

ASMS 2013

MP-632

LC/MS/MS with Novel
Online SPE Valving
Solution for the Analysis of
Sub-Parts-Per-Trillion
Contaminants in Drinking
Water

Sheher Bano Mohsin, Michael
Woodman, Agilent Technologies,
Schaumburg, IL, USA

Introduction

In recent years there have been numerous reports of pharmaceuticals and other unexpected chemicals in drinking and surface water across this country. These CEC's (Contaminants of Emerging Concern) are often at very low levels, and the number of samples presented often preclude use of extensive off line sample preparation. We describe here a novel integrated valving and liquid metering system to do on-line SPE coupled to LC/MS/MS. A very low level detection is possible, without prior sample preparation, using a previously unreported configuration that significantly reduces the complexity, cost and footprint of the HPLC system. On-line SPE has several well known advantages over off-line SPE, though the setup for doing on-line SPE can be complicated as multiple valves are needed for controlling the flow from the required multiple pumps - one for sample loading and one for analysis. This adds to the cost of doing on-line SPE and represents a technical barrier and potential technology transfer problems. The online SPE system we present here has a built in single piston pump, with solvent selection capability, and user-selectable valves integrated in a single FlexCube module.

Experimental

Instrumentation

Agilent 1200 Infinity Series Online-SPE solution system comprising:

- G1312B Binary Pump with modular degasser
- G1329B Standard Autosampler
- G4227A Flexible Cube with 2-position/10-port valves,
- G1316C Thermostatted Column Compartment.
- 6460 Triple Quadrupole LC/MS with Jet Stream Technology

LC/MS Method:

Binary Pump:

- Solvent A: Water + 0.1% formic acid.
- Solvent B: ACN + 0.1% formic acid.
- Analysis Flow rate: 0.4 mL/min.

Column: ZORBAX EclipsePlus C18 3.0x50mm 1.8 μ m 50 °C.

Flexible Cube:

- Valves: 2 of 2-position/10-port Quick-Change valves.
- Flow rate: 1.0 mL/min. Solvent: A1: 3% MeOH/Water, B1: ACN/IPA/MeOH/Water 1/1/1/1 v/v/v/v.

Standard Autosampler fitted with 900 μ L metering head

- Auto-SPE Injection volume: 900 μ L using a draw and eject speed of 1,000 μ L/min.
- Direct Injection volume: 90 μ L

Experimental

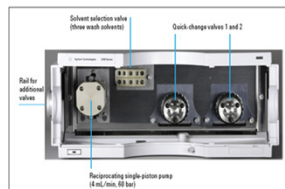


Figure 1) Flexible Cube LC module has a single piston pump with a three- solvent selection valve, and can have one or two Quick-Change valves.

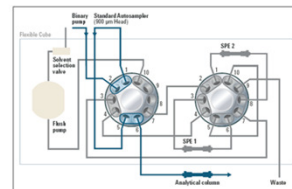


Figure 2A) Configuration showing the plumbing for direct on-column injection.

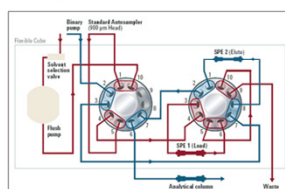


Figure 2B) Configuration showing the plumbing for injection on SPE trapping columns. The binary pump is connected with the left valve and the trapping columns (SPE2) towards the analytical column (left valve position, blue flow path). At the beginning of the analysis the piston pump is delivering the sample from the autosampler to the SPE 2 (blue flow path). The SPE 1 is meanwhile cleaned and equilibrated.

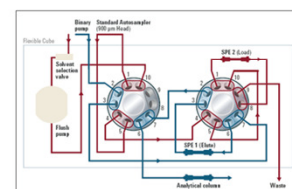


Figure 2C) Configuration showing the plumbing for injection on SPE trapping columns. The binary pump is connected with the left valve and the trapping columns towards the analytical column (left valve position, blue flow path). After loading the SPE1 in front of the analytical column (red flow path). The SPE 2 is meanwhile cleaned and equilibrated.

Triple Quadrupole MS method with Agilent Jet Stream thermal gradient focusing technology:

- Gas temperature: 300 °C. Gas flow: 10 L/min.
- Nebulizer: 45 psi
- Sheath gas temperature: 350 °C. Sheath gas flow: 11 L
- Capillary: 4,000 Volt. Nozzle: 0 Volt

Twelve contaminants, considered to be the more challenging chemicals to analyze, were selected from the Contaminant Candidate List (CCL3) identified by the EPA. The CCL3 contaminants are currently not subject to any drinking water regulations but may require regulation under the Safe Drinking Water Act (SDWA).

Experimental

Cpd Name	Prec Ion	Prod Ion	Frag (V)	CE (V)	Cell Acc (V)	Ret Time (min)	Ret Window	Polarity
4-4-diaminodiphenylmethane	199.1	106	120	28	3	6.74	1.81	Positive
Bensulide	398	356	100	1	2	11.06	1.11	Positive
Bensulide	398	314	100	6	2	11.06	1.11	Positive
Bensulide	398	158	100	26	2	11.06	1.11	Positive
Carbofuran-3-hydroxy	238.1	181	110	8	2	8.15	0.94	Positive
Carbofuran-3-hydroxy	238.1	163	110	11	2	8.15	0.94	Positive
Clethodim	360.1	206	120	12	4	11.67	1.15	Positive
Clethodim	360.1	166	130	27	4	11.67	1.15	Positive
Fenamiphos	304.1	234	150	15	3	10.28	1.03	Positive
Fenamiphos	304.1	217	150	23	3	10.28	1.03	Positive
Fenamiphos	304.1	202	150	31	3	10.28	1.03	Positive
Fenamiphos-sulfone	336.1	308	130	15	3	9.13	0.91	Positive
Fenamiphos-sulfone	336.1	266	130	18	3	9.13	0.91	Positive
Fenamiphos-sulfone	336.1	188	130	24	3	9.13	0.91	Positive
Fenamiphos-sulfoxide	320.1	292	150	9	3	8.64	0.99	Positive
Fenamiphos-sulfoxide	320.1	233	150	23	3	8.64	0.99	Positive
Fenamiphos-sulfoxide	320.1	171	150	18	3	8.64	0.99	Positive
Methomyl	163	107	170	17	2	8.15	1.14	Positive
Methomyl	163	95	170	17	2	8.15	1.14	Positive
Quinoline	130	103	120	30	3	6.97	1.81	Positive
Quinoline	130	77	120	30	3	6.97	1.81	Positive
Tebuconazole	308.1	125	130	42	3	10.49	1.05	Positive
Tebuconazole	308.1	70	130	23	3	10.49	1.05	Positive
Tebufenozide	353.2	297	85	1	3	10.85	1.09	Positive
Tebufenozide	353.2	133	85	15	3	10.85	1.09	Positive
Thiodicarb	355	163	80	2	3	9.17	1.28	Positive
Thiodicarb	355	108	80	14	3	9.17	1.28	Positive
Thiodicarb	355	88	80	17	3	9.17	1.28	Positive

Table 1
Dynamic MRM method, showing the optimum fragmentor [v] and collision energy [eV] values for the individual compound transitions.

Results and Discussion

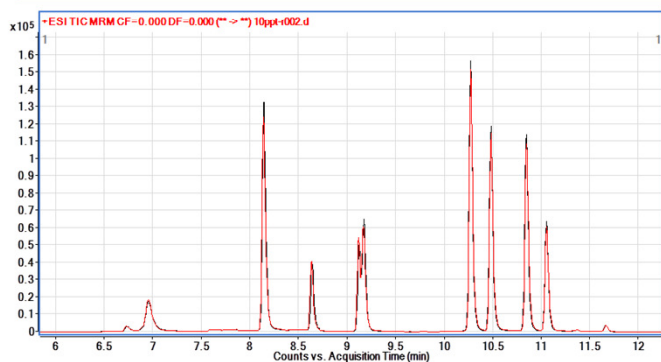


Figure 3) Superimposed chromatograms of a calibration standard with a concentration of 10 ppt (ng/L) each for all 12 compounds with quantifier and qualifier ions. Each run alternates between two different SPE cartridges.

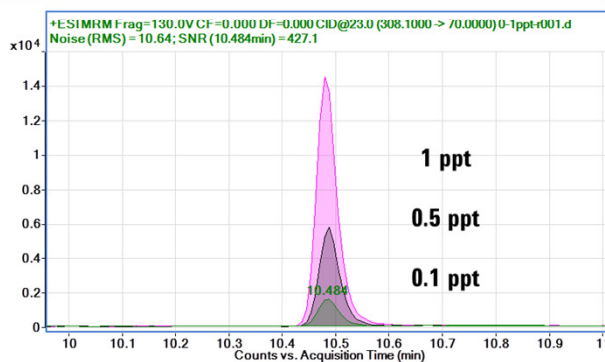


Figure 4) Chromatograms for the quantifier transition m/z 308.1 \rightarrow 70.0 of tebuconazole at concentrations of 0.1, 0.5 and 1.0 ppt. \rightarrow

Results and Discussion

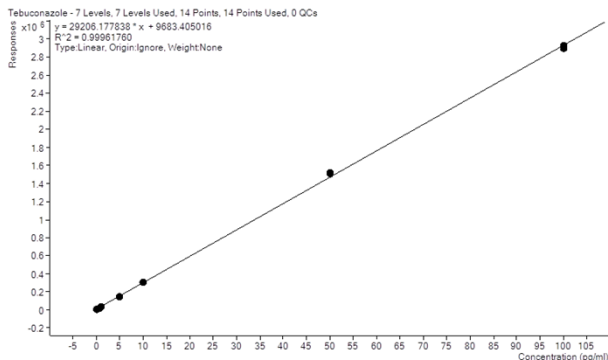


Figure 5) Calibration curve for tebuconazole based on individual solutions from 0.1 to 100 ppt via serial dilution. Each calibration standard was injected two times with a volume of 900 μ L and enriched on the SPE trapping column.

Compound Name	Level (ppt)	Signal to Noise (S/N)	Nominal LOQ @ 10:1 S/N
4-4-diaminodiphenylmethane	0.1	25	0.04
Bensulide	0.1	10.3	0.1
Carbofuran-3-hydroxy	0.1	34.4	0.03
Clethodim	0.1	7	0.15
Fenamiphos	0.1	301.2	0.005
Fenamiphos-sulfone	0.1	7.9	0.15
Fenamiphos-sulfoxide	0.1	8.2	0.15
Methomyl	0.1	8.3	0.15
Quinoline*	0.1	500	0.002
Tebuconazole	0.1	427	0.0025
Tebufenozide	0.1	9.4	0.15
Thiodicarb	0.1	9	0.15

* uncertainty due to unresolved carryover

Table 2) Performance data for all compounds present in the study based on the calculated signal to noise at 0.1 ppt and assuming an LOQ at approximately 10: 1 signal-to-noise. The signal to noise calculation is based on peak area and noise is RMS x 3.

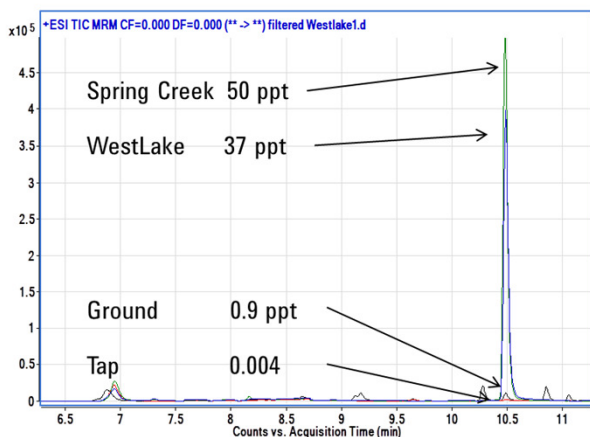


Figure 6) Water samples from a lake-fed municipal water supply (tap), residential well (ground), a suburban collection basin (WestLake) and a flood control reservoir (Spring Creek). Samples were filtered with 0.45 μ m disk filters prior to analysis. Results are based on the average of duplicate analyses, for the one quantifier transition (308.1 to 70.0) and one qualifier transition (308.1 to 125.0). Tebuconazole is used as a fungicide for turf control. Notably, both WestLake and Spring Creek are in the drainage basin of nearby public and private golf courses, respectively.

Conclusions

We have demonstrated an integrated, cost effective scheme to do on-line SPE coupled to LC/MS/MS. The technical barriers and potential technology transfer problems associated with traditional online SPE system have been avoided.

The direct coupling of the SPE cartridges (PLRP-S, 2.1x12.5mm, 15-20 μ m) to the LC/MS/MS system was done through the integrated valves. The use of Dynamic MRM enables complex mixtures to be efficiently analyzed.

We have demonstrated excellent performance with the twelve more challenging contaminants on the CCL3 Contaminant list. LOQ for all components was nominally 0.1 ppt or lower, as low as 0.002 ppt.

Results for real samples, including ground water, lake and flood control reservoir, the latter two obviously containing visible swimming organisms, produced measurable tebuconazole results as well.