TECHNICAL PAPER

Mitigating Cannabis Odor in Grow Facilities

Caitlin D. Naske
Lead Chemical Engineer
Dynamic Air Quality Solutions
Princeton, New Jersey USA

ABSTRACT:

The legal cannabis industry is growing exponentially in North America. However, it is doing so in the absence of consistent or unified regulations and standards, especially when it comes to odor mitigation. The existing requirements vary state to state and even city to city, but generally facilities are expected to have "no detectable odor" at the edge of the property. This very ambiguous statement leaves a lot of unknowns for engineers to effectively design an odor mitigation system. Absent are the specific compounds, likely upstream levels and target downstream concentrations that would be needed for an effective system design. The following is a primer to help fill in some of the blanks for the operator and designer.

ODOR COMPOUNDS

First it is important to understand the compounds responsible for the odors. The primary culprits are a family of volatile organic compounds (VOCs) called terpenes. Terpenes are produced by a wide range of plants not limited to cannabis. In addition, cannabis terpene emissions vary based on strain, sex, age, plant part, cultivation conditions [1] [2], drying, processing and storage method [3]. Variations in terpene profiles contribute to many of the different fragrances and characteristics of the product that influence consumer preferences [4]. Although terpene profiles are often unknown or unpredictable [2] there are several terpenes found in most strains. Table 1 identifies these terpenes and includes many that are attributed to the strong and distinct cannabis odor.

Table 1. Common Cannabis Terpenes and odor compounds

Found in most strains [4]	**Strong Cannabis odor** [5] [6]	**Other common terpenes** [4] [7]
β-caryophyllene	β-caryophyllene	α-pinene
α-humulene	α-humulene	limonene
β-myrcene		linalool
		bisabolol
		(E)-β-farnesene
		β-ocimene
		terpinolene

One of the challenges of cannabis odor mitigation is the variation in terpene concentrations throughout the growth cycle of the plant, as well as throughout the various stages of processing. Terpene emissions increase as the plants grow [8], peaking when they flower, and can become further intensified during drying, curing, and processing [9]. Drying results in the loss of most of the highly volatile compounds, specifically monoterpenes (limonene, myrcene, pinene), leaving the less volatile compounds (especially caryophyllene) in dried cannabis [10].

In addition to terpenes from the cannabis plants themselves, other compounds may be present in the exhaust from other indoor sources, for example fertilizer and extraction processes (butane, propane). Different fertilizer types will produce different combinations of gas emissions and some will require targeted carbons due to the small size of the gas compounds that may be present. The article "Balancing the Nutrient Equation in Cannabis Cultivation" has a good overview of the different types of fertilizers utilized in the industry. [11].

ODOR THRESHHOLDS

Beyond knowing what compounds are in the air, the next question for system design is the odor threshold of those compounds. The odor threshold or odor detection threshold is the lowest concentration of a compound that can be detected by the human nose. A high chemical concentration does not always cause a strong smell noticeable by neighbors [6]. The most abundant terpenes in cannabis plant emissions may not be the compounds responsible for the distinct cannabis odor. For example, one study found that a mixture of four terpenes associated with cannabis odor (pinene, myrcene, limonene, and caryophyllene) had low alert responses when field tested on narcotic detection dogs trained to detect cannabis [6]. Further research is still needed to identify the odor causing compounds or combination of compounds.

The majority of grow facilities working to control odors use activated carbon filters [12]. But what is activated carbon and how does it work? Activated carbon can be made from a wide variety of materials including coal, coconut shell, walnut shell, and wood. These materials are taken and activated either by thermal activation, using steam, or chemical activation, using acid and heat. The activation forms a network of small pores creating a large surface area available for adsorption. The starting material and the method of activation lead to different pore structures, pore size distributions and quality of activated carbon. In the pores the atoms or molecules of gas are held by adsorption, a bond or force between the carbon and the gas molecule. Most adsorption occurs in very small pores called mesopores (2-50 nm) and micropores (<2 nm). Two measures of activated carbon quality include BET surface area and carbon tetrachloride (CTC) activity where 60% CTC or higher indicates a high-quality carbon.

ACTIVATED CARBON

Activated carbon can come in several different physical forms including powder, granular, pellets, paper, and honeycombs. Powder activated carbon (PAC) is used in water applications and to make other forms and structures such as extruded pellets and honeycombs. Granular activated carbon (GAC) and pellets can be used in trays or cylinders or GAC and PAC can be incorporated into pleated filter media. Honeycombs are self-supporting, structured media assembled into modules typically 2-6 inches deep.

It is important to understand that not all activated carbons and adsorbents are created equal and not all are suitable for cannabis odor mitigation. When comparing different activated carbon filters, it is important to target the compounds present. Activated carbon can remove terpenes and general VOC’s easily without any additives. However, if sulfur compounds are produced from a secondary source for example from fertilizers, additives are required to effectively capture these small compounds.

There is a wide range of activated carbon products on the market- from 1-inch filters to deep bed carbon scrubbers, all target different applications and removal requirements and each promoting their product advantages and present performance data in a variety of ways. Navigating the growing number of activated carbon suppliers can be a challenge. But understanding a few basic principles and parameters can help. The three basics are capacity, efficiency, and mass transfer zone (MTZ). Activated carbon performance is typically presented as capacity and efficiency. Generally, capacity refers to the amount of a gas that a given amount of activated carbon can remove under a given condition. Efficiency represents the upstream/downstream removal rate of the activated carbon system for a given gas at a given concentration and airflow. It is very difficult to compare filter capacities and efficiencies across different products unless they are tested under the same conditions. One standard method for testing activated carbon performance is ASHRAE Standard 145.2 designed to test full size products that are used in the field. The test provides both a lifetime estimate and a filter efficiency [13].

A critical activated carbon design factor that is often overlooked is mass transfer zone (MTZ). MTZ is the section of carbon where active adsorption is occurring, or more specifically, the depth of carbon needed for complete capture of the gas, at a given airflow and concentration. As shown in Figure 1, the MTZ (blue dashed rectangle) starts at the inlet and moves through the media as it becomes consumed. The media above the MTZ is saturated with a given gas (solid green) and no longer has active adsorption. Below the MTZ there is new media (white) that the gas has not entered yet. Most applications will have multiple contaminant gases and therefore will have multiple MTZs, one for each gas. These MTZs will vary in length and will move at different rates, which can make estimating the lifetime for a system difficult. The MTZ length determines the efficiency and effective lifetime of the media rather than its capacity. For example, a carbon can have high overall capacity, but if the MTZ is long or the media depth is short, contaminants will exit the filter and lead to odor complaints. In this example, the carbon would be replaced before it could fully utilize the total capacity.

The MTZ is not only influenced by the type, concentration and number of contaminants, but also other design factors including the area of media and airflow through the media. The higher the concentration and/or air velocity, the longer the MTZ and the more depth that is required to prevent contaminant breakthrough and downstream odors.

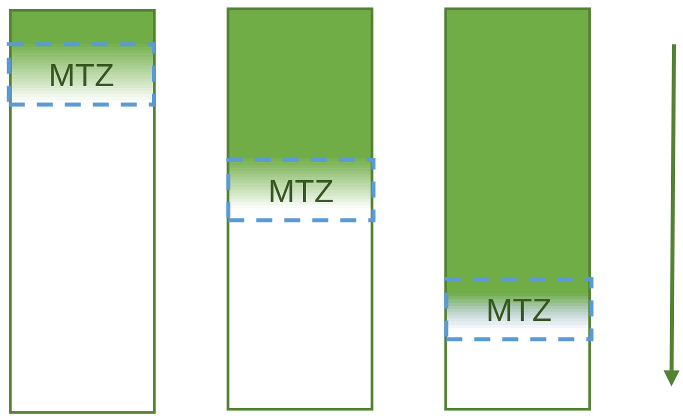

Figure 1. Progression of the mass transfer zone through a column of media

OTHER FACTORS

Outside of the activated carbon performance, there are other important factors to consider in overall system design. Whether trying to retrofit an existing system or designing a new one, pressure drop must be taken into account. Simply put, pressure drop is the resistance to airflow of the air cleaning system. Existing HVAC systems will be designed with a certain maximum pressure drop. For new and/or stand-alone systems it is an important factor that relates directly to energy consumption. It is also directly related to the format of carbon filter chosen. or example, pellet beds can be very effective, but they are very dense (think of a bag of dog food) and it takes a lot of energy to push air through them. Honeycomb modules allow for more consistent airflow and far lower pressure drops. There is a fine balance between maintaining effective odor removal and minimizing energy cost.

Another simple and often forgotten way to maintain carbon performance is to install adequate prefiltration to protect and prevent damage to the activated carbon. Debris can build up on the surface of the activated carbon over time reducing the carbon availability, inhibiting the adsorption of gases and restricting air flow. At minimum a MERV 8 filter should be used upstream of the carbon and should be replaced frequently based on the manufacture’s instruction.

Below is a real-world example of improved performance when protecting activated carbon. In a field comparison of activated carbon matrices installed in a large grow facility, in System A one set of carbon modules were protected by MERV 8 particulate filters and in System B the carbon modules were protected by active-field polarized media air cleaners. The polarized media is not only a high-efficiency particulate filter, but it can also remove 40-60% of VOCs in the air stream. After 7 months of installation a carbon module from each air handler configuration was removed and returned for spent carbon analysis. This test allowed the determination of remaining carbon capacity of the field carbon compared to unused carbon. After 7 months, the inlet of System A was 55% consumed; that of System B was only 42% consumed. Similarly, the analysis of the outlets showed that System A was 46% consumed and System B was only 37% consumed. The higher loading at the inlet demonstrates how the MTZ moves through the media consuming the inlet first.

The results show that the use of the polarized media pre-filter can significantly extend carbon life. They will also remove virtually all biologicals in the airstream.

Table 2. Spent Carbon Analysis Results (% consumed)

Filter Description	Inlet (% Consumed)	Outlet (% Consumed)
Polarized Media + Carbon	42%	37%
MERV 8 + Carbon	55%	46%

As the modules become consumed over time, their efficiency will be reduced, and odors will start to breakthrough more readily and in higher concentrations resulting in detectable odor at the exhaust. After 7 months the carbon modules still had remaining life and remained in use. It is typically recommended to replace the carbon when it is approximately 70%-80% consumed if odor is not detected prior. It was estimated that this application would be able to keep the remaining carbon in place for a total time of a year before change-out.

CONCLUSION

The implementation of a comprehensive odor mitigation strategy is more than simply buying an off-the-shelf carbon filter. Beyond what is discussed above such factors as building envelope and pressurization, air change rates, and airflow patterns all make a difference. It is important to work with an engineer and/or supplier that have experience designing activated carbon systems so the result is a long-lasting solution that will effectively remove odors without increasing energy and maintenance costs.

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