

The background of the entire page is a repeating pattern of cannabis leaves in various shades of green, set against a dark grey background. The leaves are scattered across the page, with some appearing more prominent than others.

# Commercial Cannabis Production in British Columbia:

## Best Available Control Technologies and Regulatory Oversight of Environmental Considerations

May 2019



## Acknowledgements

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## Acronyms

ACMPR	Access to Cannabis for Medical Purposes Regulation
AEMCoP	Agricultural Environmental Management Code of Practice
AGRI	Ministry of Agriculture (BC)
ALC	Agricultural Land Commission (BC)
ALR	Agricultural Land Reserve (BC)
AQMD	Air Quality Management Districts
BACT	Best Available Control Technologies
BC	British Columbia
BEFs	Basal Emission Factors
BERs	Basal Emission Rates
BMP	Best Management Practices
CBD	Cannabidiol and/or cannabinoids
CCFs	Cannabis Cultivation Facilities
CFM	Cubic Feet per Minute
DEQ	Oregon Department of Environmental Quality
EFP	Environmental Farm Plan
EMA	Environmental Management Act
ENV	Ministry of Environment and Climate Change Strategy (BC)
FFPPA	Farming and Food Production Protection Act (Ontario)
FPPA	Farm Practices Protection Act (BC)
HC	Health Canada
HEPA	High Efficiency Particulate Air
HVAC	Heating, Ventilation, and Air Conditioning
IPM	Integrated Pest Management
MECP	Ministry of Environment, Conservation, and Parks (Ontario)
MMPR	Marijuana for Medical Purposes Regulations
MSDS	Material Safety Data Sheets
MV	Metro Vancouver
OBSCR	Open Burning Smoke Control Regulation
OCP	Odour Control Plan
ODA	Oregon Department of Agriculture
OLCC	Oregon Liquor Control Commission
OMAFRA	Ontario Ministry of Agriculture, Food, and Rural Affairs
OMRR	Organic Matter Recycling Regulation
PCP Act	Pest Control Products Act
PMRA	Pest Management Regulatory Agency
THC	Tetrahydrocannabinol
USA	United States of America
VOC	Volatile Organic Compounds

## Glossary

### Cannabis

Cannabis is defined in Canada as a cannabis plant and anything referred to in Schedule 1 of the Federal *Cannabis Act*<sup>1</sup>:

- Any part of a cannabis plant, including the phytocannabinoids produced by, or found in, such a plant, regardless of whether that part has been processed or not;
- Any substance or mixture of substances that contains or has on it any part of such a plant;
- A substance identical to any phytocannabinoid produced by, or found in, such a plant, regardless of how the substance was obtained.

Cannabis does not include anything referred to in Schedule 2 of the *Cannabis Act*, for example:

- A non-viable seed of a cannabis plant;
- A mature stalk, without any leaf, flower, seed or branch, of such a plant;
- Fibre derived from a stalk; or
- The root or any part of the root of such a plant.

### Hazardous Waste

Hazardous wastes are wastes that could harm human health or the environment if not properly handled or disposed of<sup>2</sup>. Special techniques are needed to eliminate or reduce the hazards. Hazardous wastes must not be sent to ordinary landfills or discharged to sewer; more specialized facilities are required to deal safely with these wastes. Wastes may be "hazardous" for many different reasons:

- They are corrosive, ignitable, infectious, reactive and toxic (the "acute" hazard characteristics)
- They have the potential to harm human health or the environment in a subtle manner over long periods of time (the "chronic" hazards)
- They may range from paints, oils and solvents to acids, heavy metal-containing sludges and pesticides

### Hemp

Hemp and marijuana are both members of the Cannabis Sativa species, therefore they share certain similarities but have distinct differences. Marijuana is bred for psychoactive and medical substances called Cannabinoids, the most dominant of which are Tetrahydrocannabinol (THC) and Cannabidiol (CBD). Hemp is bred for industrial uses, such as food and fabric for clothing.

### Oil

Certain components of cannabis, such as THC, CBD and other cannabinoids, can be distilled into a concentrate through an extraction process. The resulting cannabis oil can then be used as an ingredient in edibles and other products.

### Tetrahydrocannabinol (THC)

While THC in hemp is low (0.3% by dry weight concentration) it is high in marijuana (upwards of 10-30% by dry weight concentration). Because of this, hemp is grown primarily for industrial purposes (e.g. biofuel, oils, fibres, building materials) while marijuana is grown for recreational and medicinal purposes.

### Trichomes

Trichomes are a blanket of crystal resin coating the cannabis plant, and they contain both terpenes and cannabinoids (CBD).

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<sup>1</sup> Cannabis Act (S.C. 2018, c. 16). <https://laws-lois.justice.gc.ca/eng/acts/C-24.5/> Accessed November 10, 2018.

<sup>2</sup> Environmental Management, BC. 2018. [Hazardous waste regulations](#).

## Executive Summary

### Scope

The commercial production and manufacturing of cannabis for the recreational market is an emerging sector within British Columbia (BC). This report explores best practices and available technologies that can help to minimize the environmental impacts associated with the cultivation and processing of commercial cannabis. It is important to note that this industry is extremely dynamic and this work was completed as a snapshot in time given the current regulatory setting. As a result, it is anticipated that the availability and quality of data, including the applicability and performance of best practices, will improve over time.

The focus of this report is on commercial cannabis production and manufacturing, as licensed by Health Canada under the *Cannabis Act* and Cannabis Regulations through the issuance of federal cultivation and processing licenses. Residential indoor production is not included within the scope of this report. The research was conducted and this report was prepared for the Province of BC by Upland Agricultural Consulting.

### Cannabis Cultivation and Extraction

Literature suggests that nutrient and water requirements for cannabis crop production are within a range commonly noted for other agricultural crops. The extraction of cannabis for the manufacturing of oils, edibles, and other secondary products, can be conducted through either a solvent-based method or a solvent-less (super-critical CO<sub>2</sub>) method. Any solvent not recovered would need to be disposed of according to the *Environmental Management Act* and the Hazardous Waste Regulation.

#### Air Emissions

The cannabis plant naturally produces Volatile Organic Compounds (VOC); some of which are comprised of a type of compound called terpenes, which are linked to cannabis' distinctive odour. These levels fluctuate and are dependent upon the type of cannabis, the stage of life of the plant, and ambient parameters such as temperature and humidity. Terpenes, which are also found in other plants such as pine, lavender, pepper, hops, and citrus, are responsible for the flavour and aroma of the plant. It is unlikely that cultivation practices will ever lead to a reduction of these compounds in cannabis.

#### Liquid Waste Discharges

Indoor and greenhouse cannabis production facilities typically reuse "over drain" water, which is rich in nutrients, such that it can be included as a fertilizer input for irrigation water. However, some wastewater will require disposal, including sanitation-based liquid wastes (e.g. bleach, detergents) associated with agricultural production practices, which are required for product safety.

#### Solid Waste Discharges

Solid waste from cannabis production can be categorized as either green (plant material) or non-green (rockwool, plastics). Some jurisdictions classify cannabis plant waste as hazardous if THC concentrations are greater than 10% dry weight. These high concentrations are typically found in the valuable flower and are therefore not included in most plant wastes post-harvest. If an entire crop were to be disposed of due to disease or other contamination, then the THC levels may be high in the green waste material.

### Best Available Control Technologies (BACTs) for Cannabis

#### BACTs for Air Emissions

The following four tools were examined for cannabis air emission management:

1. **Carbon filters**, are commonly used for emission control in cannabis facilities. They are considered environmentally effective and can be used in cultivation facilities of varying sizes.
2. **Biofilters** are used for managing other agricultural odours (e.g. hog farms and mushroom barns). The process involves passing air from the facility through a filter of wood chips or bark mulch that contain a rich microbial flora.
3. **Ozone generators** are used safely in many industries. The effectiveness at eliminating VOC depends somewhat on the chemical structure of the compounds.
4. **Odour neutralizers** bind VOC thus neutralizing and removing the odour. These are not the same as masking agents, which simply act as a strong perfume to cover up the existing odour. The effectiveness at reducing VOC is based on product set-up, use, and contact time with the VOC.

#### BACTs for Liquid Wastes

The following four tools were examined for cannabis liquid waste management:

1. **Water recapture and reuse** is used extensively in the vegetable greenhouse industry and this technology is gaining traction in the cannabis industry as well.
2. **Land application** for nutrient solution involves collecting and storing liquid solution in order to spread it onto crop fields.
3. **Small scale water treatment plants**, which are extremely effective at mitigating wastewater impacts to the environment but also require high levels of investment to establish and operate.
4. **Aerobic digestion**, which requires mechanical and biological breakdown of waste, the addition of enzymes and microbes, and denaturing of any residues.

#### BACTs for Solid Waste

The following three tools were examined for cannabis solid waste disposal:

1. **Composting** either on-site or through transportation to a composting facility off site.
2. **Incineration**, which creates gases and hot air, which can be used for heating the cultivation facility.
3. **Fermentation**, which produces gas and a digestate. The liquid fraction may be used as a fertilizer; however, the solid fraction will still require disposal.

## Jurisdictional Differences in Regulation, Compliance and Enforcement

The jurisdictional review explored how environmental regulations are applied to cannabis cultivation and extraction in Alberta, Ontario, Washington, Oregon, Colorado, and California.

Ontario: For the most part, cannabis is treated like any other agricultural crop in Ontario. Normal farm uses are promoted and protected through the *Farming and Food Production Protection Act*. The province of Ontario is not making recommendations at this time about specific tools or technologies for air emissions. Standard operating procedures for cannabis compliance and enforcement are being developed in a partnership between Ontario's Ministry of Agriculture, Food, and Rural Affairs and the Ministry of Environment, Conservation, and Parks, however it will only address odour, not other waste discharge concerns.

Alberta: There are no policies or regulations in Alberta that would set cannabis apart from other agricultural crops. The certification requirements for operators using pesticides in the cannabis industry will be the same as for those operating in the greenhouse agriculture sector. An Alberta Cannabis Secretariat has been established, which is an interdepartmental agency with representatives from health, environment, transportation, gaming and licensing, and the liquor control board.

Washington State: The Washington Department of Ecology refers air quality permitting of cannabis to regional clean air agencies. The agencies can issue requirements for air discharge control measures and respond to odour

complaints and issue violations. The State requires a permit for the discharge of wastewater to surface water or groundwater. Cannabis plant waste must be “rendered unrecognizable and unusable” through grinding/chipping/shredding of cannabis waste and incorporating it with other wastes. Washington has collaborated with agencies to develop compliance promotion materials, including a regulatory guide.

Oregon: Local jurisdictions may require air filtration, however land zoned for farm use is protected from nuisance lawsuits over odours and other emissions. The Oregon Department of Environmental Quality coordinates with the Oregon Department of Agriculture to require agricultural water quality management area plans. Cannabis-related solid waste must be composted, processed, or disposed of at solid waste facilities permitted by the Department of Environmental Quality. Compliance promotion materials include a business readiness guide, a good agricultural practices guide for cannabis, and a regulatory factsheet.

Colorado: Most cannabis production occurs in indoor facilities within the City and County of Denver. Best regulatory practices include mandating carbon filters and setting efficiency rates. Any liquid wastes must be disposed of in compliance with the applicable state Water Quality Control Division statutes and regulations. Solid waste must be made unusable and unrecognizable through grinding and/or mixing with other waste materials. Compliance promotion materials include compliance bulletins, a best practices guide for cannabis, an enforcement factsheet, and a website portal for information on the laws and health effects of cannabis.

California: Cannabis production in California includes a significant outdoor cultivation sector. The California Health and Safety Code specifically exempts nuisance related to odours emanating from the growing of agricultural crops. Cultivation licensees must provide evidence of enrollment from the State Water Resources Control Board or from the appropriate Regional Water Quality Control Board. There must also be evidence provided of exemption from, or compliance with, the *California Environmental Quality Act*. Cannabis facilities must have a waste management plan that identifies composting, land application, commercial waste collection, or self-hauling as options. Water and solid waste complaints are typically dealt with by state authorities, while odour complaints are investigated by local authorities. Several compliance promotion materials exist, including best management practices, guidelines, factsheets, and information bulletins on the waste discharge regulatory program.

## Conclusion

Commercial cannabis production for the recreational market is an emerging and dynamic industry within BC. Existing practices and technologies for minimizing environmental impacts of cannabis cultivation and extraction will continue to evolve over time. It would be worthwhile for this BACT review to be revised and updated on a regular basis to ensure that the information contained within is as current as possible.

## 1.0 Introduction

The commercial production and manufacturing of cannabis and related products for the recreational market is an emerging sector within British Columbia (BC), and Canada. Once restricted to small-scale indoor production for a black-market economy, this crop is now being produced in a variety of ways, including indoors, under glass, and in fields. With an expected increase in production and manufacturing of cannabis, questions regarding best practices and available technologies to minimize environmental impacts as they arise.

The objectives of this project are to:

1. Improve the understanding of the potential environmental impacts related to solid waste, liquid waste discharges (effluent), air emissions (including odorous) and pest management from cannabis production and extraction in BC.
2. Develop an analysis of emerging and recognized best available control technologies (and practices) for managing the environmental impacts from the cannabis industry.
3. Assess how other jurisdictions regulate the environmental impacts associated with legalization of non-medical cannabis, and the resourcing implications.

The focus of this report is on commercial cannabis production and manufacturing, as licensed by Health Canada (HC) under the *Cannabis Act* and *Cannabis Regulations* through the issuance of federal cultivation and processing licences.

### 1.1 Project Oversight

The project was led by Upland Agricultural Consulting. Project oversight was provided through a Project Steering Committee under the leadership of the BC Ministry of Environment and Climate Change Strategy, with members from the BC Ministry of Agriculture and Metro Vancouver.

### 1.2 Project Scope and Limitations

The scope of research for this project was limited to recreational and medicinal cannabis. This scope includes the potential environmental impacts of cannabis production (including indoor cultivation, greenhouse production, and field-based crops) and cannabis processing and manufacturing (e.g. extraction). The manufacturing of edible cannabis products was outside the scope of this analysis, as at the time of writing it was still prohibited in Canada. The geographic context for the best available technologies research was province-wide, with some focus provided to urban:rural conflicts that may arise in areas such as Metro Vancouver. Project limitations include the fact that there is overall a lack of published peer reviewed data that is cannabis-specific as compared to other crops for topics such as water and nutrient inputs, liquid waste discharges, and solid waste management. While there is some data available regarding odours and terpenes associated with cannabis, this is an emerging area of research, and more information is needed regarding specific types of best practices or technologies and their impacts over time. The emerging nature of this industry also means that some areas remain under-regulated, or that regulations are in the process of catching up to activities surrounding cannabis. One example is the lack of environmental regulations strictly related to extraction and processing facilities in Canada. The nature of the cannabis industry is that so much of the production and processing has occurred in a manner that was

previously covert, therefore as a result of legalization it is anticipated that the availability and quality of research methods and data, including the applicability and performance of best practices, will improve over time.

## 2.0 Methodology

The research approach for this report was three-pronged: it included a literature review of current and innovative practices, a jurisdictional scan of environmental best practices, and interviews with subject matter experts. These approaches are described in more detail below.

### 2.1 Literature review

The consulting team reviewed existing materials pertaining to best available control technologies (BACTs) and best management practices (BMPs) for cannabis production and manufacturing from across several jurisdictions, including BC. Documents included peer-reviewed articles, industry reports, government policies and regulations, and compliance and enforcement agency reports.

It is important to note that our research indicated that there is a lack of detailed, peer-reviewed information on many aspects of the environmental impacts of commercial-scale cannabis cultivation and production. Past studies have considered conditions and practices prevalent in illegal growing operations, which have not developed operations to minimize environmental damage<sup>3</sup>. There is a need for increased scientific research on environmental impacts of legal cannabis cultivation and production operations. This is an emerging research sector, and will be an interesting branch of science to watch.

In terms of specific environmental concerns, such as emissions of odours, parallels can be drawn with other existing agricultural sectors, whereby odours are generated during normal farm practices. For example, mushroom compost and poultry manure can generate odours. Whenever practical, these parallels are identified in the discussion.

### 2.2 Jurisdictional scan

The consulting team completed a jurisdictional scan to determine which BACTs exist for the production and manufacturing of cannabis within Canada, the USA (Figure 1), and other countries. The following list of six jurisdictions were the focus of the investigation because their regulatory landscapes are most aligned with that of BC.

- 1. Colorado:** has the longest history of legalization and most in-depth information available regarding enforcement of regulation and growing operations at both the state and municipal level. The City of Denver is a leader in exploring best practices for growing cannabis sustainably indoors.
- 2. Washington State:** has the second longest history with cannabis regulation and sales. The state has established regulatory guidelines addressing the environmental impacts of cannabis production, as well as compliance and enforcement.
- 3. California:** has environmental regulations addressing pest management, waste management and pollution from commercial cannabis growing operations.

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<sup>3</sup>Ashworth, K. and W. Vizuete. 2017. High time to assess the environmental impacts of cannabis cultivation. *Environmental Science and Technology*. 51: 2531-2533.

**4. Oregon:** has environmental regulations at the state level addressing air quality, wastewater, solid waste and hazardous waste from commercial cannabis operations. Oregon is also home to the Task Force for Cannabis Environmental Best Practices.

**5. Ontario:** has developed evidence briefings regarding cannabis production best practices for odour and is the headquarters for many cannabis production and manufacturing operations in Canada. It is also home to Niagara College, which is offering a Commercial Cannabis Production certificate with a focus on BMPs.

**6. Alberta:** shares a geographic border with BC, has a comprehensive framework that addresses the legalization of recreational cannabis in Canada, and a robust set of BMPs associated with its provincial Environmental Farm Program (EFP).

Other reports and resources from Alaska, Australia, and Uruguay were also included in the review.



FIGURE 1. AMERICAN STATES WHERE CANNABIS IS LEGAL AS OF NOVEMBER 15, 2018. (SOURCE: BUSINESS INSIDER<sup>4</sup>).

## 2.3 Subject Matter Expert (SME) Interviews

The consulting team conducted interviews with experts from various disciplines and across jurisdictions to identify which current BACTs could be considered feasible for BC's cannabis production and manufacturing sector. These interviews served to bridge many of the gaps that were identified in the literature. Many

<sup>4</sup> Business Insider, November 7 2018. [States where marijuana is legal](#).

individuals wished to remain anonymous, therefore personal names were withheld from the final report and the information provided was aggregated and averaged to address privacy concerns.

### 3.0 Cannabis Production and Extraction

The following section of the report provides an introduction to the plant's lifecycle (including common production timeline), nutrient and water needs, and pest and disease management. Information regarding typical manufacturing and distribution processes are also included.

In considering cannabis production, it is important to distinguish between the three types of cultivation approaches:

1. Indoor
2. Greenhouse
3. Outdoor (field)

The approach to cultivation will affect all aspects of cannabis production, including lifecycle length, pest management, water input requirements, and waste management. Indoor and greenhouse operations can be in production for 10–12 months of the year, allowing for 4-6 harvests per year (5 being typical), whereas outdoor production allows only 1-3 harvests per year. Thus, production per square foot per year is much higher with indoor or greenhouse growing over outdoor production<sup>5</sup>. These differences are further explained in applicable sections throughout this report. For reference, the three cultivation approaches are briefly described below.

#### Indoor

Indoor production occurs in buildings located in industrial, commercial, and/or agricultural areas. Residential indoor production is not included within the scope of this report. Indoor facilities typically use artificial lighting and plants are grown in soilless media or hydroponically. These facilities may vary in size. Evidence suggests that a 10,000 square foot (sqft) (929 square metre (m<sup>2</sup>) or 0.23 acre) area provides an economy of scale for indoor production<sup>6</sup>, therefore most of the indoor facilities are that size or larger.

#### Greenhouse

Greenhouse production occurs primarily on farmland, although these facilities can also be constructed in other areas such as industrial or commercial land. Greenhouse cultivation utilizes a combination of natural light and artificial light. The plants are typically grown in pots of soil or soilless media, or a combination. The facility size for greenhouse cultivation is larger than indoor production, with existing facilities in BC ranging in size from 12,000 m<sup>2</sup> (125,000 ft<sup>2</sup> or 3 acres) to over 93,000 m<sup>2</sup> (1,000,000 ft<sup>2</sup> or 23 acres) under glass<sup>7</sup>. Recent figures suggest over 440,000 m<sup>2</sup> (4.7 million ft<sup>2</sup> or 110 acres) of greenhouse production has been purchased by cannabis businesses in Metro Vancouver<sup>8</sup>. However, not all of this space is licensed and/or operational, therefore it is unclear how much of the greenhouses in BC will become converted over to cannabis cultivation.

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<sup>5</sup> Caulkins, J., [Estimating adequate licensed square footage for production of cannabis](#). BOTE Analysis Corporation.

<sup>6</sup> Campbell, S. and T. Taylor, 2018. [Guiding cannabis regulations in Canada](#). Prepared for the Canadian Cannabis Legalization and Regulation Secretariat.

<sup>7</sup> [BC Tweed adds a bit of licensed growing space](#).

<sup>8</sup> Metro Vancouver Environmental Regulation and Enforcement, personal communication, March 2019.

Not all greenhouse space is used for plant production. A 2015 study by Bauer *et al.*<sup>9</sup> determined that one cannabis plant needs just over 1 m<sup>2</sup> of greenhouse area. Ancillary space that is essential to production, but which is not itself harvested, includes space for growing plants that are not at the harvestable stage (mother plants, seedlings, etc.); dead space that is intertwined with area to be harvested (e.g., walkways); and other areas not directly involved in growing (space used for drying, storing tools, record keeping, bathrooms, etc.). Ancillary space can easily be half as large as the canopy area that is harvested<sup>10</sup>.

In BC, most vegetable and nursery greenhouse operations are located in the Fraser Valley. The average greenhouse covers an area of 5 to 10 acres with larger operations reaching sizes of greater than 50 acres<sup>11</sup>. BC Greenhouse Grower's Association suggests growing methods within a greenhouse operation mean that 10-20 times the amount of product yield (whether vegetables or other product) can be grown under glass compared to in the field<sup>12</sup>.

Humboldt County, California, noted a 19-fold increase in greenhouses from 2004–2014<sup>13</sup>, and a simultaneous decrease in nursery crop production during that timeframe. Cannabis was legalized in California for medical purposes in 1996 and it is assumed that the overall increase in greenhouses and decrease in nursery crop production is associated with the growth of the California cannabis industry during that time. Due to the BC Ministry of Agriculture policy that restricts new cultivation buildings in the Agricultural Land Reserve (ALR) to cannabis crops that are soil-based<sup>14</sup> (this applies to cannabis only, other crops can be grown in concrete-based facilities) it is unlikely that a similar increase in greenhouse development would occur in BC, unless the facilities are constructed outside of the ALR. However, conversion of existing greenhouse space from nursery, floriculture, or vegetable crops is a possibility. While it's unclear how many greenhouses in BC have been converted to cannabis production, for perspective, it's important to note that greenhouses in BC cover approximately 0.01% of farmland in total<sup>15</sup>.

### **Outdoor or Field Cultivation**

Outdoor cultivation can be an attractive method of growing cannabis because there are low overhead costs (e.g. no heating or lighting). Outdoor cannabis cultivation has been a popular method of growing in warm, dry climates. Exact estimates of cannabis land cover are difficult to find. For perspective, in California, 43% of the 3,490 cultivation licences have gone to mixed-light grow sites such as greenhouses. Over a third (40%) of licences have gone to outdoor grows, with the last 17% to indoor grows<sup>16</sup>.

Within BC, it is most likely that outdoor cultivation will take place in regions such as the Okanagan, where the threat of diseases due to high humidity will be lower. Outdoor production increases the risk of contamination from pesticides emanating from other nearby farms, which may not be permitted for use on cannabis. Security is also a challenge for cannabis operations, particularly those in proximity to urban areas, and this would need to be adequately satisfied in order to qualify for a Health Canada licence.

Outdoor production parallels can be made to the hemp industry. In 2014, only 13 of the 1,135 hemp licences in Canada were for producers in BC, with the majority of production occurring in the Prairie

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<sup>9</sup> Bauer S, Olson J, Cockrill A, van Hattem M, Miller L, Tauzer M and Leppig G 2015 Impacts of surface water diversions for marijuana cultivation on aquatic habitat in four northwestern California watersheds *PLoS One* 10 (9e): 0120016

<sup>10</sup> Caulkins, J., *Estimating adequate licensed square footage for production of cannabis*. BOTEC Analysis Corporation.

<sup>11</sup> BC Ministry of Agriculture. 2014. [Greenhouse Factsheet](#).

<sup>12</sup> BC Greenhouse, 2018. [FAQs](#).

<sup>13</sup> Humboldt County 2015 [Humboldt County Agricultural Commissioner](#).

<sup>14</sup> Agricultural Land Commission, 2018. [Information Bulletin #4: Cannabis Production in the ALR](#).

<sup>15</sup> BC Greenhouse, 2018. [FAQs](#).

<sup>16</sup> Staggs, B. E. 2018. [So far, California has 6,000 licensed cannabis businesses](#). Here's what that looks like. The Cannifornian.

provinces<sup>17</sup>. According to Health Canada figures, Saskatchewan led with more than 56,000 acres of hemp production in 2017, followed by Alberta with almost 45,000 acres and Manitoba with 30,000 acres<sup>18</sup>. Elsewhere, under 7,000 acres of industrial hemp were planted in Ontario and Quebec in 2017, while the Maritime provinces planted just over 750 acres, and just under 250 acres in B.C.

### 3.1 Overview of the Plant Lifecycle

Regardless of the type of cultivation setting, all cannabis plants undergo the same lifecycle stages. The typical cannabis production lifecycle takes about 3 to 5 months, from the cutting of clones to harvesting, curing, and packaging for sale<sup>19</sup>. The timeframe range is mainly due to differences in cultivation techniques, whereby indoor cultivation and greenhouse cultivation are typically faster than outdoor cultivation. Some strains of the cannabis plant can also mature faster than others. The life cycle is visually represented in Figure 2, below. Plant material is usually sent to an extraction facility during the bud trimming stage.

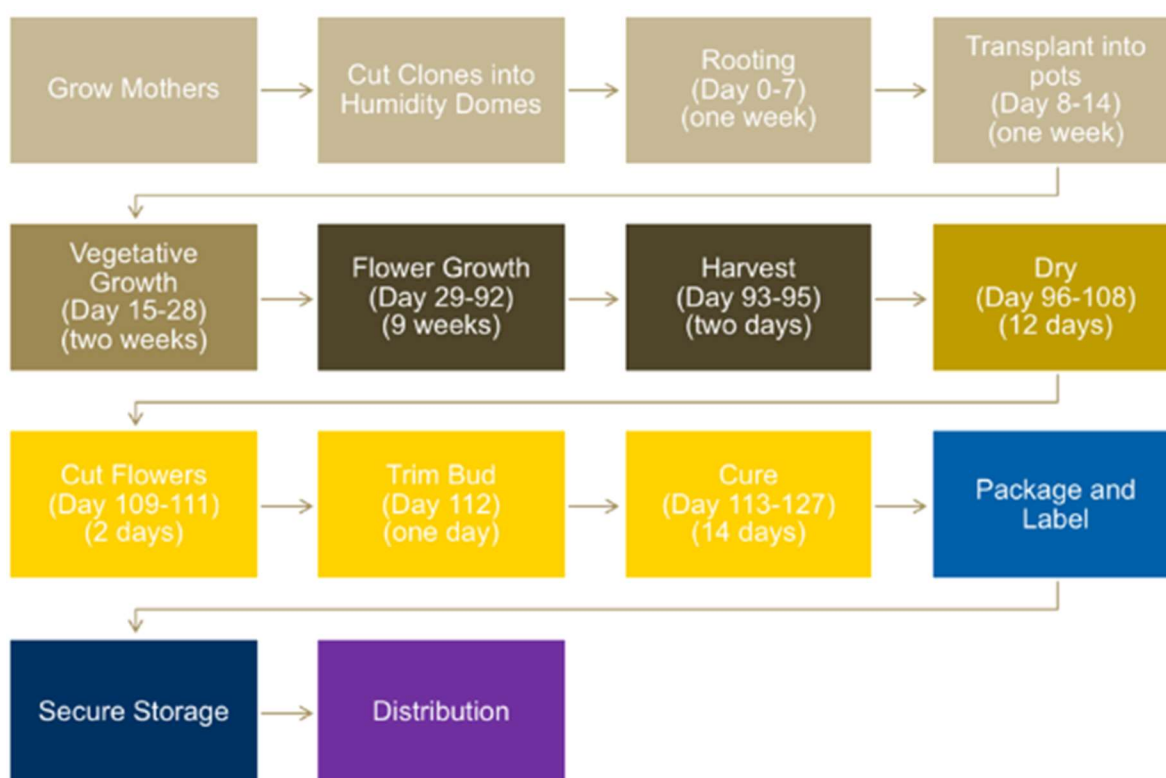


FIGURE 2. TYPICAL CANNABIS LIFE CYCLE FROM ROOTING TO DISTRIBUTION<sup>20</sup>.

Stock plants (or Mothers as they are referred to in the industry) are derived from seeds or cuttings taken from other plants under vegetative-growth (Figure 3, next page). Vegetative growth refers to the method whereby the plants are generally receiving over 18 hours of light (may be artificial/supplemental) per 24 hour cycle. Stock plants, once established, can take 8 to 12 weeks to produce enough plant material for

<sup>17</sup> Department of Agriculture and Forestry, Province of Alberta. 2015. [Seeded acreage of hemp in Alberta and Canada](#).

<sup>18</sup> Halsall, M. 2018. [Hemp area may stall in 2018](#). Country Guide Canada

<sup>19</sup> This varies depending on the type of growing facility (e.g. indoors, outdoors, under glass), climate control, and cultivation skills of the grower.

<sup>20</sup> Cannabis cultivation and the current market. Presentation to the BC Institute of Agrologists Fraser Valley Branch Fall Meeting. November 2018.

cuttings to be removed for propagation purposes. Healthy stock plants can be generally maintained in a vegetative growth state for up to 12 months.

Once cuttings (or clones as they are referred to in the industry) are removed from the stock plants they are planted into peat or rockwool pucks and allowed to root for 7 to 10 days under relative humidity above 70% (Figure 4). After roots are observed, clones are then transplanted into propagation mix in 4-inch (400 ml) pots. This typically occurs 8 days after planting. The plants are then propagated in the 4-inch pots for 14 to 28 days under vegetative growth conditions. It's important at this stage to separate male and female plants before pollination to prevent female plants from producing seeds instead of trichomes. Trichomes are a blanket of crystal resin coating the cannabis plant, and they contain both terpenes and cannabinoids.

Due to the need for vegetative growth conditions, the propagation occurs in 18 to 24 hours of sun and/or supplemental light. The optimal 24 hour temperature, average of day and night, is between 21 and 26°C. Higher or lower 24 hour temperatures will reduce flowering rates and will have a negative effect on yield and quality.



FIGURE 3. A GREENHOUSE ROOM OF STOCK PLANTS (MOTHERS).



FIGURE 4. CLONES UNDER COVER ON TRAYS.

When the clones reach 2 to 4 weeks of age, the plants are transplanted into flowering compartments and switched from vegetative growth to a flowering growth cycle. This flowering growth cycle is controlled by ensuring that the amount of light is reduced to 12 hours per day. This can be a combination of sunlight and supplemental lighting. Light deprivation techniques are employed to maintain darkness for the remaining 12 hours of the 24 hours cycle. The flowering cycle typically takes 9 full weeks, however some strains can take 10 to 11 weeks.

Once deemed ready for harvest, the entire plant is removed from the growing area. Under ideal growing conditions, the plants are typically harvested once the trichomes (resins) are observed to be clear to amber in colour. Individual plant branches are removed from the stalks, and flowers are cut from the branches and dried. The drying occurs by hanging or laying on drying racks in a separate room. This drying process typically takes 9-12 days.



FIGURE 5. HARVESTING THE FLOWER FROM THE CANNABIS PLANT.

The next stage of post-production, trimming, can be done by hand or by machine. Trimming involves removing all the leaves and other plant materials from the inflorescence (flower). The flowers are then cured over the course of about 2 weeks.

In Canada, cannabis products are delivered from cultivation facilities to retailers, through direct order at provincially-managed websites, or at provincially operated stores, or dispensaries.

## 3.2 Crop Requirements

### 3.2.1 pH and Nutrients

Cannabis can be grown in soil or soilless media or hydroponically. The optimal pH for healthy growth is slightly acidic (5.9 - 6.5), similar to tomatoes (pH 5.8). Nutrient requirements will fluctuate based on whether the cannabis plant is in a vegetative or flowering stage, particularly for nitrogen<sup>21</sup> (Table 1).

TABLE 1. TYPICAL NUTRIENT REQUIREMENTS FOR CANNABIS (SOURCE: SMART FERTILIZER MANAGEMENT).

Plant Stage	Nitrogen (ppm)	Phosphorus (ppm)	Potassium (ppm)	Zinc (ppm)	Magnesium (ppm)	Boron (ppm)
First 2 weeks	80-100	40	140	0.3	50	0.3
Growth period	300-350	60	215	0.3	60	0.3
Flowering period	100-110	70	200	0.3	60	0.3
Average	175	57	185	0.3	57	0.3

Table 2 presents an example of greenhouse cannabis input requirements alongside those of other greenhouse crops grown in BC, for comparison of input needs. The average nutrient needs of the cannabis crop is in line with these other agricultural crops.

TABLE 2. TYPICAL NUTRIENT REQUIREMENTS FOR VEGETABLE GREENHOUSE PRODUCTION (SOURCES: GOVERNMENT OF ALBERTA, 2003; HAIFA GROUP CROP GUIDE<sup>22</sup>, HORT AMERICAS, 2017<sup>23</sup>).

Crop	Nitrogen (ppm)	Phosphorus (ppm)	Potassium (ppm)	Zinc (ppm)	Magnesium (ppm)	Boron (ppm)
Tomato	200	55	300	0.2	55	0.9
Cucumber	150-200	25-50	150-200	0.1-0.5	30	0.3
Peppers	180-200	50	240-300	0.33	50	0.3
Cannabis	175	57	185	0.3	57	0.3

Most indoor and greenhouse growers use synthetic nutrients that are premixed. Many outdoor field producers will simply till compost or manure into pre-existing soil and cultivate plants without the use of any supplemental fertigation. Alternatively some outdoor growers may use plants potted in conventional soil-less media consisting of coco coir or a mix of peat and perlite (Figure 6).

Carbon dioxide supplementation occurs during vegetative and generative (flower) production and can range from 600 ppm to 1,400 ppm up to week 7 in the flower cycle. Gaseous CO<sub>2</sub> can be generated from compressed liquid or as air-stripped and compressed as an off-gas by-product of natural gas, diesel or propane combustion in a greenhouse boiler system.

<sup>21</sup> Kaparovsky, A. [Nutrient Management in Cannabis](#). SMART Fertilizer Management. Accessed November 2, 2018.

<sup>22</sup> Haifa Group, 2018. [Crop Guide: Nutrients for Cucumber](#).

<sup>23</sup> Hort Americas, 2017. [Nutrient recipe for hydroponic greenhouse peppers](#).



FIGURE 6. SOIL-LESS MEDIA.

### 3.2.2 Water

A 2016 California-based study by Butsic and Brenner<sup>24</sup> determined the average use of water to be 3.45 m<sup>3</sup> per cannabis plant per cycle (or 22.7 litres/plant/day over an average growing cycle of 150 days or 3,450 litres per plant per cycle total). The exact amount of water it takes to grow cannabis depends on several factors such as the location of the operation, the size of the plants, and type of growing media. The general consensus reached by the Emerald Growers Association in Humboldt County, is that it takes approximately 400 – 800 litres of water to produce 0.45 kg (1 lb) of processed cannabis flower<sup>25</sup>.

Up to now, most outdoor field-based cultivation systems have relied upon a combination of precipitation and basic irrigation (e.g. drip tape) systems connected to well water or surface water sources. The water requirements may be significant in areas of drought, or during times of the year when water is scarce. For example, a recent study from Northwestern California<sup>26</sup> found that water demand for cannabis cultivation had the potential to divert substantial portions of streamflow, with an estimated flow reduction of up to 23% in the study watersheds. This diminished streamflow may have lethal or sub-lethal effects on fish and may cause further decline of sensitive amphibian species.

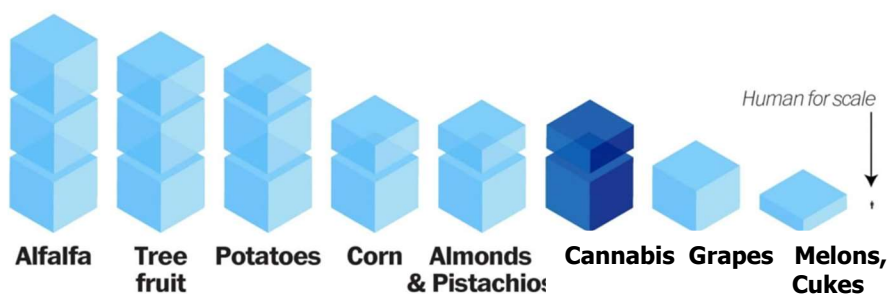


FIGURE 7. COMPARISON OF WATER NEEDS FOR OUTDOOR-GROWN CANNABIS TO OTHER CROPS IN CALIFORNIA.

<sup>24</sup> Butsic, V., & Brenner, J. C. (2016). Cannabis (*Cannabis sativa* or *C. indica*) agriculture and the environment: a systematic, spatially-explicit survey and potential impacts. *Environmental Research Letters*, 11(4), 044023.

<sup>25</sup> 3C Comprehensive Cannabis Consulting. 2018. [Cannabis cultivation: water efficiency and regulations](#).

<sup>26</sup> Bauer, S., Olson, J., van Hattum, M., Miller, L., Tauzer, M., and G. Leppig. 2015. [Impacts of surface water diversions for marijuana cultivation on aquatic habitat in four Northwestern California Watersheds](#). PLoS ONE. 10(3).

Butsic & Brenner note that the impact of cannabis production must be placed in perspective with the production of other agricultural commodities (Figure 7). The study was conducted in California, therefore they compared the mean amount of water used for the cannabis industry to other Californian crops<sup>27</sup>.

Indoor and greenhouse operations are expected to use much less water than these numbers related to outdoor cultivation in California (Figure 8). Depending on plant size, production of cannabis in containers (e.g. indoor and greenhouse) will use 1 to 2 litres of water per m<sup>2</sup> of per canopy space per day, which is similar to the watering needs of greenhouse tomatoes in their early stage of vegetative growth.

Water requirements vary depending on the type of cultivation method. An overall weakness in the available data for cannabis irrigation is that much of the information referred to in the literature and in media is related to the amounts of water required to irrigate cannabis grown outdoors in California. As is the case for other crops, indoor and greenhouse irrigation is much more automated and controlled than outdoor irrigation, therefore it is anticipated that cannabis cultivated in these types of facilities would use less water than outdoor cultivation. For a more appropriate comparison, it may be useful to look at tomato or cucumber production, which are grown in greenhouses up to 10 months a year. Therefore comparisons are made between the numbers found in the literature for outdoor cannabis irrigation and those found for greenhouse cucumber production whenever possible.



FIGURE 8. OUTDOOR FIELD CULTIVATION IN CALIFORNIA WITH IRRIGATION SHOWN.

### 3.2.3 Pesticides

Pesticides used for cannabis production are similar to the pesticides used in food crops. Common pests and diseases affecting cannabis include thrips, spider mites, aphids, fungus gnats, powdery mildew, botrytis, and fusarium.

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<sup>27</sup> Butsic, V., & Brenner, J. C. (2016). Cannabis (*Cannabis sativa* or *C. indica*) agriculture and the environment: a systematic, spatially-explicit survey and potential impacts. *Environmental Research Letters*, 11(4), 044023.

Health Canada has approved a number of pesticides for use on commercial cannabis grown indoors. At the time of writing, the pesticide label language restricts the products to indoor cultivation only.

Under Section 17(1)-(4) of the *Integrated Pest Management Act (IPM Act)*, authorization is granted for an inspector to enter land or premises, except premises or a part of premises occupied solely as a private residence, at any reasonable time if the inspector has reasonable grounds to believe that a pesticide is located on or in the land or premises [17(1)(a)]. As IPM Officers, staff are designated as inspectors and may conduct inspections regarding the use and storage of pesticides (*IPM Regulation*, Section 66).

Compliance and enforcement is based on inspection and audits of Material Safety Data Sheets (MSDS), crop records, and also through laboratory testing for residual chemicals. New rules under the *Cannabis Act* for testing of target illicit pesticides were released in 2019. Health Canada has set limits of quantification (LoQ) for pesticide active ingredients in each matrix (i.e., fresh cannabis and cannabis plants, dried cannabis, and cannabis oil). These limits are based on the identification and quantification of the molecule using current chemical analytical methods and equipment. The values may differ between each matrix because of specific constraints associated with analyzing each product type. The testing must be performed by a third-party laboratory that holds a licence for analytical testing under the *Cannabis Regulations*<sup>28</sup>. The pesticide active ingredients list will be reviewed periodically and revised as needed as Health Canada monitors the industry for pesticide active ingredients and advances in chemical analysis technology.

### 3.3 Manufacturing and Extraction

Not all forms of cannabis are yet available for legal sale under the *Cannabis Act*, which came into force on October 17, 2018. Under Section 17 of the *Cannabis Act*, a processing or micro-processing licence can be issued<sup>29</sup>. Only these licence holders may synthesize cannabis oil. The production of cannabis derivatives other than oils, which are manufactured using similar extraction methods to simple oil extraction, are not currently permitted in Canada.

Methods to extract cannabis oil can be divided into two main categories: solvent and solvent-less extractions. A solvent extraction process uses one of several chemical compounds to remove active ingredients from the plant. The most common solvents used include butane, heptane, propane, and ethanol. A solvent-less process uses super-critical carbon dioxide (CO<sub>2</sub>). Each process is described below.

#### 3.3.1 Solvent Extraction

A solvent-based extraction technique can be conducted under warm or cold conditions. An example of a warm ethanol extraction process is the Soxhlet technique<sup>30</sup>. This technique boils a solvent in a flask, then condenses the solvent vapour on a cooled-coil, such that the condensed solvent drips through packed cannabis flower material. The advantage to this approach is that the extraction is time efficient and of relatively low solvent-to-plant ratio. However, the warm technique is a small-batch method that extracts chlorophyll/waxes and decarboxylates the cannabinoids due to the heat involved<sup>31</sup>. Therefore, heated extractions might require additional dewaxing and clarification steps in order to achieve the desired end results. It is not clear if these additional steps result in further wastes or environmental discharges. Solvents

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<sup>28</sup> Government of Canada, 2019. [Mandatory Cannabis Testing for Pesticide Active Ingredients: Requirements](#).

<sup>29</sup> Government of Canada, 2018. [Cannabis Act, Section 17: Processing Licences](#).

<sup>30</sup> June-Wells, M. 2018. [Your guide to ethanol extraction](#). Cannabis Business Times.

<sup>31</sup> Decarboxylation is the conversion of THCA, for example, to THC through heating and agitation that yields carbon dioxide during the process.

can also be used under supercooled conditions. For example, using ethanol at room temperature or under cooled conditions are most common practices in the commercial production of cannabis products because these conditions allow for the retention of cannabinoid acid forms.

To extract the solutes from the feed material, the solvent must fully saturate the flower or trim. For that reason, a significant volume is needed to execute the process. While some automated machines have built-in processes to minimize the required solvent volume, it can be expected that about 4 litres of solvent is required for 1 kg of extracted material<sup>32</sup>. Much of the solvent can be recovered from the extraction material using a combination of evaporators and condensers. Any remaining solvent would be considered hazardous waste and would need to be disposed of according to the rules and regulations set forth in the *Environmental Management Act (EMA)* and *Hazardous Waste Regulation*.

Solvent residuals can be a concern for both environmental and health reasons. According to Health Canada, the *Cannabis Act* and *Cannabis Regulations* set a limit for residual solvents (e.g. butane, ethanol, heptane, pentane, propane) in cannabis oils of 5,000 ppm<sup>33</sup>. These limits mirror those found in US Food and Drug Administration (FDA) for Class 3 solvents<sup>34</sup>. Class 3 solvents<sup>35</sup> include no solvent known as a human health hazard at levels normally accepted in pharmaceuticals. They include solvents associated with cannabis manufacturing and extraction such as ethanol, heptane, butane, and propane.

There is very little information regarding the amount of water required and the air emissions and/or waste implications of solvent-based extraction processes. This could be considered a gap in the current knowledge base.

### 3.3.2 Supercritical CO<sub>2</sub> Extraction

Rather than using a solvent, the supercritical CO<sub>2</sub> method removes cannabis components from the plant with carbon dioxide that has been manipulated by high pressure and heat in a supercritical state (e.g. it acts simultaneously like a liquid and a gas). Under pressure, the temperature of the CO<sub>2</sub> is increased to about 33°C. At this temperature, CO<sub>2</sub> enters a phase that is part liquid and part gas. The supercritical fluid is an excellent solvent for oil extraction because it does not chemically interact with the oil. To remove the CO<sub>2</sub>, the pressure is decreased and it returns to a gaseous state leaving the oil extract with no residues. Once the extraction is completed, the supercritical CO<sub>2</sub> goes into a condenser and turns into a liquid that can be filtered and used again. Consequently, very little reagent is used and/or lost, and therefore this method reduces potential waste. Furthermore, CO<sub>2</sub> residual, if any, is less toxic than solvent residuals. The cost of the equipment involved in supercritical CO<sub>2</sub> extraction is much higher than solvent-based extraction, however the yields are higher and less of the valuable THC and CBD material is lost in the process. Figure 9 is a photo of a typical supercritical CO<sub>2</sub> laboratory.

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<sup>32</sup> June-Wells, M. 2018. [Your guide to ethanol extraction](#). Cannabis Business Times.

<sup>33</sup> Health Canada, 2018. [Limits for residual solvents in cannabis products](#).

<sup>34</sup> US Food and Drug Administration, 2018. [Q3C –Tables and list guidance for industry](#). Revision 4.

<sup>35</sup> International Conference on Harmonisation of Technical Requirements for Registration of Pharmaceuticals for Human Use. 2011. ICH Harmonised Tripartite Guideline. [Impurities: Guideline for Residual Solvents Q3C\(R5\)](#). Current Step 4 Version Dated 4 February 2011.



FIGURE 9. EXAMPLE OF SUPERCRITICAL CO<sub>2</sub> CANNABIS EXTRACTION LAB EQUIPMENT.

### 3.3.3 Extraction of Cannabis vs. Extraction of Essential Oils and Absolutes

In comparison to cannabis, most essential oils used in the soap and perfume industry are extracted using distillation (steam) and expression (high pressure) techniques that force the oils from the plants<sup>36</sup>. The use of solvent extraction is found in the extraction of absolutes and some botanicals. Absolutes are similar to essential oils since they are highly-aromatic, concentrated extracts from plants, but require the use of a solvent for extraction. Absolutes include vanilla, which is difficult to otherwise express, and jasmine flowers and rose petals, which are too delicate to survive the process of distillation. In the extraction of absolutes, the process utilizes solvents such as ether, and toluene, which are not used in the cannabis industry. As the solvent is added to the botanical it is absorbed and allows the release of the aromatic compounds. Ethanol extraction and supercritical CO<sub>2</sub> extraction of absolutes are also possible, though less common. Supercritical CO<sub>2</sub> extraction is considered to be a fairly new method of extraction in the essential oil industry. Therefore, it is not possible to assume that BACTs and best practices for waste and emissions reduction in the essential oil industry would necessarily be similar to the cannabis extraction industry.

## 4.0 Air, Water, and Solid Waste Discharges

This section of the report describes the types of waste discharges (air, liquid, solid) that typically occur during the production and manufacturing of cannabis. Whenever possible, differences in waste types and amounts due to production type (e.g. indoor, greenhouse, and outdoor) are explained.

### 4.1 Air Emissions

Cannabis is high in Volatile Organic Compounds (VOC). One study by Rice and Koziel identified over 200 different VOC in cannabis samples<sup>37</sup>. Cannabis plants naturally emit these compounds, although the exact

<sup>36</sup> Chagrin Valley Soap & Salve Company. 2016. [How essential oils are extracted](#).

<sup>37</sup> Rice S, Koziel JA. Characterizing the smell of cannabis by odor impact of volatile compounds: an application of simultaneous chemical and sensory analysis. PLoS One. 2015;10(12):e0144160.

amount and rate of VOC emissions from cannabis cultivation facilities is relatively unknown, and further research is required to quantify these amounts. A recent study examined the amount of cannabis-related VOC in the Denver area<sup>38</sup>. The results indicated that emissions from cannabis production increased total VOC emissions by a range of 500 to 7,000 ton/year (the range is related to the stage of life of the plants, as well as ambient parameters such as temperatures and humidity). It was predicted that Denver County alone, which is home to over 600 cannabis cultivation facilities, saw an increase in VOC emissions up to 3,500 ton/year. As an example, a common terpene emitted by cannabis,  $\alpha$ -pinene, undergoes reactions with ozone, such that the OH radical or the NO<sub>3</sub> radical lead to low-volatility species which partly condense on existing aerosols, thereby generating secondary organic aerosols. This has been shown in numerous laboratory experiments<sup>39,40</sup>.

Most of the cannabis produced in Denver is grown indoors<sup>41</sup> and a separate source indicated that the footprint is 4.2 million square feet of industrial space devoted to cannabis production in Denver, through 450 active growing operations, for an average of just under 930 m<sup>2</sup> (10,000 ft<sup>2</sup>) per facility<sup>42</sup>. This would indicate that each 930 m<sup>2</sup> (10,000 ft<sup>2</sup>) facility would be responsible for approximately 8.33 ton/year of VOC emissions.

At extraction facilities, the evaporation of solvents and other processes in the production cycle also result in VOC emissions. During manufacturing, emissions may be associated with the evaporation of solvents while transferring to vessels and while cleaning. However, in rotary evaporation vessels, most solvent is captured and reused. Solvent-less extractions methods do not typically result in VOC emissions or harmful waste products. Unfortunately, there is a lack of published data regarding the air emissions during the manufacturing and extraction process. This could be considered a gap in the knowledge base. In terms of air emissions concerns, VOC are the most significant due a class of VOC called terpenes that are associated with odours that have been linked to air quality complaints, and the ability of VOC to form ground level ozone as well as secondary particulate matter. Terpenes, and the issue of odour more broadly, are described in the following sections along with a discussion regarding the relationship to ground-level ozone and the formation of secondary aerosols.

#### 4.1.1 Terpenes

Terpenes are a form of VOC that are responsible for most of the odours associated with the cannabis plant. Common monoterpenes associated with agricultural crops include limonene,  $\alpha$ -pinene, and 3-carene. Common sesquiterpenes, which are a class of terpenes with three isoprene units that are more difficult to measure, include  $\beta$ -caryophyllene and  $\alpha$ -humulene<sup>43,44</sup>. The type and amount of terpenes in cannabis vary

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<sup>38</sup> Wang, C-T, Vizuite, W., Ashworth, K., Ortega, J.V., Wiedinmyer, C., Harley, P.C., and Urso, K. 2018. The predicted impact of VOC emissions from Cannabis spp. Cultivation facilities on ozone concentrations in Denver, Colorado. AGU 100: Advancing Earth and Space Science. Fall Meeting, Washington DC.

<sup>39</sup> Odum, J. R.; Hoffmann, T.; Bowman, F.; Collins, D.; Flagan, R.C.; Seinfeld, J. H. (1996). "Gas/particle partitioning and secondary organic aerosol yields". *Environmental Science and Technology*. 30 (8): 2580–2585.

<sup>40</sup> N. M. Donahue; K. M. Henry; T. F. Mentel; A. Kiendler-Scharr; C. Spindler; B. Bohn; T. Brauers; H. P. Dorn; H. Fuchs; R. Tillmann; A. Wahner; H. Saathoff; K.-H. Naumann; O. Mohler; T. Leisner; L. Muller; M.-C. Reinnig; T. Hoffmann; K. Salo; M. Hallquist; M. Frosch; M. Bilde; T. Tritscher; P. Barmet; A. P. Praplan; P. F. DeCarlo; J. Dommen; A. S. H. Prevot; U. Baltensperger (2012). "Aging of biogenic secondary organic aerosol via gas-phase OH radical reactions". *Proceedings of the National Academy of Sciences*. 109: 13503–13508.

<sup>41</sup> Colorado Public Radio, 2018. [Nearly 4% of Colorado's electricity is now devoted to marijuana](#).

<sup>42</sup> The Cannabist, 2017. [Denver cannabis cultivation occupies 4.2M square feet, but city's cap may freeze land rush](#).

<sup>43</sup> Bouvier-Brown, N. C., Goldstein, A. H., Gilman, J. B., Kuster, W. C., and de Gouw, J. A.: In-situ ambient quantification of monoterpenes, sesquiterpenes, and related oxygenated compounds during BEARPEX 2007: implications for gas- and particle-phase chemistry, *Atmos. Chem. Phys.*, 9, 5505–5518, doi:10.5194/acp-9-5505-2009, 2009.

<sup>44</sup> Ormeño, E., Gentner, D. R., Fares, S., Karlik, J., Park, J.-H., and Goldstein, A. H.: Sesquiterpenoid emissions from agricultural crops: correlations to monoterpenoid emissions and leaf terpene content, *Environ. Sci. Technol.*, 44, 3758–3764, 2010.

between strains and the life stage of the plant<sup>45</sup>. Terpenes are also responsible for the flavour of the plant, and therefore it is unlikely that cultivation practices will ever lead to a selection of strains of cannabis that minimize these compounds. Figure 10 shows the chemical structures of terpenes most commonly emitted by cannabis<sup>46</sup>:

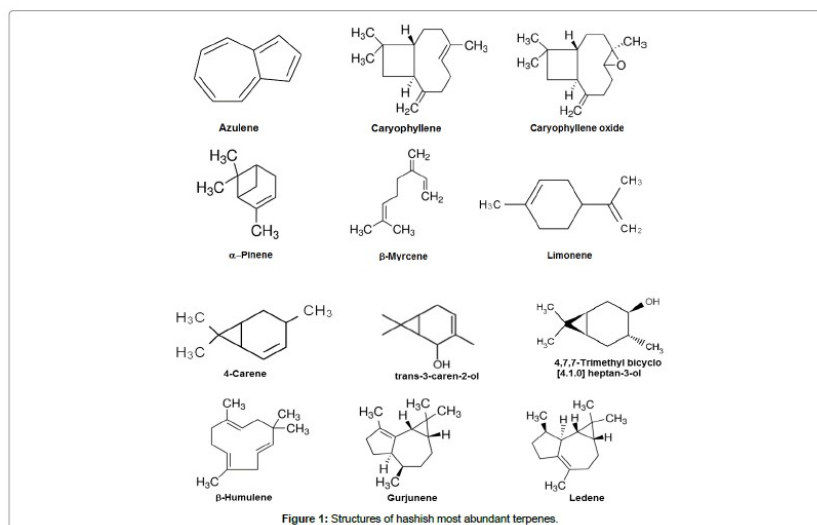


FIGURE 10. COMMON TERPENES FOUND IN CANNABIS<sup>47</sup>.

Although terpenes associated with the scent of cannabis plants are not widely considered to be harmful to human health, in some instances, exposure to cannabis odours has been reported to result in headaches, eye and throat irritation, nausea, and discomfort<sup>48</sup>. Defining and determining the odour detection threshold of odour associated with terpenes varies widely<sup>49</sup>. An odour detection threshold is the lowest concentration of an odour compound that can be perceived by the human sense of smell. Table 3 presents the odour detection thresholds of some of the terpenes associated with cannabis<sup>50,51,52</sup>:

TABLE 3. ODOUR DETECTION THRESHOLDS OF TERPENE COMPOUNDS FOUND IN CANNABIS.

Chemical Compound	Odour Detection Threshold (ppb)
Beta-Caryophyllene	64
Myrcene	13-15
Limonene	10
α-Pinene	6
β-pinene	140

<sup>45</sup> CalCannabis Cultivation Licensing. 2017. Volume 1: Main Body Final Program Environmental Impact Report. California Department of Food and Agriculture. State Clearinghouse #2016082077.

<sup>46</sup> Arnoldi, S., Roda, G., Casagni, E., Dell'Aqua, L., and M.D. Cas. 2017. Characterization of the volatile components of Cannabis preparations by solid-phase microextraction coupled to headspace-gas chromatography with mass detector (SPME-HSGC/MS). Journal of Chromatography & Separation Techniques. 8:350.

<sup>47</sup> Ibid.

<sup>48</sup> Public Health Ontario. 2018. Odours from cannabis production: Evidence brief.

<sup>49</sup> Ruth, J.H. 1986. [Odor thresholds and irritation levels of several chemical substances: A review](#). American Industrial Hygiene Association Journal (47) pA-142-151.

<sup>50</sup> Leffingwell and Associates. [Odor and flavor detection limits in water \(in parts per billion\)](#).

<sup>51</sup> Shu, Y. and R. Atkinson. 1995. Atmospheric lifetimes and fates of a series of sesquiterpenes. Journal of Geophysical Research. Vol. 100, No. D4. Pages 7275-7281.

<sup>52</sup> Guadagni, D.G., Buttery R.G., and J.J. Harris, 1966. Odour intensities of hop oil components. Journal of the Science of Food and Agriculture. 17: 142-144.

Terpenes are emitted from many plant species in varying quantities, mainly depending on seasonality and flowering (Figure 11). For example, Linalool is also found in lavender and has a similarly low odour detection threshold level as  $\alpha$ -pinene (6 ppb). Limonene (10 ppb) is also found in citrus plants.

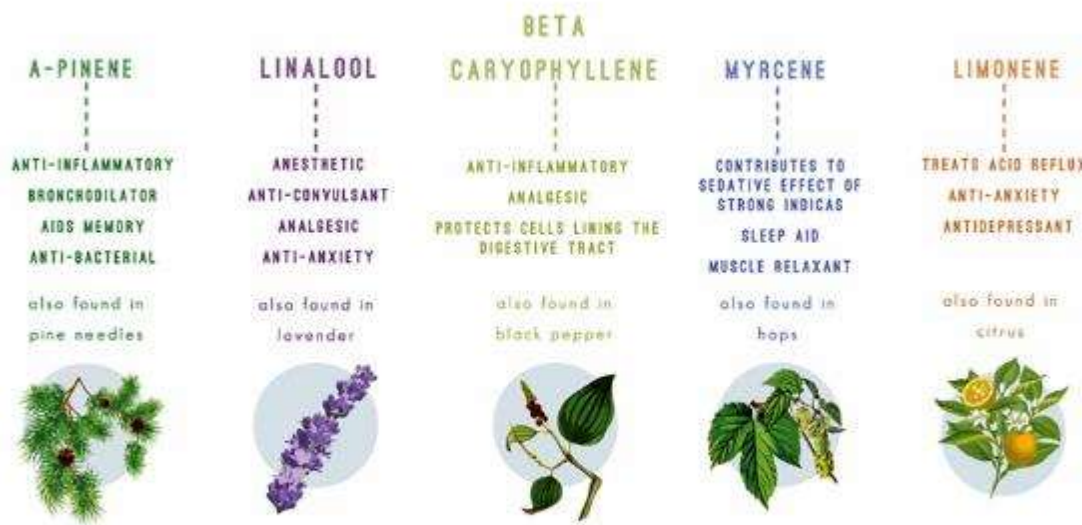


FIGURE 11. COMMON TERPENES FOUND IN CANNABIS AND OTHER ASSOCIATED PLANTS.

Myrcene is found in cannabis, allspice, hop oil, flavouring agents, and in many essential oils. Beta-myrcene has a role as a plant metabolite, as an anti-inflammatory agent<sup>53</sup>, a fragrance, and a flavouring agent<sup>54</sup>. While individual terpenes can be characterized and described, the odours detected from cannabis operations constitute a combination of terpenes. This combination can be challenging to measure and characterize, and furthermore may elicit different physical reactions, depending on the person or persons experiencing the odour.

Ashworth and Wiedinmyer<sup>55</sup> measured  $\alpha$ -Pinene,  $\beta$ -myrcene,  $\beta$ -pinene, and limonene in cannabis cultivation rooms at levels of 50 – 100 ppb or nanograms/g.

The extent of land coverage and leaf mass, together with humidity, air flow, and temperature, is likely to result in croplands representing a significant fraction of terpene emissions in agricultural regions<sup>56</sup>. To examine more detailed emissions from agricultural vegetation, 25 different crops were studied in a partially controlled greenhouse environment at UC Berkeley during the summer of 2008<sup>57</sup>. The terpene compounds were quantified through the measurement of basal emissions, which are the standardized emission factors

<sup>53</sup> Rufino AT, Ribeiro M, Sousa C, Judas F, Salgueiro L, Cavaleiro C, Mendes AF, 2015. Evaluation of the anti-inflammatory, anti-catabolic and pro-anabolic effects of E-caryophyllene, myrcene and limonene in a cell model of osteoarthritis. *European journal of pharmacology* 750, 141-150.

<sup>54</sup> Myrcene. [PubChem open chemistry database](#). Accessed December 4, 2018.

<sup>55</sup> Ashworth, K. and C. Wiedinmyer. No date. [Impacts of the Legalization of Marijuana on Emissions and Air Quality in US](#). University of Michigan, National Center for Atmospheric Research.

<sup>56</sup> Gentner, D. R., Ormeño, E., Fares, S., Ford, T. B., Weber, R., Park, J. H., Brioude, J., Angevine, W.M., Karlik, J.F., and & A.H. Goldstein. (2014). Emissions of terpenoids, benzenoids, and other biogenic gas-phase organic compounds from agricultural crops and their potential implications for air quality. *Atmospheric Chemistry and Physics*, 14(11), 5393-5413.

<sup>57</sup> Ibid.

for biogenic compounds from vegetation, and are adjusted based on the environmental parameters considered.

Basal emissions, which can be measured as Basal Emission Factors (BEFs) or as Basal Emission Rates (BERs), are calculated as the amount of carbon mass (in nanograms) per gram of dry leaf matter (gDM) per hour of time (ngC/gDM/hr). Table 4 presents the results from the study for crops mainly found in BC, with the addition of citrus (orange) for perspective<sup>58</sup>. Aside from citrus crops (which are not grown in BC), the study found that the peach tree and the tomato plant are the highest terpene emitters<sup>59</sup>.

TABLE 4. AVERAGE BASAL EMISSIONS FOR VARIOUS CROPS<sup>60</sup>.

Crop	Average Basal Emissions (ngC/gDM/hr) ± the standard deviation
Orange (flowers)	7,800 ± 4,300
Orange (no flowers)	2,500 ± 3,400
Peach	1,200 ± 270
Tomato	740 ± 260
Onion	350 ± 110
Alfalfa	270 ± 160
Potato	150 ± 10
Wine grape	91 ± 50
Cherry	84 ± 59
Carrot	78 ± 45
Plum	37 ± 20

By comparison, a recent study found that cannabis strains produced basal emissions in the range of 700 to 8,700 ngC/gDM/hr<sup>61</sup>. The range is due to the age of the cannabis plant (e.g. lower levels during vegetative growth (age 4 weeks) as compared to flowering growth (6 weeks)) and the strain of cannabis plant (e.g. Rockstar Kush strain had the lowest levels and Critical Mass strain had the highest levels). These levels of terpenes are somewhat higher than those measured in other crops in the Gentner et al. (2014) study when compared to crops commonly found in BC (see above) but within a similar range to the orange plant.

This increase in emissions based on plant stage life is further described, anecdotally, by staff working at indoor, greenhouse, and outdoor cultivation facilities. This anecdotal information is presented in Table 5.

- Negligible indicates that the odour cannot be detected by smell;
- Low indicates there is a faint smell;
- Medium indicates that the odour is easily detected; and
- High refers to a smell that is strong and unpleasant to most people.

<sup>58</sup> Ibid.

<sup>59</sup> However, the authors noted users of individual crop data should be cautious of the variability between individuals of the same species and their seasonal cycles.

<sup>60</sup> Gentner, D. R., Ormeño, E., Fares, S., Ford, T. B., Weber, R., Park, J. H., Brioude, J., Angevine, W. M., Karlik, J. F., and A. H. Goldstein. (2014). Emissions of terpenoids, benzenoids, and other biogenic gas-phase organic compounds from agricultural crops and their potential implications for air quality. *Atmospheric Chemistry and Physics*, 14(11), 5393-5413.

<sup>61</sup> Wang, C. T., Wiedinmyer, C., Ashworth, K., Harley, P. C., Ortega, J., & Vizuete, W. (2018). Leaf enclosure measurements for determining volatile organic compound emission capacity from Cannabis spp. *Atmospheric Environment*, 199..

TABLE 5. RELATIVE CONCENTRATIONS OF TERPENES AND VOC EMITTED DURING THE PLANT LIFE STAGE AND TYPE OF CULTIVATION.

Plant Stage or Cultivation Area	Indoor	Greenhouse	Outdoor
Stock Plants and Propagation	Negligible	Negligible	Negligible
Vegetative Area	Low	Negligible	Negligible
Week 1 to 3 (vegetative growth)	Low	Negligible	Negligible
Week 4 to 6 (vegetative growth transitioning to flowering growth)	Medium	Low	Low
Week 7 to 9 (flowering growth)	High	Medium	Medium
Harvesting, drying and trimming	High	High	High
Packaging	Medium	Medium	Medium

Other biogenic sources of VOC in BC include the forestry industry, particularly coniferous trees. A study by Helmig et al. (2013) examined VOC levels in four coniferous species, aged 4 to 6 years, of pine, spruce, and fir trees (*P. ponderosa*, *P. longaeva*, *P. pungens*, *P. menziesii*)<sup>62</sup>. The majority of the terpenes emitted by them were  $\alpha$ -Pinene,  $\beta$ -pinene, camphene, 3-carene, and, to a lesser extent, D-limonene. Total basal emissions of the conifers ranged from <0.10 to 7.41 microgram/gram/hour. The authors noted changes in the basal emissions depending on the season (light and temperature). To compare to the values found in the Gentner et al. (2014) study, which reported the results in nanograms rather than micrograms, the higher end of the range of these basal emissions would be closer to the orange crop values, while the lower range would be closer to grapes and potatoes.

It is important to note that many agricultural regions, like the Lower Mainland, Fraser Valley, Okanagan, and Southern Vancouver Island, feature a diverse mixture of crop types. These plants have different management cycles and harvest times, meaning that emission events, such as flowering, will occur at different times and there is less likely to be a singular burst in emissions.

#### 4.1.2 Ground Level Ozone

VOC chemically react with other types of air contaminants, specifically, nitrogen oxides (NO<sub>x</sub>) emissions in the presence of sunlight to form ground-level ozone. This is of particular concern in urban areas, where traffic-related NO<sub>x</sub> emissions are more likely to occur and combine with the VOC from cannabis cultivation facilities. Because ozone formation is driven by solar energy, harmful levels of ozone typically occur during the summer months during the afternoon and early evening hours.

High ozone concentrations can form over large regions. This can result in many respiratory ailments, as well as cardiovascular disease, which are aggravated by exposure to high ozone levels<sup>63</sup>. The results of the Gentner et al. (2014) study suggests that in rural areas (in this study the San Joaquin Valley), the anthropogenic emissions from motor vehicles are slightly higher or of the same order as summertime biogenic emissions of terpenoids from all agricultural crops.

The study by Wang et al. estimated that with 600 cannabis cultivation facilities (CCFs) in the urban area of Denver (which has an area of 21,793 km<sup>2</sup>), and assuming 10,000 plants per CCF, an emission capacity of

<sup>62</sup> Helmig, D., Daly R. W., Milford, J., Guenther A. (2013). Seasonal trends of biogenic terpene emissions. *Chemosphere*, 93, pp. 35-46.

<sup>63</sup> Santa Barbara County, 2017. Cannabis Land Use Ordinance and Licensing Program. [Final Environmental Impact Report: Air Quality and Greenhouse Emissions, Section 3.3](#)

8,700 ngC/DMg/hr would more than double the existing rate of VOC emissions from 250 tons per year to 520 metric tons per year. The total ozone formation potential from these emissions could produce 2,100 metric tons per year of ozone and 131 metric tons per year of particulate matter (PM).

#### 4.1.3 Measuring Air Emissions

The detectability and concentration of Volatile Organic Compounds generated from cannabis activities would vary drastically based on the type of licence and activities proposed or occurring at each site. For instance, greenhouses could have an impact on surrounding air quality during venting, which could allow trapped VOC to emanate. On the other hand, outdoor cultivation may continually generate VOC which may not feasibly be contained. Additionally, a greenhouse operation located adjacent to residential neighbourhoods or in proximity to sensitive receptors may require more air emission control measures to capture VOC than an operation located in a heavily farmed area.

A big challenge for monitoring and controlling emissions of odours is that compounds that can be detected by the human nose may be emitted in low concentrations, sometimes at concentrations lower than the detection limit of analytical instruments. In addition, the odour associated with cannabis can be time dependent as chemical volatilization occurs at different rates for different compounds. While both fresh and dry cannabis emit terpenes, VOC emissions may differ based on rates of chemical volatilization. As a result, it may be difficult to identify one or a select number of chemicals to measure from a facility for measurement on a continuous basis, based on traditional methods of monitoring for specific chemical species.

### 4.2 Liquid Waste Discharges

Liquid waste discharges can result from all three methods of cannabis production (indoor, greenhouse, or outdoor) as well as during the manufacturing and extraction of cannabis products. However, indoor and greenhouse production facilities are typically set up to avoid wasting any water, thereby reducing effluent discharge volumes. These processes are described below.

#### 4.2.1 Indoor and Greenhouse Liquid Waste Discharges

In indoor and greenhouse cultivation, growers irrigate such that to 10-30% of the water is expelled as “over-drain” or “flush water”, to ensure ample crop irrigation. The over-drain water is then reused through incorporation back into the irrigation system. Over-drain water typically contains macronutrients (e.g., nitrate, ammonia and phosphorus), base cations (e.g., potassium, calcium, magnesium, sodium), anions (e.g., chloride and sulphate), and micronutrients (e.g., iron, copper, manganese, and zinc). The degree of over-drain required to maintain healthy plants is strongly correlated to the salt tolerance of the crop. A 20% over-drainage is a common recommendation to keep fertilizer salts from accumulating in the substrate<sup>64</sup>. A plant pot that is irrigated to saturation and allowed to drain is referred to as being at container capacity, synonymous with the agriculture term for moisture status of field capacity. Over-

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<sup>64</sup> Cannabis Business Times, 2017. [Automated irrigation for cannabis crops](#).

drain volumes of approximately 4 to 8 m<sup>3</sup>/day for a 1 acre (approximately 40,000 ft<sup>2</sup>) facility can be anticipated<sup>65</sup>.

There is limited information on the expected concentration of total nitrogen and total phosphorus in the over-drain; however, a wide range is expected based on the life stage of the plant and the amount of new freshwater that has been introduced to the irrigation system. One interviewee representing a water purification system operation indicated that nitrate-N concentration of wastewater recently measured from a growing room was 36 mg/L and phosphorus was measured at 76 mg/L<sup>66</sup>. Another grower provided over-drain sample results that indicated 316 mg/L of nitrate-N and 43 mg/L of phosphorus. Water quality guidelines present limits for nitrogen in water bodies such as lakes, streams, and aquifers, however less information is available regarding maximum nutrient levels allowable in agricultural leachate. Insufficient information is available to establish a guideline for nitrogen in irrigation water since an allowable concentration would be dependent on soil type, irrigation rate, and other factors<sup>67</sup>, but according to BC's *Contaminated Sites Regulation*, the criteria level for nitrate-N to support aquatic life is a maximum of 400 mg/L<sup>68</sup>.

Under BC's EMA, the 2019 Code of Practice for Agricultural Environmental Management<sup>69</sup> (AEMCoP) which replaces the *Agricultural Waste Control Regulation*, states that:

Section 52(1): A person who applies nutrient sources to a crop but not to land must ensure all of the following:

- a) That nutrient sources and leachate produced by nutrient sources do not escape during transportation or piping;
- b) That, in the case of nutrient sources applied to crops in containers,
  - i) Nutrient sources are not discharged or applied directly to a watercourse, across a property boundary, or below the seasonal high water table, and
  - ii) Contaminated runoff, leachate, solids, or drift from sprayed nutrient sources does not enter a water course, cross a property boundary or go below the seasonal high water table;
- c) That the total amount of available nitrogen from all nutrient sources applied in one year of application is equal or less than the amount of nitrogen needed for optimum crop growth and yield.

In high-tech vegetable greenhouse production systems, a computer-controlled irrigation system delivers precise amounts of nutrient water as required<sup>70</sup>. Over-drain from irrigation water is typically collected in the recirculation tank and then reintroduced with incoming nutrient solution and water mixture, to maintain target nutrient feed and drain concentrations. Current operators of indoor and greenhouse cannabis systems are looking to adopt these production practices, however it is largely recognized that they are still in the learning phase.

THC and its metabolites have been detected in some over-drain samples, however, there is a lack of information regarding the impact of THC, its metabolites and transformation by-products on the aquatic

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<sup>65</sup> Assumes that 1 to 2 liters of over drain per m<sup>2</sup> of growing space is produced per day. This will be higher in the hotter months, lower in the cooler months. Plant life stage will also play a role.

<sup>66</sup> HydroLogic Purification Systems.

<sup>67</sup> Nordin, R.N. and L.W. Pommen (updated by C.L. Meays), 2009. [Water quality guidelines for Nitrogen \(Nitrate, Nitrite, and Ammonia\): Overview Report Update](#). BC Ministry of Environment.

<sup>68</sup> BC Ministry of Environment. Environmental Management Act. [Contaminated Site Regulation, Schedule 3.2](#). Generic Numerical Water Standards.

<sup>69</sup> BC Environmental Management Act, [Code of Practice for Agricultural Environmental Management](#). 2019. Ministerial Order No. M039.

<sup>70</sup> Water Canada, 2018. [Cannabis Legalization Spurs a Need for Targeted Wastewater Treatment](#).

environment<sup>71</sup>. More research is needed to determine the risk of THC and its metabolites to aquatic communities.

There are currently 24 pesticides permitted by Health Canada, although this number is somewhat fluid. The pesticides are permitted through the Pest Management Regulatory Agency (PMRA), under the Federal *Pest Control Products Act*, that are allowed as inputs to cannabis production systems, however current labeling indicates that they are only suitable for indoor use<sup>72</sup>. The pesticides that are permitted by Health Canada are strictly controlled, and final products must pass strict laboratory testing for residuals<sup>73</sup>. When used judiciously, from a liquid waste discharge perspective, they could be considered very low risk of causing environmental harm.

Sanitation-based liquid wastes may also be generated at cannabis cultivation sites. These may include bleach detergents or other cleaning agents. Greenhouses and indoor growing areas are completely cleaned and disinfected at the end of each production cycle - this is true for cannabis as well as for other crops, such as tomatoes<sup>74</sup>. This cleaning sets the stage for the new crop to minimize pest and disease problems carrying over from the previous cycle. There is a lack of information regarding the amounts of cleaning agents used and to what degree they may be present in liquid waste from cannabis operations.

#### 4.2.2 Outdoor Cultivation Liquid Waste Discharges

In outdoor field-based cultivation, wastewater can occur as runoff from over-irrigation and from precipitation or flooding events. Due to the contact of precipitation with the plants' leaves, stems, and flowers, the liquid waste discharges may contain nutrients from fertilizers (Figure 12). At this point in time, the labeling associated with pesticides that have been approved by Health Canada for cannabis use indicates indoor use only.



FIGURE 12. OUTDOOR CULTIVATION IN CALIFORNIA.

The impacts of outdoor cannabis cultivation on watershed health has been observed in dry regions of California, where many large-scale intensive outdoor cultivation practices occur and are considered as point sources of pollution for nutrient runoff into streams and groundwater sources. Stakeholders in Washington, Oregon, and Colorado had less concern about runoff from outdoor cultivation practices. In urban areas, such as Denver, virtually all of the cultivation is occurring indoors.

In BC, the 2019 AEMCoP<sup>75</sup>, contains strict regulations regarding the use of nutrients and the requirements related to minimizing runoff and leachate from land-based crop applications. Sections 49-51 list the general

<sup>71</sup> Park, Y.R., Mackie, A.L., and G.A. Gagnon. 2016. [A critical review of the occurrence, detection, and treatment of Delta9-tetrahydrocannabinol in aquatic environments](#). Environmental Review 25(3): 255-268.

<sup>72</sup> Pest Management Regulatory Agency, 2018. [Pesticide Label Search](#). Accessed December 27, 2018.

<sup>73</sup> Health Canada, 2018. [Mandatory Cannabis Testing for Pesticide Active Ingredients: Requirements](#). Cat.: H14-270/2-2018E-PDF. ISBN: 978-0-660-28014-1

<sup>74</sup> Government of Alberta. [Commercial Greenhouse Tomato Production: Pest and Disease Management](#).

<sup>75</sup> BC Environmental Management Act, [Code of Practice for Agricultural Environmental Management](#). 2019. Ministerial Order No. M039.

requirements for nutrient applications for land. A person who applies nutrients to land must ensure that the total amount of available nitrogen applied during the year is equal or less than the amount required for the crops needs. Furthermore, nutrients must not be discharged into a watercourse, across a property boundary, or below the seasonal high-water table. Furthermore, as per section 53, nitrogen and phosphorus tests must be conducted on a regular basis (every 1 to 3 years). Nutrient management plans may be required if the operation is greater than 5 ha, is located in a vulnerable aquifer recharge area, and if nitrate tests indicate more than 100 kg N/ha or more in the field.

#### 4.2.3 Manufacturing and Extraction Liquid Waste Discharges

During the manufacturing and extraction process of cannabis plants, liquid wastes can also be produced. As previously discussed, extraction of desired compounds, e.g. THC, CBD, from the cannabis plant can be performed using several methods. Specific quantities of remaining solvents were not found in the literature and individuals interviewed for this report did not have figures regarding wastewater discharges from extraction facilities.

One method of extraction involves the use of solvents such as butane and propane<sup>76</sup>. There may be liquid solvents remaining after the extraction process that need to be disposed of according to hazardous waste regulations<sup>77</sup>. Alcohol can also be used as a solvent and any residual would dissolve in water and is biodegradable at wastewater treatment facilities. In small quantities, alcohols do not present a hazard<sup>78</sup>. Solvent-based extraction processes are being used less and less, according to the stakeholders interviewed, as the industry shifts to the use of supercritical CO<sub>2</sub>.

### 4.3 Solid Waste

Solid waste from cannabis production is mainly generated from agricultural inputs and can be categorized as either green, non-green, or hazardous waste. In addition to the presence of THC and CBD residues in the crop material, cannabis also differs from other crops being produced in BC, based on the ability to produce several rotations per year. This means that the volume of waste generated may be higher on an annual basis. Forecasts suggest that by 2020, there will be over 6,000 metric tonnes of cannabis waste produced in Canada per year<sup>79</sup>.

Solid waste from cannabis production, using any production method, can include:

- Green plant material (cannabis flowers, trim, leaves, stalks, and roots);
- Growing media (cocoa, peat, rockwool);
- Growing supplies (plastics associated with potting, propagation, and other typical crop production supplies and their associated packaging); and
- Chemical containers associated with pesticides and/or cleaning agents.

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<sup>76</sup> Beginin, M. 2017. [Legal brief: Licensed activities for cannabis oil extraction](#). Submitted by Abattis Bioceuticals Corporation to House of Commons Canada.

<sup>77</sup> Fish, N. and M. Jordan. 2017. [Environmental Services Regulatory Requirements for the Cannabis Industry](#). Department of Environmental Services, City of Portland, Oregon.

<sup>78</sup> Ibid.

<sup>79</sup> Senate of Canada – Senate Standing Committee on Agriculture and Forestry. 42<sup>nd</sup> Parliament, 1<sup>st</sup> Sessions, December 3, 2015 to Present. Evidence Briefing: March 27, 2018. Topic: [Composting of cannabis residues and potential impacts on the environment](#).

Growing media is typically used for only one growing cycle and can therefore generate a significant amount of waste. Rockwool is not compostable, therefore if the growing media contains rockwool, the rootballs will be surrounded by it and will not be able to be composted. For this reason, some growers avoid using rockwool.

One issue of concern regarding cannabis waste is whether or not THC may enter the environment upon solid waste disposal. The range of THC content of various cannabis plant parts (dry weight) are<sup>80</sup>:

- 10-24% in flowers
- 1-2% in leaves
- 0.1-0.3% in stalks
- < 0.03% in the roots.

By comparison, hemp has THC content of less than 1% in the entire plant. Some jurisdictions classify cannabis plant waste as hazardous if the material being disposed of has concentrations of THC greater than 10% dry weight<sup>81,82</sup>. These high concentrations are typically found in the flower, or bud, and are therefore not likely to be included in the plant wastes since most of the flowers (buds) are harvested and sold. The remaining plant materials include leaves, stalks, and roots, which are relatively low in THC concentrations. It is expected that if soil and plant materials were to be composted, THC compounds would likely be degraded early in the process, although published data has been difficult to find. If an entire crop had to be disposed of due to disease or other contamination, then the THC levels may be higher in the waste material than in typical production waste.

#### 4.3.1 Estimating Solid Waste Production

##### Growing media waste per acre per year

Producers indicate that there is a large amount of growing media waste (such as cocoa, peat, and perlite) produced over the cannabis crop cycle. Some growers will also use a plug transplant made from rockwool, which is not fully biodegradable. However, the majority of the spent growing media is compostable. A range of production styles exists, and producers may use anywhere from 5 L to 40 L of growing media per plant per cycle. For the purposes of these calculation estimates, an average of 15 L per plant is used.

The following calculation is provided as an example to indicate realistic numbers associated with cannabis growing media production<sup>83</sup>:

- Facility size: 4,645 m<sup>2</sup> (50,000 ft<sup>2</sup> or just over 1 acre)
- Number of plants: 7,000 total or about 1.5 plants per m<sup>2</sup>
- Number of crop rotations: 3 per year (4 month growing cycle)
- 15 L per plant x 7,000 plants x 4 plant cycles per year = 420,000 L = 420 m<sup>3</sup>

Therefore, on a 1 acre cultivation site, 420 m<sup>3</sup> of growing media waste would be produced per year.

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<sup>80</sup> United Nations Office on Drugs and Crime. 2009. [Recommended methods for the identification and analysis of cannabis and cannabis products](#). Manual for use by national drug analysis laboratories. United Nations Publication Sales No. E.09.XI.15. ISBN 978-92-1-148242-3

<sup>81</sup> Report to the BC Ministry of Environment: Assessment of Means by Which Jurisdictions Regulate Waste from Medical Marijuana Operations. Prepared by Tri-Star Environmental Consulting, 2016.

<sup>82</sup> Washington Regulatory Compliance for Cannabis Operations. 2016. Interagency Resource for Achieving Cooperation.

<sup>83</sup> Ahearn, T. and P. Larouche. 2018. [Composting in the Cannabis Industry](#). Brome Compost.

Typical growing media mixes have a dry bulk density of 750 kg/m<sup>3</sup>, however this is assuming the media is dry. Saturated media, which is common at the end of a growth cycle, may have a bulk density of up to 1,000 kg/m<sup>3</sup>. Therefore, annual mass of growing media waste may range from 315,000 to 420,000 kg or 315 to 420 tons.

#### Green waste per acre per year

Plant residues (stems, trimmings) weigh an average of 0.2 kg and yield an average of 1.75 L of green waste per plant.

At a one acre site with 7,000 plants, as described above:

1.75 L per plant x 7,000 plants x 4 plant cycles per year = 49,000 L per year or 49 m<sup>3</sup> per year.

The calculated bulk density can be calculated at:

0.2 kg/1.75 L x 1,000 kg/1 m<sup>3</sup> = 114 kg/m<sup>3</sup> for green cannabis waste.

Therefore 49 m<sup>3</sup> of plants would be the equivalent of 5,586 kg per year or 5.5 tons of green waste.

#### Total growing media and green waste per acre per year

The total calculated growing media and green waste for a 1 acre site would be:

420 tons (growing media) + 5.5 tons (green waste) = 425.5 tons per year.

It is worth considering that Health Canada requires that plant waste material be rendered un-recognizable prior to disposal, and therefore many growers have chosen to mix their material 50/50 by volume with other materials such as sand or soil. This would essentially potentially double the amount of organic waste being produced. However, some producers are using the spent growing media to render their green waste unrecognizable, therefore there is no net increase in waste volumes or waste mass in these circumstances.

## 5.0 Best Available Control Technologies

BACTs refer to approaches which can achieve the best waste discharge standards, and that has been shown to be economically feasible through commercial application. The BC Ministry of Environment and Climate Change Strategy policy<sup>84</sup> provides guidance when setting waste discharge standards. The policy also assists Ministry staff in providing proponents with a clear set of expectations regarding the evaluation and selection of pollution control technologies.

This section of the report builds upon the knowledge base regarding the production and manufacturing of cannabis and the associated emissions and wastes produced and examines BACTs that can be applied and adopted to minimize environmental impacts. Within the broader regulatory framework, technology-based standards are about setting standards for both new and existing facilities. Technology assessment is conducted with regards to technology identification, environmental performance standards, and economic considerations<sup>85</sup>. While the BACTs are described and assessed, recommendations are not provided as they

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<sup>84</sup> BC Ministry of Environment and Climate Change Strategy. 2015. [Best Achievable Technology Policy](#) factsheet.

<sup>85</sup> Department of Environment, Province of Alberta. 2011. [Guidance for assessing Best Available Technology Economically Achievable and Developing Technology-Based Standards](#).

are outside the scope of this analysis. Each type of technology is therefore described, along with a cost estimate and discussion of environmental effectiveness.

Economic feasibility will determine if a BACT is viable in terms of the ability for a business to adopt the practice or technology. It can be useful to assess viability based on the commercially demonstrated and operated technologies used across several jurisdictions, particularly in circumstances whereby specific financial figures are difficult to uncover. The approach implicitly considers costs, because the assumption is that if there is commercial application of the technology within the sector, then the cost of that technology is reasonable<sup>86</sup>. The rationale for this assumption is that private industries minimize costs, so their technology choices reflect likelihood of adoption.

The challenge in assessing the costs associated with BACTs for the cannabis industry is that they will vary depending on the cultivation type (due to installation differences, or in the case of open cultivation BACTs may not be applicable) and the scale of the operation (for instance, a large greenhouse may not find that a \$50,000 odour mitigation equipment is expensive due to economies of scale, while a small indoor operation likely will). Furthermore, due to the highly competitive nature of the industry, very few businesses are willing to share economic data.

Given the above considerations, the following information is provided for each of the BACTs for air emissions, liquid waste management, and solid waste management. Note that hazardous wastes are not included in the BACT discussion, as their handling and disposal requirements are largely prescribed<sup>87</sup>. The following topics are addressed for each BACT:

- Description of the technology, installation and use
- Cost of the technology
- Environmental effectiveness
- Applicability to the BC cannabis industry (by type and scale of operation)

## 5.1 Best Available Control Technologies for Air Emissions

Of all the types of waste discharges, the air emissions associated with cannabis production and manufacturing result in the most complaints and therefore attention from compliance and enforcement agencies. The jurisdictions associated with air emission regulations are somewhat complex in Canada. For instance, Health Canada can require that cannabis cultivation facilities use specific equipment or achieve certain outcomes in order to comply with licensing, but local governments tend to be the initial recipients of the odour complaints. In the USA, odour control is considered a local ordinance, or bylaw, therefore different cities and counties have different regulations regarding the use of specific types of equipment and/or requirements to meet air quality thresholds and criteria.

Under the previous Federal *Marijuana for Medical Purposes Regulations* (MMPR) Section 50<sup>88</sup>, there was a regulatory provision relating to air filtration:

*Those areas [within a site where cannabis is present] must be equipped with a system that filters air to prevent the escape of odours and, if present, pollen.*

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<sup>86</sup> US Department of Energy, Waste Management Systems Engineering. 1988. [Best Available Technology \(economically achievable\) Guidance Document for the Hanford Site](#).

<sup>87</sup> Hazardous wastes must be handled as per the BC *Environmental Management Act*, and are therefore minimally addressed in the BACT discussion. This would largely be relegated to handling, storage, and disposal of pesticides, solvents, and any other chemicals associated with cannabis production. Generators of waste are responsible for determining if their waste is hazardous or not.

<sup>88</sup> MMPR, 2013. [Regulatory Provision Relating to Air Filtration](#).

Similar language is found in Section 85 of the 2018 *Cannabis Act*<sup>89</sup>, although reference to pollen is dropped.

- *The building or part of the building where cannabis is produced, packaged, labelled and stored must be equipped with a system that filters air to prevent the escape of odours.*

In addition to Section 85 of the *Cannabis Act*, air quality regulations associated with the *BC EMA* and the *Greater Vancouver Regional District Air Quality Management Bylaw No. 1082*<sup>90</sup> may need to be followed. The BACTs considered here focus on the ability to reduce VOC and treat odorous emissions, but not air particulates. As such, HEPA filters and negative ion generators are not included in the analysis. Heating, Ventilation and Air Conditioner (HVAC) systems are considered an important component of an air emissions control system in cannabis cultivation and extraction. Tools are often combined to provide greater effectiveness for air quality. While HVAC systems on their own may not be an effective tool in reducing odours, they are instrumental in facilitating BACTs (such as biofilters and carbon filters) in treating as much of the air within the growing system as possible. HVAC systems are incorporated into virtually all indoor growing and extraction facilities, and often for the cultivation and curing rooms within greenhouse facilities. An effective HVAC system therefore ensures that all other interconnected air treatment tools within the cultivation facility are performing optimally.

The use of air emission control practices in confined indoor cultivation and manufacturing facilities is purported to reduce VOC emissions substantially, although peer-reviewed research is generally lacking<sup>91</sup>. The use of air emission BACTs are most successful when accompanied by an odour control plan (or odour management plan) that includes measurable components and can be evaluated over time<sup>92,93</sup>. Tools for air emissions management may be located within the cultivation or manufacturing facility (e.g. in curing rooms, between the grow facility and the outdoors), or outside (e.g. HVAC system on a roof top of an indoor facility)<sup>94</sup>. Some of the most common tools used to mitigate odour from cannabis are also used in the design of odorous agricultural facilities including mushroom barns, poultry barns, and hog barns. These BACTs are further described below, along with a description of several other tools. Masking agents, which cover up odours with more pleasant smells, are included in this discussion, because although they are not likely the most effective tool, they can provide a temporary solution for an operation that may otherwise be struggling to find a more long-term or effective odour control solution. Masking agents themselves are VOC and therefore increase the VOC emissions<sup>95</sup> and may simply be useful as a stepping stone to installing more effective air emission management tools within a cannabis operation<sup>96</sup>.

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<sup>89</sup> Government of Canada, 2018. [Cannabis Act](#).

<sup>90</sup> Metro Vancouver, 2008. [Air Quality Bylaw No. 1082](#).

<sup>91</sup> City of Denver. 2018. [Cannabis Environmental Best Management Practices](#). Draft Section for Review: Air Quality.

<sup>92</sup> CalCannabis Cultivation Licensing. 2017. Volume 1: Main Body Final Program Environmental Impact Report. California Department of Food and Agriculture. State Clearinghouse #2016082077.

<sup>93</sup> City of Denver. 2017. [Governing Nuisance Odours](#).

<sup>94</sup> Public Health Ontario. 2018. Evidence Brief: Odours from cannabis production.

<sup>95</sup> Denver Public Health and Environment. [Cannabis Environmental Best Management Practices Guide](#). 2018.

<sup>96</sup> City of Denver, 2011. [Odor control Best Management Practices](#) for Commercial Medical Marijuana Cultivation.

### 5.1.1 Carbon Filters

#### Description of Installation and Use

Carbon filters use pellets of charcoal to trap VOC (including odorous terpenes) as air passes through the unit. Carbon filters are fairly simple to install but must be properly maintained and changed regularly<sup>97</sup>. The filters work by adsorbing VOC to activated carbon, which physically traps the compounds to the filter's surface. Due to its porosity, activated carbon has a very large surface area on which the adsorption can occur. However, as a filter ages, less surface area is available to trap VOC, and may become unreliable. Carbon filters are typically installed in both greenhouse and indoor cultivation systems, as well as in extraction facilities and any enclosed rooms associated with outdoor field operations (Figure 13). The filters can also be integrated into HVAC systems.



FIGURE 13. MULTIPLE CARBON FILTERS INSIDE A GREENHOUSE FACILITY.

Large cultivation areas can require the use of multiple filters, which will require regular maintenance and replacement. The number of carbon filters required is related to the total air volume and how often the air is being exchanged. A multi-jurisdictional scan of Colorado, Oregon, Washington and BC found a wide range in the number of filter units employed per greenhouse ranging from 4 to 10 filters per acre of greenhouse production. Part of the explanation for this range is that filter manufacturers offer varying sizes of filters with CFM (cubic feet per minute) ratings from 150 to 4,000<sup>98</sup> and therefore the number of filters may depend on the chosen CFM and the quantity of activated carbon within the filter.

Example for use in indoor production:

- 929 m<sup>2</sup> (10,000 ft<sup>2</sup>) indoor cultivation space with 2.4 m (8 ft) ceilings would have 2,230 m<sup>3</sup> (80,000 ft<sup>3</sup>) of air space. This volume of air could be replenished every hour if moved through 3 fans with ratings of 500 CFM. This equals 1,500 CFM total every minute for 60 minutes, which is 90,000 ft<sup>3</sup> of air space total per hour<sup>99</sup>. This rate of air replenishment is desirable in order to optimize humidity levels.

Example for use in greenhouse production:

- 1 acre of greenhouse floor area, or 3,716 m<sup>2</sup> (40,000 ft<sup>2</sup>) with 5.5 m (18 ft) ceilings would have 20,438 m<sup>3</sup> (720,000 ft<sup>3</sup>) of air space. This volume of air would require 8 units with carbon filters and fans of 1,500 CFM. This equals 12,000 CFM total every minute for 60 minutes, which is 720,000 ft<sup>3</sup> of total air space per hour.

<sup>97</sup> City of Denver. 2018. [Cannabis Environmental Best Management Practices](#). Draft Section for Review: Air Quality.

<sup>98</sup> Product specifications and costs. [Phresh Filters](#). Accessed December 4, 2018

<sup>99</sup> HTG Supply Company. [GrowBright 6" XXL Inline Fan and Carbon Filter Combo](#). Product Specifications. Accessed December 4, 2018.

### Cost and Lifetime of the Technology

Life expectancy of the filter depends on humidity and load (base or ambient air pollution). Manufacturers indicate that filters should last approximately two years, with a range of up to three years in a dry climate and down to 18 months in a humid environment. Some sources indicate that the lifetime may be lower, however this can be adjusted by the number of filters per volume of air space<sup>100</sup>. The pre-carbon filter treatment system, which collects dusts and larger air particles, must be changed every 6-8 months<sup>101</sup>. In general, the lower the flow rate through the filter, the closer the filter will operate to the limit of ideal performance. If a 4,047 m<sup>2</sup> (1 acre) greenhouse cultivation area utilized 8 carbon filters, each of which cost approximately \$500, this would be a \$4,000 investment in technology. Using an air flow of 1,500 CFM, the carbon filters would need to be 35.5 cm in diameter and a height of 101.6 cm with a 5 cm bed depth of activated granular carbon and a total carbon weight of 16.1 kg<sup>102</sup>. If the carbon filters were changed every 6 months, this would be a \$8,000 investment annually per acre of cultivation.

Carbon filters can be installed with the UV lights systems to further enhance performance and odour control. A supply company based in the USA has installed carbon filtration systems in combination with UV light systems in several cannabis cultivation and processing facilities throughout the USA and Canada, including Ontario (Figure 14). Each unit costs \$5,600 CAD and requires about \$300 CAD of maintenance per year. One unit at this price will suffice for every 185 m<sup>2</sup> (2,000 ft<sup>2</sup>) of growing area, and varying sizes also exist. The carbon filters are large, held in drums of 3 sizes ranging from 208 – 320 litres filled with 68 – 180 kg of activated carbon at bed depths of 56 – 84 cm. At air flows of 150 – 400 CFM and a vapour contact time of 3.0 seconds, the carbon can treat 92 – 186 m<sup>2</sup> of growing area. The price of the carbon filtration units start at \$7,000 CAD, which includes the costs of servicing every 6 months to inspect the performance of the carbon. Replacement carbon costs are approximately \$3,000 CAD every 6 months.



FIGURE 14. UV LIGHT SYSTEM TO ENHANCE CARBON FILTRATION REMOVAL OF VOC.

### Environmental Effectiveness

Of all the policies, best practices, and regulations reviewed the use of carbon filters was the most frequent suggestion for optimized air emissions control. Carbon filters can be used for both indoor and greenhouse operations, at all sizes and scales. The use and disposal of the filters creates physical waste; however, the carbon can typically be regenerated for reuse, and there is no indication that the filters must be treated as hazardous waste when disposed of<sup>103</sup>. If installed in a manner such that air flow is maximized through the filter (e.g. mounted on posts as per Figure 13, with air flow controlled by HVAC system and/or fans) and maintained properly (e.g. filters replaced as per product specifications) carbon filtration systems can remove 50-98% of VOC<sup>104</sup>. The systems that combine UV treatment with carbon filters are purported to reduce VOC in indoor facilities by 95%<sup>105</sup>. The UV system utilizes broad spectrum, high-intensity lights

<sup>100</sup> [Understanding air purification and activated carbon filters](#). 2017. Maximum Yield.

<sup>101</sup> City of Denver, 2011. [Odor control Best Management Practices](#) for Commercial Medical Marijuana Cultivation.

<sup>102</sup> Can-Filters. Air ventilation systems. [Product specifications for carbon filtration](#).

<sup>103</sup> City of Denver. 2011. [Best Management Practices: Commercial Medical Marijuana Cultivation](#).

<sup>104</sup> City of Denver. 2018. [Cannabis Environmental Best Management Practices](#). Draft Section for Review: Air Quality.

<sup>105</sup> Urban-gro equipment specialist. Personal communication.

targeted on a hydrated metallic catalyst to generate hydro-peroxides and hydroxides that are propelled into the cultivation facility, which bind with the VOC.

#### **Applicability to the BC Cannabis Industry (type/scale)**

While a reference to air filtration is noted in the *Cannabis Act*, Health Canada does not provide specific guidelines for the type and use of air filters, nor the disposal of the air filters. As previously mentioned, carbon filters can be used in greenhouse and indoor cannabis operations of all sizes. Most new builds and retrofits of indoor and greenhouse operations in BC are installing carbon filters. A licensed cultivator located in the Lower Mainland is using a combination of fans and carbon filters. Air is pulled through the length of the greenhouse via six 45 cm (18 inch) fans. These fans move the air, beginning above the plant canopy and eventually through it on the back end toward the rear of the greenhouse. Two 120 cm (48 inch) exhaust fans are mounted just above crop height for a total of 54,000 CFM per bay (the greenhouse has 3 bays, therefore six fans total)<sup>106</sup>.

### **5.1.2 BioFilters**

#### **Description, Installation and Use**

Biofilters treat odourous compounds by passing them through biological media (often wood chips or bark mulch) using microorganisms within the media to consume VOC and other compounds. Odorous air is forced through the wood chips and converted by the microbes into carbon dioxide and water. Key factors influencing biofilter performance include the amount of time the odorous air spends in the biofilter (contact time) and the moisture content of the filter material. Success factors also include the sizing of the biofilter bed, fans used to push the air through the biofilter, biofilter media, and moisture content<sup>107</sup>. This technology was originally developed for use in other odorous agricultural operations, such as hog farms and mushroom production facilities. Open bed biofilters are the most prevalent configuration used in agricultural systems today (Figure 15). These biofilters are typically 0.25 – 0.4 m (10-18 inches) deep and may be built indoors or outdoors.

#### **Cost and Lifetime of the Technology**

Biofilters are simple to install and require low maintenance, and there is not very much waste compared to other equipment. Over time, additional microbial agents (inoculation) may need to be added to the wood chips. The life of the organic media is at least three years and more likely five to ten years<sup>108</sup>. During this time the media decomposes and compacts which reduces the porosity (air space in the media) and increases the pressure needed to move the air through the biofilter media.

#### **Environmental Effectiveness**

An initial conditioning period of two to three weeks may be necessary to allow the microorganisms to adapt to the odorous gases in the exhaust air. During this conditioning time the biofilter efficiency is limited. Once established, the effectiveness at removing odour is high. For example, a pilot-scale system developed to test the effectiveness of a biofilter at a hog farm in central Iowa<sup>109</sup> indicated that the biofilter achieved

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<sup>106</sup> Tantalus Sun Labs, 2018. [Humidity minimization and environmental controls](#).

<sup>107</sup> Bridgnell, H. 2017. Ceres Greenhouse Solutions. [Odour control for a cannabis greenhouse](#).

<sup>108</sup> Ibid.

<sup>109</sup> Lide Chen , Steven Hoff , Lingshuang Cai , Jacek Koziel & Brian Zelle (2009) Evaluation of Wood Chip-Based Biofilters to Reduce Odor, Hydrogen Sulfide, and Ammonia from Swine Barn Ventilation Air, Journal of the Air & Waste Management Association, 59:5, 520-530, DOI: 10.3155/1047-3289.59.5.520

significant reductions in odour (70-82%). Another study used a laboratory-scale unit to test the efficiency of a biofilter removing terpenes. The results indicated a removal efficiency of more than 85% for limonene and 45% for  $\beta$ -pinene at a loading rate of 55 g/m<sup>3</sup> per hour. A maximum elimination capacity was found for 109.7 g/m<sup>3</sup> per hour for limonene and 10.3 g/m<sup>3</sup> per hour for  $\beta$ -pinene at a critical loading of 150.1 g/m<sup>3</sup> per hour<sup>110</sup>. Very little waste is created using this technique. At the end of the useful lifetime of the material (e.g. wood chips or bark mulch) it can be composted. The cost of installing a biofilter will vary, depending on the size and space required, which would be proportional to the size of cultivation area being treated, so the effectiveness per investment is challenging to calculate. However, the tool is relatively low-tech, and existing licensed producers using the biofilter as an odour reduction tool in a greenhouse environment spent between \$40,000 and \$50,000 and indicated that it was a very worthwhile investment.

#### Applicability to the BC cannabis industry (type/scale)

Currently, the first known Canadian biofilter application in a cannabis facility is being tested at a 11,150 m<sup>2</sup> (120,000 sqft) cannabis greenhouse near Maple Ridge, Canada. This biofilter was observed in a room within the greenhouse whereby air was being pumped through the bed (Figure 13). While the air in the room had a distinct strong odour, the air directly outside of the facility had only a trace of odour. It is unclear whether biofilters are being used in other jurisdictions for the purpose of cannabis cultivation odour control as information was not easily found. However, based on the literature review they are being used in other agricultural industries for effective odour control. This tool could potentially be scaled to be used in both indoor and greenhouse cannabis operations of all sizes.



FIGURE 15. EXAMPLE OF A BIOFILTER IN A CANNABIS GREENHOUSE OPERATION IN BC.

### 5.1.3 Ozone Generators

#### Description, Installation and Use

These generators release ozone gas, which is a highly reactive molecule, to quickly oxidize VOC. The three oxygen atoms break apart and bond with other compounds, including terpenes. In certain concentrations ozone is toxic to both plants and humans. Effects on human health can be observed at 60-70 ppb after an 8 hour exposure while laboring outdoors or at 300-400 ppb for an adult at rest outdoors<sup>111</sup>. Ozone generators are used safely in many industries, including water purification and temporary air freshening (e.g. in the hotel industry)<sup>112,113</sup>. Sufficient ventilation is required during use so that the ozone does not build up over time. Release of the gas



FIGURE 16. EXAMPLE OF AN OZONE GENERATOR (SOURCE: ODOR FREE MACHINES)

<sup>110</sup> Viswanathan, S., Neerackal, G., & Buyuksonmez, F. (2013). Removal of beta-pinene and limonene using compost biofilter. *Journal of the Air & Waste Management Association*, 63(2), 237-245.

<sup>111</sup> Environmental Protection Agency, 2019. [Health effects of ozone in the general population](#).

<sup>112</sup> Schiller, L. 2016. [Odor control strategies and their best applications](#). High Times.

<sup>113</sup> US Environmental Protection Agency. 2014. [Ozone Generators that are sold as air cleaners: an assessment of effectiveness and health consequences](#).

outside can also have varying local effects depending on the time of day, concentration, and dispersion factors associated with the location and weather. This technology is typically used indoors only.

### Cost and Lifetime of the Technology

Commercial ozone generators retail for approximately \$100-\$300 per unit<sup>114</sup>, and are said to be able to purify an area of 325 m<sup>2</sup> (3,500 ft<sup>2</sup>), therefore several units would be required for most commercial cultivation operations (Figure 16).

### Environmental Effectiveness

Literature suggests that if used correctly, ozone can be effective at eliminating VOC. One study examining the decomposition of terpenes and terpenoids using ozone determined that the effectiveness of using ozone was somewhat dependent on the chemical structure of the terpene compounds, whereby saturated terpenoids were unaffected by ozone, but terpenes and terpenoids containing one C–C double bond were decomposed in the order: camphene <  $\beta$ -pinene  $\approx$  myrtenal <  $\alpha$ -pinene < sabinene  $\approx$  citronellal. Interestingly, the compounds containing two or more double bonds, many of which are found in cannabis, were more significantly decomposed in the order: *d*-limonene  $\approx$  citral < linalool <  $\beta$ -ocimene < terpinolene <<  $\alpha$ -terpinene  $\approx$   $\beta$ -caryophyllene<sup>115</sup>. Research has also indicated that ozonation may be used in combination with other tools, such as biofilters, to improve VOC removal. In one study, a biofilter treating chlorobenzene was set up and operated continuously for 265 days under different ozone concentrations<sup>116</sup>. Results showed that ozone below 120 mg/m<sup>3</sup> could notably enhance the biofilter performance. The average chlorobenzene removal efficiency increased from 40 to 70% and then to 90% while the inlet ozone concentration rose from 0 to 40 mg/m<sup>3</sup> and 120 mg/m<sup>3</sup>. Reducing ozone concentration resulted in a decrease in removal efficiency from 90 to 40%. While ozone generators should not be used in the presence of people, if used with precaution, it may be able to treat high levels of VOC in specific areas of cannabis cultivation facilities (such as drying or curing areas), as it has been used successfully in water treatment and food safety, particularly when coupled with ultraviolet (UV) light treatment<sup>117</sup>.

### Applicability to the BC Cannabis Industry (type/scale)

Canadian provincial jurisdictions such as Ontario are not restricting the use of ozone generators at this time, because it has proven to be effective in other industries, and may be appropriate for some cultivation sites or extraction facilities. Meanwhile, the City of Denver's *Cannabis Environmental Best Management Practices Guide* does not recommend the use of ozone generators as a practice for odour control in indoor cannabis production<sup>118</sup>. The popularity of this tool with small scale indoor growers indicates that it may serve a useful purpose under some circumstances, particularly in well ventilated areas that can be safely managed.

## 5.1.4 Odour Neutralizers

### Description, Installation and Use

Odour neutralizers work by creating a binding reaction between VOC and the odour neutralizing compounds to remove odour. These can be sold as gels or oils in pots, which slowly emit into the air and

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<sup>114</sup> Home Depot. [Ozone Generators](#). Accessed December 2018.

<sup>115</sup> Calogirou, A., Larson, B.R., Brussol, C., Duane, M., and D. Kotzias. 1996. [Decomposition of terpenes by ozone during sampling on Tenax](#). European Commission Joint Research Centre. Analytical Chemistry. Vol. 68, Issue 9. P: 1499-1506.

<sup>116</sup> Wang, C., Xi, J.-Y., Hu, H.-Y., and Y. Yao. 2009. [Stimulative effects of ozone on a biofilter treating gaseous chlorobenzene](#). Environmental Science and Technology. Volume 43, Issue 24. P: 9407-9412.

<sup>117</sup> Shen, Y-S and Ku, Y. 1999. Treatment of gas-phase volatile organic compounds (VOC) by the UVO<sub>3</sub> process. Chemosphere. Vol. 8. Issue 8. Pp 1855-866.

<sup>118</sup> Denver Public Health and Environment. [Cannabis Environmental Best Management Practices Guide](#). 2018.

bind with terpenes, neutralizing them. The effect is not a masking one but a chemical one: the products react with the odorous compounds and neutralize the chemical function responsible for odour.

A distribution line can be installed such that it surrounds and treats the perimeter of the odour source with misting vapours that are emitted through neutralizers in piping. Neutralizing products also include odour curtains, which treat fugitive odour emissions from openings in wall and door frames. In this system the neutralizer is converted into a vapour that is dispersed and reacts with the odour compounds (e.g. VOC) within the airstream. This is not the same as a masking agent, which simply adds more VOC to an environment.

### **Cost and Lifetime of the Technology**

In a greenhouse, odour neutralizing can be accomplished by using piping around the perimeter of the cultivation areas that contain holes for the slow release of the neutralizers in a mist. This piping can also be installed in around the perimeters of greenhouses or indoor cultivation areas. According to those who have installed this type of air neutralizing system, the setup is expensive, with some estimates ranging from \$50,000 to \$70,000 (CAD) for installation and annual operating costs of \$60,000 to \$65,000 (CAD) per year<sup>119</sup>.

### **Environmental Effectiveness**

Odour neutralizers have shown to reduce VOC from cannabis cultivation sources from 20%-90%, a wide range due in part to factors such as the product set-up, use, and contact time with VOC<sup>120</sup>. The odour neutralizers themselves are quite affordable, however the cost of infrastructure involved in the products' use can be both extensive and expensive, and include the use of PVC piping around the external perimeter of a cultivation or extraction facility, including forced aeration or pumps to distribute the product. Overall, odour neutralizers are not as environmentally effective as carbon filters or biofilters. However, they are more effective than odour masking agents, which simply add additional fragrances (VOC) to cover up existing odours.

### **Applicability to the BC Cannabis Industry (type/scale)**

Odour neutralizers were originally developed to treat odorous compounds associated with wastewater treatment plants, such as hydrogen sulfide. More recently, larger cannabis operations have begun to adopt this tool. The more sophisticated odour neutralizing systems, using sprays, are mostly employed at larger operators, due to the costs involved in installation of infrastructure required to distribute the product. Products that emit the neutralizing agent slowly over time from a single point source, such as a pot of neutralizing gel, are popular among small-scale producers.

## **5.2 Best Available Control Technologies for Liquid Waste Management**

### **Regulatory Guidance for Liquid Waste Management**

Agricultural operators in BC have typically been able to determine how to manage their wastes subject to the condition that the practices do not result in pollution. The EMA's 2019 AEMCoP requires that environmentally protective agricultural practices will need to be followed and that receiving waters

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<sup>119</sup> Santa Barbara County Air Pollution Control District. 2018 [Presentation: Cannabis Odor Control Solutions](#). CAPCOA Spring Membership Meeting.

<sup>120</sup> Denver Public Health and Environment, 2018. Cannabis Environmental Best Management Practices Guide. Specific reference is on p51..

(watercourses and groundwater) will need to be protected through proper storage of nutrient sources<sup>121</sup>. Direct discharges to surface or groundwater are prohibited. Setback distances are also required for land application of agricultural products and compost to reduce risks of impacts to water quality.

Section 52 of the AEMCoP contains requirements for the application of nutrient sources in situations other than application to land, with specific requirements for container crops (e.g. indoor or greenhouse operations).

- The AEMCoP requires that nutrient sources or any leachate produced do not escape during transport or piping,
- Nutrient sources are not to be discharged or applied directly into a watercourse, across property boundaries, or go below seasonal high water tables, and;
- Contaminated runoff, leachate, and drift from sprayed nutrient sources must not enter a watercourse, cross a property boundary, or go below seasonal high water tables

The AEMCoP also specifies that the total amount of available nitrogen from all applied nutrient sources applied in one year of application is equal to, or less than the calculated amount of nitrogen required for optimum crop growth.

Operations that apply nutrient sources to crops but not to land are required to maintain records of crop nutrient requirements, the nutrient application rates and types of nutrient sources applied.

Septic disposal of commercial waste and discharges to receiving surface waters is not permitted in BC and may also be in contravention of the Federal *Fisheries Act*. They are therefore not considered within the BACTs. Section 36(3) of the *Fisheries Act* prohibits the deposit of deleterious substances into watercourses (deleterious substances could include many farm products or wastes).

BC's Environmental Farm Plan (EFP) reference guide includes several chapters and sections that pertain to water-related best practices and technologies<sup>122</sup>. The following are some examples of best practices that could be applied to cannabis cultivation in indoor, greenhouse, and/or outdoor growing scenarios whenever nutrients are being applied through an irrigation system:

- Install an efficient and uniform application system;
- Install a device to prevent backflow; and
- Match application rates and amounts to crop requirements to reduce over watering and excessive leaching (e.g., use a computerized irrigation scheduler controlling a drip system).

According to the EFP reference guide, leachate from agricultural activities (e.g. compost piles, irrigation over-drain) can be collected and treated in the following ways:

- For impervious subsoil, recover irrigation waste water in field drains for storage;
- For pervious subsoil, use concrete floors or polyethylene floor liners in greenhouses to collect all leachate; and
- In greenhouse production, use water recirculation techniques to both reuse leachate as a nutrient source and to conserve water.

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<sup>121</sup> BC Ministry of Environment, 2017. Agricultural Waste Control Regulation, [3<sup>rd</sup> Intentions Paper](#).

<sup>122</sup> BC Ministry of Agriculture, 2012. [Environmental Farm Plan Reference Guide](#).

However, it is recognized that due to disease transfer concerns, recirculation is not feasible for all operations. Any effluent discharged into the environment, which is not being used as a fertilizer for crop production, requires a permit from ENV.

### **BACTs for Liquid Waste Management**

Based on the cultivation practices associated with cannabis production and BC's regulatory environment for agricultural liquid waste, the following BACTs for liquid waste management are considered here:

- Water recapture and reuse
- Land application
- Small scale water treatment plant
- Aerobic digestion

Municipal drain disposal, which may be used by facilities that are connected to municipal wastewater treatment plants, are not considered to be a BACT and are therefore not discussed here.

## **5.2.1 Water Recapture and Reuse**

### **Description, Installation, and Use**

In indoor and greenhouse cannabis operations, rainwater can be collected from impervious surfaces (such as rooftops) and stored for reuse. Rainwater can be held in cisterns or retention ponds (Figure 17). The rainwater is collected, triple-filtered through a sand filtration system, and delivered to the plants via dripline. Other means of purifying recaptured water include UV radiation, copper technologies that can eliminate Pythium and other diseases, or using Electrochemically Activated Water<sup>123</sup>.

Additional water sources (e.g. well water or municipal water) are then used to supplement the collected water. This water recapture technology is also used in the vegetable greenhouse industry. Houweling's, a BC greenhouse vegetable producer, recycles and reuses more than 90% of its wastewater<sup>124</sup>. Similarly, Aurora Cannabis operations have a target to recycle 90% of the water used in their facilities.

Irrigation leachate created from over-drain (see section 4.2 for more details) can be integrated into these water recapture systems. The over-drain nutrient solution can also be refreshed with municipal or well water sources as needed. The nutrient solution is then fortified as required and used as a fertilizer source for other plants.

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<sup>123</sup> City of Denver, 2018. [Cannabis Environmental Best Practices Guide](#). Denver Public Health and Environment.

<sup>124</sup> Agriculture and Agri-Food Canada, 2014. [What's new in British Columbia – spotlight on greenhouse vegetables and floriculture](#).

A water recapture system is effective at reducing the volume of liquid waste produced, as the nutrient solution can be used in perpetuity, so long as salt loading (and associated Electrical Conductivity) is managed. Reverse Osmosis (RO) can also be used to reduce the volume of liquid waste, but it is costly. RO is not a treatment process with respect to removing contaminants from the water. Rather it partitions the contaminants into a more concentrated brine, and generates a fresh water permeate which can be recycled and reused in the growing operation. Consequently, while RO reduces the volume of wastewater requiring treatment, it doesn't necessarily reduce the costs for treatment overall. The brine created through the RO process would need to be disposed of through land application for other crops (depending on the salt content) or would need to be transported to a waste disposal facility.

### **Cost and Lifetime of the Technology**

The cost of installing a water capture and recirculation system is quite high, but can save the operator over time as the reliance on municipal water (or well water) is minimized. According to those in the vegetable greenhouse industry, the systems are effective over the long term but require regular maintenance.

### **Environmental Effectiveness**

The water recirculation system is very effective at reducing the amount of water inputs required from groundwater (wells) or from municipal water sources, and also at minimizing any wastewater discharges. The ability of the system to reuse the nutrient solution also reduces the volume of liquid waste that would need to be disposed of. The primary concern for water reuse and recycling is salt build-up and disease management. Overall, there are many more pros than cons with this water reuse and recapture system. The main drawback is the cost of installation and maintenance.

### **Applicability to the BC Cannabis Industry (type/scale)**

In vegetable greenhouse production water recapture and reuse systems are commonly used. It is expected that indoor and greenhouse cannabis operators will be motivated to adopt this technology particularly in areas where well water is not available. This system would be more challenging to operate in dry regions (e.g. Okanagan, Interior where precipitation is lower) or very cold regions (e.g. Kootenays, North). It would not be applicable to outdoor cultivation.



FIGURE 17. WATER RECAPTURE EQUIPMENT AT A CANNABIS FACILITY IN BC.

## **5.2.2 Land Application for Nutrient Solution**

### **Description, Installation, and Use**

Land application involves the collection and storage of liquid solution in order to spread it onto a crop field or other land base where it can be used as a nutrient source (similar to irrigation or fertigation). There is some precedent in policies regarding the spreading of manure onto agricultural lands in a manner not to exceed the agronomic requirements for crops grown in the soil. The following baseline nitrogen (N) application rates (kg N/ha/yr) are provided in the EFP guidebook (Table 6).

TABLE 6. NITROGEN APPLICATION RATES FOR BC CROPS.

Crop Type	Baseline Manure Nitrogen Application Rate (kg N/ha/yr)
Non-forage (e.g., berries, tree fruits, vegetables)	50
Forage grass (South Coastal BC)	300
Forage grass (rest of BC)	200
Forage corn	150

The land application of agricultural by-products is *not* considered to be a discharge to “groundwater”, provided it is sufficiently treated before it is discharged, or it becomes sufficiently treated as it passes through the soil depth before reaching groundwater. However, the AEMCoP should be referred to in order to ensure that all regulations are being followed, particularly in vulnerable aquifer areas.

### Cost and Lifetime of the Technology

Transportation costs associated with transporting the liquid nutrient solution to the crop for land application is the biggest cost associated with this BACT, unless it is spread on land directly adjacent to the operation. The solution may also need to be stored prior to land application in order to meet required soil conditions (e.g. no spreading permitted during wet winter months on the South Coast of BC).

### Environmental Effectiveness

Primary environmental concerns related to land application of nutrient solution are that the land application rate will exceed the soil’s ability to assimilate nutrients resulting in water and/or soil pollution. This can be exacerbated if the nutrients are applied during wet soil conditions. In part due to these concerns, nutrient management is a key section within the AEMCoP<sup>125</sup>. Depending on the location of the cannabis operation a nutrient management plan may be required. The environmental effectiveness of land application is optimized if the following practices are followed:

- Cover crops are planted to capture nutrients, which become available after harvested crop uptake ceases;
- Subsurface drainage systems are designed and managed to increase the size of the crop root zone available for nutrient capture; and
- Adequate vegetative buffers are established to capture nutrients moving through the soil to surface or groundwater.

The actual risk of nutrient runoff would depend on a variety of factors including crops being grown, yield potential, topography, proximity to watercourses, and climate. As previously mentioned, little is known about the level and activity of THC and its metabolites in liquid waste discharges from cannabis operations. It is anticipated that some residual amounts may be present, however the persistence of the compounds in the environment and their ability to biodegrade or bioaccumulate is not well understood. Furthermore, the long-term impacts of THC on soil or aquatic organisms is currently unknown<sup>126</sup>. Overall, the ability to use the wastewater from the cultivation facility as a nutrient source for other crops is a scenario that is extremely environmentally effective, provided the identified best practices are followed. This system is used in many other agricultural operations.

<sup>125</sup> BC Ministry of Environment, 2017. Agricultural Waste Control Regulation, [3<sup>rd</sup> Intentions Paper](#).

<sup>126</sup> Senate of Canada – Senate Standing Committee on Agriculture and Forestry. 42<sup>nd</sup> Parliament, 1<sup>st</sup> Sessions, December 3, 2015 to Present. Evidence Briefing: March 27, 2018. Topic: [Composting of cannabis residues and potential impacts on the environment](#).

### **Applicability to the BC Cannabis Industry (type/scale)**

This method may work well for cultivation systems that are affiliated with, and in proximity to large amounts of land and other crop production, however if the nutrient solution requires storage and transportation it could become very costly. Therefore, this method is most likely to be adopted by the outdoor and greenhouse sector. It is also possible that indoor facilities located on larger parcels of land could adopt this BACT.

## **5.2.3 Small Scale Water Treatment Plant**

### **Description, Installation, and Use**

A water treatment plant is useful for the removal of nutrients (such as nitrogen and phosphorus), pathogens, and other impurities from water prior to discharging the effluent to the environment. However, this technology is challenging to operate successfully on a small scale and it is expensive. A treatment plant, even a small one, requires regular maintenance and troubleshooting by skilled labourers. A basic water treatment system would require a fixed-film anoxic moving bed biofilm process, with addition of carbon. This would denitrify the nitrate present in the water and turn it into nitrogen gas. A chemical precipitation would then occur to remove phosphorous, and then finally a separation of solids and liquids using either a clarifier or a dissolved air flotation unit. The treated water could then be discharged to the environment or re-used for irrigation purposes. The treatment process will generate biosolids (sludge) and chemical precipitate in the form of aluminum phosphate, both of which would need to be disposed of.

### **Cost and Lifetime of the Technology**

The main costs associated with a water treatment system will depend on several factors:

- Flow rate requirements of the system (how fast the system will need to process a given volume of water);
- Chemistry of water entering the system;
- Target level of quality for treated water;
- Construction materials; and
- Level of system automation required.

A small basic water treatment system would cost an estimated \$600,000 to up to \$2,000,000 CAD (inclusive of design and engineering) to install<sup>127</sup>. An engineer would be required to be on staff to address issues and perform regular maintenance.

### **Environmental Effectiveness**

A small-scale water treatment plant would be effective at reducing the amount of nitrogen and phosphorous in the liquid waste, which could then be reused as a fertilizer input or could be land applied. However, a biological sludge and precipitated phosphorus would be byproducts that would require appropriate disposal. The complexity involved in managing a water treatment plant may result in sub-optimal performance by the BACT, unless skilled labourers are available around the clock to troubleshoot issues as they arise. Overall, this tool is environmentally effective but unlikely to become widely adopted.

### **Applicability to the BC Cannabis Industry (type/scale)**

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<sup>127</sup> Samco Water Purification Solutions, 2017. [How much does an industrial water treatment system cost?](#)

It's anticipated that the use of a small-scale water treatment plant may be a more sophisticated BACT than cannabis production facilities (or agricultural operations more generally) require. For most operations, the cost and scale of engineering associated with the water treatment system would be challenging obstacles to overcome. There would also need to be a land base requirement for the system to be in proximity to the production facility. There were no existing examples of this technology currently being used by cannabis operations in other jurisdictions.

#### 5.2.4 Aerobic Digestion

##### Description, Installation, and Use

New systems, based on the fundamentals of composting, are being developed to use aerobic digestion to manage wastewater and solid wastes from cannabis operations<sup>128,129</sup>. The steps involve a digestion of the waste and denaturing of the spent water to remove impurities (Table 7).

TABLE 7. AEROBIC DIGESTION STEPS.

Pre-treatment	Waste (solid and liquid) is introduced to a digester that contains microbes. The waste is mechanically and biologically broken down into leachate.
Stage 1-2	Additional enzymes and microbes are added to degrade Biological Oxygen Demand, Total Suspended Solids, and Chemical Oxygen Demand. At the end of this treatment phase, the leachate is 99.94% clean and meets municipal effluent discharge standards
Stage 3-4	Cannabinoid residues – including THC and CBD –are denatured.

##### Cost and Lifetime of the Technology

Currently the cost is very expensive (over \$100,000 CAD) and would likely only appeal to the larger cannabis production operators.

##### Environmental Effectiveness

This BACT is extremely environmentally effective. The technology separates the solid and liquid waste streams, and includes a sand filtration process, which is purported to result in a water fraction that is clean enough to meet all municipal effluent standards. The water could be reused into the irrigation process, thereby reducing wastewater by nearly 100%. The process occurs in a drum on-site, therefore eliminating the need for any transportation of either the effluent or the reclaimed water (Figure 18).



FIGURE 18. AEROBIC DIGESTER FOR CANNABIS WASTE. (SOURCE: BROME COMPOST).

##### Applicability to the BC Cannabis Industry (type/scale)

<sup>128</sup> Brome Compost. [Greenhouse and Cannabis Waste Solutions](#).

<sup>129</sup> Micron Waste Technologies. [A Solution for the Cannabis Industry](#).

The system is currently being trialed to confirm its efficiency in handling cannabis. For example, Aurora is piloting an aerobic digester for use at its 55,000 sqft indoor facility north of Calgary, where the company produces roughly 5,000 kg of cannabis annually<sup>130</sup>. Due to the high cost involved in purchasing and running the equipment, it is likely that only the largest facilities would contemplate using this BACT.

### 5.3 Best Available Control Technologies for Solid Waste Disposal

#### Regulatory Guidance for Solid Waste Disposal

Currently, there are no prescribed methods under the *Cannabis Act* for the disposal of cannabis waste, except that it must be rendered inert and unusable. In some jurisdictions, such as Alberta, requirements include that it be shredded and mixed with other waste products in order to achieve an unusable state. In BC, one licensed producer explained that all disposal of cannabis waste must be witnessed and signed-off on, in order to maintain the full chain of custody so that Health Canada can track all of the cannabis material. In that particular case, the producer sends all solid waste to a landfill, and remains on site at the landfill to witness the material being combined with other waste matter, shredded, and subsequently placed in an incinerator, in order to fully destroy the product.

The EMA empowers ENV to regulate pollution within BC. Waste is defined to include “air contaminants, litter, effluent, refuse, biomedical waste, hazardous wastes” and any other substance designated by Cabinet. Pollution is defined in the Act as “the presence in the environment of substances or contaminants that substantially alter or impair the usefulness of the environment.”

The AEMCoP has specific requirements regarding the collection, storage, and use of agricultural by-products. Agricultural vegetative debris from crop production is considered an agricultural by-product under the AEMCoP.

Section 30: solid agricultural by-products may be stored only in a permanent storage structure or as temporary field storage.

General storage requirements for agricultural by products in Section 34 requires that:

- Any leachate generated during storage must be collected or contained until it can be used in applying nutrients to the land.
- Runoff must be diverted away from the storage structure or storage area.
- The storage structure or storage area must be maintained so as to prevent contaminated runoff, leachate, wastewater, and solids from escaping, and if they do they must not enter a watercourse, cross a property boundary, or go below the seasonal high water table.
- Air contaminants from stored agricultural by-products must not cross a property boundary.
- Agricultural by-products must be stored in a manner that will deter the attraction of animals and vectors.

The three most common forms of cannabis waste management are landfill, compost off-site, and compost on-site<sup>131</sup>. According to the EFP reference guide, prepared and spent soil media used in indoor crop production should be stored in such a way as to prevent their release into the environment. Some local

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<sup>130</sup> Water Canada. December 17, 2018. [Cannabis legalization spurs a need for targeted wastewater treatment](#).

<sup>131</sup> Wong, A. 2018. [Cannabis Waste Implications: Regulating for clean air and water](#), Micron Waste Technologies. Recycling Council of Alberta.

jurisdictions in BC, including Metro Vancouver<sup>132</sup>, ban the disposal of agricultural wastes at landfills. The waste can be composted on site in a segregated area (i.e. the compost area must be fenced off and not accessible to the public), or it can be taken to a commercial compost operator. The waste can be incinerated at an approved incinerator, or through open burning. Newer technologies include aerobic digestion (fermentation).

The production of cannabis also includes the creation of non-plant-based material wastes such as rockwool (an inert non-degradable soilless medium manufactured from molten rock), plastics (such as strings, clips, pots), and chemical containers (used for pesticides and cleaning agents). Each of these are briefly described below, however the focus of the BACT discussion is on organic waste management.

The EFP reference guide recommends reusing rockwool (Figure 19) where possible (if handled carefully and if sterilized between crops), and when disposing of rockwool ensuring that it is done at an approved landfill, and is not buried on farm property.

Plastic disposal practices must comply with the EMA. Plastics should be reused or returned to depots for recycling, although in many areas soft plastics are not accepted for recycling. The Recycling Council of BC has a hotline to answer questions about recycling in BC (1-800-667-4321). Specific best practices regarding plastics used in the cannabis industry include:

- Reusing plant pots and bedding containers (thoroughly clean and disinfect to avoid plant disease transfer);
- Replacing non-recyclable or difficult to remove plastic products such as plant clips and twine with biodegradable materials;
- Cleaning and reusing waste sheet plastic for other purposes, such as coverings;
- Grinding up waste polystyrene for use as a potting soil amendment; and
- Not dumping or burying plastics on farm property.

The disposal of chemical containers must be in accordance with the EMA and the Hazardous Waste Regulation. Section 50 of the Regulation specifies general requirements for containers. Containers may be reused if they are in good condition or recycled. If reusing or recycling of containers is not practical they may be disposed of at a permitted facility provided that they no longer contain enough waste to qualify as hazardous or have been properly decontaminated with a suitable solvent<sup>133</sup>.

#### **Note: Disposal of an Entire Crop**

It is unclear if different waste management practices need to be followed if there is crop failure and the entire crop needs to be disposed of, which would have implications regarding the overall THC levels of the waste material. Current producers that we spoke to indicated that, if presented with this scenario, that they would likely landfill or compost the entire crop.



FIGURE 19. ROCKWOOL.

<sup>132</sup> Metro Vancouver, 2018. [Disposal Ban Program](#).

<sup>133</sup> BC Ministry of Environment, revised 2016. [Hazardous Waste Legislation Guide](#).

## BACTs for Green Waste Management

The following options for cannabis waste disposal are further described in this section:

- Composting
- Incineration
- Fermentation (Anaerobic Processing)

The practices of landfilling and open burning are not considered BACTs and they are therefore not discussed here.

### 5.3.1 Composting

#### Description, Installation, and Use

Composting of cannabis is permitted in all of the states reviewed for this report (Washington, Oregon, Colorado, and California) – see Section 6 of the report for more details. Theoretically the material could be composted on site (if space allows) or transported offsite to composting facility (Figure 20). Organizations such as the Compost Council of Canada believe that composting should be the preferred method to process cannabis residuals<sup>134</sup>.



FIGURE 20. COMMERCIAL COMPOST FACILITY IN EUGENE, OREGON THAT RECEIVES CANNABIS PLANT MATERIAL.

Composting is not the same as stockpiling, which is simply placing the plant and spent growing material in piles but not actively managing them. In vegetable greenhouse production spent soil media is often stockpiled outside the greenhouse, however it is not often actively managed as compost. Without proper on-site management, this practice may not lead to degradation and may not satisfy regulatory criteria. A managed composting process reaches high temperatures to allow pathogens and seeds to be destroyed. The process is heterogeneous and non-distinguishable, with the initial preparation including grinding and mixing into a co-mingled material. Cannabis plant material is high in carbon, therefore it will require a nitrogen source for successful composting. Pellet and powder forms are a safe option, but externally-sourced nitrogen feedstocks can increase the risk introducing pathogens into the system if the finished compost will be used in the operation.

Not all cannabis waste is compostable. In particular, rockwool, a common component of growing media, is not compostable. However, most waste elements of cannabis production can be composted<sup>135</sup>. These include:

- Coco-coir
- Peat
- Leaves and trimmings
- Stems
- Rootballs (carbon rich)

The AEMCoP sets out direction to minimize the potential for leaching from compost piles. This includes carrying out composting on a hard, impermeable surface designed to collect leachate and using covered

<sup>134</sup> Harwood, S. May 11, 2018. [Health Canada requires that marijuana waste be destroyed – but is it a missed opportunity?](#) Global News Canada.

<sup>135</sup> Ahearn, T. and P. Larouche. 2018. Composting in the cannabis industry, Brome Composting

facilities in areas receiving high rainfall. Commercial composting operations who wish to be eligible to distribute, sell, or land apply compost must satisfy a number of criteria, requirements, and standards under the Organic Matter Recycling Regulation (OMRR). Cannabis is not an approved feedstock currently under OMRR, but is considered an agricultural by-product (vegetative debris), thereby making it suitable for composting under the AEMCoP.

The BC Agricultural Land Reserve Use Regulation allows the production, storage and application of compost from agricultural wastes if the material is produced on the farm and/or if at least 50% of the compost measured by volume is used on the farm and is in compliance with pertinent regulations under the EMA.

The EMA also has conditions under the Health Hazards Regulation under Section 8(1): separation distance from wells to be at least 30 m from any probable source of contamination, which could include compost materials and associated leachate.

### **Cost and Lifetime of the Technology**

The costs associated with composting range widely, with simple on-farm setups costing under \$5,000 to large scale commercial composting facilities requiring multi-million dollar investments. Regardless of the scale of operation, composting is not an autonomous activity. It requires management and oversight to monitor moisture levels and carbon:nitrogen ratios, among other factors.

### **Environmental Effectiveness**

Composting can significantly reduce the volume of crop waste and transform it into a soil amendment and/or nutrient resource for other crops. Furthermore, composting can prevent greenhouse gas emissions that would occur if the material was otherwise transported to a landfill. Therefore, when managed properly, composting can be a very environmentally effective BACT. Potential primary environmental concerns related to compost include:

- Formation of leachate that results in soil or water pollution; and
- Odour, particulate, and gas emissions associated with the composting activity.

Fortunately, these issues can be avoided through proper maintenance and best practices as set forth in the AEMCoP. While there is a lack of detailed information available, it is generally accepted that THC and CBD residuals in cannabis waste is low, although the potential impacts of THC residuals in leachate on aquatic organisms is uncertain<sup>136,137</sup>.

### **Applicability to the Cannabis Industry (type/scale)**

In BC, on-farm composting is a fairly common agricultural practice. However, this would be problematic for indoor cannabis production occurring in locations where outdoor space does not allow for composting. In these cases, the material would need to be shipped to a commercial composting facility that is approved to accept cannabis waste as a feedstock. Other challenges to composting include the necessary separation of all organic wastes in the facilities from inorganic wastes that are not allowed in composting and the potential need to purchase compostable materials (e.g. leaves, cardboard) off-site to mix 50/50 with the cannabis wastes.

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<sup>136</sup> Senate of Canada – Senate Standing Committee on Agriculture and Forestry. 42<sup>nd</sup> Parliament, 1<sup>st</sup> Sessions, December 3, 2015 to Present. Evidence Briefing: March 27, 2018. Topic: [Composting of cannabis residues and potential impacts on the environment](#).

<sup>137</sup> Wong, A. 2018. [Cannabis Waste Implications: Regulating for clean air and water](#), Micron Waste Technologies. Recycling Council of Alberta.

### 5.3.2 Incineration

#### Description, Installation, and Use

Incineration is a waste treatment process that involves the combustion of organic substances in an enclosed vessel at high-temperatures and converts the waste into ash, flue gas and heat (Figure 21). The ash is mostly formed by the inorganic constituents of the waste. In some cases, the heat generated by incineration can be used to generate electric power.

Agricultural incineration requirements in the AEMCoP are targeted at livestock mortality disposal. Non-farm incineration, which may describe incineration associated with cannabis disposal, may require pre-authorization under the EMA. If the waste is categorized as “hazardous” then it may be prohibited from being incinerated<sup>138</sup>. Furthermore, local bylaws may prohibit incineration in some local jurisdictions.

As an alternative to incineration, cannabis plant waste could be used as a biomass fuel for agricultural boilers and heaters. However, the waste may need to be treated in order for it to align with heater and boiler requirements under the AEMCoP.

Incinerators often have two burn chambers. The primary chamber is where the material is initially combusted, and a secondary burn chamber then combusts unburned gases and particulates (Figure 20). This secondary burn process is intended to reduce stack emissions and comes at a cost for added equipment and burner fuel. The effectiveness of a secondary chamber to reduce stack emissions varies based on what is being burned and how well the incinerator is designed. Some manufacturers claim that cannabis byproducts can be reduced to just 3-5% of their original volume as ash<sup>139</sup>.

The temperature of the air space inside the combustion chamber varies depending on what is being burned. Product specifications indicate that 540°C may be adequate to burn with no visible emissions<sup>140</sup>. Incinerators can be fueled by natural gas, propane, or diesel. Fuel (diesel) consumption is less than 10 L/hr for smaller models, and up to 50 L/hr for the largest model. Burn rates are 10 kg/hr of material for the smaller incinerator models and up to 750 kg/hr for the largest model. A mid-range model would be able to burn 70 kg/hr of plant material using 15 L/hr of diesel. Outside installation is recommended with a simple metal roof or three-sided metal shelter, providing a minimum of four feet of clearance from any combustible roof materials. Incinerators can also be placed in a shipping container, or placed on a trailer in order to be mobile (Figure 22).



FIGURE 21. EXAMPLE OF INCINERATOR WITH PRIMARY AND SECONDARY BURN CHAMBERS. (SOURCE: FIRELAKE INCINERATORS).



FIGURE 22. EXAMPLE OF MOBILE INCINERATION UNIT FOR THE CANNABIS INDUSTRY (SOURCE: INCINER8 TECHNOLOGIES).

<sup>138</sup> BC Ministry of Environment, 2017. [Factsheet on Burning Requirements](#).

<sup>139</sup> Ibid.

<sup>140</sup> [Inciner8 Incinerators](#), based in Merseyside, UK.

### Cost and Lifetime of the Technology

Incinerator prices range from \$8,000 CAD to \$30,000 CAD and the life of an average incinerator is 15 years<sup>141</sup>.

### Environmental Effectiveness

Incinerating can lead to the development of fine particulates, and the remaining ash requires disposal. To minimize impacts, nearly all incineration requires authorization under the EMA. There is a high level of fossil fuel consumption associated with incineration, but the by-product of incineration is energy, which can be converted into hot air for heating or hot water for cleaning/washing.

An emissions sample sheet from an incinerator<sup>142</sup> with a secondary chamber indicates the following air quality parameters measured over a 0.5 hour average was 12 mg/m<sup>3</sup>. This compares favourably with the provincial particulate matter emission limit<sup>143</sup> of 35-50 mg/m<sup>3</sup> and the Metro Vancouver<sup>144</sup> limit of 10-18 mg/m<sup>3</sup>, whereby the range of acceptable limits is related to the size of the boiler or heater.

Overall, the use of an incinerator may be considered environmentally effective from the perspective of reducing the overall amount of solid waste. However, this must be weighed against the use of fossil fuels and the creation of smoke and particulates associated with incineration.

### Applicability to the Cannabis Industry (type/scale)

Incinerators are being used at cannabis facilities in the USA and Canada where the primary waste burned is unused green waste (e.g. no rockwool or inorganic soil waste is being incinerated). This approach could be feasible for cannabis operations in BC where space is of concern and on-site composting is not possible. In Alaska and Washington, if cannabis waste will be disposed of through a solid waste incinerator, the cannabis waste must be mixed with at least an equal amount of materials not typically considered suitable as a feedstock for composting such as paper, cardboard or plastic<sup>145,146</sup>.

## 5.3.3 Dry Anaerobic Digestion (Fermentation)

### Description, Installation, and Use

Cannabis waste can be treated anaerobically onsite using a dry anaerobic digestion process. The term “dry” is used when the organic matter is >20% dry matter<sup>147</sup>. Each digester is an airtight box, heated to a stable 37°C. The process, which takes 6-8 weeks, involve microorganisms that break down biomass (e.g. leaves, stems) in an oxygen-free environment (Figure 23). Fermentation occurs in four steps: hydrolysis, fermentation (acidogenesis), acetogenesis, and methanogenesis<sup>148</sup>. The resulting product is gas (sometimes referred to as biogas), and wet residue called digestate. Several digesters can operate in parallel to allow a constant treatment of waste over time. The system is tolerant to the input of sand, fibres, and large particles.

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<sup>141</sup> [Firelake Incinerators](#), based in Virginia, USA.

<sup>142</sup> [Inciner8 Incinerators](#), based in Merseyside, UK.

<sup>143</sup> BC Ministry of Environment, 2019. Environmental Management Act, Agricultural Environmental Management Code of Practice. Section 11.

<sup>144</sup> Metro Vancouver, 2008. [Emission Regulation Bylaw No. 1087](#), Appendix 2. Updated 2013.

<sup>145</sup> Solid Waste Program. [Marijuana Waste. Alaska Administrative Code \(3 AAC 306\)](#). Government of Alaska, Division of Environmental Health.

<sup>146</sup> State of Washington. [Marijuana waste disposal – Liquids and Solids](#). Title 314: Chapter 314-55, Section 314-55-097.

<sup>147</sup> Biogas World, 2018. [State of the art dry and wet anaerobic digestion systems for solid waste](#).

<sup>148</sup> Wageningen University. [Anaerobic fermentation](#). Accessed March 2019.

The positive benefits of fermentation are that a low level of gases are created and the liquid fraction of the digestate may be used as nutrient-rich fertilizer and is often referred to as a probiotic ‘tea’<sup>149</sup>.

However, there may be high costs associated with disposal of the remaining solid digestate or sludge. Alternatively, it may be land-applied as a soil amendment if an appropriate-sized land base is available. The commercial-scale digesters require approximately 600 m<sup>2</sup> of space and can accommodate 2,000-30,000 tonnes of waste per year.

### Cost and Lifetime of the Technology

A commercial anaerobic digestion facility is expensive due to the engineering required and the construction of the structures. Retailers suggest that the minimum number of fermenters should be two per site, which allows the operator to continuously run and process waste without any interruptions. Estimates range from \$750,000 to \$1.5 million CAD<sup>150</sup>.

### Environmental Effectiveness

Overall this is an effective method at reducing the volume and weight of solid cannabis waste. Other than the need to dispose of the solid fraction after digestion, there are few, if any, negative environmental impacts associated with dry anaerobic processing: the power requirements are low, there are no engines or pumps required. Information regarding non-CO<sub>2</sub> greenhouse gas production as part of the fermentation process indicates that methane is not produced in significant amounts, while no information on nitrous oxide has been found<sup>151</sup>. It would be possible to align this technology with co-generation for heat production using the biogas fraction. Research in this sector is ongoing and trials in the Netherlands and the USA, using non-cannabis crop and livestock wastes, are underway.



FIGURE 23. EXAMPLE OF DRY ANAEROBIC FERMENTATION BOXES ON A FARM IN FRANCE (SOURCE: BIOGAS WORLD, 2019).

### Applicability to the Cannabis Industry (type/scale)

The fermentation process can accommodate any size of cannabis operation, however the cost involved in engineering and construction will likely dictate that only the larger commercial cultivation and processing facilities would invest in this technology.

## 5.4 The Future of Best Available Control Technologies

This BACTs section has provided a review of the best available control technologies for the cannabis sector at this point in time. The industry is still emerging and the technologies used to mitigate and minimize air, water, and solid waste emissions continue to evolve. It is anticipated that some of the technologies currently applicable to larger cultivation practices may become adapted to be scaled for smaller production sites over time. This would improve overall affordability and the ability for producers at all scales to become more environmentally effective within the industry.

<sup>149</sup> Merfield, C.N. 2012. [Treating food preparation ‘waste’ by Bokashi fermentation vs. composting for crop land application: A feasibility and scoping review](#). The Biological Husbandry Unit Farming Centre.

<sup>150</sup> Biogas World, 2018. [State of the art dry and wet anaerobic digestion systems for solid waste](#).

<sup>151</sup> Merfield, C.N. 2012. [Treating food preparation ‘waste’ by Bokashi fermentation vs. composting for crop land application: A feasibility and scoping review](#). The Biological Husbandry Unit Farming Centre.

## 6.0 Jurisdictional Differences in Regulation, Compliance, and Enforcement

This section of the report explores the jurisdictional differences in regulation of cannabis production and processing with regards to environmental discharge, and presents information regarding the compliance and enforcement oversight. Throughout this discussion, a focus is placed on policies and regulations pertaining to environmental discharges from commercial cannabis operations. Issues such as retail licensing, distribution, minimum age for consumption, and personal cultivation are outside the scope of this project.

A number of questions related to regulatory oversight, compliance and enforcement, dispute resolution, and allocation of resources with regards to environmental management of licensed cannabis producers are explored for each jurisdiction. In particular, answers to the following questions were sought through a literature review, jurisdictional scan, and interviews with subject matter experts:

### Policies and Regulations:

- How are air emissions regulated?
- How are pesticides regulated?
- How are water discharges regulated?
- How is solid waste management regulated?

### Compliance, Enforcement, and Dispute Resolution:

- How are waste and air discharge complaints handled by regulators and cannabis producers?
- How can these conflicts be expected to change based on urban and rural environments?
- What are the compliance promotion activities for the cannabis industry?

### Regulatory and Compliance Costs:

- What are the estimated costs for other jurisdictions that regulate the environmental impacts of the cannabis industry, in terms of total costs relative to number of cannabis operations?
- What is the proportion of overall compliance promotion and enforcement costs attributed to cannabis operations?

Information gleaned from a literature review and interviews with key stakeholders is presented for the following jurisdictions:

- Government of Canada
- Province of Ontario
- Province of Alberta
- Washington State
- Oregon State
- Colorado State
- California State

It is worth noting that regulations of pesticides in the USA differs greatly from within Canada and the provinces, therefore information was gathered regarding pesticide regulation from Canada federally and from Ontario and Alberta, but not from the US examples. This scope focus was determined through communication with BC Ministry of Environment and Climate Change Strategy, the BC Ministry of Agriculture, and Metro Vancouver.

## 6.1. Government of Canada

### 6.1.1 Federal Acts and Regulations

At the Federal level in Canada, Health Canada regulates all cannabis cultivation and processing licensing through the *Cannabis Act* and associated Cannabis Regulations. The regulations point to Good Production Practices (Cannabis Regulations Sections 79 – 92), which include the following:

**Section 43 – Destruction** - A holder of a licence is authorized to destroy cannabis only in accordance with a method that:

- (i) complies with all federal, provincial and municipal environmental protection legislation applicable to the location where it is to be destroyed, and
- (ii) does not result in any individual being exposed to cannabis smoke or cannabis vapour;

This provision only applies to what is defined as “cannabis” under the Act and does not apply to other vegetative waste or growing media.

**Section 81 - Pest control products** - Cannabis must not be treated with a pest control product unless the product is registered for use on cannabis under the *Pest Control Products Act* or is otherwise authorized for use under that Act.

There are concerns amongst cultivators that outdoor production could be contaminated by pesticide drift from agricultural operations and result in the contamination of the cannabis crop by exposure to non-permitted pesticides. To meet testing requirements, licence holders under the Cannabis Regulations must demonstrate that none of the unauthorized pesticide active ingredients, as listed in the [Mandatory cannabis testing for pesticide active ingredients - List and limits](#) published by Health Canada, are used to treat their products or have contaminated their products.

At the Federal level, pesticides are regulated by the Pest Management Regulatory Agency (PMRA). The PMRA oversees the *Pest Control Products (PCP) Act*. Only pesticides registered under the *PCP Act* or otherwise authorized for use under that Act can be used for cannabis cultivation. The PMRA provides an online tool that lists all of the authorized PCP for cannabis. At time of writing, there were 24 PCP authorized for cannabis. The pesticides listed are for “commercial” use, are biologically active, and have been approved for use in the organic agriculture sector. At the time of writing, the pesticide label language restricts the products to indoor cultivation only.

As of January 2019, Health Canada requires regular testing of all cannabis products, before they are sold to the consumer, for pesticide residues<sup>152</sup>. This includes fresh or dried cannabis, cannabis plants and seeds, and cannabis oil, and applies to cannabis produced indoors and outdoors, and any cannabis products derived from industrial hemp. In addition, all cannabis products intended for export must be tested.

Cannabis licence holders are responsible for this testing. The objective of the mandatory testing is to ensure that:

- The requirements of the *Pest Control Products Act* and the *Cannabis Act* related to the use of PCP are met
- Individuals have access to quality-controlled cannabis products that have not been treated or contaminated with unauthorized PCP
- Individuals have accessible and accurate information to make informed decisions

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<sup>152</sup> Health Canada, 2018. Mandatory Testing for Pesticide Active Ingredients – Requirements. ISBN: 978-0-660-28014-1

**Section 85 - Filtration of air** - The building or part of the building where cannabis is produced, packaged, labelled and stored must be equipped with a system that filters air to prevent the escape of odours.

Section 85 (Filtration of air) is objective-based (i.e. escape of odours must be prevented) rather than prescriptive based (i.e. specific technologies must be installed, or specific practices must be followed). How the objective of preventing the escape of odours is achieved is at the discretion of the licensed cultivator, and may vary from location to location. This provides a level of control for the operators, such that the determination of technologies and/or practices can be made based on which solutions best fit the needs of the cultivation site.

### 6.1.2 Federal Compliance, Enforcement, and Dispute Resolution

The Health Canada Compliance and Enforcement Policy for the *Cannabis Act* is intended to help regulated parties comply with the *Cannabis Act* and Cannabis Regulations. This policy is for regulated parties who are authorized by Health Canada for activities such as cultivation, processing, and analytical testing<sup>153</sup>. Health Canada manages risks posed to public health and public safety in connection with cannabis through a variety of compliance and enforcement activities, including compliance promotion, compliance monitoring, and enforcement actions.

A new stakeholder outreach branch, based in Ottawa, is responsible for much of the communication between Health Canada and other levels of government.

Health Canada promotes compliance through educational activities and information sharing on legislative and regulatory matters. This includes policies and guidance documents intended to help regulated parties better understand the requirements and their responsibilities. These include the following information bulletins and fact sheets:

- [Task force on cannabis legalization and regulation](#);
- [Good production practices](#);
- [Pest control products for use on cannabis](#);
- [Mandatory cannabis testing for pesticide active ingredients – requirements](#);
- [Expectation of ethical conduct](#);
- [What to expect during inspections and audits](#); and
- [A summary of compliance and enforcement policy for the Cannabis Act](#).

Health Canada monitors the activities of regulated parties to verify they are complying with the Act and its regulations and to prevent non-compliance. Compliance monitoring includes gathering and analyzing information, carrying out compliance verification activities and collaborating with other regulatory agencies as appropriate. As part of monitoring and verifying compliance, Health Canada has the authority to conduct inspections. Inspections may involve actions such as:

- Visually examining a facility, inventories, equipment, packaging, labelling and websites;
- Collecting and reviewing documents and records; and
- Taking samples for laboratory analysis.

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<sup>153</sup> Health Canada, 2019. [Compliance and Enforcement Policy for the Cannabis Act](#).

When non-compliance is identified, there are a number of options to support achieving compliance: voluntary compliance, including consent to forfeiture, product detention, product disposal, product stop-sale and product recall.

Health Canada will address odour-related complaints through a site visit inspection. The tools being used at the facility to mitigate odours will be reviewed with the licensee to confirm they are operating optimally. The technology will be verified (e.g. are filters being replaced regularly), however no scientific methods or other quantifying tools are used (e.g. air samples are not collected or Nasal Rangers employed). Health Canada can request that corrective action takes place to better control odour, however it is unlikely that it would trigger a licence suspension or revocation. Rather, the issue would be cited in the inspection report, and could be listed as a minor or major infraction. On the other hand, if a licence holder approached Health Canada for an expansion request, and it had a history of odour-related complaints, then the expansion request could be denied.

Health Canada reserves the right to audit licence holders to ensure that all licence requirements are being met. Audits are expected to occur on an annual basis and typically occur 2 or 3 times a year, or more frequently if complaints are received. For solid waste, once the cannabis waste has been destroyed and rendered unusable, it could be disposed of by any number of methods. Health Canada only requires confirmation that the material is destroyed.

Health Canada is committed to providing licensed producers with information and guidance, in order to assist them in meeting regulation requirements<sup>154</sup>. However, there is also an acknowledgement that licence holders must bear a certain amount of responsibility for understanding regulations, therefore it is not a priority to provide too much additional assistance with bringing licence holders into compliance.

Information regarding compliance and enforcement that Health Canada uses to communicate to licensed producers is all on their website and include:

- A fact sheet entitled “Inspections of Licensed Producers” outlining the mandate and the activities of Health Canada, including inspections;
- Frequently Asked Questions about inspections; and
- An inspection checklist for licensed producers.

Previously under the Access to Cannabis for Medical Purposes Regulation (ACMPR) and Medical Marijuana Production Regulation (MMPR) there were information bulletins, or letters, issued regarding specific compliance topics. Under the new *Cannabis Act*, this method of communication has not been continued.

Other methods of communication include verbal meetings and inspection reports.

Health Canada only has a few tools available through which it can refuse, suspend, or revoke a cannabis cultivation and/or processing licence. Health Canada cannot refuse to issue a licence based on provincial or local bylaws, and there is a strong likelihood that there may be a lack of awareness of specific local policies and regulations. It is up to the license applicant to ensure that their facility is aligned with provincial and/or local regulations.

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<sup>154</sup> Information regarding inspections, audits, and compliance and enforcement is available for the Access to Cannabis for Medical Purposes Regulations, however this has not yet been updated to reflect the Cannabis Regulations. It is likely that the information will not significantly change.

### 6.1.3 Federal Regulatory and Compliance Costs

Based on the information available, it was not possible to determine the costs associated with the legalization of cannabis and associated compliance and enforcement costs at the federal level. However, Health Canada's cannabis licensing division staff numbers have tripled from just over 100 to nearly 400 in the last six months.

## 6.2. Provincial

Provincial and territorial governments share responsibility with the federal government for the oversight and licensing of the cannabis supply chain. Provinces and territories have the authority to authorize the distribution and sale of cannabis in their respective jurisdiction. This provincial or territorial legislation must impose certain conditions on sellers of cannabis outlined in the Act: only cannabis produced under the *Cannabis Act* may be sold; cannabis may not be sold to young persons; appropriate records must be kept; and adequate measures must be taken to reduce the risk of diversion<sup>155</sup>.

Provinces and territories as well as local governments may also tailor certain rules in their jurisdictions, such as setting a higher minimum age or restrictions on personal cultivation of cannabis, and may have compliance and enforcement policies that apply to the activities they regulate. Where necessary, Health Canada works with provincial and territorial authorities to support the public health and public safety objectives of the Act.

### 6.2.1 Ontario

Nearly half (75 of 149) of Canadian cultivation and/or processing licences have been issued for businesses that are based in Ontario, therefore this jurisdiction was selected for a review as to how environmental regulations are being used for the cannabis industry. Information for this section was obtained through a search of online documents and through interviews with staff from the Ontario Ministry of Agriculture Food and Rural Affairs (OMAFRA) and the Ontario Ministry of Environment, Conservation, and Parks (MECP).

Most (60-70%) of the cannabis produced in Ontario is grown in greenhouses. Most of these greenhouses have been converted from other uses, although there are a few new greenhouses that are purpose-built for cannabis production. Outdoor production hasn't commenced in Ontario, however OMAFRA is expecting some outdoor operations within the next few years. Due to climate, it is likely that there would only be one or two crop rotations a year.

The Ontario Provincial Policy Statement includes a reference to accommodating agriculture in rural lands. Rural lands are those that are located outside settlement areas and which are also outside of prime agricultural areas<sup>156</sup>. The Ontario Provincial Policy Statement protects and promotes agricultural viability of rural economies by permitting more on-farm diversified uses, such as agri-tourism; by providing more flexibility for agriculture-related uses; and by protecting and promoting agricultural uses, agriculture-related uses, on-farm diversified uses, and normal farm practices in accordance with provincial standards.

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<sup>155</sup> Health Canada, 2019. [Compliance and Enforcement Policy for the Cannabis Act](#).

<sup>156</sup> [An Introduction to the Provincial Policy Statement](#), 2014: Rural Ontario. Government of Ontario.

Within rural lands in municipalities, agricultural uses, agriculture-related uses, on-farm diversified uses and normal farm practices should be promoted and protected in accordance with provincial standards. This policy direction provides a level of protection for commercial cannabis operations, and other agricultural activities, against complaints regarding odour and other environmental discharges. This provides a similar function to British Columbia's *Farm Practices Protection Act* (FPPA). In Ontario, the *Farming and Food Production Protection Act* would protect the operation from any liability claims<sup>157</sup>. In addition to the Ontario FFPPA, the Ontario *Environmental Protection Act*, *Nutrient Management Act*, and *Water Resources Act* may all pertain to cannabis cultivation and extraction facilities.

## Ontario Air Discharges

Ontario's *Environmental Protection Act*<sup>158</sup> (EPA), which prohibits the discharge of contaminants without Environmental Compliance Approval or registration on the Environmental Activity and Sector Registry. Under the EPA, compliance and enforcement regarding odour is only triggered if there is a risk posed to public health. In practice it is challenging to provide evidence to show that odours are posing a risk to health. As a result, farm-related odour complaints have not been a high compliance priority in Ontario to date. Any odour complaints associated with cultivation facilities that are federally licensed are referred to Health Canada.

The purpose of Ontario's<sup>159</sup> FFPPA is to protect agricultural activities in agricultural and rural areas. Under the FFPPA, "normal farm practice" means a practice that,

- (a) is conducted in a manner consistent with proper and acceptable customs and standards as established and followed by similar agricultural operations under similar circumstances, or
- (b) makes use of innovative technology in a manner consistent with proper advanced farm management practices.

The FFPPA provides liability protection only and does not supersede the EPA or *Water Resources Act*, or other provincial policies and regulations. It is up to MECP to determine if the practice entails risk-adverse effects, and if it does then the ruling may differ from the FFPPA findings. A complainant would have to provide evidence from a health provider or other source that adverse health impacts were occurring, this has not happened to date. As such, there have not been any rulings made either for or against a cannabis producer regarding odour.

Control measures for odour emissions for other agricultural-related activities, such as from compost facilities, are regulated by subsection 14 (1) of the EPA and *Ontario Regulation 419/05 Air Pollution – Local Air Quality*, made under the EPA. The Regulation places limits on the concentration of contaminants in the natural environment that are caused by emissions from a compost facility. The concentrations in the natural environment are calculated at a nearby receptor referred to as a "point of impingement" (or POI). Demonstration of compliance with the Regulation begins with the development of an Emission Summary and Dispersion Modelling (ESDM) report, which must include a summary of total air emissions for individual contaminants from a property. Air dispersion models are then used to predict off-property concentrations of individual contaminants at nearby sensitive receptors (e.g., residences, nursing homes, health care facilities, day cares, schools) based on air emissions at the source. The Regulation requires that where a facility discharges a contaminant into the air from one or more sources, the concentration at any POI resulting from that combined discharge must be less than the standard prescribed in the Regulation. While

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<sup>157</sup> OMAFRA. 2019. [Ontario Farming and Food Production Protection Act and nuisance complaints](#). Agdex #700, Order # 05-013.

<sup>158</sup> [Ontario Environmental Protection Act](#). 2019.

<sup>159</sup> [Ontario Farm Food Protection Act](#). 2019.

hypothetically this regulation could be expanded to include cannabis facilities outside of agricultural areas, there is no indication that this will occur in the near future.

In terms of measuring odours emanating from farms, OMAFRA experimented with Nasal Rangers, but found that they are easier to use in swine barns than in greenhouses (due primarily to air flow) and in general did not find that they were effective for the measurement of cannabis odours. Odour (e.g. from emissions of terpenes) from cannabis fluctuates over the cycle of the plant's life and due to variations in air flow as the plumes of odour are difficult to locate with the Nasal Ranger. OMAFRA found that odour panels worked better than Nasal Rangers for detecting cannabis odours. The panels were able to identify differences between terpene levels in greenhouses compared to indoor operations, and also for differences between strains. It was determined that for carbon filters to function effectively, they must be used in conjunction with a HVAC system.

While municipalities cannot regulate odours, they can require a rezoning application for cannabis operations within their jurisdiction or impose setbacks. For example, Leamington has indicated that the municipality will be welcoming cannabis production. In the fall of 2018, after approving 9 rezoning applications for medical cannabis production, Kingsville decided to place a temporary suspension on the consideration of new applications. Recently in February 2019, two new rezoning applications for medical cannabis production in existing greenhouses were approved in Kingsville<sup>160</sup>. Norfolk County has imposed 300 m setbacks between cannabis operations and areas that include residences and day care facilities<sup>161</sup>, however if carbon filters are installed then the operation can be within 150 m from residential areas.

In terms of BACTs for odour management, Ontario has not ruled out the use of any tools at the date of this report. For example, ozone generators are used safely and effectively in several industries (e.g. water treatment). Ozone is regulated by Health Canada, so a permit is required to use this tool. Masking agents, while perhaps not an ideal tool to be used in the long term, can be a good temporary tool for producers who are in the process of installing more robust air filtration systems, or who are in the process of maintaining or repairing other technologies. For example, if a HVAC system needs to be upgraded and connected to a carbon filter system, the masking agents can help mitigate odours until other tools are operational.

In general, the province of Ontario is not making recommendations about specific tools or technologies for air filtration and odour management, because there is not enough information available to make these assessments. When asked about concerns regarding VOC contributing to ground level ozone, it was stated that transportation-sourced VOC from Detroit and Toronto are of much more concern than those that may arise from cannabis production. There is also an assumption by the Ontario Government that VOC from other crops are just as high as those generated by cannabis, but these are not being flagged by the public because they don't produce a distinctive odour. There is a desire to conduct more research as to what is working and what is not in terms of odour measurement and laboratory analysis. There is an understanding that when Health Canada is conducting audits with licensed producers, one of the factors that they are assessing is odour.

Since 2014, Ontario has been referring all odour complaints to Health Canada. However, designated growers are not required under Health Canada to use air filters, and some designated growers are very large. In many cases, complaints against these types of facilities are referred to law enforcement because

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<sup>160</sup> [Kingsville approves rezoning requests to allow for medical cannabis greenhouses](#). CBC News. February 11, 2019.

<sup>161</sup> [Norfolk County By-Law 25-Z-2018](#). A By-Law to amend zoning by-law 1-Z-204, as amended, for all lands within Norfolk County.

there are elements of criminal activity involved. Health Canada will only respond to odour complaints against licensed producers.

### **Ontario Pesticide Management**

At a provincial level, a province can prohibit the use of federally registered pesticides or add more restrictions or conditions to the use of the pesticides. However, a province cannot authorize the use of a pesticide that has not been approved by the federal *PCP Act*. A province can issue pesticide application certificates, pesticide licences, and permits. Agricultural operators must have a pesticide application certificate. The transportation and disposal of pesticides is also regulated at the provincial level.

In brief, the pesticide regulatory system, which applies to all users of pesticides in Ontario, works as follows:

- The Ontario MECP regulates the sale, storage, use, transportation and disposal of pesticides in Ontario.
- Ontario regulates pesticides by placing appropriate education, licensing and/or permit requirements on their use under the *Pesticides Act* and *Ontario Regulation 63/09* (O. Reg. 63/09).

To be able to apply pesticides in the province it first must be specifically classified for use in Ontario. In addition to pesticides being federally registered by the PMRA, a pesticide is placed into a specific class prior to use in Ontario. Only licensed exterminators and certified farmers are allowed to use the most toxic pesticides. By employing a pesticide classification system, the province is able to ensure that the most toxic pesticides are only being used by trained handlers. In Ontario when a pesticide is selected it first must be verified that it has been classified in Ontario. Checking that a pesticide has been classified can be done using an online [database](#). Information on licence types and pesticides used under that licence can be found in the [Guide to Pesticide Licensing](#). There are no special requirements for applying pesticides to cannabis as compared to other agricultural crops.

### **Ontario Wastewater Discharges**

There is concern about phosphorus levels in cannabis wastewater, particularly in the Lake Erie basin area, where an international agreement on nutrient loading is enacted. However, phosphorus is a problem for wastewater created from all greenhouse producers, not just cannabis producers. In circumstances where greenhouse producers of cannabis have access to municipal sewers they are generally employed for effluent discharges. OMAFRA publishes information about the Greenhouse Nutrient Feedwater Regulation and the roles of different agencies involved in managing the wastewater<sup>162</sup>. Cannabis cultivation facilities that don't have municipal sewer access tend to recycle their water, and the reuse of water is common. If outdoor production is established in the future, it is not expected to be different than other crop production in terms of fertilizer use. Outdoor producers are not expected to require irrigation. Based on interviews and research conducted, there does not appear to be any concerns regarding THC or CBDs entering waterways through wastewater discharges.

The MECP does publish a Greenhouse Compliance Strategy<sup>163</sup>, which outlines some best practices for greenhouse operators with regards to wastewater discharges. This strategy was developed primarily to respond to concerns regarding excess phosphorus entering Lake Erie. There is an expectation that commercial cannabis producers would need to follow the practices outlined in that strategy.

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<sup>162</sup> OMAFRA. [Greenhouse Nutrient Feedwater Regulation](#). O. Reg 300/14.

<sup>163</sup> Ontario Ministry of the Environment and Climate Change. 2016. [Greenhouse Compliance Strategy Outreach Session](#).

## Ontario Solid Waste Discharges

The amount of solid waste produced by the cannabis industry is expected to be similar to the amount of waste produced in the cultivation of cucumbers and tomatoes. In Ontario, crop wastes can legally be applied to land, and it is expected that solid waste from cannabis facilities will mainly be spread on to land. There are also no restrictions regarding cannabis waste being disposed of in landfills. Cannabis producers therefore have the option of disposing of waste by applying to land, being transported to landfill, or through composting. Compared to other crops, there is a financial incentive to use as much of the plant as possible, whereby cannabis materials that may not be suitable for retail sales may be used in further processing (extraction).

For processing waste, it may be considered an agricultural waste material if it was created as part of a farm operation and would be exempted from waste regulations. If an extraction facility is part of the cultivation facility, and if it at least 50% of the plant material it processes is grown on the farm, then it is considered a farm practice. If the waste was created as part of a stand-alone extraction facility then it would be considered a “non-agricultural waste material”. Producers would be responsible to determine for themselves which waste regulations and practices must be followed. The HC requirements to destroy crop wastes supersedes any provincial requirements or permissions.

## Ontario Compliance, Enforcement, and Dispute Resolution

Health Canada included stipulations regarding air filtration in the *Cannabis Act* and Cannabis Regulations, therefore Ontario is currently referring all odour and/or air emission complaints directly to HC as they arise. Most municipalities in Ontario are directing all odour complaints to HC as well. It is OMAFRA’s understanding that when a HC inspection occurs, if an odour is present then the operator will be told that it must be addressed, however the direct action requested is somewhat unclear. According to OMAFRA at this time the odours emanating from mushroom and hog operations are considered more of concern than those generated by cannabis cultivation.

If a complaint arises (odour or otherwise) and a farm is involved, the first step to resolve the issue is to have OMAFRA facilitate a mediation session between the two parties<sup>164</sup>. The purpose is to offer practical solutions to address odour, lighting, or other complaints. However, it is non-binding. If this process does not resolve the issue then the case can be brought to the Normal Farm Practices Protection Board<sup>165</sup>, which provides a more formal conflict resolution process. If it is decided that the complaint is related to a normal farm practice, then no action is required on behalf of the farmer. However, the board may rule that, for example, manure should not be stored too close to the property boundary or suggest other actions that will help to minimize future conflicts and complaints.

As an example, if a complaint occurred against a livestock operator regarding manure odours, and the Normal Farm Practices Protection Board found that the operator was employing normal farm practices and the MECP determined that the operator was following regulations set forth under the *Nutrient Management Act*, then the farm would be exempted from the requirement to ensure that no loss of enjoyment of normal use of the neighboring property was occurring. In theory, an operator could take a local government to the FFPPA Board in an effort to protect farming rights. There is precedence for this with regard to farmers clearing trees from properties in the past and local governments attempting to curtail the tree clearing.

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<sup>164</sup> OMAFRA. [Farm Practices Conflict Resolution Process](#).

<sup>165</sup> OMAFRA. [Normal Farm Practices Protection Board](#).

If an extraction facility is part of the cultivation facility, and if it at least 50% of the plant material it processes is grown on the farm, then it is considered a farm practice and OMAFRA would be involved in any complaints associated with that facility. If it is a stand-alone extraction facility and no crop production is involved, then it is not considered a farm practice. OMAFRA would not be involved but the MECP would lead compliance and enforcement.

The Ontario Greenhouse Alliance includes representation from the flower and vegetable sectors, but not cannabis sector. It is an effective way to disseminate information about waste regulations<sup>166</sup>. Generally, the large licensed producers want to be in compliance, they just don't know what rules and regulations pertain to them.

Standard operating procedures for dealing with cannabis compliance and enforcement are being developed in partnership between OMAFRA and MECP, however they are going to be addressing odour only, not other waste discharge concerns. The standard operating procedure is still in draft form and is not being distributed externally at this time. There are no specific protocols for MECP to work in partnership with municipal governments on other waste discharge issues.

### **Ontario Regulatory and Compliance Costs**

It is challenging to tease out the costs associated with cannabis compliance and enforcement specifically. In terms of resources, OMAFRA has assigned is a civil systems engineer to the Leamington-Kingsville area in Southern Ontario, where there are several cannabis cultivation facilities located in proximity to residential areas. In those communities there have been some odour complaints which have received significant media attention. These complaints are seasonal and occur mostly in the summertime. It is worth noting that the complaints are mainly directed towards the smaller-scale designated medical cannabis growing operations in the area and not at the larger commercially licensed cultivation facilities.

The issues that have arisen related to the legalization of cannabis have been brought into the departments responsible for the servicing of land use policy and within financial departments such as granting agencies. There is an industrial crop specialist at OMAFRA who focuses on hemp and is now expanding expertise into cannabis. OMAFRA is not treating cannabis much differently than other crops, and to date they have not needed to hire anyone to deal specifically with the compliance and enforcement of cannabis cultivation.

Current farm management resources offered by OMAFRA that may pertain to cannabis operations include:

- Minimum distance guide for livestock operations to reduce odour impacts.
- Self-assessment guides for greenhouse
- Nuisance management

In terms of communications regarding compliance and enforcement, the cannabis industry doesn't have a growers group in Ontario, so it's challenging to communicate with the sector. The Ontario Greenhouse Alliance will disseminate the information to vegetable and fruit producers but not necessarily to cannabis operators, who are less known within the community.

OMAFRA staff presented information regarding cannabis cultivation at a greenhouse conference last year but have no printed or online communications materials available. This is partly due to the industry

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<sup>166</sup> Ontario Ministry of the Environment and Climate Change. 2016. [Greenhouse Compliance Strategy Outreach Session](#).

changing quickly so there is no incentive to print anything yet as information could become redundant in short timescales.

### 6.2.2 Alberta

Alberta shares a geographic boundary with BC and has a history of economic agreements and partnerships, so it was selected as a jurisdiction to examine for insight into the regulation, compliance, and enforcement of cannabis-related environmental discharges. At the time of writing, 11 licences had been issued to Alberta business: 6 for both processing and cultivation, 4 that were cultivation only, and 1 that is processing only.

The information in this section is broadly based on:

- An interview with a Pesticide Policy Specialist from Alberta Environment and Parks and from information found on the following websites:
  - Alberta Cannabis Secretariat
  - [Alberta Health Services Recommendations on Cannabis Regulations for Alberta Municipalities](#)

#### **Alberta Air Discharges**

To date in Alberta there have been no documented odour complaints related to commercial cannabis production. Information has been developed to inform condo owners, tenants, and those who are growing and consuming for personal use in residential areas, but less information is available for the commercial cultivator. A thorough search of available resources did not find policies or regulations that would set cannabis apart from other agricultural crops for air discharges.

#### **Alberta Pesticide Management**

When it comes to pesticides, Alberta will follow the direction as set for through the PMRA and will allow whatever approved products the Federal Government has permitted for use on cannabis. Alberta provincial regulatory stakeholders had a discussion regarding certification for persons using pesticides in the cannabis industry. It was determined that the requirements for operators using pesticides in the cannabis industry will be the same certification as for those operating in the greenhouse agriculture sector. The provincial Pesticide Education and Training Subcommittee proposed that cannabis pesticide certification be treated in a similar manner to greenhouse pesticide certification for the time being. If and when outdoor production happens, then the certification required to be like another agricultural crop (*e.g.* soybeans or oilseeds). It is expected that security requirements related to cannabis cultivation will mean that outdoor production will be restricted, therefore there are no concerns currently regarding potential pesticide use in outdoor situations – it is not expected that outdoor production in Alberta will be similar to, or face the same issues as those in the cannabis sector in California.

Operators need to be registered to use pesticides, but not registered specifically for cannabis cultivation. Alberta is not regulating or authorizing pesticides for cannabis separately, it will be treated like any other greenhouse crop. No new policies specifically for cannabis and pesticide use have been developed and none are expected in the future.

Alberta will be looking to PMRA to conduct pesticide research and collect data about health impacts and communicate the information to provinces and to the industry. Alberta understands that HC is already conducting audits and testing for pesticide residues on cannabis.

## Alberta Wastewater Discharges

The Province of Alberta has published a [fact sheet](#) on cannabis waste management. No new policies or regulations have been developed to deal with cannabis wastewater specifically at this time. Generators of liquid cannabis waste must properly classify and characterize the waste to determine if it is hazardous or not (the licensed cultivator/processor is expected to do this). If it is hazardous (e.g. levels of THC are > 10%), it must be disposed of as outlined in the Alberta Waste Control Regulation (AR 192/1996) and the Alberta Guide for Waste Managers. Most of the solvents used in the extraction facilities are not deemed hazardous, in part because they are volatile, and dissipate quickly. Non-hazardous liquid cannabis waste can be sent to a local wastewater treatment plant or disposed of via deepwell.

The Alberta Ministry of Agriculture and Forestry publishes a set of [Environmental Farm Plan](#) guidelines, and it is expected that most commercial cannabis producers will voluntarily adopt many of these practices for water management.

Alberta regulates cannabis-related wastewater based on whether or not it is deemed to be hazardous<sup>167</sup>. Any cannabis waste that is classified and characterized as hazardous (as defined by Alberta's *Environmental Protection and Enhancement Act* and the Waste Control Regulation) must be disposed of in a deepwell or sent to a hazardous waste treatment facility. In Alberta, the characteristics which make a waste hazardous include being:

- Corrosive
- Flammable
- Reactive
- Toxic (short or long term effects)

It is up to the generators of the cannabis waste to properly classify and characterize the waste to determine if it is hazardous or non-hazardous<sup>168</sup>. The Alberta Waste Control Regulation (Schedule 1) sets out the properties of hazardous waste, in order to assist with classification. This includes properties such as flash point, toxicity, pH, and presence of dioxins and furans. The *Alberta Waste Managers Guide*<sup>169</sup> explains Alberta's waste classification procedures and test measures, waste management options, transportation and manifest requirements, and the approvals system for waste management. However, the guide was produced in 1995, prior to the legalization of medical and/or recreational cannabis. There is no discussion in the guide regarding CBD, THC, or other cannabis-related products. However, animal and vegetable oils are not listed as hazardous. Solvents associated with manufacturing and extraction are listed as Category 3 hazardous wastes, as is the same within BC regulations.

Non-hazardous liquid cannabis waste may be either sent to a local wastewater treatment plant for treatment or disposed of via deepwell. Cannabis wastes may include, but are not limited to:

- Cannabis flowers, trim and solid plant material used to create a cannabis extract;
- Flammable solvents or chemicals used in the production of retail cannabis concentrate or extract; and
- Discarded cannabis plant waste, spent solvents and laboratory wastes from any cannabis processing or laboratory testing.

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<sup>167</sup> Cannabis Waste Management Update. 2018. [Bulletin to the Solicitor General of Alberta](#).

<sup>168</sup> Government of Alberta, 2018. [Fact Sheet: Cannabis Waste Management](#).

<sup>169</sup> Government of Alberta, 1995. [Waste classification, test methods, and guidelines](#). Alberta Environmental Protection Service.

### **Alberta Solid Waste Discharges**

Non-hazardous solid cannabis waste must be made unusable and unrecognizable by grinding the cannabis solid waste and mixing it with at least an equal amount of other non-cannabis material prior to disposal. The decision on what material to mix with the waste should be based on where the cannabis waste will be disposed. Options that may be considered include green waste, food waste, sand, cooking oils, sawdust, or other materials. In Alberta, cannabis solid waste can be disposed of at a Class I or II Compost Facility or in an anaerobic digester if the material has been mixed with leaves, yard waste, food waste, wood chips, manure, grease, oils, or other compostable materials<sup>170</sup>. If it is mixed with cat litter, sand, sawdust, or plastics it must be disposed of at a Class II Landfill. If treated and processed in a way that makes the material hazardous (e.g. solvent residues), it must be managed as hazardous waste and disposed of at a Class I Landfill.

### **Alberta Compliance, Enforcement, and Dispute Resolution**

If there are any violations determined by HC or other agencies then Alberta expects to be notified by those authorities, however it is unclear if any specific processes are in place to ensure that this inter-agency communication is facilitated. The provincial pesticide compliance team enforces lack of pesticide certification, or if spraying is not being done properly. This happens from time to time for the greenhouse industry and it is complaint driven. A lack of pesticide licences and service registrations are considered chief concerns. The number of complaints and responses related to pesticides are around 100-150 per year. This is the total for all pesticide complaints, not specifically cannabis related. These are usually in agricultural areas (drift complaints) but also can be in urban areas where pesticides are being used for aesthetic purposes and a neighbour calls in a complaint. Based on interviews and research conducted, there is no information available regarding complaints for other issues, such as odours, from commercial cannabis facilities.

### **Alberta Regulatory and Compliance Costs**

The Alberta Cannabis Secretariat has been established, it is an interdepartmental agency with representatives from health, environment, transportation, gaming and licensing, and the liquor control board. The mandate is to establish responsible use programs and to regulate the security systems, transportation, and use of cannabis. The main focus is on the retail side of the cannabis industry, rather than production. The Secretariat a new agency, but nothing specific to new staff or programs related to environment or pesticides has been established.

## **6.3 State Level**

### **6.3.1 Washington State**

#### **Washington Air Discharges**

In Washington, cannabis cultivation and processing is licensed by the State Liquor and Cannabis Boards under WAC Title 314 Chapter 314-55. Cultivation may be prohibited in some areas of the state, at the discretion of local governments. All cannabis waste must be disposed of in accordance with applicable state and local laws and regulations.

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<sup>170</sup> Cannabis Waste Management Update. 2018. [Bulletin to the Solicitor General of Alberta](#).

The 1967 *Washington Clean Air Act* (Chapter 70.94 RCW) authorized counties to activate local air agencies. There are seven local air agencies in the state. The Washington Department of Ecology refers air quality permitting of cannabis to the clean air agencies to process. All cannabis production and processing facilities must therefore meet local level of compliance with odour and other emissions limits or the State requirements of the *Clean Air Act*, which states: it is unlawful for any person to cause air pollution that is injurious to health or that unreasonably interfere with the enjoyment of life and property. Requirements for compliance is agency-dependent and therefore varies throughout the state<sup>171</sup>. It does not appear as though the state has any overriding responsibilities with regard to air quality.

For example, the *Puget Sound Clean Air Agency* (PSCA) oversees a permitting program through a pre-construction application and review process that, when approved, results in a permit for a cannabis operation with site-specific conditions. The permit is issued through Notice of Construction (NOC) application, and the permit decisions are made on a case-by-case basis, depending primarily on the emission control technology options to be utilized. For cannabis producers under PSCA's jurisdiction the agency has determined that best available technologies must ensure that there is no detectible cannabis odour outside the facility property line. The agency has implemented this standard by requiring operators to design all exhaust points (e.g., vents, stacks, windows, doors) associated with an enclosure, building or greenhouse for cannabis production or processing to continuously control odours and VOC using carbon filtration systems. At a minimum, these carbon units must be replaced every quarter. An operator also must have a person who has not been exposed to the smell periodically monitor the air at the property line to determine compliance with the "no detectible odour at or beyond the property line" standard<sup>172</sup>.

The NOC application must include a description of producer and processor activities (e.g. odour control equipment details and solvent usage information) and a plan view drawing of the facility including:

- Each room, greenhouse, or outdoor area
- Location of each odour control device and associated duct-work
- Material Safety Data Sheets (MSDS) for any solvents used
- Schematic drawing of HVAC system for the facility that indicates the path of the air flowing through area where growing or processing occurs
- Specification sheet for any extraction devices
- Specification sheets for each type and model of odour control device

For another example, Spokane Regional Clean Air Agency<sup>173</sup> regulates air discharges, such that it is unlawful for any person to cause or allow the emission of any air contaminant in sufficient quantities and of such characteristics and duration as is, or is likely to be:

1. Injurious to the health or safety of human, animal, or plant life;
2. Injurious or cause damage to property; or
3. Which unreasonably interferes with enjoyment of life and property.

There are three types of producers regulated for air emissions by the Spokane Regional Clean Air Agency through Regulation I, Article VI, Section 6.18<sup>174,175</sup>:

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<sup>171</sup> [Marijuana Facilities Are Subject to Odor and Other Air Pollution Regulations in Washington State](#). July 2017.

<sup>172</sup> [Odor Issues Are Moving to the Forefront as More States Allow Recreational Cannabis](#). 2019. Lane Powell.

<sup>173</sup> Spokane Regional Clean Air Agency: [Odors and Air Quality](#).

<sup>174</sup> Spokane Regional Clean Air Agency: [Regulation I, Article VI, Section 6.18: D3\(a\)](#).

<sup>175</sup> [Marijuana Production and Processing Requirements](#). Spokane Regional Clean Air Agency.

1. Indoor producers are required to:

- Use air pollution control equipment, facility design, or both to reduce air contaminants. Equipment may include carbon adsorption, carbon filtration on exhaust points, vertical exhaust stacks.
- Keep doors and windows closed, except for active ingress and egress.
- Follow an Operations & Maintenance plan for air pollution control equipment
- Keep maintenance records.

2. Outdoor producers are required to:

- For indoor propagation, use air pollution control equipment, facility design, or both to reduce air contaminants.
- Complete and submit the agency's Harvest Schedule Notification form, no later than 30 days prior to the start of harvest. While it is impossible to know the exact harvest date(s) 30 days in advance, the expectation is to provide a window of likely "harvest date(s)" rather than a specific date(s).

3. Other producers (hoop houses, temporary structures) are required to:

- Have a written exemption from the agency.
- Comply with specific conditions of their production exemption.
- No new operations of 'other producers' are allowed as of November 2018

Annual fees are required from the Spokane Regional Clean Air Agency for all types of producer and processor. Fees range from \$418 to \$3,751 USD/year and are primarily based on the size and scope of the operation<sup>176</sup>.

### **Washington Wastewater Discharges**

Washington State's best practices guide to cannabis production indicates: "only rain down the drain." The State requires a permit for the discharge of industrial or commercial wastewater to surface water or groundwater, and the dischargers must provide "all known available and reasonable methods of treatment", prevention and control before discharge in order to protect the environment and public health. In the majority of cases to date, the volume of liquid waste from cannabis producers/processors is considered to be minimal. Other water-related best management practices for cultivation and manufacturing sites are similar to other agricultural operations, and include:

- Pesticides and fertilizers should only be mixed indoors or under cover, away from any drains, and use drip pans;
- Outside storage of liquids must be in a covered area or storage cabinet with secondary containment sufficient to contain 10% of the total volume of all containers or 110% of the volume of the largest container, whichever is greater;
- Outdoor storage of incoming growing media (soil) must be stored in such a way that rain does not come into contact with it nor can it be carried away by the wind. Weighted tarps and berms are acceptable;
- Producers and processors must develop a site-specific Spill Prevention Plan to address spills both inside and outside of buildings and have appropriate spill materials on hand; and
- If floor drains are proposed in work areas, they must be approved by the municipality for connection to sanitary sewer.

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<sup>176</sup> [Spokane Regional Clean Air Agency \(SRCAA\) - Consolidated Fee Schedule](#), 2019.

Wastewater that results from any growing, manufacturing, cleaning, or rinsing processes is considered an industrial waste (industrial wastewater) and is subject to local, state and federal regulations.

If a business is producing edible products, a Fats, Oils or Grease (FOG) removal device (grease trap/grease interceptor) must be installed and maintained to prevent fats from clogging the sewer or causing sewage to back-up.

Discharge of any material other than uncontaminated stormwater down the storm drain system, to surface waters, or to the ground, is prohibited. This includes hydroponic water and any other wastewater. The bottom line is: only rain down the drain.

### **Washington Solid Waste Discharges**

The State of Washington requires business operators to evaluate their waste to determine its classification and proper management<sup>177</sup>. If it is dangerous waste, then specific requirements for storage and disposal will apply. Dangerous wastes include pesticides, solvents, fertilizers, mercury lighting, laboratory wastes, and used batteries. In Washington State, the cannabis plant waste must be “rendered unrecognizable and unusable”, whether the disposal method is composting or landfill. This is accomplished through grinding/chipping/shredding of cannabis waste and incorporating it with non-consumable solid wastes so that the resulting mixture is comprised of at least fifty percent non-cannabis waste<sup>178</sup>. The business operator must provide the Washington State Liquor Control Board 72 hours’ notice of disposal plans, for traceability purposes. All parts of the cannabis plant (including root balls, stems, branches, leaves, trim, etc.) that contain less than 10% THC may be disposed of by compost. Any waste with THC levels >10% are considered dangerous (hazardous) waste.

Some cannabis cultivation facilities in Snohomish County Washington are sending their organic cannabis waste (frequently mixed with paper) to large-scale composting facilities within the County, however the volume of waste is unknown<sup>179</sup>. Anecdotal evidence suggests that high salt concentrations in cannabis growing medium wastes has made it difficult for some producers to find adequate methods to compost on-site.

### **Washington Compliance, Enforcement, and Dispute Resolution**

Both state and local authorities have a role to play in compliance and enforcement. At the state level, the very last stage of a producer or processor getting approval for their licence from the Washington State Liquor and Cannabis Board involves a site visit from an enforcement officer. During this visit all the permitting requirements are covered (e.g. security, buildings requirement, etc.) and a very short portion of the visit is devoted to ensuring solid waste disposal and handling rules are followed.

There are 17 enforcement officers for licensed cultivation and extraction facilities state-wide, however dealing with enforcement regarding wastes from facilities makes up a very small proportion of resources (i.e. less than 5%)<sup>180</sup>. The Washington State Liquor and Cannabis Board would like to hire more enforcement officers, but current funding is limited.

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<sup>177</sup> Washington State. 2016. Regulatory Guidance for Cannabis Operations.

<sup>178</sup> Ibid.

<sup>179</sup> Snohomish County Environmental Health Representative. Interview March 2019.

<sup>180</sup> Washington State Liquor and Cannabis Board.

The amount of resources dedicated to regulating cannabis waste in Washington is unclear. According to the Washington State Liquor and Cannabis Board, there have been issues around solid waste diversion to landfills as haulers complain about improper waste disposal. When these issues arise the officers will then go inspect the facilities and issue fines if violations are found to have occurred. If neighbours of the facilities complain about solid waste then enforcement officers are sent out, but complaints thus far have been odour-related, not related to liquid or solid wastes.

At the local level, clean air agencies such as Puget Sound Clean Air Agency and Spokane Regional Clean Air Agency can respond to odour complaints and issue violations. In Spokane, complaints are recorded into a data base and assigned an inspector. The process requires that the inspector must be able to detect the odour, the person impacted must sign a legal affidavit, and the inspector must be able to identify the source of the odour for an enforcement action to be considered. When assessing odours a ranking system is used, as follows:

- Level 0 – no odour detected
- Level 1 – odour barely detected
- Level 2 – odour is distinct
- Level 3 – odour is objectionable enough or strong enough to cause attempts at avoidance
- Level 4 – odour is so strong that a person does not want to remain present

The inspector must determine that the odour is at a Level 2 or greater to instigate a warrant enforcement action. The Clean Air Agency will typically give the violator 15 days to provide the agency with information that demonstrates that all controls and operating practices are being employed to prevent or minimize odours to the greatest degree practicable. If these practices are deemed to be appropriate, then the Agency may decline to pursue formal enforcement action. Affected persons may still decide to pursue their own legal action at that time. If the Agency determines that the facility is not employing adequate controls and operating procedures it may issue a Notice of Violation, after which point there are 30 days to respond to the allegations. The Agency will generally follow up with a fine, which typically start at \$1,000 USD for a first offence. It typically takes at least 3 months from when the time the complaint is filed until when the case is considered resolved.

Washington State has collaborated with a number of agencies to provide a one-stop shop on how to be compliant with cannabis-related rules within the state's jurisdiction.

Compliance promotion materials include:

- [Regulatory Guidance for Cannabis Operations](#). 2016. Created in partnership by the Interagency Resource for Achieving Cooperation.
- Department of Ecology, State of Washington. [Marijuana licensing and the environment](#).

Licences must be renewed annually and renewal fees for producers and processors must be paid to the Washington Liquor and Cannabis Control Board. However, it is unclear if licences expire if the renewal fees are not paid, or if they are simply required to pay a fine. Fees for environmental controls, emissions, and waste management are additional fees paid annually to the overseeing jurisdictional power (e.g. in Washington annual fees are paid to the regional clean air agencies). The Washington Liquor and Cannabis Control Board is not accepting any new applications for medical, retailers, growers, producers and processors<sup>181</sup>.

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<sup>181</sup> [Marijuana Regulations](#). Washington Liquor and Cannabis Control Board.

### 6.3.2 Oregon State

The [Oregon Health Authority](#) and the [Oregon Liquor Control Commission](#) (OLCC) are the lead agencies for medical and recreational cannabis, respectively. The Oregon Department of Agriculture (ODA) regulates agricultural waste water and pesticide use. The Oregon Department of Environmental Quality (DEQ) does not regulate the growing or processing of cannabis however, cannabis businesses must abide by existing regulations designed to protect air, land, and water. Air emissions, solid waste, hazardous waste, and wastewater management are areas where DEQ has a regulatory role.

The OLCC has approved more than 4,000 licences for recreational production<sup>182</sup>, including wholesalers, laboratories, processors and retailers. The size of the facility is related to the type of production licence. A producer is subject to the following limits<sup>183</sup>:

- Micro Tier I: 625 sqft
- Micro Tier II: 1,250 sqft
- Tier I: 5,000 sqft
- Tier II: 10,000 sqft

However, applications can be made to the OLCC to increase these limits once one is in place and are considered on a case-by-case basis.

Oregon cannabis licences expire annually and a \$250 renewal fee must be paid prior to the expiration date, otherwise a late fee of \$150 will be charged<sup>184</sup>. On May 30, 2018 the OLCC announced it would temporarily pause the processing of recreational cannabis licence applications, to allow the organization time to deal with the backlog of applications<sup>185</sup>. Environmental waste and emissions permits may be required for producers and processors depending on their size, activities and the regulations of the State and local jurisdictions.

#### **Oregon Air Discharges**

At the state level the OLCC do not require air filters for cannabis businesses, but some local jurisdictions do. Commercial cannabis facilities with a DEQ permit, such as an Air Contaminant Discharge Permit, are subject to DEQ's Nuisance Odor Strategy. In Oregon, any cannabis business emitting more than 10 ton/year of VOC may require a permit to operate, however only VOC associated with solvents from processors are referred to<sup>186</sup> and it appears that cultivators would not require a permit. According to those interviewed at the State DEQ, none of the processing facilities in Oregon are large enough to warrant such a permit. Therefore; it can be inferred that no single facility in Oregon is emitting more than 10 ton/year of VOC. The DEQ does have a Nuisance Odor Strategy that would apply to facilities with an Air Contaminant Discharge Permit. The strategy is based on voluntary cooperation and steps include administrative oversight of complaints, communicating with the business after the complaint is made, documenting and evaluation further complaints, preparing and conducting a site inspection, and informally negotiating with the source

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<sup>182</sup> Portland Business Journal, 2018. [List leaders: Meet the 5 largest cannabis businesses in Oregon.](#)

<sup>183</sup> Oregon Liquor Control Commission, 2018. [Propagation Production Endorsement.](#)

<sup>184</sup> Oregon Liquor Control Commission, 2018. [Renewal FAQs.](#)

<sup>185</sup> [Information Bulletin on Licence Application Processing Pause.](#) 2018. OLCC.

<sup>186</sup> Oregon Department of Environmental Quality. 2019. [Marijuana regulation webpage.](#)

for odour abatement<sup>187</sup>. It is unclear if any cultivation or processing facilities require an Air Contaminant Discharge Permit, as the industry is not specifically listed as an “Activity or Source”<sup>188</sup>.

### **Oregon Wastewater Discharges**

The Oregon DEQ permitting system applies to cannabis operations that discharge wastewater into a sanitary sewer system, an onsite septic system, or is being discharged directly into a surface water body through a pipe or ditch. Oregon has hydroponic operators and processing facilities located within some city boundaries, therefore these facilities have access to the municipal sanitary sewer system. In these cases, it is the responsibility of the city to regulate the wastewater entering into their systems.

DEQ coordinates with ODA to manage nonpoint source agricultural runoff through the implementation of agricultural water quality management area plans. Wastewater from cannabis facilities may be applied to land under certain DEQ approved conditions. However, dumping excess irrigation water into a stream, ditch, or pond is prohibited. Surface water discharges may require permit. A General Water Pollution Control Facilities permit<sup>189</sup> would be required from the DEQ for any facility that wishes to apply wastewater to land.

Cannabis cultivation operations on agricultural lands are considered farm uses and therefore agricultural wastewater management falls under the authority of the ODA and agricultural water quality rules<sup>190</sup>. In these cases, two important rules apply:

- Pollution Rule: Agricultural pollution cannot enter streams, ditches, or ponds, or be in a location that is likely to enter these water bodies.
- Riparian Rule: Agricultural activities must not prevent streamside vegetation from growing and establishing.

Other best management practices stipulated by ODA include:

- Dumping excess irrigation water into a stream, ditch, or pond is prohibited.
- Nitrogen testing must be done prior to land application to know the concentration in parts per million (ppm) and whether it meets the needs of the crop that it is being applied to.
- Excess irrigation water must not be spread within 48 hours after a storm event or when weather conditions will lead to runoff.
- Conservation actions must be practiced, such as:
  - Planting native grasses, shrubs, and trees for extra filtration and nutrient uptake.
  - Installation of silt fences, straw bales, mulch, in sensitive areas where runoff could reach surface water.
  - Collection of runoff in a retention basin.

### **Oregon Solid Waste Discharges**

Cannabis growers that want to establish a facility to compost vegetative material waste must apply to DEQ for a permit if the operation will compost on-site more than 100 tons per year of vegetative material<sup>191</sup>. This is much lower than BC’s *Organic Matter Recycling Regulation*, which requires a permit from the BC Ministry of Environment if 5,000 tons or greater (dry weight) per year of compost is produced. Agricultural

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<sup>187</sup> Oregon, Department of Environmental Quality 2014. [Nuisance Odor Report](#).

<sup>188</sup> Oregon, Department of Environmental Quality, 2019. Chapter 340, Division 216. Air contaminant discharge permits. 340-216-8010. [Table 1 Activities and Sources](#).

<sup>189</sup> Oregon Department of Environmental Quality. 2018. [General Water Pollution Control Facilities Permit](#).

<sup>190</sup> Oregon Department of Agriculture. [Oregon Cannabis and Water Quality](#). Factsheet.

<sup>191</sup> Oregon Department of Environmental Quality. 2018. Business Readiness Guidebook for OLCC Marijuana Operations.

crop residues, such as vegetative cannabis wastes, are considered a “type 1” composting feedstock and may be composted alone or with other organic materials. DEQ encourages potential composters to contact DEQ to discuss the proposal to determine if an application is necessary. Most cultivation sites are determined by DEQ to be small enough in scale that they do not require a permit. Cannabis waste can also be hauled off-site to permitted commercial composting facilities.

Oregon Revised Statute 459 addresses management of solid waste in Oregon. Cannabis-related solid waste must be composted, processed, or disposed of at solid waste facilities permitted by DEQ. DEQ’s materials management rules address recycling of recovered materials, composting of organic wastes, and disposal of solid waste.

- *Composting onsite:* Cannabis growers that want to establish a facility to compost waste vegetative material must apply to DEQ for a permit if the operation will compost onsite more than 100 tons per year of type 1 or 2 feedstocks (vegetative material or manures) or 20 tons per year of waste that includes meat, eggs, dairy, or animal mortality, unless they meet certain exemptions from permitting requirements.
- *Composting off-site:* Vegetative cannabis waste may also be sent off site to a DEQ- permitted composting facility where it is processed into finished compost.

No cannabis facilities in Oregon are producing over 100 tons of compost material per year, therefore no permits for composting have had to be administered by the DEQ and the cannabis facilities are not required to report their practices to the DEQ. The OLCC is unaware of the specific compost methods used by producers as they do not keep track of the cannabis producers that are composting.

Rexius is a commercial composting facility located in Eugene, Oregon, that accepts cannabis waste<sup>192</sup>. The operators treat the cannabis feedstock just like any other green waste. There have been no issues with diversion to the illegal market, because when the material arrives everything of value has been already removed from the plant.

### **Oregon Compliance, Enforcement, and Dispute Resolution**

The OLCC and DEQ have the authority to regulate odours from commercial cannabis operations, but these agencies are reluctant to do so because the air emissions aren’t deemed by them to be a health hazard<sup>193</sup>. The wording of Measure 91, the ballot measure which legalized recreational cannabis in Oregon, makes it challenging to regulate odours. Section 59 of the measure allows cities and counties to regulate the nuisance aspects of cannabis establishments, but it also stipulates that in order to impose such rules, any city or county must “make specific findings that the establishment would cause adverse effects to occur”.<sup>194</sup> Therefore, in order to regulate odours, the local government would have to determine exactly what the adverse effect is and then create a compliance and enforcement strategy. Furthermore, in Oregon, land zoned for exclusive farm use is protected under law from nuisance lawsuits over odours, dust or other similar emissions. Only cannabis operations located in residential or rural residential zones could potentially be liable to lawsuits alleging odour nuisance. No specific information regarding extraction facilities was found.

In the City of Eugene, Oregon, a section of the city code stipulates that “no person responsible shall cause or permit a nuisance on public or private property,” including “premises which are in such a state or

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<sup>192</sup> Gorrie, P. 2018. [Recycling cannabis organics](#). Biocycle, vol. 59, no. 6, p. 17.

<sup>193</sup> Hogen, J. 2016. [Pot’s pungent odor causing quite the stink](#). Eugene Register Guard newspaper.

<sup>194</sup> Ibid.

condition as to cause an offensive odour.” However, it is unclear if any compliance and enforcement activities have been directed to commercial cannabis operations based on this city code.

At the state level, compliance activities have been limited by the staff resources available. A [web page](#) with resources related to necessary DEQ permits for cannabis operations has been created. No other activities for environmental regulation compliance have been undertaken. The DEQ only received one environmental complaint regarding a hydroponic facility that was discharging wastewater onto streets and into the storm water sewers. The DEQ followed up with the facility about proper permitting required for wastewater disposal.

Compliance promotion materials include:

- [Business Readiness Guidebook for Oregon Liquor Control Commission Marijuana Operations](#). 2018. Inter-agency publication.
- Oregon Farm Bureau Federation. 2016. [Cannabis: Good Agricultural Practices](#).
- Oregon Department of Agriculture. 2019. [Oregon Cannabis: Cannabis and Water Quality Factsheet](#).

### 6.3.3 Colorado State

#### Colorado Air Discharges

Colorado State’s *Odor Control Regulation* sets standards for allowable odour contaminants for different land-use areas in the state and outlines control measures that can be taken to bring violators into compliance. Best regulatory practices include mandating carbon filters and setting efficiency rates, and setting efficiency limits/thresholds on solvent extraction processes. APEN (air pollutant emissions notice) and permitting thresholds for annual VOC emissions range from 1 to 5 tons per year, depending on the whether or not the facility is in an “ozone non-attainment area”. Only businesses exceeding the reporting thresholds must report their emissions, and no cannabis cultivation facilities exceeding the thresholds were found. Industries listed as requiring APEN include dry cleaning, feed mills, fuel stations, oil and gas operations, but do not include cannabis cultivation or processing. The APEN resources include a VOC calculation sheet and specifies using Material Safety Data Sheet numbers for solvents<sup>195</sup>. There is no reference to calculating VOC from plant sources. Companies must pay for an engineer to come assess the facility and conduct the calculations required to determine the parameters needed to obtain the permit to emit VOC. This cost can range from \$5,000-\$10,000 USD per permit depending on facility characteristics and size. Once a company’s emissions have been determined by the mass balance calculation, the companies pay a fee based on tonnes of emissions (\$80 USD per ton)<sup>196</sup>. There was no information found regarding the use and/or requirement of APEN for cannabis. Exemptions to APEN include individual emission points of having uncontrolled actual emissions of any individual non-criteria reportable pollutant less than 250 pounds per year as well as agricultural operations such as farming, cultivating, harvesting, and seasonal crop drying. Other exemptions include facilities with uncontrolled actual emissions that are annually less than 2 tonnes of VOC<sup>197</sup>.

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<sup>195</sup> Colorado Air Pollution Control Division Small Business Assistance Program. [A simple guide to calculating and reporting air emissions for VOCs and HAPs](#).

<sup>196</sup> Ibid.

<sup>197</sup> Colorado Air Pollution Control Division Small Business Assistance Program. [Reporting your air emissions and applying for air permits step-by-step for Colorado businesses](#).

The City of Denver, Colorado has released a Best Management Practices<sup>198</sup> document for commercial medical cannabis producers, which are all using indoor production methods. Odour control is a local ordinance (bylaw), therefore cities differ in their approach across Colorado. In Denver, all cultivation and processing facilities are indoors (there is no outdoor cultivation occurring within Denver) and must submit an odour control plan (OCP)<sup>199</sup> that has been reviewed by a Professional Engineer. The City is somewhat flexible regarding the methods they approve, however carbon filtration has become the gold standard. Other recommended technologies include negative ion generators, air scrubbers, masking agents, and the use of negative pressure to keep odours within the facility. In situations where odour is inadequately mitigated and is perceived to be excessive, residents are asked to file a nuisance odour complaint with the Denver Department of Environmental Health.

The City and County of Denver have also developed *Environmental Health Rules and Regulations Governing Nuisance Odors*<sup>200</sup>. This document specifies when an OCP is required, what needs to be included, and details the approval process. These plans must be submitted by all cannabis growing, processing, and manufacturing facilities. The plan must include facility emissions information including a floor plan, description of odour-emitting activities and odour mitigation practices. Facilities are expected to use “industry-specific best control technologies and best management practices.” The rules and regulations state that the best control technology for cannabis cultivation facilities is carbon filtration. A Professional Engineer or a Certified Industrial Hygienist must review and certify the OCP, including system design (e.g. desired air exchanges per hour, odour capture mechanisms, exhaust flow rates, rates of carbon adsorption consumption, etc.), operational processes, and a maintenance plan (e.g. frequency of carbon filter changes). The OCP must also include a complaint tracking system, which identifies the staff involved in receiving the complaints, how the complaints will be addressed, and how the complaint and response will be recorded. The plan must be submitted as part of the business licensing process. The Department reserves the right to conduct inspections of the facility to assess the odour mitigation practices, identify odour sources, and review record-keeping. Denver’s Department of Environmental Health (DEH) is responsible for regulating nuisance odours as defined under Denver Revised Municipal Code<sup>201</sup>. Under the Code, odour intensity is based upon the Colorado State law, and includes an odour definition, specific occurrences that result in a violation, affirmative defenses to a violation, and exemptions.

The Colorado Springs Fire Department provides guidance to indoor licensed cannabis production facilities based on recommendations in a *Marijuana Facility Guidance* document from the Fire Marshals Association of Colorado<sup>202</sup>. The guidance recommends that appropriate ventilation and filtration systems be implemented and maintained to satisfy applicable local odour nuisance standards. In addition, the adoption of best practices and state-of-the-art technologies in odour mitigation are strongly encouraged.

## Colorado Wastewater Discharges

Any liquid wastes must be disposed of in compliance with the applicable Water Quality Control Division statutes and regulations. All cannabis facilities in Colorado are indoor facilities and the majority are using municipal water as the water source for irrigation. Runoff water goes back into municipal wastewater system and some municipal wastewater treatment plants are reportedly having to deal with high nutrient loads<sup>203</sup>.

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<sup>198</sup> Denver Public Health and Environment. 2018. [Cannabis Environmental Best Practices Guide](#).

<sup>199</sup> [Odour control plan resources](#): City of Denver.

<sup>200</sup> City and County of Denver. [Environmental Health Rules and Regulations Governing Nuisance Odors](#).

<sup>201</sup> City of Denver, 2015. [Guide to Odor Regulations](#).

<sup>202</sup> Colorado Fire Marshals’ Special Task Group, 2016. [Marijuana Facility Guidance v.1](#).

<sup>203</sup> Colorado Department of Public Health and Environment.

One of the best practices suggested by the City of Denver includes the recapture and reuse of water created as condensation on HVAC equipment<sup>204</sup>. While passing through a cooling, ventilation and/or dehumidification unit, the water vapour will condense back to relatively clean liquid water and can be directed to a facility's water storage area. It is unclear if any cannabis facilities have adopted this recommended practice. The use of RO has been used by some cannabis cultivators in the Denver area<sup>205</sup>. RO can be used to reduce the volume of wastewater that has to be treated, but it is not a treatment process in and of itself. Consequently, while RO reduces the volume of wastewater requiring treatment, it doesn't reduce the costs for treatment. However, if recycled and reused, the freshwater permeates recovered can be used to reduce the amount of input water that is required.

### **Colorado Solid Waste Discharges**

Solid waste must be made unusable and unrecognizable through grinding and/or mixing with other waste materials. The waste may then be disposed of in a secured waste receptacle in possession and control of the licensee. This may include a certified solid waste or compost facility or onsite, in compliance with regulations set out by the Department of Public Health and Environment. In terms of solid waste, some companies are sending stalks/stems to pellet/fibre manufacturing facilities. If a material from the processing or manufacturing of a hazardous waste is above the threshold of 24% flammable (e.g. plant material is soaked in solvent) it must go to a hazardous waste disposal facility.

Colorado published a solid and hazardous waste compliance bulletin<sup>206</sup> to provide guidance on how to handle and dispose of wastes in accordance with the relevant state regulations. A "Marijuana Establishment" includes cannabis cultivation facilities, testing facilities, product manufacturing facilities or a retail operation. Wastes may be regulated as solid or hazardous wastes and may include marijuana plant material, marijuana-infused products, pesticides, fertilizers, solvents, wastewater, mercury-containing lighting and other wastes. There was no information available regarding additional staff being hired to manage the compliance and enforcement of regulations for the solid or liquid waste environmental impacts, but existing staff are taking on that work.

Composting of cannabis wastes can occur on-site at a facility owned by the generator of the waste and operated in compliance with the Regulations Pertaining to Solid Waste Sites and Facilities (6 CCR 1007-2, Part 1) from the Colorado Department of Public Health and Environment<sup>207</sup>. However, composting has not become a common practice for producers due to regulatory issues (e.g. finding a certified hauler and composting facility) making it difficult to dispose via compost. Some producers outside of the County of Denver are using the Bokashi method of composting, as this method requires less space and inputs than conventional composting methods, however volumes of composted waste are unknown.

### **Colorado Compliance, Enforcement, and Dispute Resolution**

The Colorado Department of Revenue, Marijuana Enforcement Division is responsible for the licensing of producers, processors and retailers and licences must be renewed each year<sup>208</sup>. There are no specific expiry terms.

As of March 1<sup>st</sup> 2019 there were 1,901 licences:

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<sup>204</sup> City of Denver, 2018. [Cannabis Environmental Best Practices Guide](#). Denver Public Health and Environment.

<sup>205</sup> Ibid.

<sup>206</sup> Compliance Bulletin - Solid and Hazardous Waste. Marijuana and Marijuana-Related Waste Disposal. Updated January 2019

<sup>207</sup> Ibid.

<sup>208</sup> [MED Business Licence Renewal](#). Colorado Department of Revenue, Enforcement Division.

- Recreational: 716 cultivation and 285 product manufacturing
- Medical: 662 cultivation and 238 product manufacturing

Colorado has received odour complaints regarding cannabis, but has not received solid or liquid waste complaints<sup>209</sup>. When a complaint is made, an inspector contacts the complainant to gather specific information on the odour and source. As part of the investigation, the inspector may attempt to identify and determine the odour intensity using a portable measuring device, called the Nasal Ranger. The Nasal Ranger provides a scientific method of quantifying odour strength in terms of ‘dilution to threshold’ (D/T) ratios<sup>210</sup>. To make a D/T measurement, carbon-filtered air is mixed with specific volumes of odorous ambient air. The D/T ratio is a measure of the number of dilutions needed to take the odorous air to a threshold that can be detected by the evaluator.

Citations can only be issued under the following circumstances:

- If the odorous contaminants are over the threshold of the 7/1 dilution standard; or
- When DEH receives five or more complaints about a single odour source from individual residents representing separate households within a 12-hour period.

The problem with the 7/1 dilution standard for cannabis production and manufacturing is that cannabis facilities rarely meet this threshold, and are therefore not found to be in violation, even if odour is present. The penalty assessed for an odour citation is based on a range of criteria, including actual or threatened impacts to public health and the environment, history of previous violations, willingness of cooperation to resolve the issue, and other factors. The minimum penalty is \$150 USD, maximum is \$2,000 USD<sup>211</sup>. The Denver ordinance requires a single odour source to be clearly identified to violate the ordinance. Given that there are often multiple industries (including other cannabis cultivation operations) in one area this can be challenging as odours are transient and not limited to normal working hours, they are typically made up of several different chemical combinations, and sometimes are located outside Denver’s borders<sup>212</sup>.

The Colorado Department of Public Health and Environment and Denver Environmental Health are receiving approximately 20 complaints a day related to cannabis odour from various companies around the City and County of Denver. These can include cultivation, manufacturing, and retail operations. It is worth noting that all of the cultivation occurs at indoor facilities (e.g. no greenhouse or outdoor cultivation within the City and County of Denver).

The State of Colorado spent just over \$7 million USD on the enforcement division in 2015/2016 and just over \$5 million USD in 2016/2017<sup>213</sup>. This compares to the income from fees and taxes that the industry provides of \$157 million in 2015/2016 and \$145 million in 2016/2017, so about 3-4% of the revenues are spent on compliance and enforcement per year. The Enforcement Division conducted 1,668 regulatory and criminal enforcement investigations, which include compliance and monitoring activities, in 2016. It is important to note that these investigations were not only related to environmental discharge concerns. This represents a multi-pronged approach, including site visits, tracking data, and partnering with other law enforcement agencies. Out of the 1,668 investigations, 39 suspensions and 105 stipulations, agreements, and orders were issued. For perspective, there were 459 licensed stores, 633 cultivators, 244 product

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<sup>209</sup> Ibid.

<sup>210</sup> City of Denver, 2015. [Guide to Odor Regulations](#).

<sup>211</sup> Ibid.

<sup>212</sup> Ibid.

<sup>213</sup> Colorado Department of Revenue – Enforcement Division - Marijuana. 2017. [State Licensing Authority Annual Report](#).

manufacturers, and 14 testing facilities in Colorado in 2016. This totaled 1,350 retail cannabis establishment licensees.

Colorado plans to continue compliance promotion and education efforts within the cannabis industry for the next 1-2 years to bring operators 'up to speed' with regulations. For now, any enforcement efforts are driven by complaints.

Compliance promotion materials include:

- Denver Environmental Health Cannabis Sustainability Work Group. 2018. Cannabis Environmental Best Management Practices Guide.
- Colorado Department of Revenue. [Marijuana Enforcement](#).
- Colorado State Portal: [Official state information on the laws and health effects of retail marijuana](#)

The State of Colorado is building an online database where cannabis businesses can anonymously self-report air emissions, energy and water usage, etc.<sup>214</sup> This will provide a database of average environmental impacts across the state's cannabis industry. Eventually other jurisdictions (including Canadian producers) will be able to input data and use the database to compare their company to others in the industry.

It is very challenging to quantify regulatory costs specifically related to the environmental impacts of cannabis as there are also a myriad of other regulations and associated costs connected to enforcement within the industry (e.g. licensing costs, security costs, 'track and trace' system, etc.).

#### 6.3.4 California State

In California, the new *California Code of Regulations – Cannabis Cultivation* are effective state-wide as of 2019<sup>215</sup>. The state regulations regarding permitting applications include environmental considerations, such as water source and waste management plan. Initial licence application fees range from \$135 for specialty cottage outdoor (maximum of 25 plants) licence to \$8,655 for a medium indoor (between 929 m<sup>2</sup> to 2,044 m<sup>2</sup> or 10,001 to 22,000 sqft of total canopy space) licence. The annual licence renewal fee is much higher, ranging from \$1,205 to \$77,905 for these same categories.

Cultivation licensees must provide evidence of enrollment in an order or waiver of waste discharge requirements from the State Water Resources Control Board or from the appropriate Regional Water Quality Control Board. There must also be evidence provided of exemption from, or compliance with, the *California Environmental Quality Act*. Indoor cultivation licences must identify water sources used for cultivation activities (e.g. well, rainwater catchment system, or diversion from surface water). If applicable, evidence will be provided that indicates that a proposed premise is not located in a watershed that the State Water Resources Control Board or the Department of Fish and Wildlife has determined to be significantly adversely impacted by cannabis cultivation. Cultivation facilities must be located outside a 183 m (600 ft) radius from daycares and schools. The cultivation plan requirements must include designated pesticide and other agricultural chemical storage area(s), and a cannabis waste management plan indicating designated composting area(s), and designated secured area(s) for cannabis waste if not being composted.

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<sup>214</sup> Ibid.

<sup>215</sup> California Code of Regulations. Title 3 Food and Agriculture. [Division 8. Cannabis Cultivations. Chapter 1 Cannabis cultivation programs](#). January 2019.

## California Air Discharges

Currently, California State law doesn't do much to address odours, with the only requirement being that cannabis operations limit emissions from generators and from solvents used in extraction processes. For the most part, air emissions are regulated at the county and city level, as per other states. The California Department of Food and Agriculture has identified cannabis as an agricultural product and the California Health and Safety Code specifically exempts nuisance related to odours emanating from the growing of agricultural crops. However, as a controlled substance, crop waste from cannabis cultivation is not eligible for agricultural burning<sup>216</sup>.

Primary responsibility for permitting all sources, except vehicular sources, rests with the local and regional air pollution control authorities known as Air Pollution Control Districts (APCD) or Air Quality Management Districts (AQMD)<sup>217</sup>. California has 28 AQMDs, and anyone operating a facility that emits air pollution must obtain an operating permit from one of these local air districts.

For example, the Bay Area AQMD odour regulation states that: "A person shall not discharge any odorous substance which remains odorous after dilution with odor-free air as specified in Table I" (Figure 24) and "A person shall not discharge any odorous substance which causes the ambient air at or beyond the property line of such person to be odorous and to remain odorous after dilution with four parts of odor-free air<sup>218</sup>". It is unclear from preliminary research if and how many cannabis facilities have been found to be in violation of these regulations.

**TABLE I  
DILUTION RATES**

Elevation of Emission Point above Grade in Meters (Feet)	Dilution Rate (Volumes of odor-free air per volume of source sample)
Less than 9 (30)	1,000
9 to 18 (30 to 60)	3,000
18 to 30 (60 to 100)	9,000
30 to 55 (100 to 180)	30,000
greater than 55 (180)	50,000

FIGURE 24. THE BAY AREA ODOUR REGULATION DILUTION RATES.

It is legal for California city jurisdictions to ban cannabis businesses if they wish, and of the 482 cities within the state, only 92 allow recreational commercial cannabis cultivation facilities<sup>219</sup>. Many of the cities and counties that do permit them simply include a line or two in their regulations that say cannabis odours must not be noticeable.

For example, the Los Angeles's cannabis regulation is 33 pages long, but only three sentences of which address odour control. The rules state that air vented from cannabis businesses must be filtered so that odours can't be detected outside, or in adjoining sites, by a person with a "normal sense of smell<sup>220</sup>." Specifically, Los Angeles' *Regulation No. 10 (Operational Requirements and Violations)* Section 12 states that: A Business Premises shall be properly ventilated, and the exhaust air filtered to neutralize the odour from cannabis so that the odour cannot be detected by a person with a normal sense of smell at the exterior of the Business Premises or on any adjoining property. No operable windows or exhaust vents shall be located on the building façade that abuts a residential use or zone. Exhaust vents on rooftops shall direct exhaust away from residential uses or zones.

<sup>216</sup> [Cannabis Cultivation](#). San Luis Obispo County Air Pollution Control District.

<sup>217</sup> California Air Resources Board [website](#). Accessed March 2019.

<sup>218</sup> [REGULATION 7 - ODOROUS SUBSTANCES](#). Bay Area Air Quality Management District

<sup>219</sup> Staggs, B.E., Aitken, D., Wheeler, I., and P. Lawrence. [2018. Searchable database: See how cannabis laws, support differ among California cities](#). The Cannifornian.

<sup>220</sup> City of Los Angeles, California. Revised July 2018. [Rules and Regulations for Cannabis Procedures](#).

Similarly, the County of San Luis Obispo states that “all cannabis cultivation shall be sited and/or operated in a manner that prevents cannabis nuisance odours from being detected offsite. All structures utilized for indoor cannabis cultivation shall be equipped and/or maintained with sufficient ventilation controls (e.g. carbon scrubbers) to eliminate nuisance odour emissions from being detected offsite”<sup>221</sup>.

In Carpinteria, California, Ever-Bloom is a 15-acre greenhouse (650,000 square feet of cannabis) located next to a residential area and nearby to a high school (Figure 25)<sup>222</sup>. In November 2017 vapour-phase odour

neutralizer system (odour scrubber) called Eco-Scrub by Byers Scientific was installed. Three months later, in February 2018, the cannabis cultivation company toured local government staff through the greenhouse to allow them to inspect the system. According to local government staff, the odours from inside the greenhouse could not be detected directly outside the greenhouse or at the property line. A recent article in the New York Times regarding cannabis production notes that a Santa Barbara County official charged with cannabis implementation says the odour control has been largely successful but it can be expensive to install<sup>223</sup>. However, letters from residents to



FIGURE 25. CARPINTERIA GREENHOUSE IN CALIFORNIA.

local government continue to point to odours emanating from cannabis cultivation operations in the community more generally. Given the number of producers in Carpinteria (more than 50), it is likely that a great majority of operations to date have not adopted technologies (like the Eco-Scrub system) and thereby the wider community has yet to benefit from this type of technology.

### California Wastewater Discharges

General environmental protection measures noted in the *California Code of Regulations – Cannabis Cultivation* include:

- Compliance with the Water Code as implemented by the State Water Resources Control Board, Regional Water Quality Control Boards, or California Department of Fish and Wildlife;
- Compliance with any conditions requested by the California Department of Fish and Wildlife or the State Water Resources Control Board; and
- Compliance with pesticide laws and regulations as enforced by the *Department of Pesticide Regulation*.

Examples of wastewater regulation within the state are described below:

#### State Water Resources Control Board – Indoor Cultivation<sup>224</sup>

Indoor commercial cannabis cultivation may be performed using hydroponic growing systems, soil, or other growth media. To maintain suitable growing conditions, wastewater must be discharged from hydroponic systems when the irrigation water contains excessive salinity or nutrients. Indoor facilities must:

<sup>221</sup> [AN ORDINANCE AMENDING THE LAND USE ORDINANCE – TITLE 22 OF THE COUNTY CODE, RELATING TO CANNABIS ACTIVITIES](#). County of San Luis Obispo.

<sup>222</sup> Genet, A.A. 2018. Santa Barbara County Air Pollution Control District. [Cannabis odor control solutions](#).

<sup>223</sup> Fuller, T. December 19, 2018. ‘Dead Skunk’ stench from marijuana farms outrages Californians. The New York Times.

<sup>224</sup> [Proposed Updates to the Cannabis Cultivation Policy](#). 2019. State Water Resources Control Board.

- Discharge all industrial wastewaters generated to a permitted wastewater treatment collection system and facility that accepts cannabis cultivation wastewater; or
- Collect all industrial wastewater in an appropriate storage container to be stored and properly disposed of by a permitted wastewater hauler at a permitted wastewater treatment facility that accepts cannabis cultivation wastewater.

#### State Water Resources Control Board – General Order for Outdoor Cultivation Activities<sup>225</sup>

The General Order classifies cannabis cultivation operations into three different Tiers based on threat to water quality, as determined by specific physical characteristics of the operation and its surroundings. The greater the threat to water quality that a cannabis cultivation operation poses, the more that is required of the cultivator for the protection of water quality and to comply with the General Order.

- Cultivation activities that occupy and/or disturb less than 93 m<sup>2</sup> (1,000 feet<sup>2</sup>), have not been demonstrated to cause more than *de minimis* impacts to water quality. Such cultivation activities do not pose a significant threat to water quality and are not covered under this General Order.
- Tier 1 (low threat): cannabis cultivators whose cultivation activities are located on slopes less than 30%, occupy and/or disturb less than 1,000 m<sup>2</sup> (0.25 acre), and are not located within 61 m (200 feet) of an aquatic life bearing water body.
- Tier 2 (moderate threat): cannabis cultivators whose cultivation activities are located on slopes less than 30%, occupy and/or disturb less than an acre and no more than 50% of the cultivator's/landowner's parcel(s), and are not located within 61 m (200 feet) of an aquatic life bearing water body.
- Tier 3 (elevated threat): cultivation operation is located on slopes greater than 30%, occupies and/or disturbs more than an acre or more than 50% of the cultivator's/landowner's parcel(s), or is located within 61 m (200 feet) of an aquatic life bearing water body.

### **California Solid Waste Discharges**

A cannabis waste management plan must identify one or more of the following methods for managing cannabis waste generated on its licensed premises:

- a) Composting on-site (must comply with these State wide composting [regulations](#)<sup>226</sup>)
- b) Collection and processing of waste by a local agency or a waste hauler
- c) Self-hauling of waste to a landfill, composting facility, in-vessel digestion operation, transfer/processing facility, chip and grind operation, or a recycling centre.
- d) Reintroducing waste back into the agricultural operation through on premises organic waste recycling methods, such as tilling directly into agricultural land or through no-till farming, is also permitted.

Some companies are providing cannabis solid waste management services. GaiaCA, with facilities based in several counties, claims to have helped divert over 750,000 lbs of cannabis waste through zero waste services, including composting, recycling, and material recovery<sup>227</sup>. Composting is a large part of their waste services program.

<sup>225</sup> [Cannabis Cultivation Waste Discharge Regulatory Program General Order Information](#). State Water Resources Control Board.

<sup>226</sup> California Integrated Waste Management Board. Regulations: Title 14, Natural Resources – Division 7, CIWMB. Chapter 3.1 [Compostable material handling operations and facilities regulatory requirements](#).

<sup>227</sup> GaiaCA cannabis waste management services. [Website](#) accessed March 2019.

## California Dispute Resolution, Compliance, and Enforcement<sup>228</sup>

Water and solid waste complaints are typically dealt with by state authorities, while odour complaints are investigated by local authorities. The California Air Pollution Control Officers Association admits that odour complaints can be difficult to investigate, as smells tend to dissipate quickly, and the offensiveness of certain smells can be subjective<sup>229</sup>. Since January 2016, the South Coast Air Quality Management District (which monitors air quality issues for most of Los Angeles, Orange, Riverside and San Bernardino counties) has received 11 complaints of odours allegedly created by marijuana growers, dispensaries or processing facilities<sup>230</sup>.

The State may take a licensing or an administrative action at any time within five years after the department discovers, or with reasonable diligence should have discovered, any violation of state law or local ordinances. The State uses the violation classes and applicable fine amounts as follows (repeat violations may result in an escalation of violation class):

- “Serious.” Violations which preclude or significantly interfere with enforcement of any state law, or those that cause significant false, misleading, or deceptive business practices, potential for significant level of public or environmental harm, or for any violation that is a repeat of a Moderate violation that occurred within a two-year period and that resulted in an administrative civil penalty. All Serious violations are subject to licence suspension or revocation.
- “Moderate.” Violations that undermine enforcement of any state law, are likely to cause public or environmental harm, or are a repeat of a Minor violation that occurred within a two-year period and resulted in an administrative civil penalty.
- “Minor.” Violations that are not likely to have an adverse effect on public safety or environmental health.

Examples of state-level environmental violations:

- Licensee used a water source that was not identified in the licence application.
- Failure to dispose of cannabis waste as identified in the licensee’s approved management plan.
- Failure to deposit cannabis waste at permitted facilities.

Compliance promotion materials include:

- North Coast Regional Water Quality Control Board. 2016. Quick Guide to Watershed Best Management Practices. Adapted from the Mendocino County Resource Conservation District’s Watershed Best Management Practices for Cannabis Growers and other Rural Gardeners.
- State Water Resources Control Board. 2017. Cannabis Cultivation Policy: Principles and Guidelines for Cannabis Cultivation.
- California Water Boards. [Cannabis Cultivation Best Management Practices](#).
- California Water Boards. [Cannabis Enforcement Factsheets and Quick Links](#).
- [California Cannabis Portal](#)
- California Water Boards. [Cannabis Cultivation Waste Discharge Regulatory Program](#)

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<sup>228</sup> California Code of Regulations. Title 3 Food and Agriculture. Division 8. Cannabis Cultivations. [Chapter 1 Cannabis cultivation programs](#). January 2019.

<sup>229</sup> Staggs, B.E. 2018. Marijuana stinks. [Here’s what cities, businesses, and neighbors can do about it](#). The Cannifornian

<sup>230</sup> Ibid.

In Santa Barbara County, which has more cannabis cultivation licences than any other location in California, the *Environmental Thresholds and Guidance Manual*<sup>231</sup> can be used to assess if significant impact from individual or cumulative effects results in any of the following:

- Interferes with progress toward the attainment of the ozone standard by releasing emissions which equal or exceed the established long-term quantitative thresholds for NO<sub>x</sub> and VOC.
- Equals or exceeds the state or federal ambient air quality standards for any criteria pollutant (as determined by modeling).
- Produces emissions which may affect sensitive receptors (e.g., children, elderly, or acutely ill).
- Produces toxic or hazardous air pollutants in amounts which may increase cancer risk for the affected population.
- Creates odour or another air quality nuisance problem impacting a considerable number of people.

Local health and safety officials must sign off on all odour control systems employed by Santa Barbara County growers<sup>232</sup>. If the County authorities receive three odour complaints regarding a business within a year, the company must take steps to fix the problem. If the problem is not resolved, the county may revoke local permits<sup>233</sup>. Santa Barbara County has restricted outdoor cannabis cultivation in the region, which includes the community of Carpinteria, and has frequently been in the media regarding odour nuisance complaints<sup>234</sup>. A hotline has been set up by the county for residents to report any suspected violation. Planning and Development staff at the county have opened enforcement cases and issued nine violation notices; not related to odours, but rather for operators not having valid state licences, as well as for using lights<sup>235</sup>.

## 7.0 Conclusion

The legal cultivation of recreational cannabis is a new and emerging commercial enterprise in British Columbia. By bringing the industry out of the black market, there is substantial opportunity to regulate it in such a way as to minimize impacts to the environment. This report provides an overview of the production and manufacturing processes, including input requirements, and explored the issues and challenges associated with air, water, and solid waste discharges. The focus of the report is on the description and discussion of best available control technologies for the management of air emissions, and liquid and solid waste.

In many ways, the production of cannabis and its associated environmental impacts can be compared to most other agricultural crops, particularly in cultivation practices associated with greenhouse and outdoor production. The main differences are that the solid and liquid wastes may contain cannabinoids, and odour nuisances associated with cultivation and processing may be high. Perhaps the most difficult aspect to regulate from an environmental standpoint is the outdoor cultivation model, which will result in the least control over air emissions, pesticide drift, and liquid waste discharges. Much of the focus of this report has been on air emissions and associated best practices for odour control. This focus is the result of input from stakeholders and from direction within the literature regarding nuisance complaints associated the

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<sup>231</sup> Santa Barbara County, 2017. Cannabis Land Use Ordinance and Licensing Program. [Final Environmental Impact Report: Air Quality and Greenhouse Emissions. Section 3.3](#)

<sup>232</sup> Sandy, E. 2019. [How Glass House Farms Helped Santa Barbara County Address Cannabis Odor Issues](#). Cannabis Business Times.

<sup>233</sup> Staggs, B.E. 2018. Marijuana stinks. [Here's what cities, businesses, and neighbors can do about it](#). The Cannifornian.

<sup>234</sup> Fuller, T. 2018. ['Dead Skunk' Stench from Marijuana Farms Outrages Californians](#). New York Times.

<sup>235</sup> Magnoli, G. 2018. [Marijuana Growers, Storefront Owners Work Way Through Santa Barbara Permit and Licensing Process](#). Noozhawk Santa Barbara News.

industry, particularly in urban areas. Existing technology continues to evolve and may be able to mitigate many odour problems associated with indoor and greenhouse production as well as manufacturing and extraction. While upfront investment costs may be an initial challenge for some of the smaller operations, the requirements by HC and other jurisdictions is expected to result in wide-scale adoption.

British Columbia, and Canada, may be relatively new to the legal recreational cannabis industry, but much can be learned from both the successes and failures of other jurisdictions such as Washington State, Oregon, California, and Colorado. Whether it is laboratory testing for pesticide residues, or requiring an odour abatement plan in order to successfully obtain a permit, regulation of the industry can be developed in such a way that best practices are strived for and achieved.