

Introduction

The analysis of metals in cannabis has been difficult for many labs because of a lack of official methods in the industry. In August 2021, AOAC adopted an ICP-MS method for the determination of arsenic (As), cadmium (Cd), mercury (Hg), and lead (Pb) in a variety of cannabis and cannabis-derived products. The new method is adopted as an Official Method of Analysis in First Action status. This AOAC method has undergone rigorous assessment by the AOAC Expert Review Panel (ERP) and achieved consensus through AOAC members.



The method specifies microwave acid digestion of homogenized cannabis or hemp samples, followed by quantitative analysis by ICP-MS.

Experimental

Instrumentation

The 7850 ICP-MS, with the Ultra High Matrix Introduction (UHMI) system and ORS4 CRC, was used for the analysis. The Agilent SPS 4 autosampler was used. The 7850 was configured:

- MicroMist glass concentric nebulizer
- Quartz spray chamber
- Quartz torch with 2.5 mm id injector
- Nickel-plated copper sampling cone and a nickel skimmer cone

Parameter	Value
RF Power (W)	1600
Sampling Depth (mm)	10
Carrier Gas (L/min)	0.80
Dilution (UHMI) Gas (L/min)	0.15
UHMI Setting	4
Helium Cell Gas (mL/min)	4.3
KED (V)	3.0



Table 1. Agilent 7850 ICP-MS operating conditions.

Experimental

Standard and samples

To verify the sample preparation digestion process and the accuracy of the ICP-MS method, four NIST SRMs were analyzed. The SRMs included NIST 1547 Peach Leaves, NIST 1573a Tomato Leaves, NIST 1575 Pine Needles, and NIST Apple Leaves 1515. The AOAC method is suitable for the analysis of the range of cannabis and hemp-based products that are listed in Table 2. A sample from each category was analyzed in this study for a spiking study.

Sample Category	Sample
Inhaled	Hemp flower
	Cannabinoid (CBD) vape oil
	Hemp isolate extract
	Full spectrum softgel capsules
	Full spectrum tincture
Oral	Isolate tincture
	CBD coffee grounds
	Hemp butter
	Hemp seed oil
	CBD beef jerky
Topical	CBD hard candy
	CBD pineapple drink
	Full spectrum balm
	Pain relief cream
	CBD balm
Manufacturing	CBD topical oil
	Hemp soap
	Hemp biomass
	Spent hemp biomass
	Trichomes
Manufacturing	CBD crude extract
	CBD distillate
	CBD isolate

Table 2. Types of cannabis and hemp samples that can be analyzed by the AOAC ICP-MS method. The samples in bold italics were used in the spiking study.



Sample preparation

Calibration standards were prepared using a mix of 1% HNO₃ and 0.5% HCl.

- A variety of cannabis and cannabis-containing samples (NC, USA)
- Approximately 0.5 g of cannabis plant or cannabis product were weighed into TFM MARSXpress Plus vessels (CEM).
- 9 mL HNO₃ and 1 mL HCl were added.
- ARS 6 microwave digestion system (CEM) was used to digest the samples and a method blanks.

Results and Discussion

Calibration and calibration verification

Representative calibration curves for As, Cd, Hg and Pb are shown in Figure 1. All show excellent linearity across the calibration range. A summary of the calibration data for As, Cd, Hg, and Pb, including detection limits (DLs) and background equivalent concentrations (BECs) is given in Table 3. The Limits of Quantitation (LOQ) were calculated from 3 x standard deviation (low-level spike) x 100 (dilution factor). The LOQs were within the AOAC SMPR of ≤10 ppb in the original sample.

SRM recoveries

To check the effectiveness of the sample digestion process and the accuracy of the ICP-MS method, each of the four NIST SRMs was prepared in triplicate. Each of the three preparations of the SRMs was analyzed three times using the 7850 ICP-MS. As shown in Table 4, the mean concentrations were in good agreement with the certified concentrations, where values were provided, meeting the AOAC method SMPR acceptance criteria of 80–120%. Blank cells indicate the absence of a certified or reference value.

Element	NIST 1547 Peach Leaves				NIST 1573a Tomato Leaves			
	Measured Conc (ppm, µg/kg)*		Certified Conc (mg/kg)	Recovery (%)	Measured Conc (ppm, µg/kg)*		Certified Conc (mg/kg)	Recovery (%)
	Mean	SD			Mean	SD		
75 As	0.06	0.01	0.06	99	0.109	0.021	0.112	97
111 Cd	0.025	0.001	0.026	96	1.39	0.01	1.52	91
201 Hg	0.034	0.003	0.031	108	0.032	0.002	0.034	96
Pb**	0.78	0.02	0.87	90	0.555	0.098		
52 Cr	1.04	0.08	1R	(104)	2.09	0.51	1.99	105
55 Mn	95.4	3.3	98	97	238.67	34.91		
59 Co	0.068	0.004	0.07R	(97)	0.504	0.014	0.57	88
60 Ni	0.79	0.01	0.69	114	1.50	0.03	1.59	94
63 Cu	3.31	0.08	3.7	89	4.25	0.34	4.7	90
66 Zn	16.38	0.56	17.9	92	26.19	0.27	30.9	85
78 Se	0.108	0.032	0.12	90	0.062	0.009	0.054	114
107 Ag	0.006	0.000			0.023	0.002	0.017R	(135)
137 Ba	128	4	124	103	60.07	0.56	63R	(95)

Element	NIST 1575 Pine Needles				NIST 1515 Apple Leaves			
	Measured Conc (ppm, µg/kg)*		Certified Conc (mg/kg)	Recovery (%)	Measured Conc (ppm, µg/kg)*		Certified Conc (mg/kg)	Recovery (%)
	Mean	SD			Mean	SD		
75 As	0.047	0.008	0.039R	(121)	0.029	0.009		
111 Cd	0.210	0.006	0.233	90	0.014	0.003	0.013	108
201 Hg	0.0380	0.0010	0.0399	96	0.0420	0	0.0432	98
Pb**	0.144	0.002	0.167R	(86)	0.41	0.01	0.47	86
52 Cr	3.4	0.9	3R	(113)	0.46	0.23	0.3R	(153)
55 Mn	434	12	488R	(89)	49.2	1.1	54.1	91
59 Co	0.060	0.005	0.061R	(98)	0.086	0.005	0.09R	(96)
60 Ni	1.43	0.10	1.47R	(97)	0.787	0.024	0.936	84
63 Cu	3.22	0.30	2.8	115	4.79	0.13	5.69	84
66 Zn	32.01	0.77	30.9	104	10.14	0.29	12.45	81
78 Se	0.110	0.007	0.099R	(111)	0.118	0.024		
107 Ag	0.0167	0.004			0.006	0.001		
137 Ba	4.99	0.08	6	83	45.06	1.52	48.8	92

Table 4. Mean concentrations (ppm) of three repeat measurements of four plant-based SRMs, including comparison with reference values, and recoveries for certified elements. Blank cells indicate the absence of a reference or certified value.

Spike recoveries

A spike recovery test was carried out to check the accuracy of the 7850 ICP-MS method. Table 5 shows the results for all SMPR elements spiked at three concentration levels (low, medium, and high) for four cannabis samples (from Table 2).

Mass	Element	MassHunter Software			Calculated Limit of Quantitation (LOQ), µg/kg
		R	DL (ppb)	BEC (ppb)	
75	As*	1.000	0.0158	0.0142	9.18
111	Cd	1.000	0.0026	0.0015	6.25
201	Hg	1.000	0.0068	0.0120	2.16
208**	Pb	1.000	0.0010	0.0150	7.85

*Data for As using half mass correction. **Pb results were based on the sum of the signals measured at mass 206, 207, and 208.
Table 3. Calibration data, DLs, BECs, and LOQs for As, Cd, Hg, Pb.

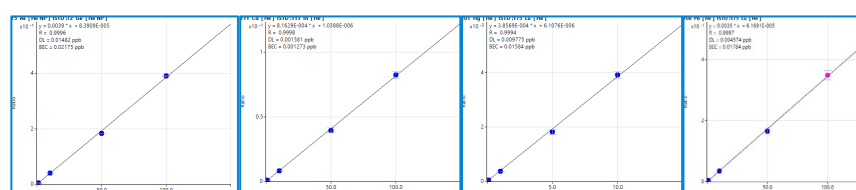


Figure 1. Calibration Curves for As, Cd, Hg, Pb.

Results and Discussion

Mass	Element	Native Level in Matrix ppb, µg/kg	Recovery %		
			Low Spike ≥10 to 100 ppb	Medium Spike >100 ppb to 1 ppm	High Spike >1 to 10 ppm
Flower (Inhaled)					
75	As	91.2	87	95	107
111	Cd	209	99	101	100
201	Hg	16.9	95	94	102
208	Pb	306	66	109	100
Hemp Butter (Oral)					
75	As	0.48	108	103	102
111	Cd	0.16	98	100	95
201	Hg	<LOQ	103	104	101
208	Pb	3.73	95	102	98
Pain Relief Cream (Topical)					
75	As	11.8	64	97	100
111	Cd	2.26	93	99	98
201	Hg	6.86	78	89	103
208	Pb	12.4	69	100	102
CBD Crude Extract (Manufacturing)					
75	As	3.15	88	99	100
111	Cd	1.11	98	97	98
201	Hg	5.76	85	91	94
208	Pb	188	63	89	100

In addition to the quantitative analysis, IntelliQuant data was also acquired to provide semiquantitative results for other elements. Some plant materials can accumulate high enough levels of less typical elements to cause unexpected and unusual interferences. One example is if the rare earth elements (REEs) are present at high enough concentration in a sample they can form doubly charged ion (REE²⁺) interferences. From this data, and many other Cannabis samples we have analyzed, we see Rare Earth Elements (REE) present, see figure 2.

Conclusions

- The AOAC First Action method for the ICP-MS determination of As, Cd, Hg, and Pb and additional optional elements in cannabis samples.
- The accuracy of the method was evaluated by analyzing four plant-based SRMs and conducting a spike recovery test at different concentration levels for As, Cd, Hg, and Pb in four cannabis samples.
- Excellent recoveries achieved for all elements, within the requirements specified in the AOAC method. The ICP-MS also met the LOQ requirements for As, Cd, Hg, and Pb of ≤10 ppb in the original samples, as specified in the SMPR.

References

1. AOAC Expert Panel Review (ERP) for Chemical Contaminants in Cannabis Methods, August 2021 Analytical Methods Week Highlights, accessed August 2021
2. Agilent IntelliQuant for ICP-MS, Fast, automated semiquantitative ICP-MS analysis provides greater sample insight and confidence in the results, Agilent publication, 5994-2796EN
3. Tetsuo Kubota, Simplifying Correction of Doubly Charged Ion Interferences with Agilent ICP-MS MassHunter, Fast, automated M2+ correction routine improves data accuracy for Zn, As, and Se, Agilent publication, 5994-1435EN

Table 5. Mean recovery results of As, Cd, Hg, and Pb in cannabis sample digests. Mean calculated from three separate digests, each measured in triplicate. The recoveries for As, Cd, Hg, Pb in all the cannabis samples were within the AOAC SMPR recovery requirements of 60–115% for low spikes, and 80–115% for medium and high spikes.

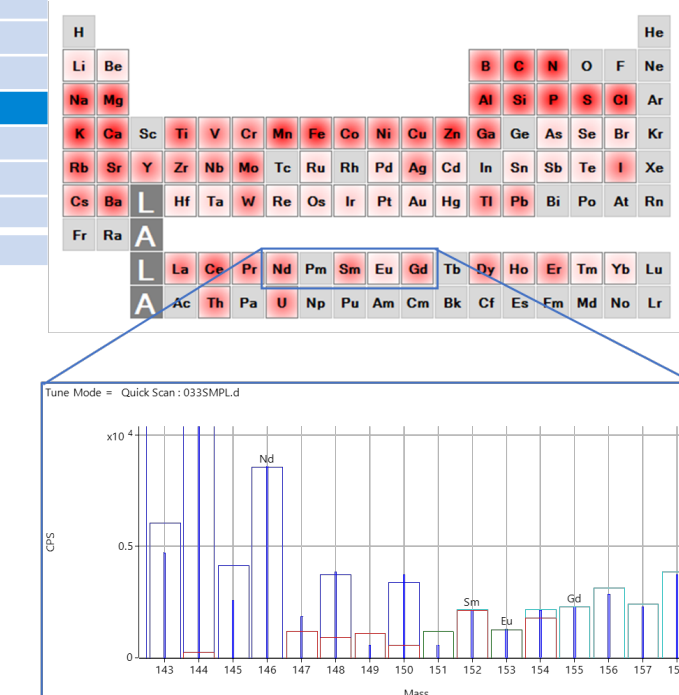


Figure 2. IntelliQuant data of Cannabis Plant, with REE present.

