Cannabis Contaminants: Regulating Solvents, Microbes, and Metals in Legal Weed

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Abstract

In June 2019, Illinois became the 11th U.S. state—plus the District of Columbia—to legalize recreational cannabis sales or use.[1] Many more permit medical cannabis.[2] Tax collectors, entrepreneurs, and law enforcement officials have all watched closely as legalization has hopscotched across the United States since 2014.

So have some environmental health experts. That's because products derived from cannabis can deliver a number of contaminants to the user, including pesticides, molds, bacteria, metals, and solvents.[3,4] Although many of these contaminants are also found in our food, water, and air, the potential exposures and health consequences are less well understood in the context of cannabis use.

EHP previously reported on the regulation of pesticides on cannabis, including the difficulty of setting specific residue limits.[5] But solvent residues, microbes, and heavy metals each pose regulatory challenges of their own.

Policing the quality and safety of cannabis products is far from straightforward. Such products come in many forms and infusions that can be inhaled or ingested, including traditional cured "flower" for smoking or vaporizing; a range of concentrates, oils, and tinctures; and all manner of foods and drinks. Further complicating the matter is the plant's dual role as both a recreational and a medical drug used to treat a wide range of conditions.[6] Cannabis users include not only healthy adults but also more sensitive or vulnerable members of the population, including children and patients with cancer or HIV.

Photograph of an older woman rolling a joint

In 2017, a committee of the National Academies of Sciences, Engineering and Medicine concluded there is "conclusive or substantial" evidence that cannabis or cannabinoids may be helpful in treating chronic pain, chemotherapy-induced nausea, and spasticity related to multiple sclerosis.[6] Evidence is less clear for the many other conditions treated with cannabis, partly because the drug's illegal status has made it difficult to study. Image: © iStockphoto/Instants.

At the federal level in the United States, cannabis is still considered an illegal drug.[7] As a result, neither the Food and Drug Administration nor the Environmental Protection Agency has provided any guidance on how to regulate contaminants or on which cannabis-related exposures can be considered safe. States have had to determine on their own how to protect millions[8] of cannabis users, and they have come up with widely varying responses. The result is an uncertain and occasionally incoherent regulatory landscape.

"States have become experts at taxing and controlling this industry, and public health and safety has generally been a secondary or even-later-down-the-line consideration," says Ben Gelt, board chair of the Cannabis Certification Council, a national organization based in Colorado. "I think that is shifting, to some degree. I think that these issues are going to inevitably bubble up."

Chemical Solvents

Chemical solvents are used to extract valuable therapeutic and psychoactive compounds from cannabis flowers, including cannabinoids like tetrahydrocannabinol (THC) and cannabidiol (CBD) as well as terpenes like limonene and pinene. The highly concentrated oily or waxy extracts that result can be heated and inhaled directly or infused in foods, drinks, and other products.[9]

Cannabis extracts have proven to be an integral part of legal markets. A recent report from market research firm BDS Analytics indicates that inhalable concentrated products in particular are the fastest-growing segment in legal markets nationwide. They are outpacing not just flower but also edibles (which themselves contain a concentrated form of the plant) and in 2018 represented more than a quarter of total sales, up from just 10% in 2014.[10,11] But from an environmental health standpoint, they also represent a potential risk given that solvents used to manufacture cannabis extracts can persist in the final product.[12]

Side-by-side photographs of cannabis shatter and wax produced from butane hash oil

Concentrates designed to be heated and inhaled such as shatter (top) and wax (bottom) are produced using solvents. Some of these solvents, including butane and propane, can persist in finished products. Images: top © iStockphoto/HighGradeRoots, bottom © iStockphoto/rgbspace.

In many ways, solvents have been the easiest cannabis contaminant for regulators to tackle. That's because many states have borrowed from guidelines[13] established by the U.S. Pharmacopeial Convention (USP), a nonprofit organization independent of the federal government.

These guidelines divide 59 solvents that can be used to manufacture herbal medicines and other drug products into three different classes: those that should be avoided, those that should be limited, and those that may be regarded as safer than the others on the list because existing data indicate that they are "less toxic in acute or short-term studies and negative in genotoxicity studies."[13] (The USP does note that long-term toxicity and carcinogenicity studies are lacking for many of the solvents in the "less toxic" category.[13])

For each of the 59 solvents, the USP suggests a specific concentration below which residues in the final product may be considered safe. Many states have lifted directly from these limits in developing their own regulations and testing criteria.

Still, the USP's guidelines have at least one glaring omission: They do not include butane and propane. These petroleum-derived solvents are not commonly used in processing herbal medicines and other drug products. But they became popular in the illicit cannabis industry in the early 2010s—in part because they are easy to buy and use[14]—and later moved to legal markets.

Both are efficient at extracting cannabinoids and terpenes, but the solvents must be cleared from the final product lest they leave potentially harmful residues.[15] Although harder to purge, butane is more common in legal and illicit markets alike because it is cheaper. It produces popular extracts with names like wax, shatter, batter, and budder, depending on texture and consistency, which are heated to the point of aerosolization or combustion, then directly inhaled.

Because the USP does not address either butane or propane, state regulators are left to their own devices. This has led to a huge range of residue limits for the solvents among legal states.

California's Bureau of Cannabis Control has set a residue limit of 5,000 ppm5,000ppm for both solvents in the final product,[16] which is the same limit that the USP assigns across the board to its list of 26 "less toxic" solvents. The limit in Massachusetts is a scant 12 ppm12ppm.[17] And Colorado's Marijuana Enforcement Division initially set its limit at 800 ppm800ppm, bumped it up to 5,000 ppm5,000ppm a few years later,[18] and settled on 1,000 ppm1,000ppm in 2018.[19,20]

"The states have chosen to make up their own limits, and I see them all over the map," says Chris Hudalla, founder of Massachusetts cannabis- and hemp-testing lab ProVerde Laboratories. "There's a huge disparity among hydrocarbon residuals."

Supercritical carbon dioxide (CO2CO2) extraction is a much safer method for deriving concentrates, but it is also more difficult and costly. This method employs CO2CO2 in a fluid form as a solvent. Using sophisticated machines to control temperature and pressure, processors of plant botanicals, nutraceuticals, hops, and cannabis can target different components of the plant material to separate and drop out of the mix.[21] After pressure is released, the supercritical CO2CO2 becomes gas and disappears from the solid or oil extract and thus does not represent a health risk to the consumer.

Microbial Contamination

State-certified labs typically use a technique called gas chromatography to determine residual solvents—at least they can agree on that.[13] With microbial contamination, there's no such consensus. On top of that, states do not agree on which microbial contaminants to test for in the first place or which constitute a health risk.

Cannabis plants and products can pick up molds or bacteria while growing (particularly if they are grown outdoors or in a nonsanitary indoor environment) or during subsequent handling and processing.[22] Most molds are relatively harmless and ubiquitous in the environment, but some may present a health threat when inhaled, particularly to immunocompromised individuals like some medical cannabis users.[22]

Although pathogenic spores may be able to withstand combustion, some states consider mold to be a low-risk contaminant. But even in places where mold is grounds for rejecting cannabis flower, the moldy buds can still be used to produce concentrates. Image: Courtesy American Herbal Pharmacopoeia.

Case in point: *Aspergillus*. The genus includes approximately 180 individual species of mold, many of which are very common in indoor and outdoor environments; most people breathe in *Aspergillus* spores every day. Even in individuals with weakened immune systems, fewer than 40 *Aspergillus* species are known to cause infections.[23] Among those, only 4 species—*A. fumigatus*, *A. flavus*, *A. niger*, and *A. terreus*—have been singled out to date for testing on cannabis due to their association with the plant and potential health effects.[22]

Even though pathogenic *Aspergillus* spores may be able to survive the heat of combustion, some states consider the risk of harm to be low enough that they do not bother testing for them. “The mold is so common in the environment that a person could pick it up many different ways,” reads a 2015 report[24] detailing recommendations for Oregon’s cannabis contaminant-testing regime. “A positive test result would not mean the product is unsafe for most uses for most people.”

The Oregon report recommends that, rather than testing for the four strains, the state health authority simply require that product labels carry a warning of the risk for people with suppressed immune systems. In the end, the state chose not to do even that. Instead, Oregon currently relies on a measure known as “water activity” to monitor mold and other microbial contaminants on cured flower.[25] This measure, which is also used in food processing, reflects the amount of water available to microorganisms. Samples with water activity levels below a certain threshold are considered too dry for microbes to flourish and, thus, safe.

Oregon’s policies are partially at odds with the recommendations of a white paper on microbial testing published by the independent Cannabis Safety Institute in 2015.[22] The paper concluded that, although water activity is a useful metric, the four *Aspergillus* species in particular represent a significant health risk to immunocompromised individuals. Therefore, they should be screened for independently, and any samples that test positive should be rejected.

California regulators seem to have taken this message to heart.[16] Three different *Aspergillus* testing options are available to labs: Live culture of the entire genus[26]; polymerase chain reaction (PCR), a genomic test that hunts for the DNA of the target strains; and the latest method, quantitative PCR, which can not only detect but also quantify mold spores and cell fragments.

The state does not stipulate which method should be used, says Bureau of Cannabis Control spokesman Aaron Francis—and the result, ultimately, is even more uncertainty about test results. That’s because the differences among the methods are not purely academic. Although the PCR-based genomic methods are faster and more precise, they also come with drawbacks.

Most importantly, says Roy Upton, president of the American Herbal Pharmacopoeia (AHP) and lead editor of its 2013 cannabis monograph,[27] molecular techniques may not always distinguish between living and dead microbes and thus may detect nonviable pathogens. Standard plating remains a reliable technique widely used in microbiological testing.

The time-tested method of generating plate counts, however, has an Achilles' heel of its own: There is no way to grow only the targeted species in a culture. Instead, a trained mycologist must be able to identify them by eye among the many other species that may be present.

That's exactly how it's been done in the industry, says Josh Wurzer, president of the cannabis-testing lab SC Labs, which serves both California and Oregon, and itself has transitioned to using genomic methods of testing for microbial contaminants. "You can, and 20 years ago you had to, identify and count specific species using culture-based methods. I'm assuming some labs may [still] be doing that," Wurzer says. "The drawbacks would be misidentification of the target species, causing either false positives or false negatives."

Like Oregon, Massachusetts does not require any specific tests for *Aspergillus*. But instead of relying on water activity as a proxy for microbial contamination, its Cannabis Control Commission has taken a third approach: testing for total yeast and mold counts using classic plate-based culture assays.[17] Hudalla of ProVerde Laboratories acknowledges that this method cannot distinguish harmless microbes from potential threats and may lead to the rejection of perfectly safe cannabis flower. But he also argues that failed flower can be remediated through extraction and then resold in concentrated form—and that because total yeast and mold counts cover a broader range of potentially harmful microbes, they are also more protective of public health.

Aspergillus is not the only point of contention when it comes to microbial testing. There's also disagreement among states regarding the value of hunting for the pathogenic bacteria *Salmonella* and *Escherichia coli* as well as for mycotoxins[28]—toxic and carcinogenic compounds produced by the spores of certain molds (including *Aspergillus*) that are costly to test for and rarely encountered, says Susan Audino, a consultant who chairs the Cannabis Advisory Panel and Working Group of the Association of Official Analytical Chemists (AOAC). The AOAC and AHP are both currently working to bring some clarity to the matter of microbiological contamination of cannabis. They seek to develop new sets of standards and best practices to help guide regulators and the industry toward a more cohesive, empirical, and science-based approach.

Getting there will take time, but for many in the industry it cannot happen soon enough, says Audino. "The challenge we have right now is that we are struggling to keep up with the stakeholder needs." Meanwhile, she adds, "I think it is important to highlight the necessity to derive regulations based on science, and not base them on instrument capability."

Metals

Metals are the final class of contaminants that cannabis regulators must contend with. The cannabis plant is known as a hyperaccumulator; as it grows, it can take up unusually high levels of metals from the soil or growing medium through its roots and potentially into its flowers.[3] The plant may also become contaminated through the spraying of fertilizers, even those certified organic, if the products or the water used to mix them contain trace levels of metals, says Russell Pace, president of the California-based Cannabis Horticultural Association. Although such spraying is likely to occur before the formation of flowers that will later be harvested, Pace says, “if [the fertilizer] is applied to the plant surface, there’s a higher chance that the plant would uptake [the metal] directly, and it could be stored in the flowers.”

Cannabis is a hyperaccumulator, meaning it can take up higher levels of metals from soil than other crops. Metals can occur naturally in soil, or they may have made their way from industrial sources. In areas with a history of farming, legacy contamination may be left over from long-ago spraying with pesticides that contained lead, mercury, cadmium, and other potentially toxic metals.[29] Image: © Bettmann/Contributor.

Metals in the plant could also be carried into and concentrated in extracts,[30] depending on the extraction method used, such that any cannabis product could conceivably become contaminated, from cured flower to inhalable concentrates to edibles. In a sense, the solution is straightforward: Test products for heavy metals just as for pesticides, solvent residues, and microbes.

But by now we know that managing cannabis contaminants is rarely so simple. Even if legalized states were unanimous in requiring that all cannabis products be tested for heavy metals, they'd still miss another potentially significant source of exposure: Presale batch testing cannot screen for exposures associated with the operation of handheld cannabis vaporizers.

These devices, sometimes known as vape pens, employ metal coils or ceramic elements powered by small batteries to heat and aerosolize liquid or solid cannabis concentrates prior to inhalation. They have become highly popular in legal markets because they are accessible, discreet, and easy to use. But if e-cigarettes are any indication—being similarly designed and operated to aerosolize nicotine-laced fluids—vape pens are also capable of releasing metals from their heating coils and other components.

Ana Rule, an assistant professor of environmental health and engineering at Johns Hopkins University, has researched metal emissions from e-cigarettes and other electronic vaporizers.[31,32] She says she has never studied vaporizers intended specifically for use with cannabis concentrates and prefilled cartridges. But some devices are dual-purpose and, in any case, certain assumptions can be made based upon common elements and principles.

"What we can definitely say is that no matter what you put in it, if there's a metal coil, even if it's lower concentrations of metals being emitted, there are metals," she says. "No matter what flavor you put in it, no matter if it's with nicotine or without nicotine, the coil is leaching metals."

Additionally, Rule says, it is possible that other metal components in both e-cigarettes and cannabis vaporizers, including various wires and joints, may release particles when heated. "Not all of the concentrations can be explained by just the metal coil," she notes. "The coil, in theory, does not have any lead. In theory, it does not have any zinc. [But in our studies] there's zinc, and there's lead, and there's tin, and so we think they are coming from other parts of the vaping device."

Extrapolating from the results of her team's most recent study, which evaluated the impact of vaporizer power levels on metal emissions, the authors predicted that inhalation from certain devices by typical e-cigarette users could exceed chronic minimal risk levels[33] for both manganese and nickel.[32]

And there's yet another potential source of metal exposure that regulatory and testing regimes are likely to miss, says Alec Dixon, co-founder and director of client relations for SC Laboratories: the cartridges themselves. Testing has suggested that lead can leach from solders and cartridge components into the liquid contents.[34]

Although not considered safe at any level by the World Health Organization,[35] lead is allowed by California's Bureau of Cannabis Control in flower and other finished cannabis-based goods at concentrations below 500 ppb500ppb.[16] According to Dixon, about 1% of prefilled cartridges sent to his lab fail for exceeding that limit. But at least 50% have some level of detectable lead in the liquid extract.

And based on his own testing, Dixon believes this contamination is not an all-or-nothing, one-time event. Instead, he thinks it occurs gradually in prefilled cartridges, which can sit on dispensary shelves and in consumers' homes for months at a time. "What we're seeing is there's this leaching effect taking place over time," he says. "So the longer that an extract is sitting in a cartridge, the more potential leaching is taking place over time."

Still, Wurzer says he commends state regulators for requiring that cannabis products be tested for metals in their final form, which is what led to the discovery that cartridges can be a potential source of lead contamination. California tests up to 3% of cartridges prior to sale, depending on the manufacturer's batch size.[36] That's a huge leap from next-door Oregon, which does not test cannabis for metals at all.[25]

"No state has it right, and there's still a long way to go, and there's still a lot of research that needs to be done," concludes Gelt of the Cannabis Certification Council, whose #whatsinmyweed social media campaign is designed to raise consumer awareness about cannabis contaminants. "All of the states have significant gaps in their policies when it comes to testing and ensuring product quality and quality assurance. It just depends on what state you're in where the gap is."

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