Optimizing GC-MS/MS Multiresidue Pesticides Analysis with RMX-5Sil MS Columns

A Comparison of Column Sensitivity and Lifetime by NOW Foods

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Key Highlights

- RMX-5Sil MS columns outperform traditional 5sil columns for analysis of 230 pesticides in more than 100 complex botanical matrices.
- Exceptional inertness improves peak shape and response, improving sensitivity and trace-level accuracy.
- Ideal for high-throughput labs—longer lifetime and stable retention times reduce downtime and increase sample throughput.

Abstract

Accurate trace-level GC-MS/MS multiresidue pesticides analysis in botanical matrices requires analytical methods capable of addressing both analyte diversity and matrix complexity. This study compares the performance of RMX-5Sil MS columns to a traditional 5-silarylene (5sil) type column across 230 pesticides and more than 100 botanicals. RMX-5Sil MS columns, engineered with TriMax deactivation technology, produced superior peak shapes and higher responses at 10 ppb and 50 ppb, even for adsorptive or matrix-sensitive pesticides. They also delivered excellent recoveries, longer lifetimes, and exceptional retention time stability. These advantages enhance sensitivity, robustness, and efficiency, supporting improved laboratory productivity and food safety testing reliability.

Related Products

- *RMX-5Sil MS GC Capillary Column, 30 m, 0.25 mm ID, 0.25 µm, with 5 m Integra-Guard (cat.# 17323-124)*
- *RMX-5Sil MS GC Capillary Column, 30 m, 0.25 mm ID, 0.25 µm, with 5 m Integra-Guard & Integra-Transfer Line (cat.# 17323-124177)*
- *Topaz, Single Taper Inlet Liner, 4.0 mm x 6.5 x 78.5, for Thermo TRACE 1300/1310, 1600/1610 GCs w/SSL inlets, w/Quartz Wool (cat.# 23447)*
- *Leak detector (cat.# 28500)*
- *Flowmeter (cat.# 22656)*
- *Q-sep original unbuffered extraction salt packets (cat.# 25847)*
- *Q-sep AOAC QuEChERS extraction kit (cat.# 25852)*

Introduction

The global importance of food safety and the expanding market for plant-based nutritional supplements have intensified the need for robust analytical methods capable of detecting pesticide residues at trace concentrations. Reliable multiresidue analytical methods are essential to ensuring consumer safety through quality control testing and routine monitoring programs. GC-MS/MS is a leading technique for pesticide residue testing due to its high selectivity, sensitivity, and ability to simultaneously quantify chemically diverse analytes within a single analytical run. However, the accurate determination of pesticides at trace levels in complex botanical matrices remains a significant analytical challenge.

One of the primary obstacles in GC-MS/MS multiresidue pesticides analysis is the sheer chemical diversity of the analytes of interest. Pesticides encompass numerous structural classes—including organochlorines, organophosphates, pyrethroids, triazoles, and fumigants—with wide-ranging volatilities, polarities, and thermal stabilities. Botanical matrices further complicate trace-level multiresidue analysis because they often contain high concentrations of sugars, lipids, pigments, organic acids, terpenes, and other endogenous compounds. These sample components can reduce analytical accuracy by suppressing or enhancing pesticide ionization as well as by accumulating in the inlet or column and reacting with target analytes.

One critical factor in overcoming matrix-related losses is the inertness of the GC system, particularly the inlet liner, metal surfaces, and the GC column. Many pesticides, especially those containing reactive functional groups, such as phosphates, carbamates, or chlorinated moieties, are highly susceptible to degradation or adsorption on active sites along the sample flow path. Silanol groups or surface contaminants in the column can trap analytes, resulting in poor peak shapes and reduced responses, which decreases sensitivity and causes inconsistent quantification. These interactions are exacerbated when matrices deposit nonvolatile residues that expose or generate new active sites over time. Highly inert GC columns can improve analyte recovery and overall method sensitivity by minimizing these surface-driven losses.

In this study, we compared the chromatographic performance of RMX-5Sil MS columns to a traditional 5sil column for GC-MS/MS multiresidue pesticides analysis. RMX-5Sil MS columns were selected for comparison to test the effectiveness of the TriMax deactivation technology used to neutralize the column surface. This novel technology produces an exceptionally inert flow path that is free of active sites and has been demonstrated to improve peak shape and sensitivity for a wide range of active compounds [1,2], making it beneficial for trace-level GC-MS/MS multiresidue pesticides analysis.

Experimental

Sample and Standard Preparation

To assess column performance under real-world conditions, more than 100 challenging matrices that differed significantly in chemical composition were tested (Table I). Samples were fortified with 230 pesticides at 10 and 50 ppb and extracted according to a QuEChERS-based sample preparation procedure followed by SPE cleanup (Figure 1). Although this study utilized only GC-MS/MS for analysis, the extraction procedure was originally developed to produce extracts suitable for both GC and LC analysis, making it a useful protocol for laboratories using both techniques for pesticides analysis.

Matrix-matched calibration standards were prepared by reconstituting five individual matrix extracts with five different GC standard solutions (2, 5, 10, 20, and 50 ppb in toluene). A total of twenty-two internal standards were used for sample analysis. Sixteen internal standards were present in the extraction solvent and used to determine how successful the QuEChERS extraction and cleanup steps were. Six additional standards (QC standards) were later added to the reconstituted calibration standards and sample extracts to measure autosampler performance.

Table I: Sample Matrices Tested During RMX-5Sil MS Column Performance Evaluation

Sample Number	Matrix Description
1	Apple Pectin Powder
2	Apple Pectin Powder
3	Vitamin E RM-Matrix
4	Shea Butter
5	Uva Ursi Extract (NLT 15% Arbutin) Powder
6	Mucuna spp. Extract (15% L-Dopa) Powder
7	Curcumin Complex
8	NGMO Lime Oil
9	Organic Raw Pecans
10	Organic Goji Berries
11	Lanolin Oil
12	DHA/EPA Fish Oil Enteric Soft Gels
13	Omega 3 Enteric Coating Soft Gels
14	Uva Ursi Extract (NLT 15% Arbutin) Powder
15	Mucuna spp. Extract (15% L-Dopa) Powder
16	Oat Flour
17	Creatine Monohydrate 200 Mesh
18	Organic Red Yeast Rice Powder
19	Urox Herbal Powder Blend
20	Cinnamon Honey Almond (w/ Rosemary Extract) Qualification
21	Organic Non-GMO Tamanu Oil
22	Melissa (Lemon Balm) Essential Oil
23	Omega 3 Fatty Acid Fish Oil
24	Omega 3 Fatty Acid Fish Oil
25	Milk Thistle Extract Powder
26	Organic Goji Berries
27	Organic Goji Berries
28	Evening Primrose Oil Bulk Liquid
29	Panax Ginseng Root Powder
30	Organic Eleuthero Root Powder
31	Quercetin with Bromelain Vegetarian Capsules
32	Garlic 500 mg EC Tablets

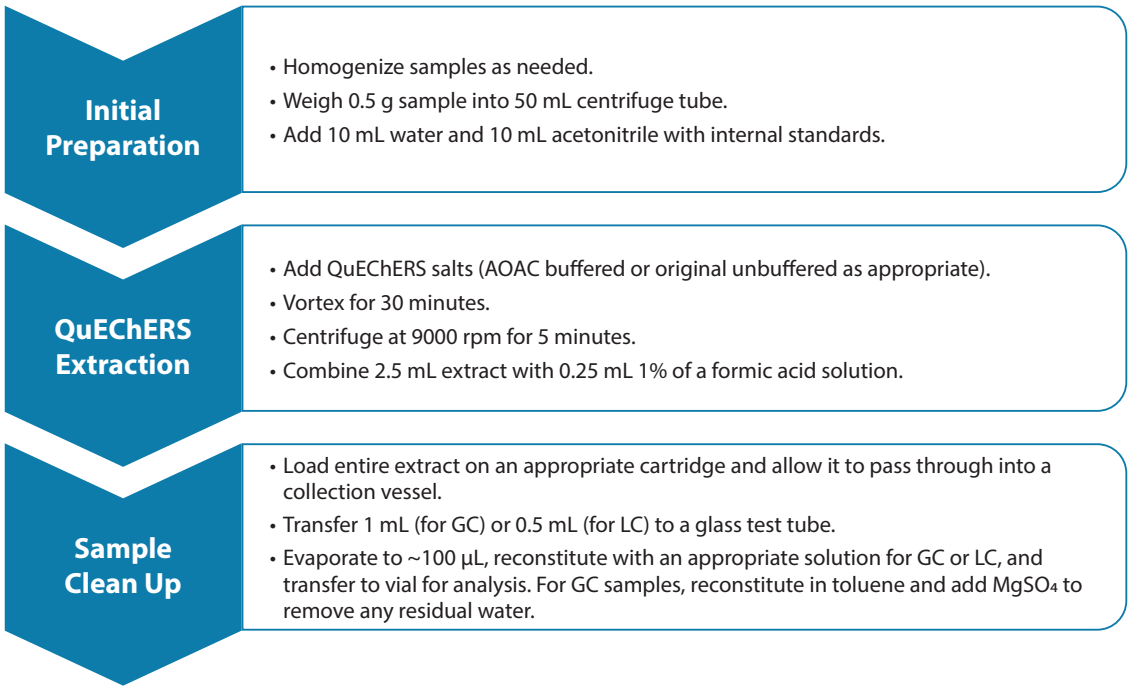
(Continued)

Table I *(Continued)*

Sample Number	Matrix Description
33	Organic Toasted Sesame Oil
34	Organic Goji Berries (Sunshine Produce New Sample Qualification)
35	Organic Non-GMO Raw Hulled Sunflower Seeds
36	Pau D'Arco Chai Tea Blend
37	Non-GMO Ginger Mint Comfort Tea Blend
38	Non-GMO Oregano Oil
39	Organic Turmeric Root Powder
40	Organic Non-GMO Rose Hip Seed Oil
41	Organic Non-GMO Coconut Sugar
42	Goldenseal Root Powder
43	Milk Thistle Extract Powder
44	Milk Thistle Extract Powder
45	Organic non-GMO Lemon Oil
46	Organic Shea Butter
47	Organic Raw Pecans
48	Ashwagandha Root Standardized Extract Powder
49	Vegetarian Capsules
50	Organic Coconut Sugar
51	American Ginseng Root Extract
52	Ashwagandha Root Standardized Extract Powder
53	Ashwagandha Root Standardized Extract Powder
54	Organic Coconut Milk (50% Fat) Powder
55	Molybdenum Glycinate Powder
56	Floradapt (TM) Intensive GI (AB-i3.1) Probiotic Blend Powder
57	Milk Thistle Extract Powder
58	Organic Non-GMO Rose Hip Seed Oil
59	Organic non-GMO Orange Oil
60	Organic non-GMO Orange Oil (re-injection)
61	Ashwagandha Root Standardized Extract Powder
62	00el Elongated Vegetarian Capsules (R) Plus
63	Organic Non-GMO Pumpkin Seeds
64	Non-GMO Pumpkin Seeds
65	Creatine HMB Powder with Betaine & D3
66	Rhodiola Root Extract (NLT 3% Total Rosavins) Powder
67	Organic non-GMO Virgin Coconut Oil
68	AC Keratin Hydrolysate 30 PF (Active Concepts)
69	Rhodiola Root Extract (NLT 3% Total Rosavins) Powder
70	Organic non-GMO Virgin Coconut Oil

Sample Number	Matrix Description
71	Gigawhite (TM)
72	Organic Textured Vegetable Protein Granules
73	Organic non-GMO Erythritol Powder
74	Milk Thistle Extract Powder
75	Organic Inulin 95% from Chicory Powder
76	Plantservative WSr (Glenn Corp-Campo Cosmetics)
77	Organic Eleuthero Root Powder
78	Chicken Bone Broth (Stock) Powder
79	Chicken Bone Broth (Stock) Powder
80	Organic Red Yeast Rice Powder
81	Rhodiola Root Extract Powder
82	Organic Non-GMO Natural Raw Cocoa Powder
83	Curcumin Complex (Turmeric Extract [Roots/Rhizomes]) min 95% Granular
84	Organic Non-GMO Regular Rolled Oats
85	Psyllium Husk Powder
86	Astragalus Root Extract (70% Polysaccharides) Powder
87	Black Walnut Hulls Powder
88	Organic Moringa Tea
89	Maca Root Powder
90	Organic Argan Oil
91	Instant Micellar Casein Powder
92	Glucosamine HCL Powder
93	Organic Non-GMO Amaranth Grain
94	Goldenberries (Inca Berries), Dried Organic
95	Organic Inulin from Jerusalem Artichoke
96	NPD Organic Inulin from Chicory
97	Organic D-Mannose Powder
98	Tribulus Extract (NLT 45% Saponins) Powder
99	Horse Chestnut Extract (NLT 20% Aescin) Powder
100	Organic Non-GMO Dandelion Herb FC
101	Panax ginseng Root Powder
102	Organic Aloe Vera Inner-Leaf 200x Powder
103	Organic Inulin from Jerusalem Artichoke
104	Organic Fenugreek Seed Powder
105	Epimedium Extract (3% Icariin) Granular Powder
106	Zanthin Natural Astaxanthin Complex (10% Extract) Liquid
107	Organic NGMO Enzyme-Treated Stevia Powder

Figure 1: Sample Preparation Protocol



Analytical Conditions

GC-MS/MS multiresidue pesticides analysis was performed using a Thermo Scientific TRACE 1610 GC equipped with a TSQ 9610 triple quadrupole mass spectrometer. Data acquisition and processing were accomplished using Thermo Scientific Chromeleon chromatography software. Instrument conditions and ion transitions are presented in Figure 2 and Appendix I.

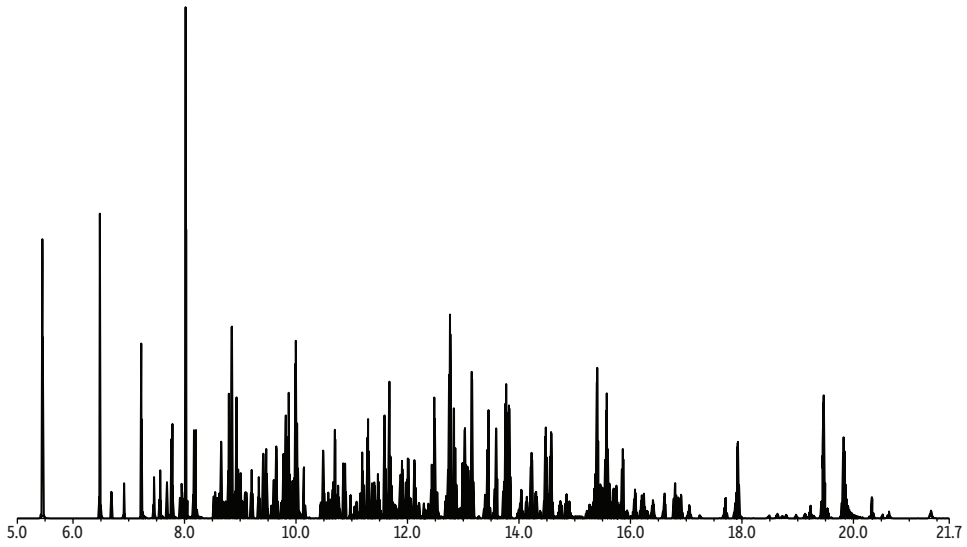
The performance of RMX-5Sil MS columns was compared to a traditional 5sil type column. All columns tested were 30 m x 0.25 mm ID x 0.25 µm. The traditional column was installed with a 10 m integrated guard column to protect the analytical column from matrix contamination. For the RMX-5Sil MS column, two formats were tested: an Integra-Guard column and a dual Integra-Guard and Integra-transfer line column. Both formats are a continuous piece of tubing that houses the 5Sil MS analytical stationary phase as well as uncoated sections of deactivated tubing at the inlet side (guard) and/or detector side (transfer line). These formats were selected because they both provide a high degree of protection from matrix contamination without the need for manual connections that can leak and require downtime for maintenance. The dual format provides an additional benefit because the lack of stationary phase in the Integra-transfer line going to the detector means less bleed at high temperatures, so the MS stays cleaner and signal-to-noise ratios can be improved.

Results and Discussion

Chromatographic Performance

All 230 pesticides were successfully analyzed on both RMX-5Sil MS column formats in a fast, 22-minute analysis with a total injection-to-injection cycle time of just 35 minutes, which met our requirements for high-throughput testing. Column selectivity was a drop-in replacement for the traditional 5sil column, and a representative total ion chromatogram for the RMX-5Sil MS with Integra-Guard column is shown in Figure 2. (The same chromatographic profile is also obtained using a dual Integra-Guard and Integra-transfer line format RMX-5Sil MS column.) The data reported in subsequent experiments were generated on the RMX-5Sil MS with Integra-Guard column.

Figure 2: TIC for 230 Compound GC-MS/MS Multiresidue Pesticides Analysis on an RMX-5Sil MS Column (50 ppb in Toluene, see peak list in Appendix I)



Column	RMX-5Sil MS GC capillary column with 5 m Integra-Guard, 30 m, 0.25 mm ID, 0.25 µm (cat.# 17323-124)
Standard/Sample	Custom standards
Conc.:	50 pg on-column concentration
Injection	
Inj. Vol.:	1 µL splitless (hold 0.8 min)
Liner:	Topaz 4.0 mm ID single taper liner w/wool (cat.# 23447)
Inj. Temp.:	260 °C
Purge Flow:	60 mL/min
Oven	
Oven Temp.:	40 °C (hold 1.5 min) to 90 °C at 40 °C/min (hold 1.5 min) to 180 °C at 40 °C/min to 250 °C at 10 °C/min to 280 °C at 5 °C/min to 320 °C at 10 °C/min (hold 5 min)
Carrier Gas	He, constant flow
Flow Rate:	1.4 mL/min
Linear Velocity:	32 cm/sec @ 40 °C
Dead Time:	1.56 min @ 40 °C
Detector	Thermo Scientific TSQ 9610 Triple Quadrupole GC-MS
Transfer Line Temp.:	280 °C
Analyzer Type:	Quadrupole
Tune Type:	PFTBA
Ionization Mode:	EI
Instrument	Thermo Scientific Trace 1610 GC
Notes	See Appendix for compound names, retention times, MRMs, and collision energies.
Acknowledgement	NOW Foods

While the overall runtime for all columns met high-throughput requirements, notable differences in column performance were seen when looking in greater detail at peak shapes and responses for challenging compounds in particularly difficult matrices. Figures 3-6 demonstrate some of the key performance advantages that RMX-5Sil MS columns offer due to their higher inertness and ruggedness compared to a traditional 5sil column.

Figures 3 and 4 show the results for three compounds (metalaxyl, chlorfenapyr, and beta-BHC) at 50 ppb in two matrices (ashwagandha and lime oil). Ashwagandha is rich in alkaloids; triterpenoid steroidal lactones (withanolides being a primary active component); sugars; and oils, which can cause signal enhancements or suppression. These components may also adhere in the column where they can interact with analytes and/or shorten column lifetime. Lime oil is similarly challenging as it contains terpenes, terpenoids, oils, and pigments that can mask pesticides and foul the column. Metalaxyl is prone to adsorption if active sites are present in the liner or column, which can lead to poor accuracy and reproducibility, particularly at trace levels. Chlorfenapyr is vulnerable to matrix components as well, particularly lipids and terpenes, which can make low-level detection difficult. Beta-BHC is particularly complex to analyze because it must be fully resolved from other isomeric forms and is prone to matrix enhancement in high-fat samples. In addition, beta-BHC readily sticks to the surface of liners and columns, which can significantly reduce sensitivity.

As shown in the chromatographic comparisons, even these sensitive compounds respond well in the presence of difficult matrices on RMX-5Sil MS columns. For example, as seen in Figure 3, metalaxyl and chlorfenapyr could not be properly analyzed on the traditional 5sil column because only one product ion was measurable, whereas SANTE guidelines require two for MS/MS detection. In contrast, on the RMX-5Sil MS column, the highly inert surface produced two or three signals with excellent peak shapes and intensities that allowed for definitive identification and integration. Similarly, for beta-BHC in lime oil, more symmetric peaks with higher signal-to-noise (S/N) ratios were obtained on the RMX-5Sil MS column (Figure 4). Most notably, the RMX-5Sil MS column provided much better separation of beta-BHC from an interference peak (Peak A) for m/z 146.60, which is shown in pink. The resolution value between the beta-BHC qualifier ion and Peak A was 1.21 on the RMX-5Sil MS column and just 0.79 on the traditional 5sil column.

Figure 3: Compared to traditional 5sil columns, highly inert RMX-5Sil MS columns produce clear peaks for multiple ions, allowing metalaxyl and chlorfenapyr (50 ppb) to be accurately analyzed in ashwagandha.

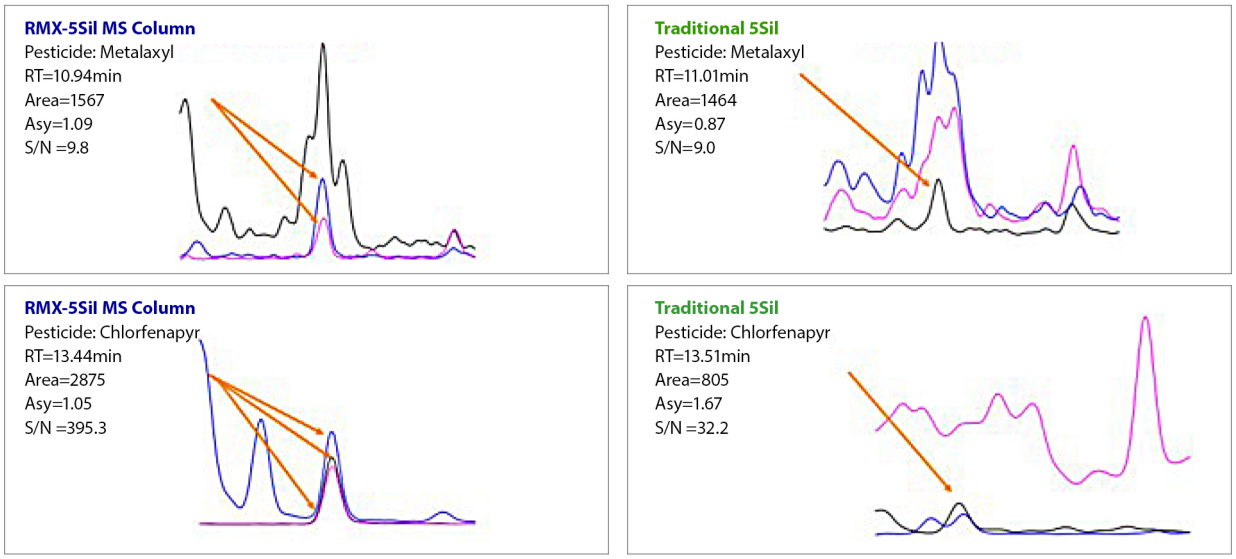


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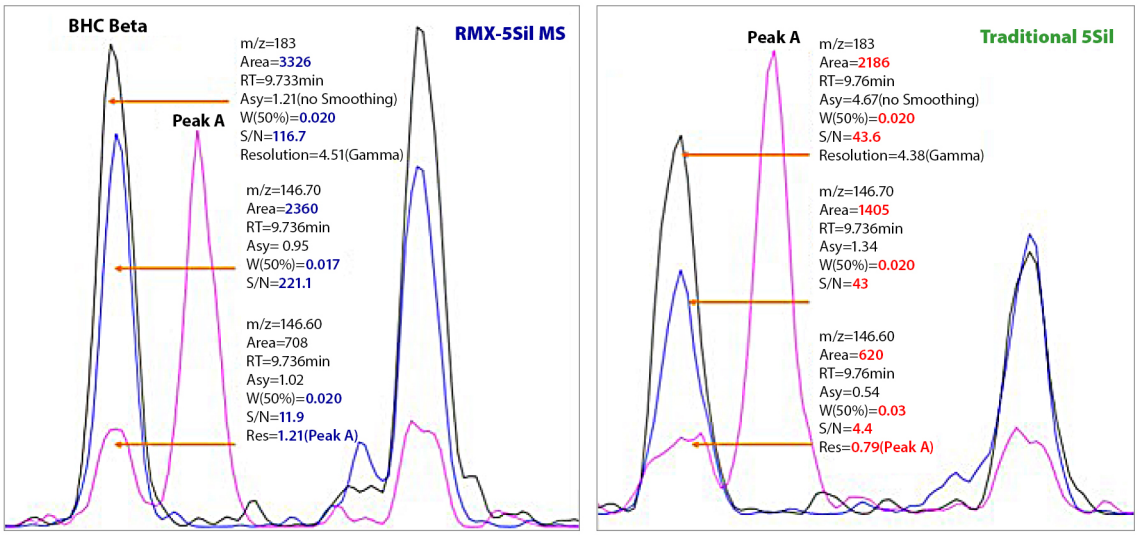
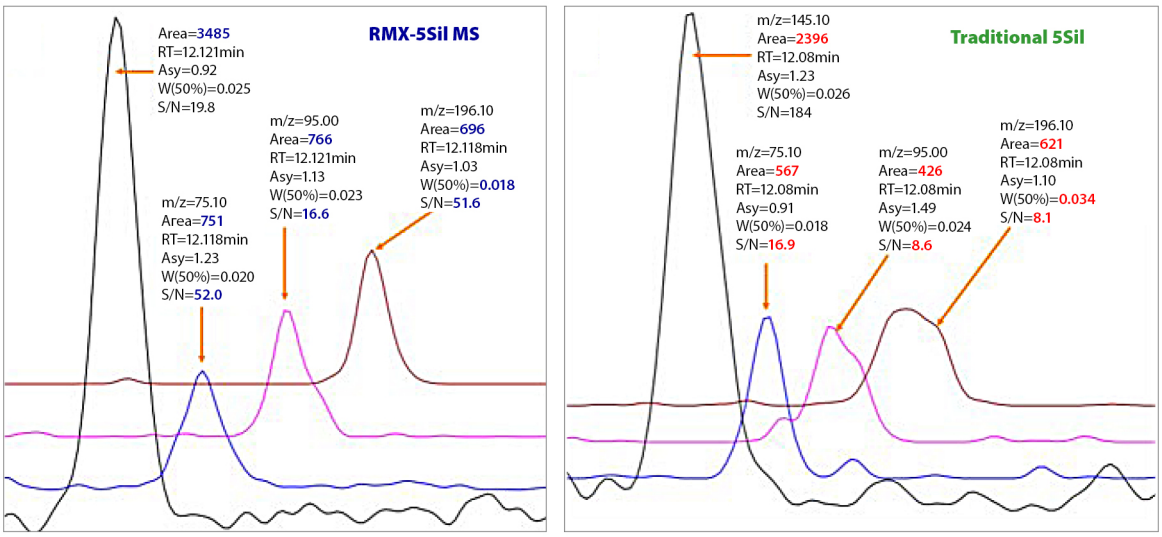
Figure 4: RMX-5Sil MS columns produce more symmetric peaks with higher S/N ratios for 50 ppb beta-BHC in lime oil. Better separation from an interference peak (Peak A) was also achieved.



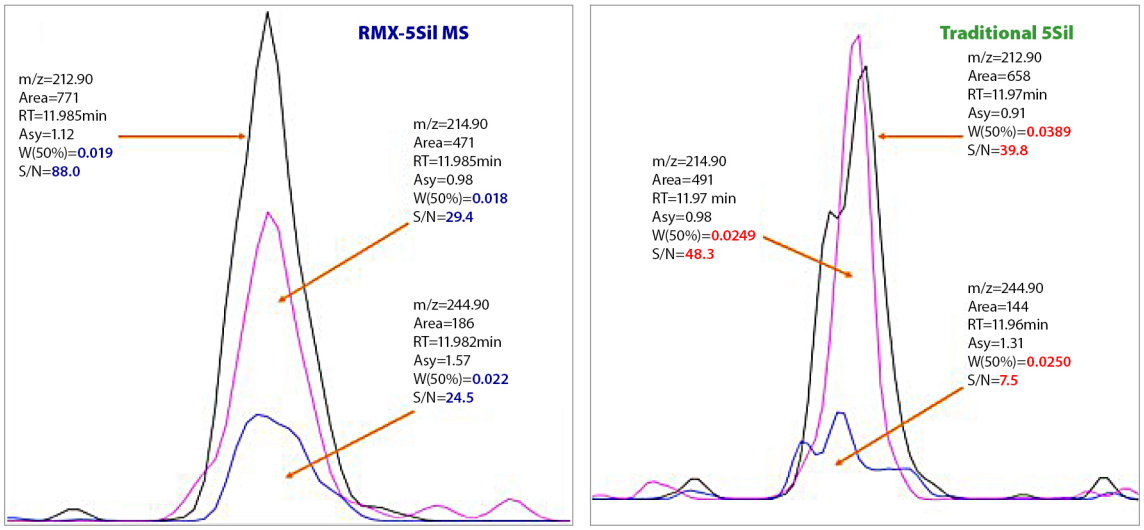
In addition to the 50-ppb assessment, the chromatographic performance of RMX-5Sil MS and traditional 5sil columns was also compared at 10 ppb. As demonstrated in Figures 5 and 6, at this more stringent level, the results obtained for fluopyram in raw pecans and fipronil in rice were similar to those achieved for the other pesticides and matrices that were evaluated at 50 ppb. Fluopyram is susceptible to ion suppression in the presence of lipids, so the benefits of the RMX-5Sil MS column were clear in high-fat pecan samples where improvements were seen in peak shape, peak area, and S/N ratio (Figure 5). Fipronil is strongly adsorptive, so an inert sample flow path is essential. Again, the more inert RMX-5Sil MS column produced symmetrical peaks and stronger responses (Figure 6). In contrast, with the traditional 5sil column, peak splitting was observed for both the quantitation ion and a qualifier ion, and the quantitation ion peak was shorter and had a lower S/N ratio than the qualifier. Table II details similar peak shape and response improvements for additional pesticides at 10 ppb in other complex matrices, demonstrating the broadly effective inertness and performance benefits of the RMX-5Sil MS column.

Figure 5: At 10 ppb, RMX-5Sil MS columns produce better peak shapes and responses for fluopyram in raw pecan samples.



GC_FS0622

Figure 6: RMX-5Sil MS columns produced higher S/N ratios and better peak shapes for fipronil at 10 ppb in rice compared to the lower response and peak splitting generated on the traditional 5sil column.



GC_FS0623

Table II: Better peak shapes and responses are seen for a wide range of pesticides in diverse and challenging botanical matrices on RMX-5Sil MS columns compared to traditional 5sil columns.

			Quantitation Ion			Confirmation Ion		
Column	Pesticide	Matrix	m/z	S/N	Asymmetry	m/z	S/N	Asymmetry
RMX-5Sil MS	Trifluralin	Rosemary oil	264.10	61.9	0.99	159.70	8.2	1
Traditional 5sil	Trifluralin	Rosemary oil	264.10	33.1	1.04	159.70	12.5	0.91
RMX-5Sil MS	Chlorpyrifos	Cinnamon bark	258.00	58.7	1.08	286.00	26.9	0.73
Traditional 5sil	Chlorpyrifos	Cinnamon bark	258.00	63.4	1.14	286.00	7.6	1.01
RMX-5Sil MS	Chlorpyrifos	Tapioca starch	258.00	68.4	0.97	286.00	6.2	0.81
Traditional 5sil	Chlorpyrifos	Tapioca starch	258.00	24.9	0.89	286.00	3.6	1.27
RMX-5Sil MS	Propyzamide	Millet (hulled)	145.00	25.4	0.98	74.00	34.5	0.98
Traditional 5sil	Propyzamide	Millet (hulled)	145.00	6.9	1.01	74.00	19.0	1.13
RMX-5Sil MS	Piperonyl butoxide	Egg powder	131.10	30.3	0.97	117.00	41.8	1.22
Traditional 5sil	Piperonyl butoxide	Egg powder	131.10	19.3	1.13	117.00	11.3	0.96
RMX-5Sil MS	Terbufos	Egg powder	128.90	36.8	1.02	174.90	15.9	1.02
Traditional 5sil	Terbufos	Egg powder	128.90	13.4	1.11	174.90	5.2	0.77
RMX-5Sil MS	Chlordane (alpha cis)	Shelled almonds	265.80	135.6	1	268.00	24.9	0.99
Traditional 5sil	Chlordane (alpha cis)	Shelled almonds	265.80	21.4	1.06	268.00	18.1	0.74
RMX-5Sil MS	Permethrin I	Nighttime teas	165.10	19.5	1.17	153.00	8.7	0.93
Traditional 5sil	Permethrin I	Nighttime teas	165.10	3.8	0.97	153.00	4	0.95

Recovery Evaluation

In addition to comparing the chromatographic performance of RMX-5Sil MS columns to traditional 5sil columns for GC-MS/MS multi-residue pesticides analysis, recovery experiments were also conducted. For this assessment, 35 pesticides representing a range of different chemistries were fortified at 50 ppb in curcumin and cinnamon-honey coated almonds. Curcumin is an extremely complex sample, and the high levels of curcuminoids (phenolic pigments) and volatile oils are known to cause matrix interference, which can compromise reporting accuracy. Similarly, cinnamon-honey coated almonds are also likely to cause matrix effects because they are high in fats and sugars, and the presence of cinnamon contributes pigments and other complex plant components. Overall, acceptable recoveries (70-120%) were obtained on both columns, but the RMX-5Sil MS column delivered better performance with an average percent recovery across all pesticides of 94% vs. 88% in curcumin (Figure 7) and 95% vs. 93% in cinnamon-honey coated almonds (Figure 8). Matrix effects impact individual pesticides differently, but on both columns the recoveries for all pesticides in both matrices were fairly consistent (%RSD range = 7-16%).

Figure 7: Recovery Data for 35 Pesticides in Curcumin at 50 ppb

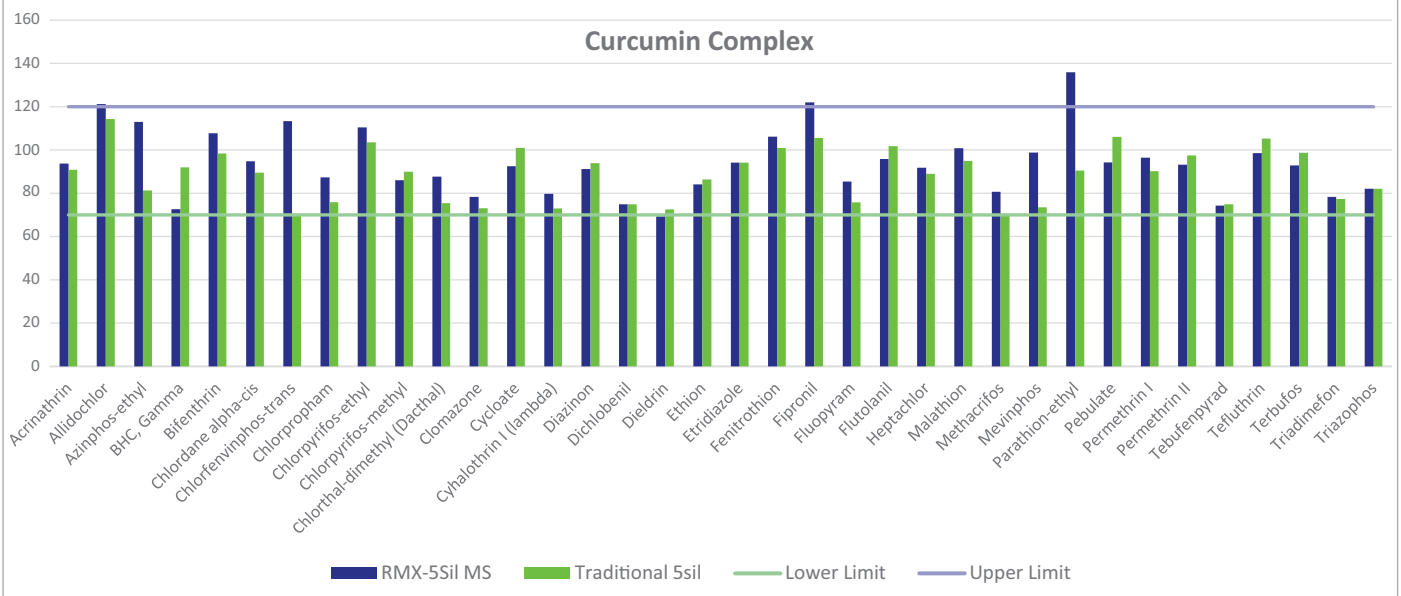
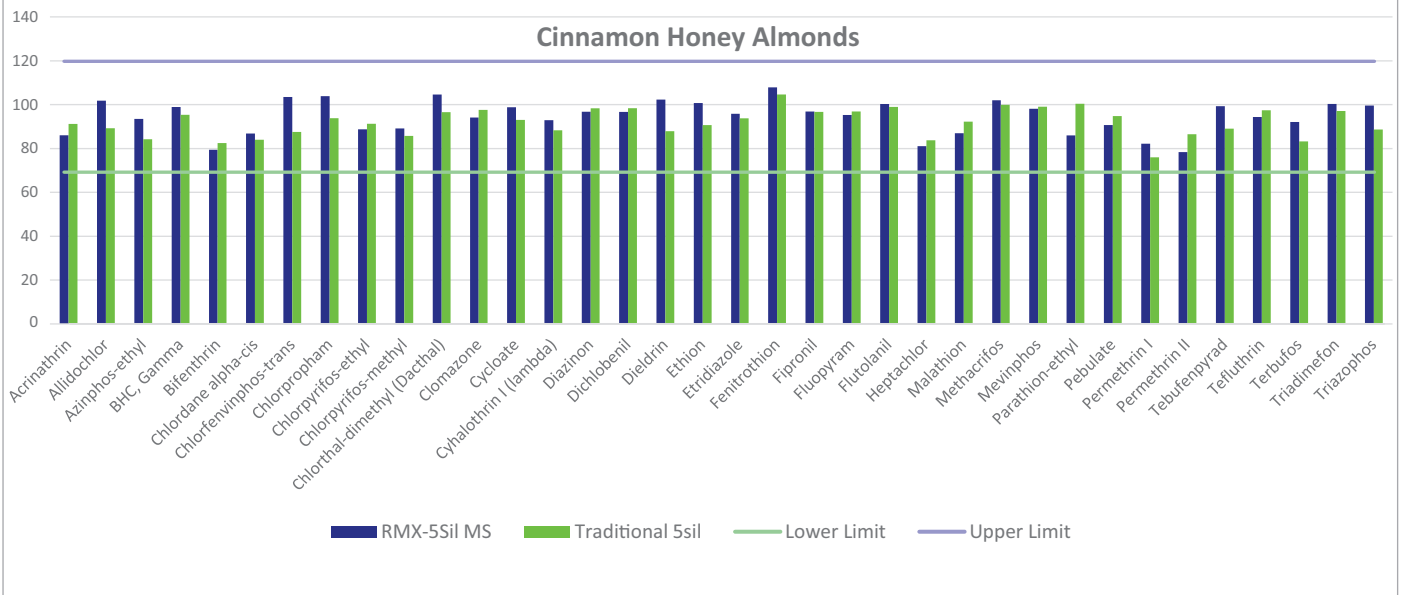


Figure 8: Recovery Data for 35 Pesticides in Cinnamon-Honey Coated Almonds at 50 ppb



Column Lifetime

While good chromatographic performance is the most essential column characteristic for GC-MS/MS multiresidue pesticides analysis, particularly when labs need to test large panels in a wide range of sample matrices, column lifetime is another practical consideration. Especially for high-throughput labs, longer column lifetimes are beneficial because less downtime for maintenance means more uptime for sample analysis. During this lifetime study, a routine maintenance protocol of replacing the septum and inlet liner every 40 hours was conducted for all columns. Performance of the RMX-5Sil MS and the traditional 5sil column was monitored throughout routine use, and each column was trimmed only when performance began to degrade.

As shown in Table III, the traditional column required more frequent trims and ultimately failed to meet performance requirements after 1131 injections and 659 hours of use. In contrast, both RMX-5Sil MS column formats needed only two or three trims and met performance requirements for much longer. At the end of the study, both RMX-5Sil MS columns continued to deliver good performance and were still suitable for use after 1800 injections (1005 hours) for the Integra-Guard format and 1995 injections (1164 hours) for the dual Integra-Guard and Integra-transfer line format. It should be noted that this study was conducted during routine sample testing, and results were accumulated for each column during the period of time when it was installed, so the lower numbers for guard-only format reflect the fact it was not installed in the instrument as long. For both formats, the inertness of the RMX-5Sil MS column significantly reduced downtime for maintenance and sample analysis could continue even after running challenging matrices, such as oils, that usually require that the column be trimmed before another matrix can be run.

Table III: Lifetime of the RMX-5Sil MS column in both formats exceeded the traditional 5sil column, and more samples could be analyzed with fewer column trims.

	RMX-5Sil MS (Integra-Guard Format)	RMX-5Sil MS (Dual Integra-Guard and Integra Transfer Line Format)	Traditional 5sil with Guard
Number of injections	1800	1995	1131
Run time (hours)	1005	1164	659
Number of column trims	2	3	7
Status at end of experiment	still meets performance requirements	still meets performance requirements	end of lifetime

Retention Time Stability

Over the course of a column's lifetime or when changing columns, analyte retention times often shift, which necessitates an update of retention time windows in the chromatographic software. For GC-MS/MS multiresidue pesticides analysis, this is quite time-consuming with large analyte panels and, in our case, means 780 transitions must be evaluated and updated in the acquisition and processing methods. When using highly inert RMX-5Sil MS columns, we observed that the retention times were stable and that variation was minimal. Table IV shows that when retention times were compared on one column at installation and then later after 1800 injections, retention time changes were negligible throughout the run. Retention time stability was evaluated for the first eluting compound (dichlorvos); a mid-run compound (chlorpyrifos ethyl); and the last eluting compound (deltamethrin), and their retention times shifted by only 0.086, 0.125, and 0.201 minutes, respectively. Despite exposure to hundreds of injections of complex sample matrices, column performance remained resilient. Moreover, when installing a new RMX-5Sil MS column, we also observed that the retention time windows did not shift; they stayed consistent both throughout routine analysis and between different columns. High retention time stability resulted in less downtime for method updates and allowed sample analysis to resume much sooner than when using traditional columns.

Table IV: Retention times were highly consistent on RMX-5Sil MS columns even after exposure to hundreds of injections of challenging sample matrices.

Pesticide	Retention Time at Initial Column Installation (min)	Retention Time at Injection 1800 (min)	Retention Time Change (min)
Dichlorvos	6.757	6.671	0.086
Chlorpyrifos ethyl	11.429	11.304	0.125
Deltamethrin	21.560	21.359	0.201

Conclusion

Ensuring accurate quantification of pesticides in botanical samples requires methods capable of overcoming both the chemical diversity of the target analytes and the complexity of natural product matrices. This comparative study demonstrates that GC MS/MS multiresidue pesticides analysis is significantly influenced by the inertness of the chromatographic system, particularly the GC column. Across a broad range of 230 different pesticides and more than 100 challenging botanical matrices, RMX 5Sil MS columns consistently delivered superior chromatographic performance compared to a traditional 5sil column. The enhanced inertness provided by TriMax deactivation technology resulted in improved peak shapes, higher signal-to-noise ratios, and more accurate results at both 10 ppb and 50 ppb. These benefits were especially pronounced for highly adsorptive or matrix sensitive pesticides, whereas traditional columns exhibited signal loss and peak distortion.

In addition to chromatographic improvements, RMX 5Sil MS columns provided accurate, consistent recoveries and demonstrated markedly longer operational lifetimes with reduced need for column trimming. Notably, their exceptional retention time stability—both over the course of hundreds of injections and between different column installations—further minimized system maintenance and downtime. Collectively, these advantages show that RMX 5Sil MS columns offer meaningful performance advantages for trace-level GC-MS/MS multiresidue pesticides analysis by improving both sensitivity and operational efficiency. Their use can help laboratories maintain data quality while increasing productivity, ultimately supporting more effective food safety and quality control programs.

References

1. E. Pack, J. Hoisington, C. English, R. Dhandapani, and C. Myers, Comprehensive trace-level semivolatiles analysis by GC-MS/MS (EPA Method 8270E), Application note, EVAN4919-US, Restek Corporation, 2025. https://discover.restek.com/application-notes/evan4919/comprehensive-trace-level-gc-ms-ms-semivolatiles-method-epa-method-8270e

2. Y. Hiramatsu and R. Dhandapani, Trace-level semivolatiles analysis: an evaluation of the RMX-5Sil MS column published in collaboration with Shimadzu Corporation, Application note, EVAN5254-UNV, Restek Corporation, 2026. https://discover.restek.com/en/application-notes/evan5254/trace-level-semivolatiles-analysis-an-evaluation-of-the-rmx-5sil-ms-column

Appendix I

Name	RT	Precursor	Product	Collision Energy
1,4-Dichlorobenzene-d4 ISTD	5.351	149.9	78	28
1,4-Dichlorobenzene-d4 ISTD	5.351	149.9	115	14
1,4-Dichlorobenzene-d4 ISTD	5.351	115	78	12
Naphthalene-d8 ISTD	6.436	136	108.1	18
Naphthalene-d8 ISTD	6.436	136	134.1	18
Naphthalene-d8 ISTD	6.436	136	84.1	20
Dichlorvos-d6 ISTD	6.657	191	99.1	10
Dichlorvos-d6 ISTD	6.657	191	115	15
Dichlorvos-d6 ISTD	6.657	226	115.1	15
Dichlorvos-d6 ISTD	6.657	226	191	5
Dichlorvos	6.669	185	93	10
Dichlorvos	6.669	145	109	10
Dichlorvos	6.669	220	185	5
Dichlorvos	6.669	145	113	15
Allidochlor	6.906	132	49	24
Allidochlor	6.906	132	56.1	8
Allidochlor	6.906	138.1	95.9	6
Dichlobenil	7.224	170.9	99.9	24
Dichlobenil	7.224	170.9	136	14
Dichlobenil	7.224	172.8	99.8	24
Biphenyl	7.451	151.8	125.8	24
Biphenyl	7.451	154.1	115	26
Biphenyl	7.451	154.1	127.4	30
Mevinphos	7.564	127	95	14
Mevinphos	7.564	127	109	10
Mevinphos	7.564	192	127	10
3,4'-Dichloroaniline	7.683	161	90	20
3,4'-Dichloroaniline	7.683	161	98.9	22
3,4'-Dichloroaniline	7.683	161	125.5	14
Etridiazole	7.758	182.8	139.9	14
Etridiazole	7.758	211	139.9	20
Etridiazole	7.758	211	182.9	10
Propham	7.759	120.1	77.1	15
Propham	7.759	137	93.1	10
Propham	7.759	179.1	120.2	15
Propham	7.759	179.1	137.1	10
Pebulate	7.777	128.1	57.1	8
Pebulate	7.777	161	128	10
Pebulate	7.777	203	160	15
N-(2,4-dimethylphenyl)formamide	7.919	120	77.1	15
N-(2,4-dimethylphenyl)formamide	7.919	149.1	106.1	16
N-(2,4-dimethylphenyl)formamide	7.919	149.1	121.1	6
Methacrifos	7.946	125	79	6
Methacrifos	7.946	180	93	10
Methacrifos	7.946	240	180	10
Tetrahydrophthalimide (THPI)	7.98	151	77.1	20
Tetrahydrophthalimide (THPI)	7.98	151	79.9	6
Tetrahydrophthalimide (THPI)	7.98	151	122.1	8
Acenaphthene-d10 ISTD	8.024	160.1	132	24
Acenaphthene-d10 ISTD	8.024	162.1	160.1	18
Acenaphthene-d10 ISTD	8.024	164	162.1	16
Chloroneb	8.033	190.9	113	14
Chloroneb	8.033	193	113	8
Chloroneb	8.033	206	141	20
2-Phenylphenol	8.171	170.1	115	34
2-Phenylphenol	8.171	170.1	141.1	22
2-Phenylphenol	8.171	171	142	25
Pentachlorobenzene	8.204	249.8	143.6	38
Pentachlorobenzene	8.204	249.8	178.5	24
Pentachlorobenzene	8.204	249.8	214.8	16
Tecnazene	8.205	214.8	143.6	20
Tecnazene	8.205	214.8	178.7	10
Tecnazene	8.205	214.8	179.9	15
Fluorene-d10 ISTD	8.619	174.2	94.1	40
Fluorene-d10 ISTD	8.619	174.2	146.1	25
Fluorene-d10 ISTD	8.619	176.2	122.1	40
Propachlor	8.656	120	50.9	35
Propachlor	8.656	120	77	15
Propachlor	8.656	120	92	15
Diphenylamine	8.798	168.1	139	24
Diphenylamine	8.798	168.1	167.1	22
Diphenylamine	8.798	169.2	167.1	14
Ethalfluralin	8.828	276	202	14
Ethalfluralin	8.828	276	248.1	8
Ethalfluralin	8.828	315.9	276.1	8

Name	RT	Precursor	Product	Collision Energy
2,3,5,6-Tetrachloroaniline	8.844	230.8	157.9	18
2,3,5,6-Tetrachloroaniline	8.844	230.8	159.8	18
2,3,5,6-Tetrachloroaniline	8.844	230.8	194.8	10
Cycloate	8.848	83.1	55.1	6
Cycloate	8.848	154.1	55.1	18
Cycloate	8.848	154.1	83.1	8
Trifluralin	8.923	306.1	159.7	20
Trifluralin	8.923	306.1	206	10
Trifluralin	8.923	306.1	264.1	8
Chlorpropham	8.933	171	127	8
Chlorpropham	8.933	213	127	14
Chlorpropham	8.933	213	171	6
Benfluralin	8.957	292	159.7	20
Benfluralin	8.957	292	206.1	10
Benfluralin	8.957	292	264	8
Sulfotepp	9.008	202	145.9	10
Sulfotepp	9.008	265.9	145.9	15
Sulfotepp	9.008	322	202	10
Phorate	9.203	75	47	8
Phorate	9.203	121	65	8
Phorate	9.203	260	75	8
Diallate-cis	9.205	234.1	150	18
Diallate-cis	9.205	235.8	152	18
Diallate-cis	9.205	235.8	194	12
Diallate-trans	9.323	234.1	150	18
Diallate-trans	9.323	235.8	152	18
Diallate-trans	9.323	235.8	194	12
BHC, Alpha	9.331	182.8	146.7	12
BHC, Alpha	9.331	218.8	146.6	20
BHC, Alpha	9.331	218.8	183	8
Hexachlorobenzene-C13 ISTD	9.419	287.8	217.9	30
Hexachlorobenzene-C13 ISTD	9.419	287.8	252.9	20
Hexachlorobenzene-C13 ISTD	9.419	287.8	182.9	40
Hexachlorobenzene	9.42	283.8	213.8	30
Hexachlorobenzene	9.42	283.8	248.8	18
Hexachlorobenzene	9.42	285.8	250.8	18
Pentachloroanisole	9.473	266.8	238.9	12
Pentachloroanisole	9.473	279.9	236.9	22
Pentachloroanisole	9.473	279.9	264.9	10
Dichloran (Botran)	9.49	160	124.1	8
Dichloran (Botran)	9.49	176	148	12
Dichloran (Botran)	9.49	206	176	10
Atrazine-d5	9.55	220.2	205.1	10
Atrazine-d5	9.55	205.1	105.1	15
Atrazine-d5	9.55	205.1	127.1	10
Atrazine	9.561	200	122.1	8
Atrazine	9.561	200	132	8
Atrazine	9.561	215.1	58.1	12
Diazinon oxon	9.604	137.1	84.1	10
Diazinon oxon	9.604	217	119.1	10
Diazinon oxon	9.604	273.1	137.1	10
Diazinon oxon	9.604	273.1	217.1	10
BHC, Beta	9.643	182.8	146.7	12
BHC, Beta	9.643	218.8	146.6	20
BHC, Beta	9.643	218.8	183	8
Clomazone	9.645	125	89	14
Clomazone	9.645	138	74.9	24
Clomazone	9.645	138	111	12
Profluralin	9.661	318.1	199	15
Profluralin	9.661	318.1	284.1	10
Profluralin	9.661	330.2	69.1	20
Quintozene	9.735	213.8	141.9	28
Quintozene	9.735	213.8	178.9	14
Quintozene	9.735	294.8	236.9	14
Terbuthylazine	9.758	214	71	16
Terbuthylazine	9.758	214.1	104	16
Terbuthylazine	9.758	214.1	132	10
Diazinon-d10	9.764	314.2	183.2	15
Diazinon-d10	9.764	183.2	139.2	20
Diazinon-d10	9.764	232.1	135.1	15
Terbufos	9.776	230.9	128.9	22
Terbufos	9.776	230.9	174.9	12
Terbufos	9.776	230.9	203	8
BHC, Gamma	9.782	182.8	146.7	12
BHC, Gamma	9.782	218.8	146.6	20

(Continued)

Appendix I *(continued)*

Name	RT	Precursor	Product	Collision Energy
BHC, Gamma	9.782	218.8	183	8
Pentachlorobenzonitrile	9.783	272.9	237.9	16
Pentachlorobenzonitrile	9.783	274.8	204.9	28
Pentachlorobenzonitrile	9.783	274.8	239.9	18
Diazinon	9.812	137.1	54.1	20
Diazinon	9.812	137.1	84.1	12
Diazinon	9.812	179.1	121.5	26
Propyzamide	9.821	172.9	74	38
Propyzamide	9.821	172.9	109	8
Propyzamide	9.821	172.9	145	14
Fluchloralin	9.833	264	159.5	14
Fluchloralin	9.833	264	206.1	8
Fluchloralin	9.833	306	264	8
Fonofos	9.867	137	109	6
Fonofos	9.867	246	109	10
Fonofos	9.867	246	137	6
PCB 18 ISTD	9.924	186.1	151.1	18
PCB 18 ISTD	9.924	256	186	22
PCB 18 ISTD	9.924	258	186	22
Pyrimethanil	9.939	198.1	117.9	30
Pyrimethanil	9.939	198.1	157.6	18
Pyrimethanil	9.939	198.1	182.9	14
Tefluthrin	9.993	177	127	14
Tefluthrin	9.993	177	137	16
Tefluthrin	9.993	197	141.1	10
Phenanthrene-d10 ISTD	9.998	188	158.1	34
Phenanthrene-d10 ISTD	9.998	188	160.1	20
Phenanthrene-d10 ISTD	9.998	188	184.1	28
Isazophos	10	161	119	8
Isazophos	10	161	146	6
Isazophos	10	118.9	76	18
Chlorothalonil	10.006	263.9	168	24
Chlorothalonil	10.006	263.9	228.9	18
Chlorothalonil	10.006	265.8	133	36
Terbacil	10.017	160	76	12
Terbacil	10.017	160	117	8
Terbacil	10.017	161.2	144	12
Disulfoton	10.024	88	45	18
Disulfoton	10.024	88	59.8	6
Disulfoton	10.024	185.9	96.9	16
Triallate	10.144	86.1	43.3	6
Triallate	10.144	268	183.9	18
Triallate	10.144	268	226	12
BHC, Delta	10.151	182.8	146.7	12
BHC, Delta	10.151	218.8	146.6	20
BHC, Delta	10.151	218.8	183	8
Pentachloroaniline	10.455	264.8	193.6	18
Pentachloroaniline	10.455	264.8	202.8	20
Pentachloroaniline	10.455	264.8	229.3	12
Endosulfan ether	10.467	238.9	203.9	16
Endosulfan ether	10.467	241	206	15
Endosulfan ether	10.467	307	241	10
Dimethachlor	10.489	134	77	24
Dimethachlor	10.489	134	105.1	12
Dimethachlor	10.489	197	148.1	10
Propanil	10.5	160.9	99	24
Propanil	10.5	160.9	125.7	16
Propanil	10.5	217	161	8
Acetochlor	10.543	223.1	132.1	20
Acetochlor	10.543	174.1	146.1	15
Acetochlor	10.543	162.1	147.1	15
Acetochlor	10.543	162.1	144.1	10
Chlorpyrifos-methyl	10.582	125	47	12
Chlorpyrifos-methyl	10.582	125	79	10
Chlorpyrifos-methyl	10.582	286	93	12
Vinclozolin	10.622	186.8	124	18
Vinclozolin	10.622	198	145	14
Vinclozolin	10.622	212	172	14
PCB 28 ISTD	10.643	186.1	151.1	18
PCB 28 ISTD	10.643	256	186	22
PCB 28 ISTD	10.643	258	186	22
Transfluthrin	10.669	127	91.1	8
Transfluthrin	10.669	163	91.1	12
Transfluthrin	10.669	163	143	14
Parathion-methyl	10.67	246	106.1	20
Parathion-methyl	10.67	246	136.1	10
Parathion-methyl	10.67	263	109	15
Alachlor	10.686	160.1	130.1	25
Alachlor	10.686	188.1	132.1	20
Alachlor	10.686	188.1	130	32
Alachlor	10.686	188.1	160.1	8
Tolclofos methyl	10.698	265	219.9	20
Tolclofos methyl	10.698	265	250	12
Tolclofos methyl	10.698	266.8	252	12
Propisochlor	10.752	162	144	10
Propisochlor	10.752	223.1	132.1	20
Propisochlor	10.752	223.1	147.1	10
Cymiazole	10.759	218.1	144.1	15
Cymiazole	10.759	218.1	185.1	10
Cymiazole	10.759	130.1	77	20
Cymiazole	10.759	170.1	155.1	15
Metalaxyl	10.781	206	132	12
Metalaxyl	10.781	249.2	146.1	22
Metalaxyl	10.781	249.2	190.1	8
Fenchlorfos	10.85	124.9	79	6
Fenchlorfos	10.85	285	240	20
Fenchlorfos	10.85	285	270	13
Heptachlor	10.88	99.8	39	26
Heptachlor	10.88	99.8	65	12
Heptachlor	10.88	271.8	236.9	12
Pirimiphos-methyl	10.978	290.1	125	20
Pirimiphos-methyl	10.978	290.1	233	8
Pirimiphos-methyl	10.978	305.1	180.1	8
Prodiamine	10.988	321	203	15
Prodiamine	10.988	321	216	15
Prodiamine	10.988	321.1	279.1	6
Fenitrothion	11.044	260	125.1	12
Fenitrothion	11.044	277	109	16
Fenitrothion	11.044	277	260	6
o,p-dicofol	11.091	139	75.1	25
o,p-dicofol	11.091	139	111	15
o,p-dicofol	11.091	141	113	15
o,p-dicofol	11.091	250	139	15
Malathion	11.154	92.8	63	8
Malathion	11.154	125	79	6
Malathion	11.154	173.1	99	12
Linuron	11.165	160	73	30
Linuron	11.165	160	133	15
Linuron	11.165	248	61.1	10
PCB 52 ISTD	11.168	220	150	30
PCB 52 ISTD	11.168	255	220	14
PCB 52 ISTD	11.168	290	220	24
Dichlofluanid	11.189	123	51	32
Dichlofluanid	11.189	123	77	18
Dichlofluanid	11.189	223.9	123	10
Pentachlorothioanisole	11.219	262.7	192.9	28
Pentachlorothioanisole	11.219	295.7	245.9	30
Pentachlorothioanisole	11.219	295.7	262.9	12
Chlorpyrifos-diethyl-d10	11.253	197.9	170	15
Chlorpyrifos-diethyl-d10	11.253	324.1	260	15
Chlorpyrifos-diethyl-d10	11.253	259.9	167	20
Metolachlor	11.297	162.1	132.9	14
Metolachlor	11.297	238.1	132.8	26
Metolachlor	11.297	238.1	162.2	10
Chlorpyrifos-ethyl	11.315	196.7	168.9	12
Chlorpyrifos-ethyl	11.315	314	258	15
Chlorpyrifos-ethyl	11.315	314	286	12
Fenthion	11.37	278	79	30
Fenthion	11.37	278	109	18
Fenthion	11.37	278	169	14
Chlorthal-dimethyl (Dacthal)	11.41	300.7	222.9	22
Chlorthal-dimethyl (Dacthal)	11.41	300.7	272.9	12
Chlorthal-dimethyl (Dacthal)	11.41	332	301	15
Parathion-ethyl	11.429	139.1	81.1	10
Parathion-ethyl	11.429	291.1	81	24
Parathion-ethyl	11.429	291.1	137	6
Aldrin	11.458	262.7	191	30
Aldrin	11.458	262.7	192.9	28
Aldrin	11.458	298	193	35
Anthraquinone	11.466	180	152	12

(Continued)

Appendix I *(continued)*

Name	RT	Precursor	Product	Collision Energy
Anthraquinone	11.466	208	151.7	22
Anthraquinone	11.466	208	180	10
Triadimefon	11.486	208	111	20
Triadimefon	11.486	208	126.7	12
Triadimefon	11.486	208	180.8	8
Dichlorobenzophenone, 4,4'	11.586	111	74.9	12
Dichlorobenzophenone, 4,4'	11.586	139	74.9	26
Dichlorobenzophenone, 4,4'	11.586	139	111	12
Pirimiphos-ethyl	11.612	304	168.1	12
Pirimiphos-ethyl	11.612	318.1	166.1	12
Pirimiphos-ethyl	11.612	318.1	182.1	10
Triphenylmethane ISTD	11.615	244.2	165.1	30
Triphenylmethane ISTD	11.615	244.2	167.2	10
Triphenylmethane ISTD	11.615	244.2	243.2	10
Diphenamid	11.681	166.8	152	16
Diphenamid	11.681	239.1	72.1	10
Diphenamid	11.681	239.1	167.1	8
Fenson	11.681	77	51	14
Fenson	11.681	141	50.9	30
Fenson	11.681	141	77	8
Bromophos-methyl (Bromophos)	11.691	125	79	6
Bromophos-methyl (Bromophos)	11.691	328.9	313.8	14
Bromophos-methyl (Bromophos)	11.691	330.8	315.8	14
MGK264-1	11.706	164.1	67	8
MGK264-1	11.706	164.1	80	24
MGK264-1	11.706	164.1	98	12
Isopropalin	11.721	280.1	117.8	26
Isopropalin	11.721	280.1	180.2	10
Isopropalin	11.721	280.1	238.2	8
Chlorfenvinphos-cis	11.824	266.9	159	14
Chlorfenvinphos-cis	11.824	266.9	203	10
Chlorfenvinphos-cis	11.824	323	266.9	14
Pendimethalin	11.859	252.1	161	14
Pendimethalin	11.859	252.1	162	8
Pendimethalin	11.859	252.1	191.3	8
Cyprodinil	11.87	224.1	196.9	20
Cyprodinil	11.87	224.1	208	18
Cyprodinil	11.87	225.1	209.7	16
Fipronil	11.88	366.9	212.9	28
Fipronil	11.88	366.9	244.9	20
Fipronil	11.88	368.8	214.9	30
Metazachlor	11.899	133.1	117.3	22
Metazachlor	11.899	133.1	132.1	12
Metazachlor	11.899	209	132.1	16
MGK264-2	11.909	164.1	67	8
MGK264-2	11.909	164.1	80	24
MGK264-2	11.909	164.1	98	12
Isodrin	11.945	146.8	111.1	10
Isodrin	11.945	192.9	123	28
Isodrin	11.945	192.9	157.2	20
Chlozolinate	11.949	259	152.9	26
Chlozolinate	11.949	259	187.9	12
Chlozolinate	11.949	331	259	8
Penconazole	11.973	158.9	89	28
Penconazole	11.973	248	157	22
Penconazole	11.973	248	192	12
Chlorfenvinphos-trans	11.995	266.9	159	14
Chlorfenvinphos-trans	11.995	266.9	203	10
Chlorfenvinphos-trans	11.995	323	266.9	14
Fluopyram	12.007	173	75.1	40
Fluopyram	12.007	173	95	25
Fluopyram	12.007	173	145.1	15
Fluopyram	12.007	223	196.1	15
Tolylfluanid	12.016	137	65.1	28
Tolylfluanid	12.016	137	91.1	18
Tolylfluanid	12.016	238	137	10
Bromfenvinphos-methyl	12.033	109	79	6
Bromfenvinphos-methyl	12.033	294.9	79.1	30
Bromfenvinphos-methyl	12.033	294.9	109	16
Allethrin (Bioallethrin)	12.054	123.1	41.1	24
Allethrin (Bioallethrin)	12.054	123.1	81.1	8
Allethrin (Bioallethrin)	12.054	136.1	93.1	12
Heptachlor epoxide	12.086	262.9	192.9	30
Heptachlor epoxide	12.086	352.8	262.9	16
Heptachlor epoxide	12.086	354.7	264.9	12

Name	RT	Precursor	Product	Collision Energy
Quinalphos	12.124	146	118.1	10
Quinalphos	12.124	157.1	102	22
Quinalphos	12.124	157.1	129	14
Triadimenol	12.188	112	57.6	8
Triadimenol	12.188	128	65	18
Triadimenol	12.188	168.2	70	10
Triflumizole	12.198	179	144	14
Triflumizole	12.198	206	179	14
Triflumizole	12.198	206	186	8
Captan	12.199	149	70	20
Captan	12.199	149	78.8	14
Captan	12.199	149	105	6
Procymidone	12.199	212	172	10
Procymidone	12.199	285.1	96.1	10
Procymidone	12.199	285.1	257.1	10
Folpet	12.303	104	76	10
Folpet	12.303	130	102	12
Folpet	12.303	259.9	130.1	14
Bromophos-ethyl	12.368	96.9	65	16
Bromophos-ethyl	12.368	96.9	78.9	12
Bromophos-ethyl	12.368	302.7	284.8	14
Chlorbenside	12.442	125	62.8	28
Chlorbenside	12.442	125	89	14
Chlorbenside	12.442	125	99	16
Tetrachlorvinphos	12.462	109	79	6
Tetrachlorvinphos	12.462	328.9	109	18
Tetrachlorvinphos	12.462	330.8	109	18
Chlordane alpha-cis	12.477	372.8	265.8	20
Chlordane alpha-cis	12.477	374.7	265.8	20
Chlordane alpha-cis	12.477	376.6	268	20
DDE-o,p'	12.479	246	176.1	28
DDE-o,p'	12.479	317.8	246	20
DDE-o,p'	12.479	317.8	248	18
Paclobutrazol	12.515	125	89	14
Paclobutrazol	12.515	236	125	12
Paclobutrazol	12.515	236	167	10
Paclobutrazole-phenyl-d4	12.515	240.1	129.1	15
Paclobutrazole-phenyl-d4	12.515	240.1	171.1	10
Paclobutrazole-phenyl-d4	12.515	242.1	131.1	15
Bromfenvinphos	12.685	266.9	159	14
Bromfenvinphos	12.685	266.9	203	10
Bromfenvinphos	12.685	323.1	266.9	10
Fenamiphos	12.689	154	139	10
Fenamiphos	12.689	216.9	202	12
Fenamiphos	12.689	303.1	195.2	8
Chlordane gamma-trans	12.697	372.8	265.8	20
Chlordane gamma-trans	12.697	374.7	265.8	20
Chlordane gamma-trans	12.697	376.6	268	20
Endosulfan I	12.712	194.7	125	22
Endosulfan I	12.712	194.7	159.4	8
Endosulfan I	12.712	240.6	205.9	14
Flutriafol	12.716	123	75	24
Flutriafol	12.716	123	95	12
Flutriafol	12.716	219	123	12
Nonachlor-cis	12.75	406.8	297.9	15
Nonachlor-cis	12.75	406.8	299.9	15
Nonachlor-cis	12.75	406.8	334.9	10
Flutolanil	12.751	173	95	28
Flutolanil	12.751	173	145	14
Flutolanil	12.751	281	173	10
Iodofenfos	12.831	125	47	12
Iodofenfos	12.831	125	79	6
Iodofenfos	12.831	376.8	361.8	16
Chlorfenson	12.832	111	75	14
Chlorfenson	12.832	174.9	75	28
Chlorfenson	12.832	174.9	111	10
Fludioxonil	12.834	153.7	127	8
Fludioxonil	12.834	248	127	26
Fludioxonil	12.834	248	153.8	18
Prothiofos	12.872	266.7	220.9	18
Prothiofos	12.872	266.7	238.9	8
Prothiofos	12.872	308.9	239	14
Pretilachlor	12.893	202.1	145.5	14
Pretilachlor	12.893	202.1	174.2	8
Pretilachlor	12.893	238.1	146.1	10

(Continued)

Appendix I *(continued)*

Name	RT	Precursor	Product	Collision Energy
Profenofos	12.946	296.7	268.9	10
Profenofos	12.946	336.9	266.9	12
Profenofos	12.946	336.9	308.9	8
Oxadiazon	12.991	174.9	76	28
Oxadiazon	12.991	174.9	112	12
Oxadiazon	12.991	174.9	147.2	6
Tricyclazole	13.027	162.1	135	10
Tricyclazole	13.027	189	161.9	10
Tricyclazole	13.027	189.2	135.1	15
DDE-p,p'	13.035	246	176.1	28
DDE-p,p'	13.035	317.8	246	20
DDE-p,p'	13.035	317.8	248	18
Oxyfluorfen	13.075	252	146	30
Oxyfluorfen	13.075	252	169.8	28
Oxyfluorfen	13.075	252	224	10
Myclobutanil	13.084	179	90	28
Myclobutanil	13.084	179	125	14
Myclobutanil	13.084	179	151.7	8
Bupirimate	13.105	208.1	140.1	12
Bupirimate	13.105	208.1	165	12
Bupirimate	13.105	273.1	193.2	8
Flusilazole	13.115	206	151.3	14
Flusilazole	13.115	233	151.9	14
Flusilazole	13.115	233	164.9	16
DDD-o,p'	13.16	235	165.1	20
DDD-o,p'	13.16	235	199	14
DDD-o,p'	13.16	236.8	165	20
Dieldrin	13.184	262.8	192.9	28
Dieldrin	13.184	262.8	227.8	16
Dieldrin	13.184	262.9	191	30
Dieldrin	13.184	277	241	10
Chlorfenapyr	13.276	136.9	102	12
Chlorfenapyr	13.276	248.9	112	24
Chlorfenapyr	13.276	248.9	137.1	18
Fluazifop-butyl	13.399	282	91.1	18
Fluazifop-butyl	13.399	282	238.1	16
Fluazifop-butyl	13.399	383.1	282.1	14
Perthane (Ethylan)	13.461	223.1	167	12
Perthane (Ethylan)	13.461	223.1	179	20
Perthane (Ethylan)	13.461	223.1	193	28
Nitrofen	13.462	202	139	24
Nitrofen	13.462	283	202	10
Nitrofen	13.462	283	253	10
Endrin	13.549	262.8	192.9	28
Endrin	13.549	280.8	245.3	8
Endrin	13.549	245	173	16
Chlorobenzilate	13.586	111	75.1	14
Chlorobenzilate	13.586	139	74.9	26
Chlorobenzilate	13.586	139	111	12
Endosulfan II	13.728	158.9	123	12
Endosulfan II	13.728	194.7	159	8
Endosulfan II	13.728	240.6	205.8	12
Ethion	13.733	153	97	10
Ethion	13.733	230.9	128.9	22
Ethion	13.733	230.9	174.9	12
DDD-p,p'	13.777	235	165.1	20
DDD-p,p'	13.777	235	199	14
DDD-p,p'	13.777	236.8	165	20
Chlorthiophos	13.788	268.9	205	14
Chlorthiophos	13.788	296.9	268.9	8
Chlorthiophos	13.788	324.9	269	12
Endosulfan sulfate	13.813	238.7	203.9	12
Endosulfan sulfate	13.813	271.7	234.9	12
Endosulfan sulfate	13.813	271.7	236.8	12
Nonachlor-trans	13.817	406.8	297.9	15
Nonachlor-trans	13.817	406.8	299.9	15
Nonachlor-trans	13.817	406.8	334.9	10
Aclonifen	13.828	212	182.1	15
Aclonifen	13.828	264	194	15
Aclonifen	13.828	212	127.1	30
Aclonifen	13.828	212	155.1	20
DDT-o,p'	13.832	235	165.1	20
DDT-o,p'	13.832	235	199.5	10
DDT-o,p'	13.832	236.8	165	20
Endrin aldehyde	13.988	173	138.1	16
Endrin aldehyde	13.988	344.9	281	8
Endrin aldehyde	13.988	249.9	214.9	25
Endrin aldehyde	13.988	345	245	15
Triazophos	14.003	161	105.7	12
Triazophos	14.003	161	134.1	8
Triazophos	14.003	257	162	12
Sulprofos	14.045	156	108	30
Sulprofos	14.045	156	141	14
Sulprofos	14.045	322	156.1	10
Tris(1,3-dichloroisopropyl)phosphate ISTD	14.119	75	49	16
Tris(1,3-dichloroisopropyl)phosphate ISTD	14.119	378.9	159	10
Tris(1,3-dichloroisopropyl)phosphate ISTD	14.119	380.9	159	10
Carfentrazone-ethyl	14.146	290	99.9	36
Carfentrazone-ethyl	14.146	311.9	150.7	18
Carfentrazone-ethyl	14.146	340.1	312.1	10
4,4'-Methoxychlor olefin	14.232	238.1	152.1	30
4,4'-Methoxychlor olefin	14.232	238.1	223.1	10
4,4'-Methoxychlor olefin	14.232	308	238.1	16
Carbophenothion	14.237	157	45	12
Carbophenothion	14.237	199	142.9	10
Carbophenothion	14.237	342	157	10
Norflurazon	14.258	145	74.7	28
Norflurazon	14.258	145	95	12
Norflurazon	14.258	303	145	20
Edifenphos	14.312	172.9	65.1	30
Edifenphos	14.312	172.9	109	8
Edifenphos	14.312	310	109	26
Lenacil	14.382	153	82.1	16
Lenacil	14.382	153	110	14
Lenacil	14.382	153	135.6	12
DDT-d8 ISTD	14.43	243.1	206.1	15
DDT-d8 ISTD	14.43	244.1	174.1	20
DDT-d8 ISTD	14.43	245.1	173.1	20
DDT-p,p'	14.48	235	165.1	20
DDT-p,p'	14.48	235	199.5	10
DDT-p,p'	14.48	236.8	165	20
Hexazinone	14.551	127.7	83	10
Hexazinone	14.551	171.1	71.1	14
Hexazinone	14.551	171.1	85.1	12
o,p'-Methoxychlor	14.581	121.1	78.1	20
o,p'-Methoxychlor	14.581	227.1	121.1	16
o,p'-Methoxychlor	14.581	228.1	122.1	16
Tebuconazole	14.742	125	89	14
Tebuconazole	14.742	125	99	16
Tebuconazole	14.742	250	125	20
Propargite	14.744	135.1	107.1	15
Propargite	14.744	150.1	135.1	8
Propargite	14.744	173	135	12
Triphenylphosphate (TPP) ISTD	14.802	215	168.1	16
Triphenylphosphate (TPP) ISTD	14.802	326.1	168.6	28
Triphenylphosphate (TPP) ISTD	14.802	326.1	325.3	10
Piperonyl butoxide	14.856	176.1	103.1	22
Piperonyl butoxide	14.856	176.1	117	18
Piperonyl butoxide	14.856	176.1	131.1	12
Nitralin	14.871	274	169	12
Nitralin	14.871	274	216	8
Nitralin	14.871	316.2	274	8
Resmethrin	14.895	123.1	81.1	8
Resmethrin	14.895	143	128	10
Resmethrin	14.895	171	127.9	14
Captafol	14.911	150.1	77.2	24
Captafol	14.911	150.1	79	6
Captafol	14.911	183.1	79.1	8
Pyridaphenthion	15.203	199	77.1	24
Pyridaphenthion	15.203	199	92.1	14
Pyridaphenthion	15.203	340	199.1	8
Carbosulfan	15.217	323.2	160.2	10
Carbosulfan	15.217	160.1	104.1	10
Carbosulfan	15.217	118.1	62.1	10
Carbosulfan	15.217	160.1	62.1	15
Iprodione	15.227	314	245	10
Iprodione	15.227	315.7	247	10
Iprodione	15.227	315.7	273	8
Tetramethrin peak 1	15.277	164	77.1	22
Tetramethrin peak 1	15.277	164	107.1	12

(Continued)

Appendix I *(continued)*

Name	RT	Precursor	Product	Collision Energy
Tetramethrin peak 1	15.277	164	135.1	8
Endrin ketone	15.366	209.2	138.4	30
Endrin ketone	15.366	316.8	208.9	28
Endrin ketone	15.366	316.8	281	10
Phosmet	15.387	160	50.9	34
Phosmet	15.387	160	76.9	22
Phosmet	15.387	160	133	10
Bifenthrin	15.391	165.1	163.6	24
Bifenthrin	15.391	181	165.9	10
Bifenthrin	15.391	181	179	12
EPN	15.447	157	77	22
EPN	15.447	169	77	22
EPN	15.447	169	141	8
Tetramethrin peak 2	15.452	164	77.1	22
Tetramethrin peak 2	15.452	164	107.1	12
Tetramethrin peak 2	15.452	164	135.1	8
Bromopropylate	15.481	184.9	75.5	30
Bromopropylate	15.481	184.9	156.9	12
Bromopropylate	15.481	340.8	185	14
Bifenazate	15.512	196.1	141.1	20
Bifenazate	15.512	199.1	170.1	15
Bifenazate	15.512	258.1	199.1	10
Bifenazate	15.512	300.2	258.1	10
Chrysene-d12 ISTD	15.567	240.2	212.1	28
Chrysene-d12 ISTD	15.567	240.2	236.1	32
Chrysene-d12 ISTD	15.567	240.2	238.2	16
Methoxychlor	15.576	227.1	141.1	32
Methoxychlor	15.576	227.1	169.1	22
Methoxychlor	15.576	227.1	212.1	8
Fenpropathrin	15.609	97.1	55.1	6
Fenpropathrin	15.609	181	126.8	28
Fenpropathrin	15.609	181	151.9	22
p,p'-Dicofol	15.709	139	75.1	25
p,p'-Dicofol	15.709	139	111	10
p,p'-Dicofol	15.709	252	111	30
p,p'-Dicofol	15.709	252	139	10
Tebufenpyrad	15.727	276.1	171	10
Tebufenpyrad	15.727	318.1	131.1	14
Tebufenpyrad	15.727	318.1	145.1	14
Fenazaquin	15.85	146.2	118.2	15
Fenazaquin	15.85	160.1	117.1	20
Fenazaquin	15.85	160.1	145.1	10
Phenothrin-cis Test	15.917	123.1	81.1	10
Phenothrin-cis Test	15.917	183.1	153.1	15
Phenothrin-cis Test	15.917	183.1	165.1	10
Phenothrin-cis Test	15.917	183.1	168.1	10
Phenothrin-cis	15.921	123.1	41.1	24
Phenothrin-cis	15.921	123.1	79.1	14
Phenothrin-cis	15.921	123.1	81.1	8
Phenothrin-trans Test	16.068	123.1	81.1	10
Phenothrin-trans Test	16.068	183.1	153.1	15
Phenothrin-trans Test	16.068	183.1	165.1	10
Phenothrin-trans Test	16.068	183.1	168.1	10
Tetradifon	16.071	159	74.8	32
Tetradifon	16.071	159	111	20
Tetradifon	16.071	159	131	6
Phenothrin-trans	16.073	123.1	41.1	24
Phenothrin-trans	16.073	123.1	79.1	14
Phenothrin-trans	16.073	123.1	81.1	8
Phosalone	16.193	121.1	65	10
Phosalone	16.193	182	74.8	30
Phosalone	16.193	182	111	14
Leptophos	16.234	171	51	38
Leptophos	16.234	171	77.1	18
Leptophos	16.234	171	124.3	10
Azinphos-methyl	16.277	132	77	12
Azinphos-methyl	16.277	160	50.9	34
Azinphos-methyl	16.277	160	77	16
Pyriproxyfen	16.385	136.1	78	20
Pyriproxyfen	16.385	136.1	96	10
Pyriproxyfen	16.385	226.1	186.1	12
Cyhalothrin I (lambda)	16.597	180.9	152	22
Cyhalothrin I (lambda)	16.597	197.1	141.1	10
Cyhalothrin I (lambda)	16.597	207.9	180.9	8
Mirex	16.798	236.8	142.9	24
Mirex	16.798	273.8	238.8	14
Mirex	16.798	272	236.8	14
Acrinathrin	16.82	181	152	22
Acrinathrin	16.82	208.1	180.9	8
Acrinathrin	16.82	289	93.1	8
Pyrazophos	16.849	221	148.7	14
Pyrazophos	16.849	221	193.1	8
Pyrazophos	16.849	231.9	204.1	10
Fenarimol	16.895	139	74.9	26
Fenarimol	16.895	139	111	12
Fenarimol	16.895	219	107	10
Azinphos-ethyl	17.042	132	51	26
Azinphos-ethyl	17.042	132	77	12
Azinphos-ethyl	17.042	160	77	16
Pyraclofos	17.231	139.2	96.9	6
Pyraclofos	17.231	194	138	18
Pyraclofos	17.231	360	194.1	12
Trans-Permethrin-Phenoxy-d5 1	17.686	163	127.1	10
Trans-Permethrin-Phenoxy-d5 1	17.686	188.1	160.2	10
Trans-Permethrin-Phenoxy-d5 1	17.686	188.1	172.2	15
Permethrin I	17.698	183	165.1	10
Permethrin I	17.698	183	168.1	10
Permethrin I	17.698	183.1	153	8
Trans-Permethrin-Phenoxy-d5 2	17.866	163	127.1	10
Trans-Permethrin-Phenoxy-d5 2	17.866	188.1	160.2	10
Trans-Permethrin-Phenoxy-d5 2	17.866	188.1	172.2	15
Permethrin II	17.874	183	165.1	10
Permethrin II	17.874	183	168.1	10
Permethrin II	17.874	183.1	153	8
Coumaphos	17.882	362	99	10
Coumaphos	17.882	362	226	25
Coumaphos	17.882	209.9	182	10
Fluquinconazole	17.896	340	108.1	36
Fluquinconazole	17.896	340	298	16
Fluquinconazole	17.896	340	313	14
Pyridaben	17.914	147.1	117.1	20
Pyridaben	17.914	147.1	119.1	8
Pyridaben	17.914	147.1	132.1	12
Prochloraz	17.996	180.1	69.1	15
Prochloraz	17.996	180.1	138.1	12
Prochloraz	17.996	308	70	12
Cyfluthrin I	18.475	199.1	170.1	20
Cyfluthrin I	18.475	206.1	151.1	20
Cyfluthrin I	18.475	226	206.1	10
Cyfluthrin I	18.475	163	127.1	6
Cyfluthrin II	18.624	163	127.1	6
Cyfluthrin II	18.624	199.1	170.1	20
Cyfluthrin II	18.624	206.1	151.1	20
Cyfluthrin II	18.624	226	206.1	10
Cyfluthrin III	18.705	163	127.1	6
Cyfluthrin III	18.705	199.1	170.1	20
Cyfluthrin III	18.705	206.1	151.1	20
Cyfluthrin III	18.705	226	206.1	10
Cyfluthrin IV	18.791	163	127.1	6
Cyfluthrin IV	18.791	199.1	170.1	20
Cyfluthrin IV	18.791	206.1	151.1	20
Cyfluthrin IV	18.791	226	206.1	10
Cypermethrin I	18.958	163	127.1	6
Cypermethrin I	18.958	165	127.1	10
Cypermethrin I	18.958	165	129.1	10
Cypermethrin II	19.121	163	127.1	6
Cypermethrin II	19.121	165	127.1	10
Cypermethrin II	19.121	165	129.1	10
Cypermethrin III	19.21	163	127.1	6
Cypermethrin III	19.21	165	127.1	10
Cypermethrin III	19.21	165	129.1	10
Flucythrinate peak 1	19.215	157	107.1	12
Flucythrinate peak 1	19.215	199.1	107.1	22
Flucythrinate peak 1	19.215	199.1	157.1	8
Cypermethrin IV	19.271	163	127.1	6
Cypermethrin IV	19.271	165	127.1	10
Cypermethrin IV	19.271	165	129.1	10
Etofenprox	19.459	163.1	77.1	32
Etofenprox	19.459	163.1	107.1	10
Etofenprox	19.459	163.1	135.1	6

(Continued)

Appendix I *(continued)*

Name	RT	Precursor	Product	Collision Energy
Acequinocyl (degradant)	19.467	188.1	131.1	20
Acequinocyl (degradant)	19.467	189.1	115.1	20
Acequinocyl (degradant)	19.467	342.2	160.1	22
Flucythrinate peak 2	19.53	157	107.1	12
Flucythrinate peak 2	19.53	199.1	107.1	22
Flucythrinate peak 2	19.53	199.1	157.1	8
Perylene-d12	19.82	132.2	118.1	12
Perylene-d12	19.82	260.1	256.1	34
Perylene-d12	19.82	264.2	260.1	36
Fluridone	19.875	328.1	189.1	38
Fluridone	19.875	328.1	258.8	24
Fluridone	19.875	329.1	328.5	12
Fenvalerate 1	20.311	125	89	14
Fenvalerate 1	20.311	167	89	32

Name	RT	Precursor	Product	Collision Energy
Fenvalerate 1	20.311	167	125	10
Fluvalinate peak 1	20.506	180.8	152.1	22
Fluvalinate peak 1	20.506	250	55.1	16
Fluvalinate peak 1	20.506	250	199.9	18
Fluvalinate peak 2	20.617	180.8	152.1	22
Fluvalinate peak 2	20.617	250	55.1	16
Fluvalinate peak 2	20.617	250	199.9	18
Fenvalerate 2	20.626	125	89	14
Fenvalerate 2	20.626	167	89	32
Fenvalerate 2	20.626	167	125	10
Deltamethrin	21.377	252.8	172	8
Deltamethrin	21.377	181	152.1	20
Deltamethrin	21.377	252.8	92.9	16

Featured Products

RMX-5Sil MS GC Capillary Column

- Next-generation TriMax deactivation creates a resilient stationary phase and exceptionally neutral sample flow path, delivering the stability needed for extended calibration intervals and more reliable data.
- Maximum inertness improves peak shape for problematic active compound classes, achieving lower detection limits and picogram-level sensitivity for confident quantification of a wide range of analytes.
- Superior column performance supports method consolidation for increased productivity and scaled down sample extraction volumes for reduced solvent use.

Catalog No.	Product Name	Units
17323-124	RMX-5Sil MS GC Capillary Column, 30 m, 0.25 mm ID, 0.25 µm, with 5 m Integra-Guard	ea.
17323-124177	RMX-5Sil MS GC Capillary Column, 30 m, 0.25 mm ID, 0.25 µm, with 5 m Integra-Guard & Integra-Transfer Line	ea.

Topaz Single Taper Inlet Liner

Catalog No.	Product Name	Units
23447	Topaz, Single Taper Inlet Liner, 4.0 mm x 6.5 x 78.5, for Thermo TRACE 1300/1310, 1600/1610 GCs w/SSL inlets, w/Quartz Wool, Premium Deactivation	5-pk.

Restek Electronic Leak Detector

Catalog No.	Product Name	Units
28500	Restek Electronic Leak Detector (includes carrying case; universal AC power adaptor [U.S., UK, Europe, Australia, Japan]; 6-ft USB charging cable)	ea.

Restek ProFLOW 6000 Electronic Flowmeter

Catalog No.	Product Name	Units
22656	Restek ProFLOW 6000 Electronic Flowmeter	ea.

Q-sep QuEChERS Extraction Salt Packets Only (Original)

Catalog No.	Product Name	Units
25847	Q-sep QuEChERS Extraction Salt Packets Only (Original), 4 g $MgSO_4$, 1 g NaCl	50 packets

Q-sep QuEChERS Extraction Kit (AOAC)

Catalog No.	Product Name	Units
25852	Q-sep QuEChERS Extraction Kit (AOAC), 6 g $MgSO_4$, 1.5 g NaOAc with 50 mL Centrifuge Tube	50 packets & 50 tubes