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What the Cannabis Industry Should Know About Glass

Article

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This article takes a critical look at the quality of glass used in the cannabis industry and, in particular, asks the question whether the optimum grades are being used for processing, storage, and delivery systems used for the wide array of liquid cannabis consumer products manufactured and consumed today. It compares the different types of glassware used for carrying out ultra-trace element analysis using inductively coupled plasma mass spectrometry (ICP-MS), together with exhaustive studies carried out by the pharmaceutical industry to better understand the corrosive nature of pharmaceutical liquids on glass storage bottles and vails.

The article concludes with with possible examples of using inferior quality glass for two specific application areas, one using dropper bottles with lead-based ink graduation marks and the other a study of legal and illicit vaping devices that found high levels of toxic metals in the THC extracts. Both examples highlighted potential contamination that might have contributed to some cannabis consumer products being over the regulated limit for a panel of heavy metals.

Laboratory applications of glassware

Depending on its application, glass is manufactured from raw materials that are typically extracted from the ground including sand, silica, feldspar (aluminum silicate), limestone, and soda ash. As a result, it could potentially contain elements that are found in the earth's crust, including transition elements, rare earths and the classic heavy metals. For that reason, it is well recognized by analytical chemists carrying out trace element analysis that glassware is a material to be avoided when dissolving, preparing, and diluting samples for analysis by ICP-MS, especially where high temperature is being used for digestion procedures. It is well accepted when working at the ultra-trace level that many types of glasses including Pyrex, borosilicate, and soda lime are just not suitable because they are contaminated with metallic impurities, which could not only leach out during digestion and preparation of the samples but also negatively affect the calibration standards and impact the accuracy of the measurements. For that reason, plastics and polymers are the most widely used materials to prepare samples for trace element analysis. However, the type of polymer is also important because many of them are manufactured from low quality raw materials and can be problematic for trace element analysis. In their 1977 landmark paper in Analytical Chemistry, John R. Moody and Richard M. Lindstrom evaluated some common laboratory container materials for trace element impurities and showed that many of them are just not suitable when working in the ultra-trace environment[1]. Table 1 shows typical elemental impurities in common plastics, compared to borosilicate glass, which, in addition to the major elements, silicon (Si), sodium (Na), aluminum (Al) and boron (B), also contains parts per million (ppm) levels of other metal impurities, such as chromium (Cr), manganese (Mn), iron (Fe), nickel (Ni), zinc (Zn), lead (Pb), titanium (Ti), molybdenum (Mo), and zircon (Zr)[2].

Table 1: Summary of metal impurities in some common labware materials[2]**.**

Material	**Number of Elements**	**Total ppm**	**Typical Impurities**
Polystyrene (PS)	8	4	Na, Ti, Al
Tetrafluoroethylene (TFE)	24	19	Ca, Pb, Fe, Cu
Low-density polyethylene (LDPE)	18	23	Ca, Cl, K, Ti, Zn
Polycarbonate (PC)	10	85	Cl, Br, Al
Polymethyl pentene (PMP)	14	178	Ca, Mg, Zn
Fluorinated ethylene propylene (FEP)	25	241	K, Ca, Mg
Borosilicate glass (BSG)	14	497	Si, B, Na, Al (majors), Cr, Mn, Fe, Ni, Zn, Pb, Ti, Mo, Zr (impurities)
Polypropylene (PP)	21	519	Cl, Mg, Ca
High-density polyethylene	22	654	Ca, Zn, Si

(HDPE)			

Glass used in the pharmaceutical industry

In the late 2000s, in response to a number of product recalls from glass flakes being found in glass vials, the United States Pharmacopeai (USP) proposed a new general chapter – Chapter <1660> Evaluation of the Inner Surface Durability of Glass Containers[3] – to update and provide additional information to the already published Chapter <660> on Containers Used in Pharmaceutical Packaging/Delivery Systems[4]. The updated chapter recommended approaches to predict potential formation of glass particles and delamination in glass storage vessels and containers. It provided information about factors that affected the durability of the inner surface of glass containers and recommended approaches to predict the potential of a drug product to cause formation of glass particles and delamination and to detect their occurrence in the presence of common pharmaceutical products, preparations, and liquids. The scope of the chapter was to address bottles and vials manufactured with molded glass, together with ampules, cartridges, vials, and pre-filled syringes manufactured from tubular glass.

To build on the USP chapter and to better understand the suitability of glass for drug product storage and delivery systems used today, Haines and co-workers from Schott AG in Germany recently carried out a comprehensive investigation that was published in the Journal of Pharmaceutical Science and Technology entitled **Comparative Predictive Glass Delamination** Study[5]. They wanted to assess the corrosion properties of glass and, in particular, its interaction with drug products and various chemicals used in the manufacturing process, which can potentially alter the interior glass surface and generate adverse effects. In this study, the chemical durability of the most common types of glass used in the pharmaceutical industry were evaluated, including tubular **borosilicate glass** (Type 1), molded borosilicate glass (Type 1), and molded soda lime glass (Type 2) vials and bottles using different solutions including citrates, phosphates, and chlorides defined in USP Chapter <1660>, Evaluation of the Inner Surface Durability of Glass Containers[3].

The suitability of the three different kinds of glass vails were investigated for chemical attack based on differences in the interior glass surface using scanning electron microscopy (SEM), the number and concentration of elements leached into solution, changes in the solution pH, and visual inspection of suspended particles. The observed chemical durability differences are directly related to a combination of the glass composition and manufacturing and processing conditions. While all three types behaved similarly when filled with ultrapure H_2O, significant differences were observed when the vials were filled with a more aggressive solutions, such as 15% potassium chloride (KCl).

The study is recommended reading, but in summarizing the findings, it was found that, with the more aggressive solutions, the tubular borosilicate glass containers were more durable than the molded glass variety, while the soda glass was the least durable of the three types, with significantly more reactive sites and discoloration. Table 2 shows one dataset from the study, concentrations of the major elements in the three different types of glass by ICP-OES (inductively coupled plasma-optical emission spectroscopy) over an extended period of time at elevated temperatures, emphasizing that the tubular borosilicate glass is slightly more corrosion-resistant than the molded variety, with the molded soda glass faring the worst. This is reasonable to expect based on the reduced chemical durability of soda lime compositions and their known susceptibility for dissolution and surface cracking in the presence of corrosive solutions.

Table 2: Concentration of leached glass elements by ICP-OES in µg/mL after 24 weeks of storage at 40°C

with 15% KCl solution (Note: 0.5 μg/ml was the detection limit by ICP-OES)[5].

Type of Glass	Na [μg/ml]	Si [μg/ml]	B [μg/ml]	Al [μg/ml]	Ca [μg/ml]	Ba [μg/ml]
Type 1 Borosilicate Glass (Tubular)	2.1	1.0	<0.5	<0.5	<0.5	<0.5
Type 1 Borosilicate Glass (Molded)	2.5	1.5	<0.5	<0.5	<0.5	<0.5
Type 2 Soda Lime Glass (Molded)	22	67	<0.5	<0.5	19	<0.5

The overall conclusion of the study was that these factors should be given prime considerations when selecting containers and vails for drugs with active ingredients as well as excipients and water-based diluents with high levels of salt components. For that reason, soda glass would not be a good choice for parenteral applications for intravenous drug delivery.

Use of glass in the cannabis industry

This study could potentially have serious implications for the cannabis industry where glass is one of the most widely-used materials for storage of cannabis extracts, oils, and diluent oils, and often for the equipment used in the cannabinoid extraction, distillation, and purification process. So, it is a very pertinent question to ask whether the optimum grades of glass are being used for the different applications including distillation vessels, storage containers, dropper bottles, consumer delivery devices such vape pens and carts etc., especially if the application uses elevated temperatures. Let us take a closer at a couple of examples.

Metallic particles in vaping carts

It is estimated that vaping accounts for almost 50% of all cannabis consumption. So, any information in the public domain about vaping and the potential of heavy metals finding their way into the vape juice, is of critical importance. We know there has been limited research on the corrosion of metallic components including stainless steel, brass, and nichrome inside the vaping devices that find their way into the extract. However, there have been very few studies carried out on understanding if any of those metal particles find their way into the vaping aerosol at elevated vaping temperatures. This is a challenging analysis that requires a high level of operator expertise to trap and collect the aerosol containing mixtures of cannabinoids, terpenes, diluent oils, and other hydrophobic liquid in the vape tank and introduce them into the ICP-MS for analysis. One would assume that the high temperature vaping process of up to 600°C would be the obvious reason for corrosion of the metallic components. However, that might not necessarily be the case. A recent study by researchers at the National Resource Council of Canada took 20 legal and 20 illicit unused THC vape cartridges and characterized them for a panel of 13 elemental contaminants[6]. The legal ones were purchased at a local vape store, while the illicit ones were obtained from local law enforcement. Using ICP-MS they found extremely high levels for 9 of those metals. Based on the distribution and variable sizes of the metal particles in the different vape carts, they found they were dispersed throughout the liquid in a heterogenous manner. Moreover, on further investigation using scanning electron microscopy (SEM) coupled with energy dispersive XRF (EDS), the research team confirmed these in fact were metal particles suspended in the THC liquid. It appeared the corrosion had taken place while the vape carts were on retailers' shelves for several months; the older devices showed higher levels of metal contaminants. To exemplify this, Figure 1 is a bar graph of the results for all 20 of the legal and 20 of the illegal vape samples.

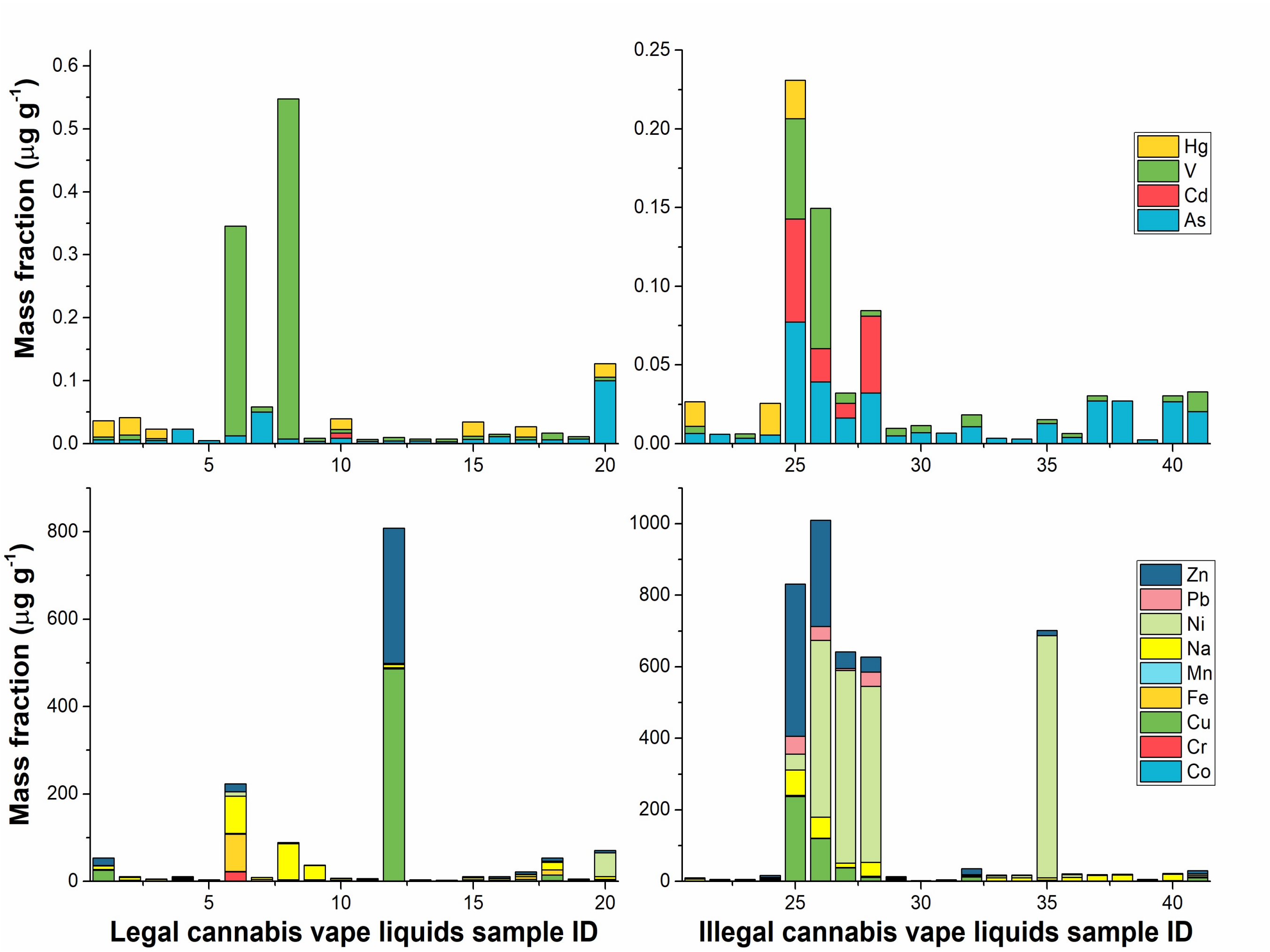

Figure 1: Elemental mass fractions of studied cannabis vape liquids from legally purchased vaping devices (sample IDs 1–20) and illegal vaping devices (sample IDs 21–41)**6. Note:** Used with kind permission from the authors.

It can be seen that even though the "big four" heavy metals in most cases were below the inhalation product regulated limits (for most US states), in many of the samples (refer to Table 3) the other metals were in the hundreds of ppm, which would escape the scrutiny of most state regulators. In fact, the researchers found high levels of sodium (Na) in some of the extracts, which indicated that perhaps the glass tank was being attacked. On further investigation using laser ablation ICP-MS, the research team found extremely high levels of Si, Na, and Al in some of the particles, which strongly suggested that there could have been delamination taking place, resulting in minute particles of glass shards floating around in the vaping liquid. This is demonstrated in Figure 2, which shows **an elemental map of the three major elements found in glass, Si, Na, and Al, with three identical "hotspots" (circled in red) indicating they are likely shards of glass from the vaping device**. These findings beg the question, what type of glass is being used in the manufacturing of vape carts and pods? And is it the optimum purity for this type of application?

Note: It should be emphasized that the researchers have not ruled out small particles of glass entering the liquid when cutting open the glass tank. They plan to investigate this in the next phase of the study, together with finding out if the metal particles find their way into the aerosol at elevated vaping temperatures.

Table 3: Regulated limits for the big four heavy metals in inhalation products for the vast majority of states in the US.

Regulations for inhalation products	Pb	As	Cd	Hg
Majority of US states' required limit in µg/g (ppm)	0.5	0.2	0.3	0.1

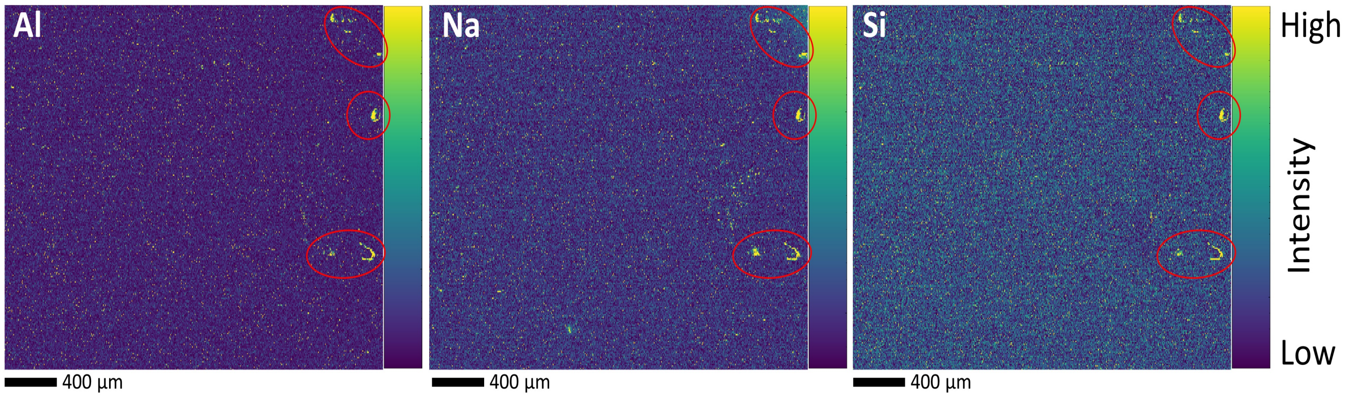

Figure 2: An elemental map of three elements, Si, Na, and Al, with three identical "hotspots" (circled in red), indicating they are likely shards of glass from the vaping device[5]. **Note:** Used with kind permission from the author.

Contaminated dropper bottles

Graduated glass dropper bottles are widely used for cannabis consumer products such as tinctures, topicals, and oils. But what type of glass is typically used to store these types of liquids? There was great interest in a study carried out by the Florida Dept. of Agriculture, Consumer Services Food Safety Lab to monitor a group of toxic metals in over 200 hemp extract oils stored in graduated droppers[7]. The good news was that lead (Pb) was the only heavy metal that was found in appreciable amounts. Forty-two of the samples tested positive for Pb, but below the regulatory limit for of 0.5 ppm. However, the bad news was that 10 of the samples exceeded the regulated limit, with two of them being over the Environmental Protection Agency's Resource Conservation and Recovery Act (EPA's RCRA) limit for a hazardous waste of 5 ppm (10x regulated limit for FL), while one of them was 19 ppm (38x higher than the limit). On further investigation of the samples being stored in glass bottles, they found that the lead levels increased over time, which suggested the Pb was either being leached out of the glass bottle or it was a component of the ink that was used for the graduated markings. The researchers did not rule out the glass dropper bottles being the culprit because, as mentioned previously, we know that some glasses are known to contain transition and heavy metals contaminants from the manufacturing process. Their study is still on-going, but it now seems likely that the ink is a Pb-based formulation similar to leaded household paint and was slowly dissolving and leaching out lead into the oil. However, why did only a few of the oils have high Pb levels? One would think if it was the graduated markings, they would all be high. So that is still an unanswered question that needs to be resolved.

Note: Pb-based household paint was banned in the US in 1978..

Final thoughts

It is well-recognized that glass could potentially contain elements that are found in the earth's crust, including transition elements, rare earths, and the classic heavy metals. That is why polymer or plastic labware is always used for carrying ultra-trace element analysis using ultra-sensitive techniques like ICP-MS. Even when plastic cannot be used for the measurement of elements like mercury, because the metal ions can stick to the side of the plastic container, then high purity quartz is used instead, which is significantly cleaner than glass[8].

In addition, the pharmaceutical industry has conducted an exhaustive evaluation on the characteristics of different types of glass material for the storage and delivery of drug formulations and published comprehensive guidelines defined in USP Chapter <1660> and recently supported by an extensive study carried out by researchers at Schott AG. This therefore becomes a strong incentive to use the right material, because with FDA (Food and Drug Administration) oversight, pharmaceutical manufacturers understand the penalties if they do not abide by the rules.

The cannabis industry would be well-advised to follow those guidelines and give serious thought to selecting the optimum purity of glass, particularly if high temperatures are being used in the application. It is clear from the two examples cited in this article that when the wrong type of glass material is used, it could result in cannabis consumer products being over the regulated limit for a panel of elemental contaminants, especially if the liquid is being stored for long periods of time. The problem with a fractured state-driven regulatory system is that there is no federal oversight advising cannabis producers what to do. One just has to hope that enough companies value their reputation and put a high priority on consumer safety. Only time will tell!

*This article was updated on May 25, 2023, to include figures with higher resolution.

References

1. Selection and Cleaning of Plastic Containers for Storage of Trace Element Samples, J. R. Moody and R. M. Lindstrom, ANALYTICAL CHEMISTRY, Vol. 49, No. 14, Pages 2264-2268, DECEMBER 1977, **https://pubs.acs.org/doi/pdf/10.1021/ac50022a039?utm_source=314798&utm_medium=pdf&utm_can**
2. Guide to Reducing Errors and Contaminating Using Plasma Spectrochemistry, P. Atkins, Measuring Heavy Metal Contaminants in Cannabis and Hemp, CRC Press, Boca Raton, FL, ISBN: 978-0-367-55472-9, December 2021
3. USP Chapter <1660> Evaluation of the Inner Surface Durability of Glass Containers, United States Pharmacopeail Convention, **Rockville, MD**,

https://www.uspnf.com/sites/default/files/usp_pdf/EN/USPNF/revisions/c1660.pdf?utm_source=3147

4. USP Chapter <660> Containers Used in Pharmaceutical Packaging/Delivery Systems United States Pharmacopeail Convention, Rockville, MD, **https://www.usp.org/sites/default/files/usp/document/workshops/660_glass_containers_used_in_ph**
5. Comparative Predictive Glass Delamination Study, D. Haines, E. Gober-Mangan, M. Klause, U. Rothhaar, Schott AG, Germany, Pharmaceutical Industry, Cantor Verlag, Aulendorf, Vol. 84, No. 8, 1001–1012 (2022), **https://www.researchgate.net/publication/363315970_Comparative_Predictive_Glass_Delamination_**
6. Evidence That Metal Particles in Cannabis Vape Liquids Limit Measurement Reproducibility, Z. Gajdosechova et. al., ACS Omega 2022, 7, 42783−42792, **https://pubs.acs.org/doi/10.1021/acsomega.2c03797?ref=PDF?utm_source=314798&utm_medium=pdf**
7. Heavy Metals in Hemp Extracts, D. Picket, S. Giovinazzi Florida Dpt of Agriculture, Science of Cannabis Symposium, Analytical Cannabis, September, 2021, **https://www.analyticalcannabis.com/videos/heavy-metals-in-hemp-extract-products-313423?utm_source=314798&utm_medium=pdf&utm_campaign=pdf_lead_conversion?utm_source=31**
8. Contamination Control During Sample Preparation for Trace Element Analysis of Electronic Cigarette Aerosol with Inductively Coupled Plasma-Mass SpectrometryR. Steven Pappas, Naudia Gray. Spectroscopy, May 2023, Volume 38, Issue 5, Pages: 8–13, **https://doi.org/10.56530/spectroscopy.kj2187f7?utm_source=314798&utm_medium=pdf&utm_campa**