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Odor Control in the Cannabis Industry: Lessons from the New Kid on the Block

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For centuries before germ theory became widely accepted, people believed that foul odors caused devastating diseases such as bubonic plague, cholera, and malaria (whose name literally means "bad air.")[1,2] Now bad odors are recognized as affecting human health through psychological pathways, including stress-mediated headaches and sleep disruption.[3–9] These effects may occur along with the more direct physiological harms of air pollution, which include cancer, heart disease, and respiratory disease.[10]

The brunt of bad odors is frequently borne by lower-income communities already struggling with other exposure and health disparities.[11–18] Odor is an underappreciated driver of environmental injustice within communities near industrial facilities, landfills, wastewater treatment plants, asphalt plants, and concentrated animal feeding operations (CAFOs), where bad odors can occur daily. In addition to the unpleasantness of the odors themselves, residents may worry about the environmental conditions that give rise to the smells,[13] adding to their distress.

Although the U.S. Clean Air Act sets emissions standards for a handful of air pollutants,[19] the federal government does not regulate environmental odors. Some states and cities do have odor regulations, although short-term exposures can be difficult to document, and exemptions may be allowed for major sources, such as manufacturing and CAFOs.[20]

Now, however, a more precautionary perspective is being advanced by an unexpected source: the cannabis cultivation industry. Perhaps in a bid to gain acceptance for this newly legalized and sometimes controversial crop, growers and regulators are embracing new attitudes and contributing new insights into how unwelcome or offensive odors may cause harm, including to some of our most vulnerable citizens.

Cannabis: The New Neighbor

The cannabis industry is expanding rapidly around the world, and every year new jurisdictions allow its recreational or medical use.[21] But increased cultivation of this long-banned crop is giving rise to concerns among some neighbors about the pungent odors it can produce. The smells are especially strong during flowering,

Cannabis, grown both indoors and outdoors, releases odors throughout its growing cycle, especially just prior to harvest. These odors can be overpowering or offensive to some, and the resulting annoyance may impact mental or physical health. Images, left to right: © Bloomberg, Matthew Staver/Getty Images; © Sean Horton, Stocksy/stock.adobe.com.

A few key terpenes are often detected at high levels in and around cannabis grows, yielding scents that may be piney, grassy, citrusy, woody, floral, or earthy. The skunky odor commonly reported to emanate from mature cannabis plants is attributable to sulfurous compounds. Images, clockwise from top left: © Svt/stock.adobe.com; © iStock.com/luca gavagna; © Geoffrey Kuchera/Shutterstock.com; © iStock.com/Leslie Lauren; © iStock.com/phet phu.

which typically lasts 4–5 weeks before harvest, and subsequent processing, which can take another 3–4 weeks.[22] These smells are distinct from those produced by burning cannabis; they are the aromas of the plants themselves, which vary depending on cultivar or strain.

Brittany Heaton, principal cannabis analyst with the Southern California county of Santa Barbara, says odors have been a significant concern across the region for years, ever since cannabis cultivation facilities were first proposed and permitted following California's legalization of recreational use in 2016. "A lot of the appeals in the beginning were around odor," she says. "Someone would come in for a land-use entitlement to try and cultivate cannabis, and a lot of the complaints [from the public] started out as 'This is an area where the smell is going to affect people.'"

Depending on the type of grow—outdoors in open air, indoors under light emitting diode (LED) lights, or inside vented greenhouses—cannabis cultivation facilities can be sited in a wide range of settings, from rich to poor, urban to rural, industrial to pastoral. Odor can be issue in any of them. According to one study, nuisance legal actions may pose a greater financial threat to the cannabis industry in the United States than regulation.[23]

Santa Barbara's many cannabis grows—including some of the nation's largest[24]—are predominately outdoors or in greenhouses, allowing for easy escape of nuisance odors when conditions are right. Heaton acknowledges that the scents can carry far and that some individuals appear to be acutely sensitive to them, even in passing. "There are areas of the county that you drive through during different parts of the year when the plants are mature," she says, "and some people can be bothered by that smell."

In the southern part of the county, where many residents are accustomed to leaving their windows open day and night, unwelcome cannabis odors can waft in with the ocean breeze. The smell can be particularly prominent around the City of Carpinteria, which is ringed by former flower greenhouses that local officials have embraced as cannabis grow sites.[24,25] Located just east of the wealthier City of Santa Barbara, the population of this small beach town is predominantly Latino.

The county has yet to deny or withdraw a permit based on odor impacts, Heaton says. But her office has received occasional complaints suggesting that some residents consider odors more than a mere nuisance, and potentially a health threat. "I have heard from individuals that it's irritating, that they have headaches, or maybe irritated lungs or sore throats. But to date, it hasn't been substantiated," she says. "I believe them, I believe that they're experiencing something. It's just been anecdotal."

Volatile Organics and Ozone

More than 1,000 miles up the Pacific Coast, Vancouver, Canada, is another center of cannabis cultivation. And where goes cannabis, so goes its scent. In a 2021 analysis of the "urban smellscape" of metro Vancouver, cannabis cultivation facilities were associated with nearly a quarter of the 261 odor reports made by residents to a web-based application during the 20-week study period.[26] That was twice as many as reported for the next most odorous source: wastewater treatment plants. To learn more about how neighbors of cannabis grows may be affected by odors, many of the same researchers who worked on that study authored a March 2022 review of the literature related to the air-quality impacts of these facilities.[27]

Cannabis odors are largely attributable to a class of volatile organic compounds (VOCs) called terpenes.[28] More than 150 distinct terpenes have been identified in different cannabis strains,[29] from among approximately 30,000 expressed across the plant world.[30] In their review, the authors identified a few key terpenes often detected at high levels in and around grows: myrcene (earthy,

The animal waste produced by CAFOs is stored in lagoons and frequently sprayed on agricultural fields as a fertilizer. The emissions from CAFOs are notoriously foul smelling and have been implicated in physical and mental health effects among neighboring residents.[53,54] Images: lagoon © Gerry Broome/AP Photo; inset © Allen G. Breed/AP Photo.

musky), limonene (citrusy), terpinolene (woody, floral), and pinene (piney, grassy).[31] The "skunky" odor emanating from mature flowers of some strains was once thought to also be produced by terpenes, but recent research suggests that sulfurous compounds are responsible, in particular one called 3-methyl-2-butene-1-thiol.[32–35]

Although the scents of these chemicals may be overpowering or offensive to some, and the resulting annoyance may impact mental or physical health, a key question remains: Can they cause direct physiological harm?

Research published in 2002[36] showed that mice exposed to oxidation products of limonene and pinene experienced transient adverse effects to the upper and lower airways. However, these effects occurred at concentrations higher than are likely to be found anywhere outdoors. More relevant to the real world, emitting terpene VOCs in a "VOC-limited" region—one with a low ratio of VOCs to nitrogen oxides, as is common in cities—may favor the formation of ground-level ozone,[31] a pollutant associated with respiratory and cardiovascular diseases and related deaths in humans.[37,38]

"Current studies suggest that cannabis cultivation facilities might already be changing the ozone concentration where they are located," the Vancouver researchers wrote in their review.[27] For example, a 2019 study in Denver, Colorado, found that VOC emissions from local cannabis cultivation facilities could increase hourly ozone concentrations by up to 0.34 ppb in the morning and 0.67 ppb at night.[39] Review coauthor Naomi Zimmerman, an assistant professor of mechanical engineering at the University of British Columbia, says the significance of such changes depends on how close a region is to exceeding the National Ambient Air Quality Standard for ozone. "For some areas that are exceeding or close to exceeding ambient air-quality standards, this can be a concern," she explains. "If ozone levels are well below thresholds, it's less of a concern."

The authors concluded that health effects from cannabis cultivation facility emissions are mostly driven by odor annoyance. "There's a subjective experience of how offensive odors are, in particular from cannabis cultivation facilities," says coauthor Amanda Giang, an assistant professor in the Institute for Resources, Environment and Sustainability at the University of British Columbia. "But the degree of offensiveness that someone perceives or feels, research has indicated, can have an effect on the stress response that they experience."

Pinpointing a Culprit

Back in Santa Barbara County, odor remains a subject of considerable interest—and occasional strife—among local officials, residents, and cultivators. Although odor has yet to derail any cannabis cultivation plans, the county does typically require odor

control at grow sites, Heaton says, and the current grace period for compliance at many recently permitted facilities is set to expire soon.

"We're confident that once we get everybody into the fully licensed space we'll be able to better enforce," she says. "Our compliance team is going to be doing regular reviews, and we're looking at technologies to measure and monitor odor."

In the meantime, a local industry group known as the Cannabis Association for Responsible Producers (CARP) Growers is taking action on odor abatement. CARP Growers president Autumn Shelton, who also runs her own cannabis farm, says that years ago local greenhouse growers began installing a dry vapor–producing technology to neutralize airborne odors.

It worked—to a point. "The odor got significantly better here once more farms came on with that technology, but it still existed," Shelton says. "We still were getting complaints about the skunky smell. And that was really hard to understand, because if you walk into somebody's greenhouse, it doesn't smell like a skunk. It smells like terpenes, like different varieties that they're growing, sometimes more fruity, sometimes a little more pungent, but certainly never the skunky smell."

This mystery sent CARP Growers and its consultants down a road that eventually led to thiols, volatile sulfur compounds that also produce odors found in garlic, rotten eggs, and skunk musk—and that were only recently widely recognized as components of cannabis odors.[32,34,35] The issue, it turned out, is that although terpenes are the dominant odor source up close, cannabis thiols avoiding neutralization by dry vapor were dispersing across significant distances under some weather conditions, says CARP Growers executive director Peter Dugré. These odors were being detected by neighbors at very low concentrations.[40] Now that CARP Growers has its culprit, the association is testing a new air-filtration device that uses carbon scrubbing in combination with other odor-abatement technologies to more effectively remove thiols at the source.

From Cannabis to CAFOs

The evolving drama around cannabis odors in Santa Barbara offers a valuable lesson: Identifying the specific chemical constitutions of problematic odors may be a key to monitoring, mitigating, and regulating them.

Don Wright agrees—in fact, it is a message the Texas-based odor specialist and consultant has repeated for years in an effort to improve upon the traditional approach of viewing humans as the ideal sensors of environmental odors. Often, he explains, it is assumed that odor makeup and perception is so complex and inherently "squishy" that the best way to assess its character and impact is through a trained odor inspector.[20,41]

Wright, however, advocates for an instrument-based approach. "I have always argued that an analytical approach to environmental odor assessment stands a much better chance of encouraging primary odor-source operators to take ownership of significant environmental odor impacts originating from their operations," he says. His method, developed over the past three decades and applied to cases from CAFOs to breweries, involves using multidimensional gas chromatography–mass spectrometry to parse complex odors down to their constituent parts. With that information, authorities and operators can prioritize key compounds for management.[42]

"If you look at it from the perspective of the downwind citizen and can define what it is that they are primarily responding to, very often that's not a hundred or a thousand compounds that are being emitted from the source," Wright says. "There's typically just a handful of compounds, in some cases one or two, that people are actually perceiving."

The far-reaching skunky smell of cannabis grow operations is a perfect illustration, he says. In fact, he and his collaborators recently used this approach to investigate the role of thiols in skunky odors produced at a large cultivation facility in Texas.[43] He also used it to demonstrate that a "barnyard"-scented compound called *p*-cresol is a dominant signature odorant far downwind of large cattle feedlots and swine CAFOs.[44]

"In all these cases, these character-defining compounds are emerging from extremely complex emission backgrounds," Wright says. "When I first studied the swine CAFO industry back in the late 1990s, the count was up to several hundred compounds.[45] Seemingly, from an analytical standpoint, the odor was being chased by seeing how many compounds we could define."

However, with respect to problem solving, it can be more effective to determine the smallest subset of impactful compounds. The work by Wright and colleagues[44] on *p*-cresol informed subsequent research into reducing odor from CAFO waste lagoons by adding hydrogen peroxide and an enzyme called horseradish peroxidase. These compounds react with *p*-cresol to form an odorless compound called Pummerer's ketone.[46]

Crowdsourcing Odor Data

In another strategy to corral odor data—and perhaps lead to solutions for affected communities—researchers and web developers are increasingly turning to crowdsourcing. The Vancouver researchers' "urban smellscape" project, now dubbed Smell Vancouver, continues to collect odor reports via a website as part of a larger ongoing research project.[47] And they are far from alone.

The greater Pittsburgh area has its own share of cannabis grows, but the city is more notorious for other sources of odors.[48] Although Pittsburgh has improved its air quality remarkably in recent decades, the city is still prone to frequent atmospheric inversions that trap emissions from the steel and power plants surrounding the city.[49] In March 2022, the city suffered under a pall of particularly bad air for 4 days. The sulfuric stench drove a huge spike in odor reports to Smell Pittsburgh, a smartphone app that since 2016 has tracked residents' subjective experience of local air quality.[50]

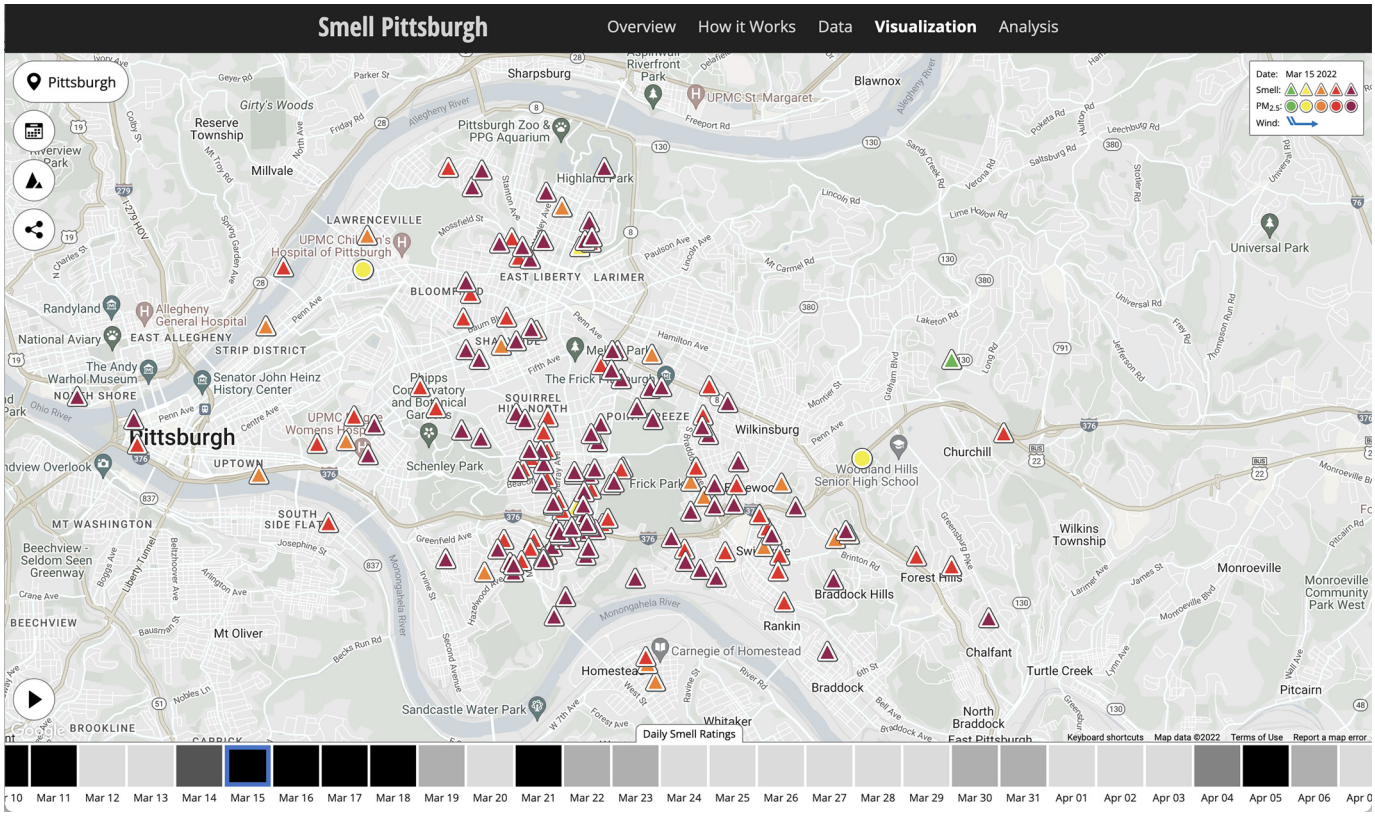
"This is the worst it's smelled all year," read one March 15 report to the app. "Dry burning sulfur, completely unacceptable, why is this still allowed?" Another user wrote, "This horrible sulfur smell seeps into my house even with windows and doors closed. It's sickening some days, like today."

Smell Pittsburgh registered 185 reports of malodorous air that day, with an average "smell value" of 4.36 on a scale of 1 to 5. March 16 was even worse, registering 193 reports. Many respondents noted not only what the air smelled like, but also how it made them feel. "Rotten eggs. Migraine, nausea, throat irritation, and general irritation that I can't even open my windows for fresh air. This is absurd. We can't keep dealing with days like this," one resident lamented.

Another reported an "exhaust industrial" odor that left them with a headache and nausea: "Cannot sleep, cannot live in this place."[51]

Although not all harmful chemicals have off-putting smells, unwelcome odors can serve as a sentinel of the presence of harmful pollutants. To further explore these relationships, the developers of Smell Pittsburgh created a second app for a nationwide audience called Smell MyCity, which launched in 2019. The app's intended users are local residents, organizations, and regulators, who can use smell report data to help track down potential sources of pollution in neighborhoods.

Although the U.S. Environmental Protection Agency (EPA) does not regulate odors, it is getting in on the crowdsourced smell-tracking game too. A new app called Odor Explore is being



Residents of Pittsburgh, Pennsylvania, can submit odor reports to a smartphone app called Smell Pittsburgh. This screenshot from 15 March 2022 reflects a spike in reports resulting from a 4-day odor-trapping inversion. Crowdsourcing platforms like this can help produce a fuller picture of how environmental odors and air pollution are experienced by those exposed. Image: Courtesy Smell Pittsburgh.

developed and tested in Louisville, Kentucky. If rolled out nationwide, it will allow members of the public to report odors in their community and view reports submitted by others.[52]

The goal is for state and local agencies to use data from the app to facilitate responses to odor complaints, says U.S. EPA project lead Rachelle Duvall. "By gathering detailed information on odors with the help of community scientists," she says, "we hope that ultimately this app will engage and empower communities and help state, local, and Tribal governments, as well as industry, in evaluating air pollution and odor-control strategies."

Compiling such reports on a national scale and comparing them with air-quality data could also provide valuable new insights into the full impacts of air pollution on public health and well-being. And it could advance environmental justice by contributing to a more accurate accounting of disparities in harmful exposures, a benefit acknowledged by the U.S. EPA. "Many communities impacted by odors also have environmental justice concerns," Duvall says, "so this app and data generated could support addressing those issues."

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