ozone generators, and small-scale activated carbon filters to decrease odour.[37] Activated carbon filters are widely promoted by the cannabis community as the most effective means, but have not been formally evaluated. Masking agents and ozone generators are **not** recommended as they may

b For example, incense, perfumes, or scented candles.

contribute to indoor air quality issues. Air filtration units (above) are relatively ineffective at reducing VOCs, and so may not be useful for odours.[36]

Discourage use of ignition devices indoors. Because gas-powered CO_2 generators are readily available in Canada and also used outside of the home (e.g., greenhouses), banning the sale of such devices may be challenging. Sacramento County, California, has banned the use of CO_2 generators in indoor grows.[38] It is unclear how this ban might be enforced; because home growers in Sacramento also require a landlord's permission, it is possible that landlord inspections may deter the use of such devices in rental properties.

INAPPROPRIATE USE OF PESTICIDES

Cannabis cultivation can be impacted by a number of pests including moulds, blights, and insects that attack living plants, as well as fungi that attack dead plants as they are being dried or cured.[23] Because of the time and cost required to complete a full cannabis growth cycle, growers may adopt risky pest control practices to avoid crop loss. However, although Health Canada provides general guidance regarding the use of pesticides in the home,[39] specific guidance regarding pest control for cannabis is lacking.

Due to this lack of guidance, home growers may resort to potentially hazardous products to control cannabis pests. Peer advice on popular cannabis cultivation forums[c] indicates that potentially hazardous products are in widespread use by home growers and that misinformation about these products abounds.

One example of a potentially dangerous product is myclobutanil, which is available under the trade names Nova 40W and Eagle 20 in Canada. Because myclobutanil is approved for use on a number of food crops, some home growers may mistakenly assume that this product is likewise safe to use on cannabis. However, myclobutanil and many other products commonly used on cannabis are considered inappropriate for products that may be smoked. This is because even when cannabis is smoked, contaminants like pesticide residues are not completely combusted, and the remaining residue or its combustion products can then be absorbed through the lung.[41] In addition, contaminants that are smoked or inhaled may be more easily absorbed by the lung than the gut, especially if smoke is inhaled deeply and held.[42]

Growers may also increase their risk of pesticide exposure through cannabis processing, as pesticide residues may become concentrated in hash oils, hashish, and other concentrates (wax, shatter, rosin, etc.),[43] for which reason the use of any extraneous product should be limited. In addition to contamination of the crop or product, indoor pesticide use carries a general exposure risk to all occupants of the home, as residues may linger longer on surfaces or other objects when applied indoors.[44] Finally, cannabis-related pesticide use may pose a risk to home growers if appropriate storage facilities do not exist.

Policy considerations for pesticide use

Developing Canadian policy around pest control products is facilitated by our national approach to legalization and past experience dealing with this issue for medical cannabis. This is in contrast to the US, where decriminalizing or legalizing states have been unable to request the guidance or participation of federal regulators (Environmental Protection Agency), as cannabis remains an illicit substance.[45,46]

In Canada, pest control products are reviewed and registered for use by the Pest Management Regulatory Agency (PMRA). PMRA has registered a number of products for use on medical cannabis, which are considered low-risk when used according to label directions.[d] At the time of writing, PMRA-approved pesticides included plant oils (garlic, neem, canola, etc.), insecticidal soaps, and biological control agents (bacteria). Notably absent from this PMRA-approved list are any and all synthetic pesticides, although some synthetics have been allowed under specific conditions in some US states.[14,46]

However, it should be noted that some PMRA-approved products may not be appropriate for use in homes. For example, vaporized sulfur (for treatment of powdery mildew)

c For an example, please see a recent thread on the THC Farmer Cannabis Cultivation network[40]: https://www.thcfarmer.com/community/threads/eagle-20-info-please.78838/.

d An updated list of pesticides registered for use on cannabis can be accessed through PMRA's online label search tool (http://pr-rp.hc-sc.gc.ca/ls-re/index-eng.php)[47] or through PMRA's Pesticide Labels App on your mobile.

is intended for commercial indoor use. The applicator requires personal protective equipment, access to the treated area must be controlled, and the space must have higher ventilation rates (at least 4 air changes per hour)[48] than are typical in a home (0.3 air changes per hour).[20] Thus, although products approved for commercial use in Canada are generally low-risk, additional risk assessment is needed to evaluate them for home use.

A number of measures could be taken to protect home growers from pesticide exposures. These include:

- ***Growing outside.*** As with indoor air quality issues, moving the grow outdoors or to a secure, non-attached structure on the property will reduce the risk of children, pets or adults coming into contact with pesticide products in containers or on plants. Because environmental conditions affect the rate of chemical degradation (and degradation and/or dissipation may be slower indoors),[44] growing outdoors may also reduce the risk of exposure to residues on the harvested product.
- ***Identification and promotion of low-risk products.*** In the commercial cannabis sector, regulators in Canada and the US have taken aggressive action to eliminate the use of high-risk products, including guidance, inspections, testing, recalls, and fines.[49-52] Similar (but appropriate) efforts must be made for home growers. At the minimum, products approved for commercial producers must be re-evaluated for home use. Without specific changes, such as product labelling that **clearly indicates home use on cannabis**, the public may continue to utilize potentially dangerous products intended for use on other crops.
- ***Develop cannabis-specific pesticide guidance.*** Although the current PMRA-approved products are generally considered low-risk, novice growers may require guidance provided on product labels, particularly with respect to general provisions for indoor use. Although general guidance on indoor use already exists,[39] packaging and targeting this information to cannabis growers may be more effective in communicating key messages, such as the need for proper clean up and storage, as well as the specific risks identified above (e.g., the dangers of off-label use, concentrating residues through processing, etc.).

ELECTRICAL AND FIRE HAZARDS

Despite media attention on the risk of fires related to licit and illicit home growing,[53] data regarding the relative risk of cannabis-related residential fires relative to all other types of fires are lacking.[e] Nevertheless, there are several potential electrical and fire hazards associated with home cultivation, which may be related to inappropriate or improperly installed equipment, the presence of combustible materials and, specifically, illegal cannabis processing.

Cannabis grow equipment has been identified as an electrical and fire risk.[55] High-wattage grow lamps (500-1000 W) produce enough heat to cause serious burns, and draw large amounts of power that, in addition to other grow equipment, increase the risk of shocks and overloads, leading to fires. Some homeowners may exacerbate these risks by installing larger circuit breakers to avoid power interruptions, or by making non-code alterations to the home's wiring.[3] Other fire hazards include the presence of fertilizers, compressed gas (for CO_2 generation, see above), and dried plant material. In the event of a fire, these items may increase the risk of explosion and may decrease time to escape. Because of these and other physical and structural hazards, home grows are considered more risky to first responders than typical residential fires,[56] and presumably also to occupants in need of rescue.

Illegal cannabis processing poses additional risks of fire, burns, and explosions. Under the proposed Cannabis Act (2017),[1] individuals will be also permitted to process cannabis at home, with some limitations. Although cannabis concentrates can be produced through various means,[f] extraction using butane or other organic solvents is of particular concern. The process involves "blasting" a pressurized organic solvent (e.g., compressed butane) through an open-ended tube or column packed with cannabis, collecting the liquid product that flows from the bottom, and then purging the solvent using a heat source until only the thick, golden-coloured hash oil remains. The product may then be treated with additional solvents (e.g., acetone, toluene) to remove plant waxes.[57] Purging or evaporating out the flammable solvent(s) creates not only a respiratory hazard (and has resulted in death due to asphyxiation[58]), but may also result in fires or explosions

e The recent launch of Canada's National Fire Incident Database (http://www.cafc.ca/?page=NFID)[54] presents a unique opportunity to evaluate the relative risk of cannabis-related fires.

f For example, oil-based infusions, tinctures, resins produced using heat and pressure, and ice water extraction, among others.

if an ignition source is present.[g] Because butane is denser than air and accumulates in enclosed spaces, relatively little vapour is required to create a powerful explosion.[57] Finally, if the solvent is not fully purged from the finished product, users may be exposed to residual solvent through smoking the concentrate.[43]

Despite these dangers, hash oil remains appealing not only because of its high potency (60-90% tetrahydrocannabinol (THC) in some cases), but also because it can be produced cheaply from cannabis trimmings that would otherwise be discarded, allowing home growers to avoid "waste" and maximize their return on investment. As the raw material has become more available due to medical or commercial legalization, serious burn injuries due to hash oil explosions have also increased in both Colorado[59] (29 cases over 2008-2014) and California[60] (101 cases over 2007-2014).

Cannabis oil can be produced cheaply from plant waste trimmings, which may increase the appeal of making oil at home.

Hash oil explosions may also be increasing in frequency in Canada. From 2012 to May 2017, 30 hash oil-related incidents were investigated in Ontario alone.[57] In BC, information from the Office of the Fire Commissioner indicates that approximately 36 hash oil-related incidents, involving 20 injuries and more than $2 million dollars in damage, occurred from 1996 to present.[h] Overall, 17 (47%) of these incidents and 9 (45%) of the injuries occurred in the last five years alone. These data may suggest that interest in hash oil production is increasing over time.

Policy considerations for equipment-related risks vs. hash oil processing

It is unclear what effect legalization will have on residential electrical and fire risks in Canada, or the home manufacture of concentrates. Although some growers may still resort to hazardous practices, legalization may encourage safety-conscious growers to contract professional installers or electricians rather than attempt modifications on their own. There are several existing or suggested approaches to mitigating equipment-related electrical and fire risks:

- ***Regulating the sale of equipment.*** Use municipal building, electrical, and fire codes and/or federal legislation to regulate the sale and installation of high-wattage hydroponic systems.[55]
- ***Encourage use of lower-risk equipment.*** Cannabis equipment retailers are now selling LED lighting systems that not only reduce energy usage and heat output, but are also claimed to provide other production-related benefits.[61] As the quality and price point of these systems continues to improve, the high-wattage, heat-emitting high-pressure sodium and metal halide lamps may become less used or obsolete.[60]

Legalizing home grows without provision for how people may try to process the material may increase the risks of explosions. Interventions aimed at reducing in-home production of hash oil must consider several factors: 1) the availability of the raw material; 2) the severity of the legal consequences; and 3) access to legally produced, regulated, commercial concentrates. A number of interventions have been used to jointly address these issues:

- ***Limit or restrict materials necessary for hash oil production.*** Because the ability to produce hash oil is partly dependent on access to sufficient raw material, restricting the number of plants (to the extent that it is enforceable) may reduce the incentive to produce hash oil. Another option may be to reduce access to solvents, as in Sacramento County, CA, which has imposed personal purchase limits on butane products.[62]
- ***Increasing penalties.*** Both California and Colorado have attempted to control hash oil production through

g Ignition sources may include smoking, using a gas stove, sparking electric motors (e.g., in fans), or "testing" whether the purge is complete by touching the hash oil with a burning match.

h The OFC's FIRE System was queried on January 4th, 2018, using the keywords "hash oil." Due to variation in how fires are investigated and documented, this value is likely an underestimation of the number of such incidents in BC.

legislation. In 2016, Colorado made home butane hash oil extraction a level 2 drug felony, punishable by up to 8 years in prison or a $750,000 fine (Colorado Revised Statutes §18-18-406.6 [2016]).[63] In 2016, California made chemical extraction of hash oil punishable by up to 7 years in prison or a $50,000 fine (California Health & Safety Code §11379.6[a]).[64] It is currently unclear whether these actions have substantially decreased hash oil explosions since implementation. In Canada, the proposed *Cannabis Act (2017)*[1] prohibits the alteration of the chemical or physical properties of cannabis by the use of an organic solvent, and will be punishable by ticketing for small amounts or up to 14 years in jail for large amounts (Section 12(9)).

- ***Legalizing commercial concentrates.*** Providing access to commercial concentrates produced in regulated facilities may help to eliminate incentives for at-home production. For example, hash oil explosions have not been as widely reported in Washington.[65] This may be the cumulative result of limiting personal cultivation to zero plants (i.e., prohibition, except for medical users), banning chemical extraction, as well as simultaneously providing legal access to commercial concentrates.

  Legalizing concentrates may thus promote public safety from this perspective. However, there are still concerns about the short- and long-term health effects of using high-potency concentrates,[43] and therefore precaution in legalizing these products remains justified.

- ***Legalizing out-of-home processing for home growers.*** Another means to reduce home hash oil production may be to allow home growers to process their cannabis at licensed extraction/processing facilities. Currently, Health Canada is proposing two classes of commercial processing licenses (standard and micro processing),[66] but it is unclear whether these licenses could be extended to processing material from private individuals, similar to the way in which laboratories have recently been permitted to analyze cannabis from unlicensed producers.

Promote less hazardous methods. Finally, explosion risk and exposure to residual solvent can be reduced by promoting non-organic solvent-based extraction processes either at home (ice water extraction) or in commercial operations (e.g., supercritical CO_2 extraction).[i]

RADIATION HAZARDS

Grow lamps may also be used to intentionally produce high-intensity *ultraviolet (UV) light*, with the aim of either increasing the THC content of the resin produced by the cannabis flower (UV-A/B),[67] and/or controlling fungal spores in the air or on surfaces (UV-C).[68] Although sophisticated UV systems have become common in larger-scale commercial operations (which has led to calls for UV protection for cannabis workers[33,69]), even small-scale growers can access inexpensive UV equipment, which may sometimes involve tampering with UV bulbs (removing filters) to increase UV-C output. These practices can therefore increase the risk of UV-related skin and eye damage, depending on the amount of time they are used and whether any shielding (e.g., grow tents) or personal protective equipment (e.g., glasses or clothing) are used.

Policy considerations for radiation hazards

UV-emitting lamps are widely and commercially available for a variety of applications, including drinking water treatment, air purification, aquaria, etc. These products also vary widely in quality, and may or may not be certified for a particular use. At present, it is the responsibility of the consumer to read and obey manufacturers' recommendations on safe use of UV-emitting products, if any. To our knowledge, the potential risks of UV-emitting devices have not been addressed in other jurisdictions outside of occupational settings.[32,33]

Cannabis plant under LED lighting in a growbox.

i It should be noted that the capital cost of supercritical CO_2 extraction is so high that it is only feasible for larger commercial enterprises.

INNOVATIONS IN CANNABIS CULTIVATION

Some members of the cannabis industry have recognized the difficulties faced by consumers who wish to cultivate their own cannabis in a safe and efficient manner. Currently, a number of "grow-your-own" products are on or entering the Canadian marketplace. These include basic kits containing seeds and instructions for fully enclosed, energy-efficient, hydroponic grow systems or cabinets that automatically regulate inputs (nutrients and water) and growing conditions (lighting, pH, temperature, and humidity), and also feature security measures (lockable doors) and odour control.

Although such enclosed, automated systems are more costly (typically costing $1500-$2500), these systems mitigate many of the environmental health concerns identified above. A key concern with these systems, however, is that some permit the growth of more than the maximum permitted number of plants. One option may be to limit the capacity of such grow systems, although these systems may also be purchased by medicinal users for whom personal cultivation limits may be much higher.

PUBLIC RISK MESSAGING

Because legalization in Canada is still evolving, and interventions are limited, proactive and focused risk messaging is critical to address the environmental health risks of home growing. Furthermore, as discussed throughout the policy consideration sections above, enforcement will be challenging even after regulations and guidelines have been fully developed and implemented. This will make education campaigns and public discourse on cannabis cultivation key to promoting health and safety at home. Below, we have developed a table with recommended public risk messages relating to each of the five environmental health risks outlined in the previous section.

Table 1. Recommendations for public health risk messaging.

Environmental Health Risks	RECOMMENDATIONS FOR PUBLIC RISK MESSAGING
ACCIDENTAL POISONING	• Treat all cannabis products as hazardous to children and pets, even those not considered particularly appealing (e.g., unfinished joints). • Create a dedicated grow space with controlled access (i.e., strong locks and other safeguards such as an alarm).[70] • Label cannabis products and keep them in a locked cupboard or container. • Keep information for the local poison control centres on hand for immediate, anonymous assistance with suspected cannabis intoxication.
INDOOR AIR QUALITY	• Scale production according to the home's ventilation capacity, occupants' sensitivity to indoor mould (i.e., presence of asthmatics), and ability to control odour. • Control humidity by assessing and reducing indoor moisture sources, restricting cultivation to a humidity-controlled (ventilated) room or apparatus, and using a dehumidifier as required. Monitor relative humidity using an inexpensive hygrometer.j • Be vigilant for signs of dampness or mould16 and consult professionals as needed. • Dispose of mould-infested plants safely and quickly. • Consider non-ignition methods of CO_2 enrichment. • Equip all homes with a CO detector, a proven life-saving intervention, particularly homes with a fuel-burning appliance (regardless of whether cannabis is cultivated).

j Suggested for inclusion in the cannabis safety kit.

Environmental Health Risks	RECOMMENDATIONS FOR PUBLIC RISK MESSAGING
PESTICIDES	• Create good production practices as the first line of defence against pests. • Limit pesticide use and avoid non-PMRA-approved pesticides. • Follow Health Canada's general guidance on safe use of pesticides indoors.[39] • Include general advice on pest control and promote least-risky-means first in cannabis safety kits.
ELECTRICAL AND FIRE HAZARDS	• Legal home grows remain subject to building, electrical, and fire codes. • Growers may wish to consider high-efficiency, low-power LED lights intended for cannabis cultivation. • Always follow safety and installation instructions or hire certified installers for new equipment. • Be aware of the dangers (and legal consequences) of using organic solvents in cannabis processing.
RADIATION HAZARDS	• Limit UV exposure by turning off UV-emitting lights while in the grow space, or keep skin covered and eyes protected.

CONCLUSIONS

Although there is some evidence to suggest that personal cannabis cultivation will introduce or exacerbate environmental health risks in the home, a number of key uncertainties remain. The magnitude and duration of these potential risks depend on the *extent* of cannabis cultivation (number of people that opt to grow **in** the home), the *scale* of grows (abiding by plant limits vs. overgrowth), and the *persistence* of home growers ("sticking with it" vs. abandoning grows for more convenient retail cannabis). These factors in turn depend on policy and regulatory decisions not yet clarified at the provincial or municipal level, such as the ability of provinces to ban personal cultivation entirely, to permit outdoor growth, and to influence consumer behaviour through manipulation of the retail price. At the local level, municipalities must also make strategic decisions around their capacity or willingness to enforce plant limits or otherwise regulate home grows.[71]

Another challenge in addressing the environmental health risks of personal cultivation is the overall *feasibility of regulatory and enforcement tools* to control home cultivation or processing, and the lack of alternatives. In BC, municipalities have previously approached the public health risks of residential cultivation through nuisance bylaws mandating public safety inspections of homes used to produce or process controlled substances. Both licit (medical) and illicit grows were inspected and (where deemed necessary) required to undergo remediation before further occupancy. Although this administrative approach reduced the re-occupancy of potentially hazardous homes (and reduced the number of home grows overall),[72] it is unclear whether such an approach will remain feasible as home growing becomes more common and/or as the public interest changes. In the US, the state of Washington is currently considering several options for regulating home grows, although it is recognized that these options increase the burden on local governments without resolving issues of enforcement and non-compliance.[73]

Due to the acknowledged issues in taking a regulatory or enforcement approach, public education and additional supports to *incentivize safe practices* are critical to avoiding or reducing the environmental health risks identified here. Safety campaigns should consider cannabis in all its forms, including raw plant material, products (concentrates, edibles, joints), and waste. Safe practices should include secure storage, least-risky means of processing, appropriate packaging and labelling, and appropriate disposal.

One means to encourage these practices is through the promotion or marketing of *"cannabis safety kits"* targeted toward home growers, particularly homes with children. Kits could exist as checklists created by public health agencies, physical kits sold or subsidized by public health agencies, or commercial products developed in partnership with the cannabis industry. Such kits might contain stickers with a standardized cannabis symbol,[66] child-resistant bags or lock-boxes, locks to install on cupboards, and most importantly, first aid and contact information for the local poison control center. Possible additions to this type of cannabis safety kit are described in ***Appendix B***.

Timely and targeted public education on the environmental health risks of personal cultivation is crucial to shaping safe cannabis culture and eliminating problems before they occur. However, interest in cannabis legalization may also serve to increase engagement around certain long-standing and impactful environmental public health issues that are not unique to cannabis. Examples of these include humidity and indoor mould; the dangers of CO; safe use of pesticides, particularly indoors; and indoor air quality more generally. For example, the inclusion of CO_2 generators and CO poisoning in cannabis risk messaging may help to increase general awareness and safety, particularly if homeowners are prompted to install CO detectors. Thus, leveraging the current public interest in cannabis cultivation could be one means to reduce the approximately 300 deaths that are wholly or partly attributable to CO poisoning every year in Canada.[74]

Given these key policy considerations, public education will remain the most important tool to reduce environmental health risks to home growers, and this document has key messages for inclusion in risk messaging campaigns **(Table 1)**. However, the challenge will be to insert these messages among those already being actively promoted by public health organizations, including the risks of underage use, addiction, mental health, and prenatal use, and to do so in a way that is balanced and provides a clear understanding of relative risk.

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Appendix A: Literature Search Strategy and Review

English-language articles (with no date restriction) were identified though EBSCOhost (to access MEDLINE, CINAHL, PsycINFO, Biomedical Reference Collection, and Academic Search Complete), Ovid (to access Elsevier Science Direct, Embase, Evidence Based Medicine, SAGE journals online, and Cochrane Database of Systematic Reviews), Web of Science, Google Scholar (to access books, book chapters, older articles, and articles from journals not indexed through major database platforms), and Google web, using the following search terms (variants and Boolean operator combinations thereof):

Topic Area	SEARCH TERMS
Operation of cannabis production facilities, both licit and illicit, with an emphasis on indoor air quality (humidity and mould), inspection and regulation	(marijuana OR marihuana OR cannabis OR hemp OR "medicinal plant")
	AND
	(residen* OR home OR hous* OR commercial OR indoor OR facilit* OR building OR "indoor space" OR garage OR condo OR apartment OR warehouse)
	AND
	(grow OR cultivat* OR produc* OR inspect* OR regulation OR protocol OR set-up OR setup OR standard OR code OR building OR design OR procedures OR guidance OR guideline)
	Additional statements
	(moisture OR mold OR mould OR mildew OR humidity)
	("indoor air" OR "air quality") AND (inspect* OR test OR protocol) AND (marijuana OR marihuana OR cannabis OR hemp OR "medicinal plant" OR clandestine)
	site:.gov OR site:.gc.ca
Pesticides	(marijuana OR marihuana OR cannabis OR hemp OR "medicinal plant")
	AND
	(antimicrobial OR disinfectant OR fungicide OR herbicide OR insecticide OR miticide OR rodenticide OR rooting hormone OR surfactant)
Odour, annoyance, and second-hand smoke, with emphasis on potential health impacts and multi-residential buildings	(cannabis OR cannabinoid OR marijuana OR marihuana OR delta9-tetrahydrocannabinol OR 11-nor-9-carboxytetrahydrocannabinol OR cannabinoid OR delta)
	AND
	("indoor air" OR "air quality" OR "second-hand" OR "third-hand" OR passive OR incident OR secondhand OR thirdhand OR exposure)
	Additional strings
	(odour OR odor OR annoyance OR pungent OR smell)
	AND
	(perception OR psychosocial OR social OR artery OR endothelium OR "flow-mediated dilation" OR vasodilation OR health OR illness OR cognition)
	AND
	smoke
Energy use and theft	(cannabis OR marijuana OR marihuana)
	AND
	(production OR cultivation OR cultivate OR grow OR dry OR cost)
	AND
	(energy OR efficiency OR power OR electricity OR electrical OR cost OR green OR theft)
Fire safety	(marijuana OR cannabis OR hemp)
	AND
	(production OR cultivation OR cultivate OR grow OR dry)
	AND
	("fire safety" OR "first responder" OR "fire code")

The search results were subjected to title and abstract review to identify relevant documents, which were then subjected to full-text review. In addition to database searches, documents relevant to the topic were identified through citation chaining and solicited from public health and industry experts. In addition, the environmental health or public health webpages of state and municipal governments within previously legalized jurisdictions were reviewed for additional grey literature.

Appendix B: Cannabis Safety Kits

In addition to public education and risk awareness campaigns, promulgation of a "cannabis safety kit" may be used to directly and physically place educational and safety tools in the hands of those who wish to grow at home. As indicated in this document, a cannabis safety kit would contain resources relevant to protecting the health and safety of all family members. Such a kit might contain:

Area of Concern	TOOLS AND RESOURCES
ACCESS AND POISONING	• Child-resistant plastic bags; • A food-safe lock box; • Stickers bearing the universal cannabis symbol for labelling packaged products; • Locks for cupboards; • Contact information for the local poison control centre.
INDOOR AIR QUALITY	• Digital thermometer/hygrometer for monitoring humidity control; • Guidance on odour control techniques that do not compromise indoor air quality.
PEST CONTROL AND PESTICIDES	• Specific guidance on indoor pesticide use for cannabis, including a list of approved, commercially available products.
ELECTRICAL AND FIRE HAZARDS	• Basic information on typical home power supply and what types of equipment may require a certified installer.
RADIATION HAZARDS	• UV-resistant goggles.
CARBON MONOXIDE	• Information on carbon monoxide detectors, a proven life-saving device regardless of whether cannabis is cultivated.
SAFE PROCESSING	• Information on the risks of common processing activities.