Application Note

Consumer Products

Analysis of 1,4-Dioxane in Consumer Products by Solid Phase Microextraction and Triple Quadrupole GC/MS

Authors

Katherine Castor,
Anne Cooper Doherty,
Kelly Grant, and Mui Koltunov
California Dept. of Toxic Substances Control (DTSC)

Ron Honnold,
Jessica Westland,
Shannon Coleman, and
Tim Conjelko
Agilent Technologies, Inc.

Abstract

1,4-Dioxane is an industrial chemical contaminant that is of concern even at trace levels in consumer products.[1-6] Government jurisdictions are beginning to regulate the amount of 1,4-dioxane allowed in consumer products globally. It has already been deemed unsafe for use in cosmetics in Canada, and it is a regulated substance in Europe. The allowable concentrations in the United States are expected to vary from state to state, typically at part per billion to low part per million levels. There have been several methods developed to test for 1,4-dioxane, but none of these methods are adequate to detect 1,4-dioxane in consumer products with complex mixtures and solutions.[7,8]

The current study shows methodology for low level detection of 1,4-dioxane in consumer products (cosmetics, liquid soaps, shampoos, and cleaning products). The extraction was performed using an Agilent PAL3 autosampler with solid phase microextraction (SPME) tool. The analysis was performed on an attached Agilent 7890 GC with an Agilent 7000 triple quadrupole GC/MS using Agilent MassHunter software. The previously mentioned analysis was also reproduced (with minor method modifications) on a newer system with an Agilent 8890 GC. Similar autosampler, triple quadrupole GC/MS, and software were used for the latter analysis.

The quantitation of the target analyte 1,4-dioxane is performed using isotope dilution by adding deuterated 1,4-dioxane-d_8 as an internal standard to all samples, controls, and calibrators. This method has a linear quantitation range from 10 to 20,000 ng/g (ppb). Sample size ranges from 0.05 to 1.0 g depending on the matrix. The method detection limit was determined to be 0.05 ppb on the 7890 GC system and 0.01 ppb on the 8890 GC system.

Introduction

1,4-Dioxane is a heterocyclic organic compound, classified as an ether, with a faint sweet odor similar to that of diethyl ether. 1,4-Dioxane ($C_4H_8O_2$) is a colorless liquid or solid at cool temperatures (below its melting point, 53.24 °F). 1,4-Dioxane is highly water-soluble, does not readily biodegrade, and is mobile in the environment.

Due to the myriad of problems attributed to 1,4-dioxane in the environment, it has been identified as a chemical warranting further research toward its removal from consumer products by California DTSC (Department of Toxic Substances Control).[9] The New York State Environmental Conservation Law has been amended to include limits on the maximum allowable concentration of 1,4-dioxane in consumer products. The limit for household cleaning and personal care products is set to 2 ppm effective December 31, 2022 and decreases to 1 ppm December 31, 2023. The maximum allowable concentration of 1,4-dioxane in cosmetic products will be 10 ppm effective December 31, 2022.[10] The state of New York has also adopted a first-in-the-nation drinking water standard for 1,4-dioxane and set the maximum contaminant level of 1 ppb.[10]

1,4-Dioxane is a by-product formed during the synthesis of ethoxylated ingredients used in finished consumer products (cosmetic, personal care, and cleaning products). It is not used as an ingredient in these products but may be present as a trace contaminant by forming inadvertently during ethoxylation. 1,4-Dioxane can form when two consecutive ethylene oxide units are cleaved from a chain of ethylene oxides and form a ring of 1,4-dioxane. It can also form when the ethylene oxide ring opens to form ethylene glycol, and then two ethylene glycols dimerize to form 1,4-dioxane. Both reaction pathways are shown in Figure 1. These ingredients

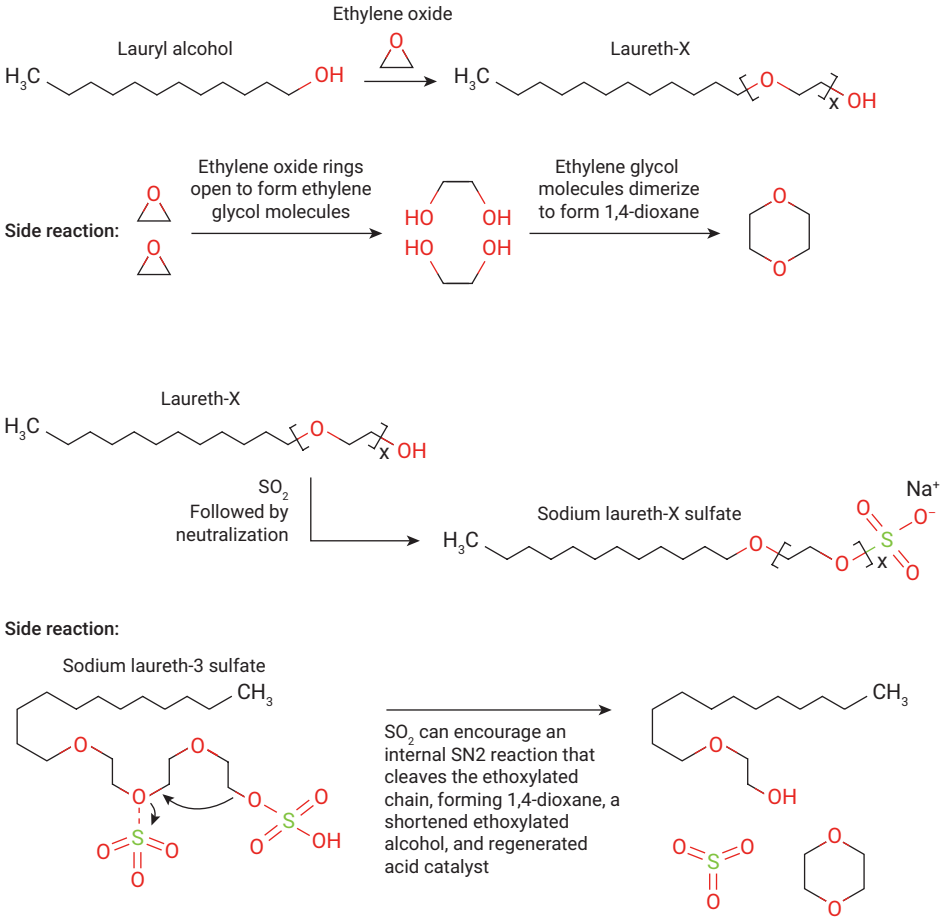

Figure 1. Two reaction pathways for synthesizing 1,4-dioxane (Environment Canada and Health Canada 2010 and C&EN March 22, 2020 volume 90, issue 11).

include certain detergents, foaming agents, emulsifiers, and solvents identifiable by the prefix, suffix, word, or syllables: PEG, polyethylene, polyethylene glycol, polyoxyethylene, -eth- (e.g., laureth sulfate), or -oxynol-.

There have been several methods developed to test for 1,4-dioxane, primarily for soil, water, air, cleaning products, and cosmetics. Without modification, none of the standard methods can quantify 1,4-dioxane at the single-digit ppm level. Consumer products are challenging to analyze due to the complex matrices associated with foaming and viscous products like detergents and gels. None of these methods meet the requirements to accurately detect low levels of 1,4-dioxane in consumer products, thus the need to develop a testing method using SPME, backflush, and triple quadrupole GC/MS technologies.[7,8]

SPME is a sample extraction technique involving the use of a sorbent coated fiber inserted into the headspace of a vial containing an aliquot of the sample to be analyzed. SPME is a nonexhaustive extraction approach that relies on the principle of equilibrium between the sample and the fiber.[11] As it is a nonexhaustive approach on the microscale, the act of sampling does not change the overall sample composition, allowing for repeated sampling when necessary. SPME extraction is considered to be complete when the analyte concentration has

reached distribution equilibrium between the sample matrix and the fiber coating. This equilibrium results in maximum sensitivity and proportional linearity between the analyte concentration in the sample and on the fiber.[12] The equilibrium conditions can be described by the law of mass conservation for a two-phase system (for example, the sample matrix and the fiber coating). The fiber is inserted into the headspace of the vial rather than into the sample matrix directly, thus achieving full distribution.

This traditional SPME method uses a pre-equilibrium state whereby the sample is heated and agitated during extraction. Heat and agitation allow for rapid and convenient solvent-free sample preparation and high-throughput analysis, while still achieving proportional linearity between analyte concentration in the sample and on the fiber.[11,12]

The consumer products analyzed using this method are highly complex and contain a myriad of volatile and semivolatile compounds that are co-extracted with the 1,4-dioxane. To compensate for these matrix effects, the isotope dilution quantitation technique is used.[13] Isotope dilution involves the addition of a known and constant amount of deuterated 1,4-dioxane (1,4-dioxane-d_8) as internal standard to each sample, quality control, calibrator, and calibration verification. The deuterated analog of 1,4-dioxane behaves the same as 1,4-dioxane, both physically and chemically, allowing for the reproducible and accurate quantitation of 1,4-dioxane in complex matrices.

Experimental

Acquisition method

All analyses were performed on the 7890 GC system equipped with a PAL3 autosampler with SPME tool and a 7000 triple quadrupole GC/MS. The second system was an 8890 GC system equipped with similar autosampler and triple quadrupole GC/MS. Triple quadrupole GC/MS and post column backflush were used to enhance sensitivity and selectivity.

After initial full autotune (using atunes.eihs.tune.xml file), a passing check tune must be performed before the start of a batch or every 24 hours. If the check tune does not pass, then corrective action must be performed, followed by a full autotune.

GC method parameters are shown in Table 1. SPME method details are in Table 2. Triple quadrupole GC/MS parameters are listed in Tables 3 and 4.

Table 1. GC method parameters used for the analysis of 1,4-dioxane.

	Agilent 7890 GC, System 1	Agilent 8890 GC, System 2
Temperature	310 °C	280 °C
Pressure	12.6 psi	13.677 psi
Septum Purge Flow	3 mL/min	3 mL/min
Inlet Mode	Splitless	Splitless
Purge Flow to Split Vent	50 mL/min at 2 min	50 mL/min at 2 min
Liner	Agilent inlet liner, splitless, straight, deactivated, quartz (part number 5181-8818)	Agilent inlet liner, Ultra Inert, splitless, straight, 0.75 mm id, recommended for SPME injections (part number 5190-4048)
Column 1	Agilent J&W DB-8270D Ultra Inert GC column, 30 m, 0.25 mm, 0.25 µm (part number 122-9732)	Agilent J&W DB-8270D Ultra Inert GC column, 30 m, 0.25 mm, 0.25 µm (part number 122-9732)
Column 2 (1 m Deactivated FS)	Agilent Ultimate Plus deactivated fused silica tubing, 5 m, 0.15 mm (part number CP801505)	Agilent Ultimate Plus deactivated fused silica tubing, 5 m, 0.15 mm (part number CP801505)
Column 1	1.0 mL/min	1.0 mL/min
Column 2	2.2 mL/min	2.2 mL/min
Run Time	12 min	12 min
Initial Temperature	40 °C	40 °C
Initial Hold Time	4 min	4 min
Column Ramp #1	10 °C/min	10 °C/min
Ramp 1 Final Temperature	100 °C	100 °C
Column Ramp 2	50 °C/min	50 °C/min
Ramp 2 Final Temperature	160 °C	160 °C
Ramp 2 Hold Time	0.8 min	0.8 min
Postrun Time	1.0 min	1.0 min
Postrun Temperature	320 °C	280 °C

Materials and supplies

- Volumetric flasks, class A, 1 and 10 mL with ground glass stoppers
- Analytical balance
- Glass Pasteur pipets
- Volumetric air-displacement pipettes 50 to 1,000 µL with disposable tips
- Agilent headspace vials, screw top, amber, round bottom, 20 mL (part number 5188-6537)
- Agilent screw cap, headspace, steel, magnetic cap, PTFE/silicone septa (part number 5188-2759)
- Screw cap glass vials, 12 mL
- Ultrahigh purity helium
- Ultrahigh purity nitrogen
- Methanol: pesticide residue grade, purge and trap grade

Calibrator and internal standard preparation

- SPME working reference material preparation and SPME 1,4-dioxane solution preparation are performed according to California DTSC.[9]
- Prepare two stock solutions of 1,4-dioxane at 20 and 2 mg/L, and prepare one stock solution of 1,4-dioxane-d_8 at 20 mg/L. All three stock solutions should be prepared in methanol.
- Use class A volumetric flasks and pipettes to make the calibrator solutions of 1,4-dioxane.
- A series of calibration standards to encompass the desired calibration range were also prepared.

Table 2. Agilent PAL3 autosampler method parameters used for the analysis of 1,4-dioxane.

	Agilent PAL3 Autosampler, System 1	Agilent PAL3 Autosampler, System 2
SPME Fiber	Agilent SPME fiber, carboxen/PDMS, StableFlex, autosampler, 1 cm, 85 µm, 24 gauge, light blue (part number SU57335U)	Agilent SPME fiber, C-WR/PDMS/10, dark blue (part number 5191-5875)
Script	SPME-STD-V3.0	SPME-STD-V3.4
Incubation Temperature	50 °C	50 °C
Incubation Time (Pre-Extraction)	1.0 min	1.0 min
Agitation Speed	250 rpm	250 rpm
Fiber Pre-Extraction Conditioning Time	0.5 min	0.5 min
Fiber Pre-Extraction Conditioning Temperature	300 °C	300 °C
Vial Penetration Depth	45 mm	45 mm
Vial Penetration Speed	20 mm/s	20 mm/s
Sample Extraction Time	2.5 min	2.5 min
Inlet Penetration Depth	40 mm	40 mm
Inlet Penetration Speed	100 mm/s	100 mm/s
Sample Desorption Time	2.0 min	2.0 min
Desorption Signal Mode	Before fiber expose	Before fiber expose
Post Desorption Conditioning Time	10 min	10 min
Post Desorption Conditioning Temperature	300 °C	295 °C

Table 3. Agilent 7000 triple quadrupole GC/MS method parameters used for the analysis of 1,4-dioxane.

	Agilent 7000 Triple Quadrupole GC/MS, System 1	Agilent 7000 Triple Quadrupole GC/MS, System 2
Tune File	Atunes.eiex.tune.xml	Atunes.eiex.tune.xml
Transfer Line Temperature	260 °C	260 °C
Helium Quench Flow	2.25 mL/min	2.25 mL/min
N_2 Collision Gas	1.5 mL/min	1.5 mL/min
Source Temperature	270 °C	270 °C

Table 4. Compound-specific dMRM parameters for the analysis of 1,4-dioxane.

dMRM Parameters		Transition (*m/z*)	Retention Time (min)	Left RT Delta (min)	Right RT Delta (min)	Collision Energy (eV)
Target, System 1	1,4-Dioxane	88 → 58.1 88 → 56.9	5.0	3.0	2.0	5 5
Internal Standard, System 1	1,4-Dioxane-d_8	96 → 64.1 96 → 61.9	4.9	3.0	2.0	5 5
Target, System 2	1,4-Dioxane	88 → 58.1 88 → 56.9	5.5	3.0	2.0	5 5
Internal Standard, System 2	1,4-Dioxane-d_8	96 → 64.1 96 → 61.9	5.4	3.0	2.0	5 5
Gain 35, wide/wide windows, 5 cycles/s to 3 cycles/s						

- Calibration levels are created by pipetting 50 µL of the appropriate 1,4-dioxane solution and 50 µL of the 20 mg/L 1,4-dioxane-d_8 internal standard into a 20 mL headspace vial with magnetic cap with PTFE-lined septum. When calculating the concentration levels of the calibration solutions, a 100% transfer of material is assumed for total amount. Thus, for the low calibration level, 50 µL of 0.2 mg/L 1,4-dioxane is 10 ng on fiber.
- The linear calibration range for this analysis as validated was 10 to 20,000 ng.
- Quality control checks require the average response factor for the calibration curve to have an accuracy (RSD) of less than 20%. An exception is made when the limit of quantitation is being verified, then the RSD must be less than 50% of the actual value of the data point.
- The limit of quantitation must have a peak-to-peak signal-to-noise value of greater than 3:1 to be classified as a peak.

Sample preparation

- Make sure that clean glassware is used in the preparation of standards and samples. All glassware is rinsed with Milli-Q water before use. Use certified vials to transfer neat standards if available.
- Use an analytical balance to weigh the consumer product sample, typical weight is between 100 to 200 mg. Note the weight.
- Add 50 µL of 20 mg/L 1,4-dioxane-d_8 internal standard to each sample and QC vial. The vials are vortexed at 700 rpm for 5 minutes on a multitube bench mixer.
- When calculating a dilution factor, the sample amount is scaled to 1 g by dividing the sample weight by 1 g. The instrument amount is multiplied by the dilution factor for ng/g (ppb), or it is multiplied by the dilution factor and divided by 1,000 for µg/g (ppm).

Quality control

Each batch of 10 samples includes a method blank (MB), a laboratory control sample (LCS), a laboratory control sample duplicate (LCSD), a matrix spike (MS), and a matrix spike duplicate (MSD). A sample duplicate is included for each sample prepared in the same manner as the sample.

- For the MB, add 50 µL of 20 mg/L 1,4-dioxane-d^8 to an empty vial.
- For the LCS and LCSD, add 50 µL of 50 mg/L 1,4-dioxane and 50 µL of 20 mg/L 1,4-dioxane-d_8 to an empty vial.
- For the MS and MSD, add 50 µL of 50 mg/L 1,4-dioxane and 50 µL of 20 mg/L 1,4-dioxane-d_8 to vials containing the appropriate sample.

A continuing calibration verification (CCV) is prepared in the same manner as the LCS and LCSD. The CCV is analyzed at the beginning of each analytical batch and after every 10th analytical analysis excluding instrument blanks.

Results and discussion

Agilent 7890 GC system

An eight-point calibration curve was used for quantification in the range of 10 ppb to 20 ppm. The first set of calibration data was completed. The average response factor of the curve was 10.06, the R^2 value was greater than 0.994, the origin was ignored, and weighting was none, as shown in Figure 2.

Continuing calibration checks were run 16 hours apart after calibration with an average accuracy of 86%. Quality control for this method was monitored throughout data collection. Method blanks yielded nondetectable levels to ensure that there was no carryover. Laboratory control spikes were analyzed, and the accuracy ranged from 90 to 110% (run after the first continuing calibration).

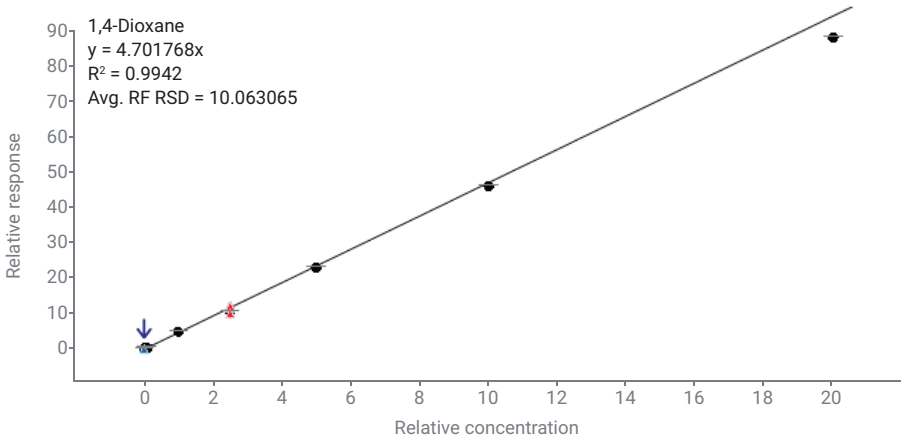

Figure 2. Calibration curve for 1,4-dioxane analysis on the Agilent 7890 GC system.

The method detection limit (MDL) for 1,4-dioxane was calculated based on EPA methodology (EPA 821-R-16-006). The MDL was determined by spiking a sample (predetermined to contain nondetectable levels of 1,4-dioxane) at a concentration of 1 ppb 1,4-dioxane. Seven replicates of the spiked sample were injected over several days, an example chromatogram is shown in Figure 3. The MDL was determined to be 0.046 ppb, as detailed in Table 5.

Quality control checks were performed on the second day. Method blanks yielded nondetectable levels to ensure that there was no carryover. Two laboratory control spikes (2,500 ppb) were analyzed and the accuracy ranged from 99 to 106%. Finally, a matrix spike and matrix spike duplicate were analyzed. The matrix spike samples were analyzed after spiking with a known amount (8,000 ppb) of 1,4-dioxane. The results are shown in Table 6.

Table 5. Method detection limit was determined using 1 ppb samples. Calculations were done automatically from Agilent MassHunter software with an average signal-to-noise of 22.

Name	Retention Time (min)	Transition (*m/z*)	Concentration Average (ppb)	Concentration RSD (%)	Method Detection Limit (ppb)	Limit of Quantitation (ppb)
1,4-Dioxane	5.00	88.0 → 56.9	0.65	2.3	0.046	0.148

Table 6. Data from the second day quality control checks, showing accuracy.

Type	Level	1,4-Dioxane Method	1,4-Dioxane Results		Accuracy (%)
		Experimental Concentration (ppb)	Retention Time (min)	Calculated Concentration (ppb)	
Blank					
QC	9	2,500	4.987	2,641	105.7
QC	9	2,500	4.988	2,492	99.7
Sample			4.981	4,800	
Matrix Spike 1			4.987	7,741	
Matrix Spike 2			4.981	7,902	
Sample			4.988	8,344	
Sample			4.981	4,818	
Blank					

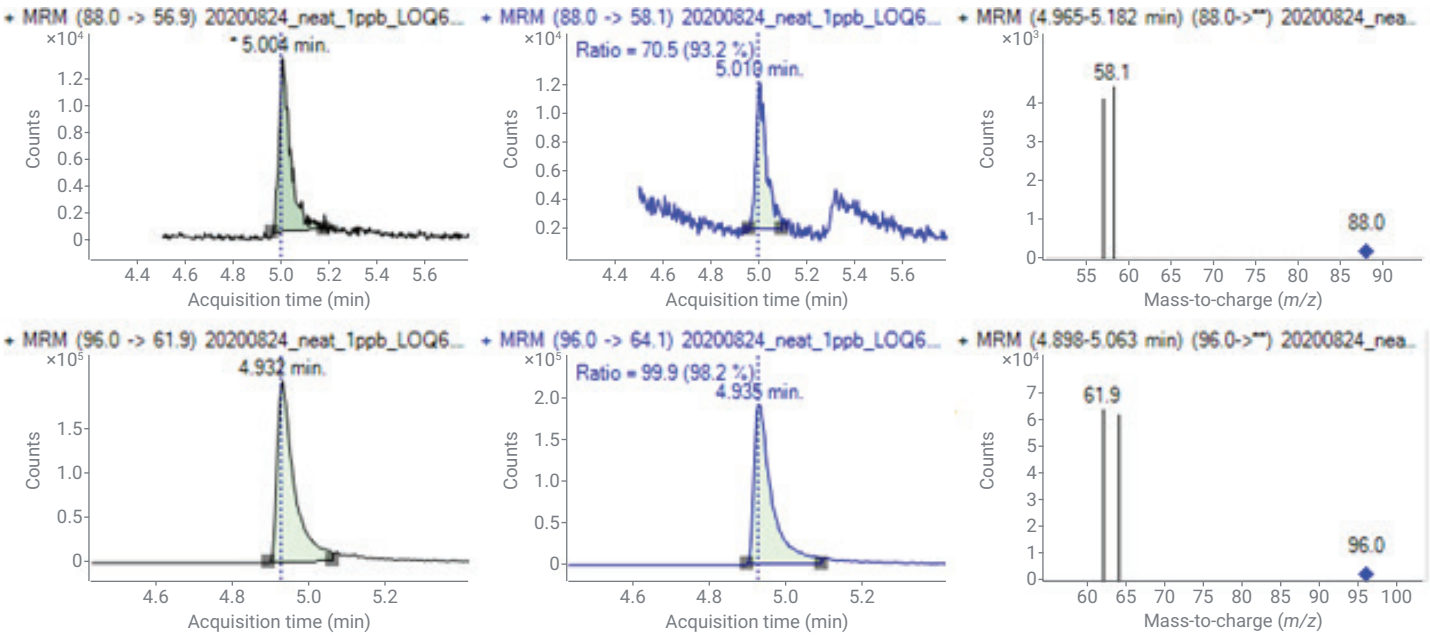

Figure 3. Example chromatography from one of the 1 ppb sample injections used for the method detection limit calculation of 1,4-dioxane on the Agilent 7890 GC system.

A new eight-point calibration curve was used for quantification in the range of 10 to 20,000 ppb. The R^2 value was greater than 0.999. The average response factor of the curve was 5.845. Two continuing calibration checks were run. The first was run after calibration, and the second was run two weeks later. Accuracy was 96.8 and 94.2% for the first and second continuing calibration checks respectively. Calibration data are shown in Figure 4.

The quality control study was performed over multiple days to determine the stability of the system using a 2,500 ppb standard. For quality control (QC), the accuracy must be in the range of 70 to 130%. The actual responses were from 93 to 104%. For continuing calibrations, the accuracy must be in the range of 80 to 120%. The actual responses were from 91 to 97%, as shown in Table 7.

Agilent 8890 GC system

Method parameters from the 7890 GC system can be transferred to the 8890 GC system with minor changes due to the different SPME fiber, which has a lower maximum temperature.

A nine-point calibration curve was used for quantification in the range of 0.1 to 400 ppb. The R^2 value was greater than 0.999 using a linear calibration, ignoring the origin, and using a 1/x weighting in this calibration. Calibration data are shown in Figure 4.

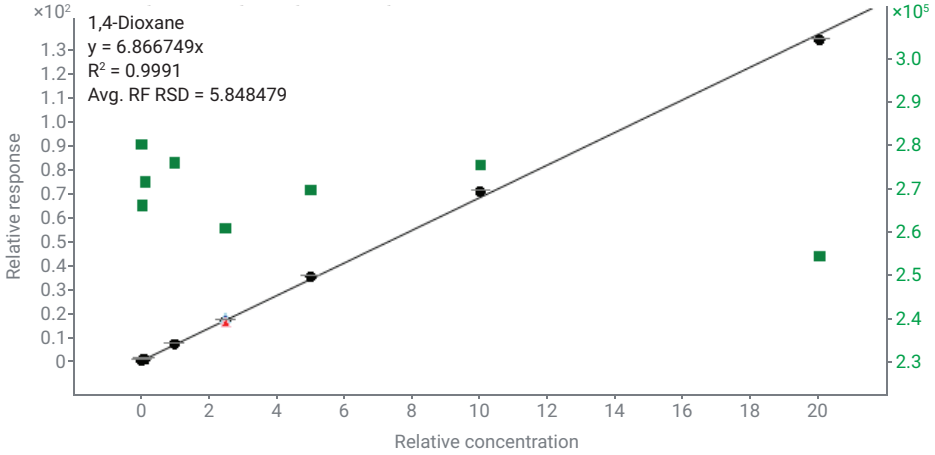

Figure 4. New calibration (10 to 20,000 ppb) showing internal standards (green squares) run two weeks after first calibration curve on the Agilent 7890 GC system.

Table 7. Stability study of continuing calibration and quality control samples using a 2,500 ppb standard. Calculations were done automatically from Agilent MassHunter Software.

Sample		1,4-Dioxane Results			
Type	Level	Retention Time (min)	Response	Calculated Concentration (ppb)	Accuracy (%)
CC	9	5.004	5,006,199	2,420	96.81
CC	9	4.998	4,755,096	2,354	94.18
QC	9	4.997	4,742,679	2,596	103.86
QC	9	4.998	4,712,119	2,337	93.49
CC	9	5.004	4,755,785	2,387	95.48
CC	9	5.012	4,520,649	2,301	92.04
QC	9	5.008	4,376,779	2,345	93.83
QC	9	4.994	4,395,601	2,331	93.26
CC	9	4.999	4,356,393	2,377	95.11
CC	9	4.997	4,464,291	2,335	93.40
CC	9	5.001	4,417,353	2,284	91.39
			Average Response	Average Concentration (ppb)	Concentration RSD (%)
			4,556,794	2,403	5.4

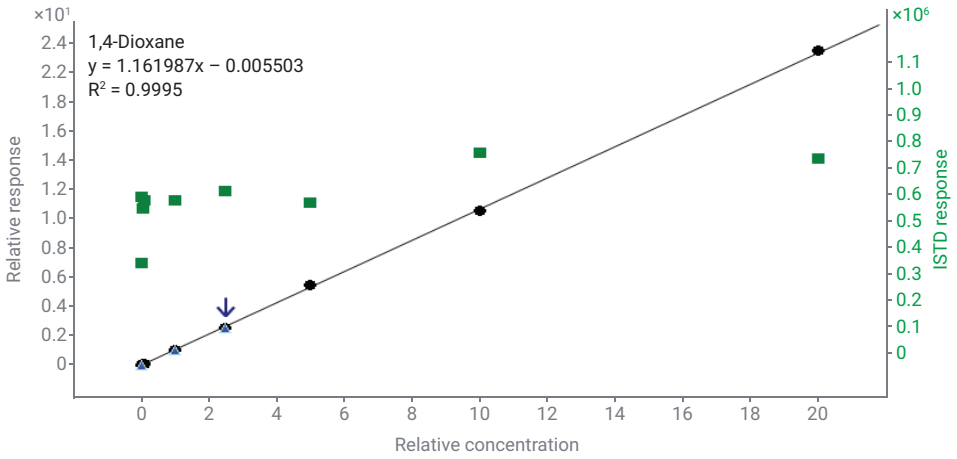

Figure 5. Calibration curve for 1,4-dioxane analysis on the Agilent 8890 GC system from 0.1 to 400 ppb. Internal standard response is shown with green squares.

The initial calibration was verified with the use of a certified reference material that was diluted and analyzed at 10, 1, and 0.1 ppb. In each case, the percent difference was less than 10%.

Quality control for this method was monitored throughout data collection. Method blanks yielded nondetectable levels to ensure that there was no carryover. Twelve quality control samples were analyzed, and the accuracy ranged from 90 to 110%.

The MDL for 1,4-dioxane was calculated based on EPA methodology (EPA 821-R-16-006). The MDL was determined by spiking a sample (predetermined to contain nondetectable levels of 1,4-dioxane) at a concentration of 0.1 ppb 1,4-dioxane. Eight replicates of the spiked sample were injected over several days, an example chromatogram is shown in Figure 6. The MDL was determined to be 0.011 ppb, as detailed in Table 8.

Table 8. Method detection limit was determined using 0.1 ppb samples. Calculations were done automatically from Agilent MassHunter software with an average signal-to-noise of 88.6.

Name	Retention Time (min)	Transition (*m/z*)	Concentration Average (ppb)	Concentration RSD (%)	Method Detection Limit (ppb)	Limit of Quantitation (ppb)
1,4-Dioxane	5.49	88.0 → 56.9	0.1	3.7	0.011	0.037

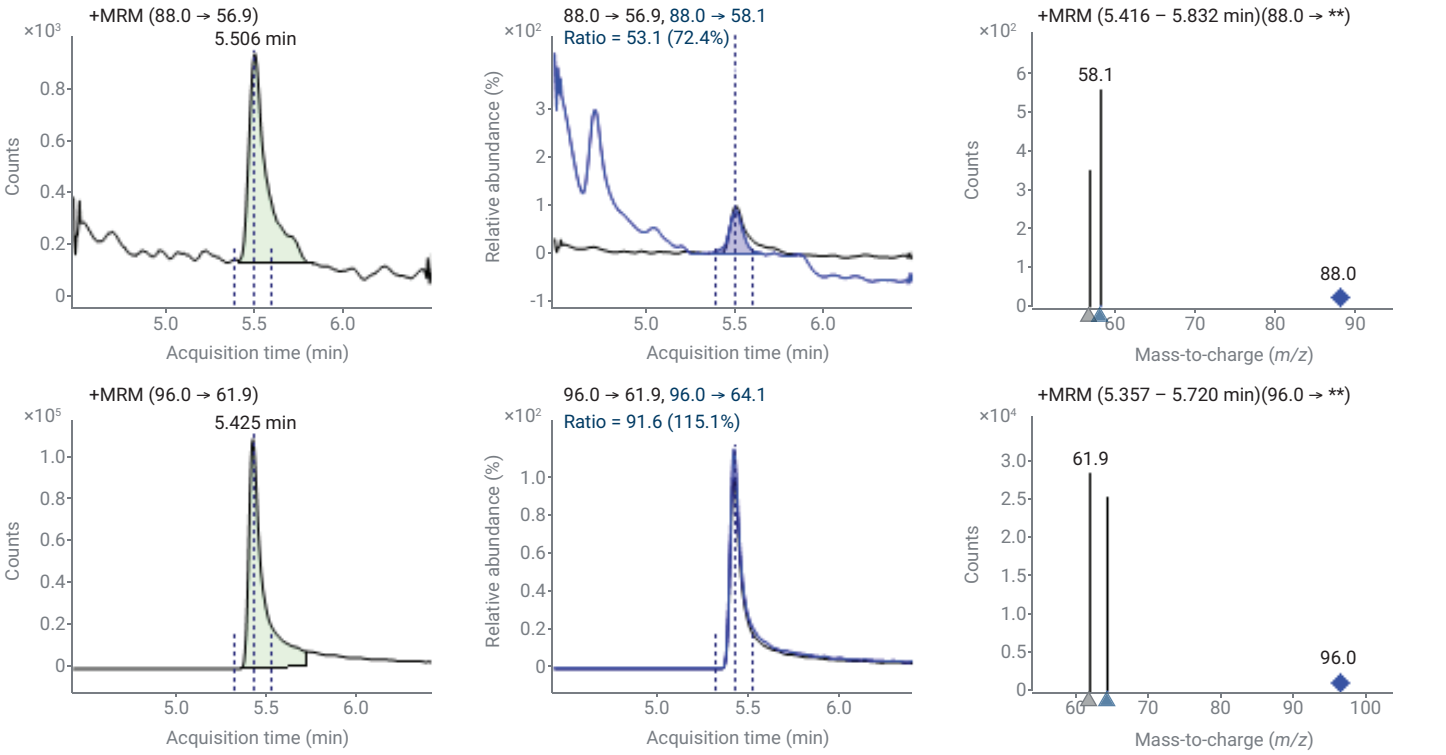

Figure 6. Example chromatography from one of the spiked sample injections (0.1 ppb) used for method detection limit calculation of 1,4-dioxane on the Agilent 8890 GC system.

Best practices

Best practices for the analysis of 1,4-dioxane in consumer products by SPME with triple quadrupole GC/MS are listed in Table 9.

Table 9. Best practices for the analysis of 1,4-dioxane.

Instrument Measure	Frequency	Requirement	Correction
Initial Calibration Verification (ICV)	Immediately after calibration	ICV ±30% true value	Reanalyze ICV, rerun calibration, corrective action
Continuing Calibration Verification (CCV)	Before batch and after every 10 analytical runs excluding blanks	CCV ±20% true value	Reanalyze CCV, rerun calibration, corrective action
Internal Standard (ISTD)	Added to every sample, QC, calibration, and instrument check		
Retention Time (RT)	Evaluate in every sample	ISTD RT ±0.33 min Analyte RT <10 s To midpoint ICAL or first CCV	Inspect and perform instrument maintenance
Matrix Blank (MB)	With every batch of 10 or fewer samples	Analyte <LOQ	Replace fiber and recalibrate
Laboratory Control Spike and Duplicate (LCS, LCSD)	With every batch of 10 or fewer samples	Reproducibility of LCS and LCSD <20%	Reanalyze, corrective action
Matrix Spike and Duplicate (MS, MSD)	With every batch of 10 or fewer samples	Spike recovery ±30% Reproducibility of MS and MSD <20%	Reanalyze, corrective action
Replace reference materials when responses do not pass criteria are low compared to past calibrations or reach their expiration date.			
Replace the SPME fiber if the peak shape is degraded, or other problems are suspected.			
Recalibrate when the CCV no longer passes within 20% of true value or maintenance has been performed.			

Conclusion

This method presents a sensitive, robust, and selective method to determine 1,4-dioxane in consumer products including cosmetic, personal care, and cleaning products. The benefits of using the Agilent triple quadrupole GC/MS capabilities and SPME cannot be underestimated in reducing sample matrix interference and improving signal-to-noise. This method provides high selectivity and sensitivity with a more confidence driven solution for the analysis of 1,4-dioxane. To enhance detection limits, an Agilent SPME Arrow with a higher sorption phase and larger surface area could be used.

References

1. 1,4-Dioxane. *Environmental Working Group* **2008**.
2. Spath, D. 1,4-Dioxane Action Level. *California Office of Environmental Health Hazard Assessment* **1998**.
3. Integrated Risk Information System: Chemical Assessment Summary for 1,4 Dioxane (CASRN 123-91-1). *United States Environmental Protection Agency* **2008**.
4. Report on Carcinogens, 11th Edition. National Toxicology Program, *U.S. Department of Health and Human Services* **2008**.
5. Chemicals Known to the State to Cause Cancer or Reproductive Toxicity. *California Office of Environmental Health Hazard Assessment* **2008**.
6. Natural Consumer Products Found Contaminated with Cancer-Causing 1,4-Dioxane in Groundbreaking Analysis Released by OCA. *Organic Consumers Association* **2008**.
7. Black, R.; Hurley, F.; Havery, D. Occurrence of 1,4-Dioxane in Cosmetic Raw Materials and Finished Cosmetic Products. *Journal of AOAC International* **2001**, *84(3)*, 666–670.
8. Tahara, M.; Obama, T.; Ikarashi, Y. Development of Analytical Method for Determination of 1,4-Dioxane in Cleaning Products. *International Journal of Cosmetic Science* **2013**, *35(6)*, 575–580.
9. Work Plan Implementation: 1,4-Dioxane in Personal Care and Cleaning Products. *California DTSC Safer Consumer Products* **2019**.
10. Kaminsky, T. An Act to Amend the Environmental Conservation Law, in Relation to Prohibiting Household Cleansing Products, Cosmetic Products and Personal Care Products that Contain 1,4-Dioxane. *The New York State Senate*, bill S4389B, **2020**.
11. Pawliszyn, J. Handbook of Solid Phase Microextraction **2012**, 1–12.
12. Tugulea, A. Principles of SPME. *Chromedia Analytical Sciences* **2020**.
13. Giri, A.; Zelinkova, Z.; Wenzl, T. Experimental Design-Based Isotope-Dilution SPME-GC/MS Method Development for the Analysis of Smoke Flavoring Products. *Food Additives & Contaminants: Part A* **2017**, *(34)12*, 2069–2084.

www.agilent.com/chem

DE44319.7624537037

Printed in the USA, May 14, 2021
5994-3553EN

Agilent
Trusted Answers