Analysis of N-nitrosamines in water by Gas Chromatography, Electron Ionization Tandem Mass Spectrometry

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Introduction

The goal of this project is to show the applicability of EI GC/MS/MS measurement for the detection of N-nitrosamines in drinking water. Nitrosamines like NDMA are inadvertent by-products of wastewater treatment through chlorination. Bench-top GC–MS/MS with EI is rapidly gaining prominence in many environmental and water quality control laboratories around the world. Accordingly, a sensitive and reliable analytical method for the analysis of N-nitrosamines using tandem quadrupole GC–MS/MS with EI is of particular interest to the water industry. Current developments in GC-MS tandem quadrupole technology deliver very high sensitivity and selectivity in the small molecule mass range and allow the detection of nitrosamines meeting and exceeding

Experimental

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This method shows the advancements in instrumentation and sensitivity to achieve detection limits below those currently being used. The analytical method was developed on the Agilent 7890B Gas Chromatograph (GC) coupled to the 7010 Mass Spectrometer (MS) in positive electron ionization mode (EI), using HES (high efficiency source). The GC was configured with a multi-mode inlet (MMI), 30 meter DB-1701 column, and a 7693 Autosampler (A/S). The analysis time was less than 14.0 minutes. Duplicate calibration curves were set up using 5 levels from 1.0 ng L^{-1} to 20 ng L^{-1} extracted and 1.25 ng L^{-1} to 20 ng L^{-1} solvent standards. Data analysis was carried out using MassHunter Software.

EPA method 521, (2004) outlines employing ion trap MS based liquid CI/MS/MS measurements for the detection of N-nitrosamines, but these types of instruments are no longer available from any vendor. The method presented was designed to offer current instrumentation to determine eight nitrosamines in drinking water satisfying EPA method 521 requirements. This method used the sample preparation protocol outlined in the EPA method to determine eight nitrosamines in drinking water by solid phase extraction and gas chromatography with a 0.5 microliter injection and electron ionization tandem mass spectrometry (MS/MS). The required lowest minimum reporting limit (MRL) is 1.2 ng L^{-1} (NDPA) and higher for all the other analytes using liquid PCI. EPA method 521 utilizes large volume injections (20µL) to reach these limits. The use of a

Experimental

Table 1. List of analytes
Retention Times, Quantitation Mass, and Linearity

Name	ABR	R/T	Quant Mass	R^2
N-nitrosodimethylamine	NDMA-d6	7.10	80>50	IS/Surr
N-nitrosodimethylamine	NDMA	7.15	74>44	0.99968
N-nitrosomethyethylamine	NMEA	8.28	88>71	0.99981
N-nitrosodiethylamine	NDEA-d10	9.10	112>94	IS
N-nitrosodiethylamine	NDEA	9.13	102>85	0.99996
N-nitrosodipropylamine	NDPA-14	11.00	144>126	IS
N-nitrosodipropylamine	NDPA	11.08	113>71	0.99922
N-nitrosomorpholine	NMOR	11.47	86>56	0.99993
N-nitrosopyrrolidine	NPYR	11.64	100>70	0.99131
N-nitrosopiperdine	NPIP	11.85	114>84	0.99837
N-nitrosodi-n-butylamine	NDBA	12.56	116>99	0.99937

GC and MS Conditions:		
Column	DB-1701ms, 30 m, 0.25 mm ID, 1.0 µm film thickness	
Injection volume	0.5 µL	2mm Dimpled, UI Liner
Splitless	Purge flow to split vent	100 mL min^{-1} at 0.8 min
MMI inlet temperature	35 °C for 0.1 min, 600 °C min^{-1} to 260 °C	
Oven temperature program	50 °C for 1 min	
	10 °C min^{-1} to 80 °C, for 0 min.	
	15 °C min^{-1} to 180 °C, for 3 min 35 °C min^{-1} to 260 °C for 0.5 min	
Carrier gas	Helium at 0.9 mL min^{-1} constant flow	
Transfer line temperature	260 °C	
MS parameters used in the method:		
Ionization mode	EI; using HES ion source	
Source temperature	280°C	
Quadrupole temperatures	150°C	
Collision gas Quench gas	1.5 mL min^{-1} 4.0 mL min^{-1}	

Compound	Transition	CE		Compound	Transition	CE
NDMA-d6	80>50.1	6		NDPA	130>43	20
NDMA-d6	80>48.1	14		NDPA	130>113	8
NDMA	74>42.1	14		NMOR	116>56.1	20
NDMA	74>44.1	6		NMOR	116>86	4
NMEA	88>71	6		NPYR-d8	108>78.1	10
NMEA	88>43	10		NPYR-d8	108>62.1	14
NDEA-d10	112>94.1	10		NPYR	100>70	10
NDEA-d10	112>62	20		NPYR	100>55	10
NDEA	102>56.1	20		NPIP	114>97	10
NDEA	102>85	10		NPIP	114>84	10
NDPA-d14	144>126.1	4		NDBA	158>99	20
NDPA-d14	144>50.1	20		NDBA	158>141.1	12

Results and Discussion

Figure 1. NDMA results
Calibration from 1.0 to 20 ng L^{-1}

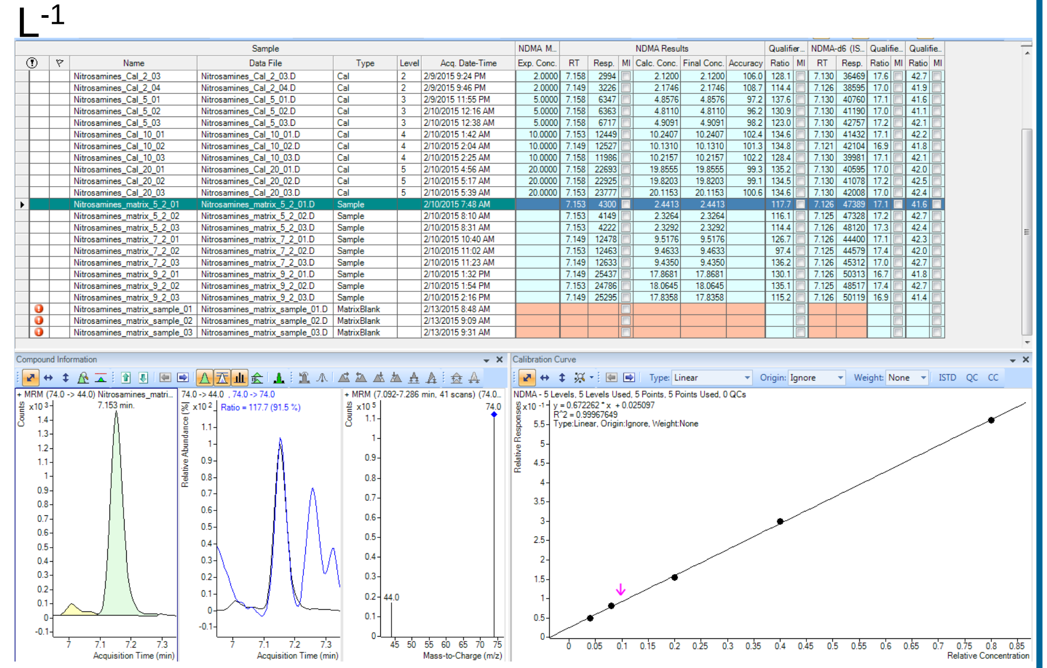


Figure 2. NMEA results
Calibration from 1.0 to 20 ng L^{-1}

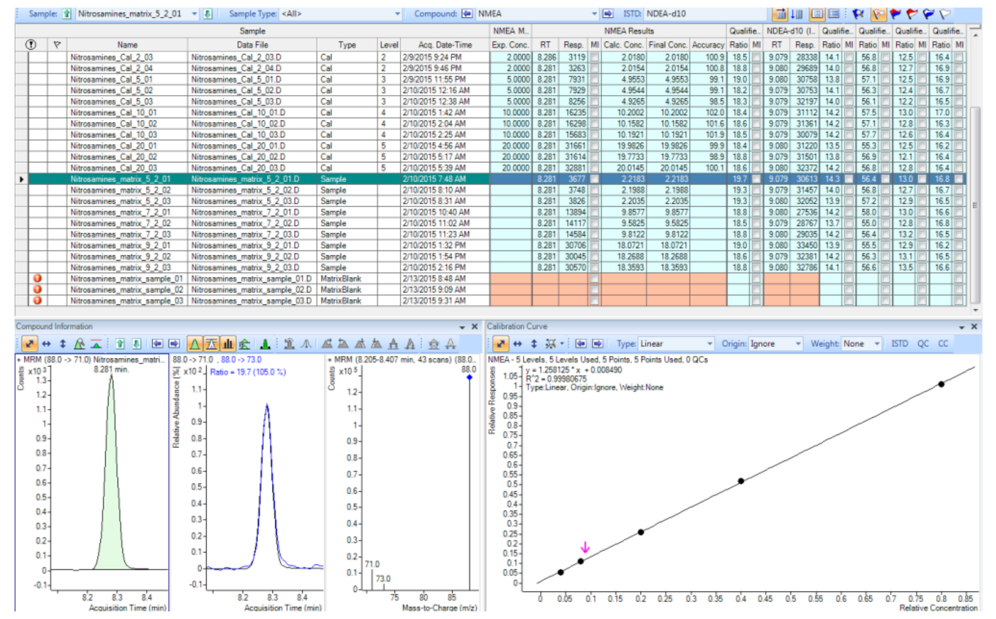


Figure 3. NDEA results
Calibration from 1.0 to 20 ng L^{-1}

Figure 4. NDPA results
Calibration from 1.0 to 20 ng L^{-1}

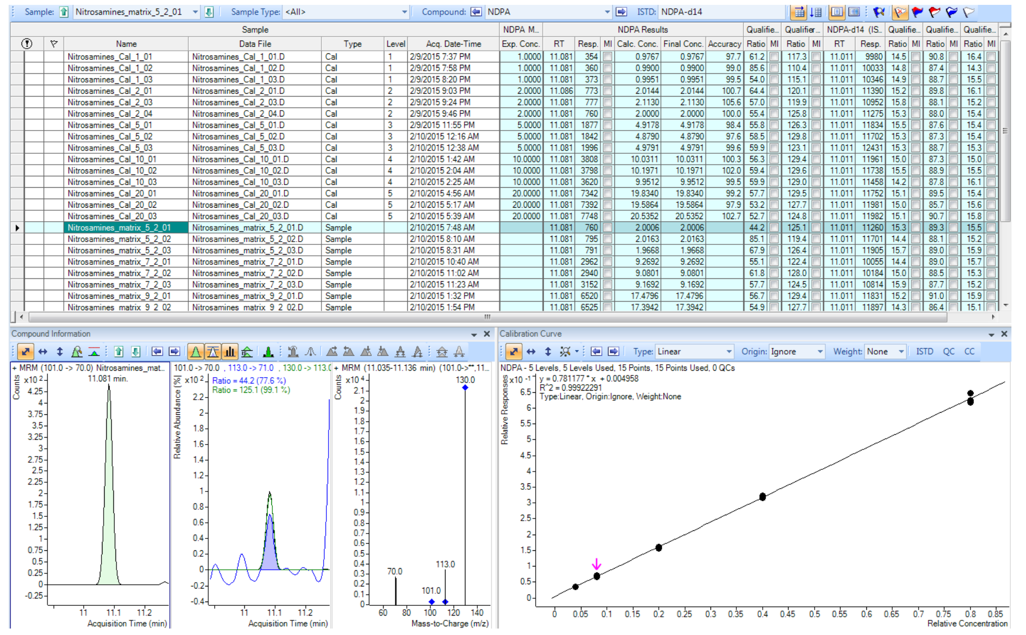


Figure 5. NMOR results
Calibration from 1.0 to 20 ng L^{-1}

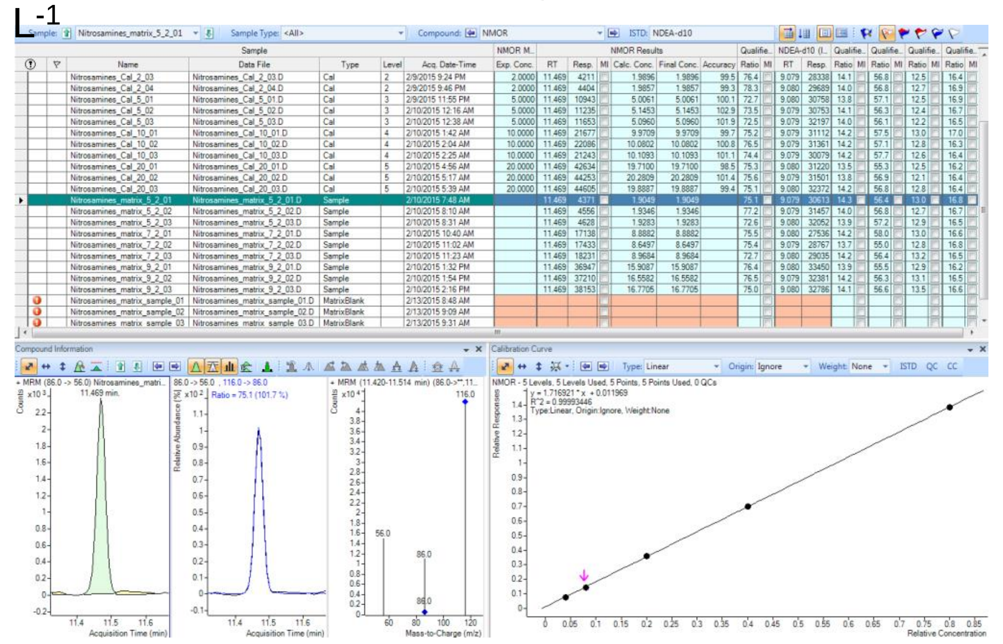
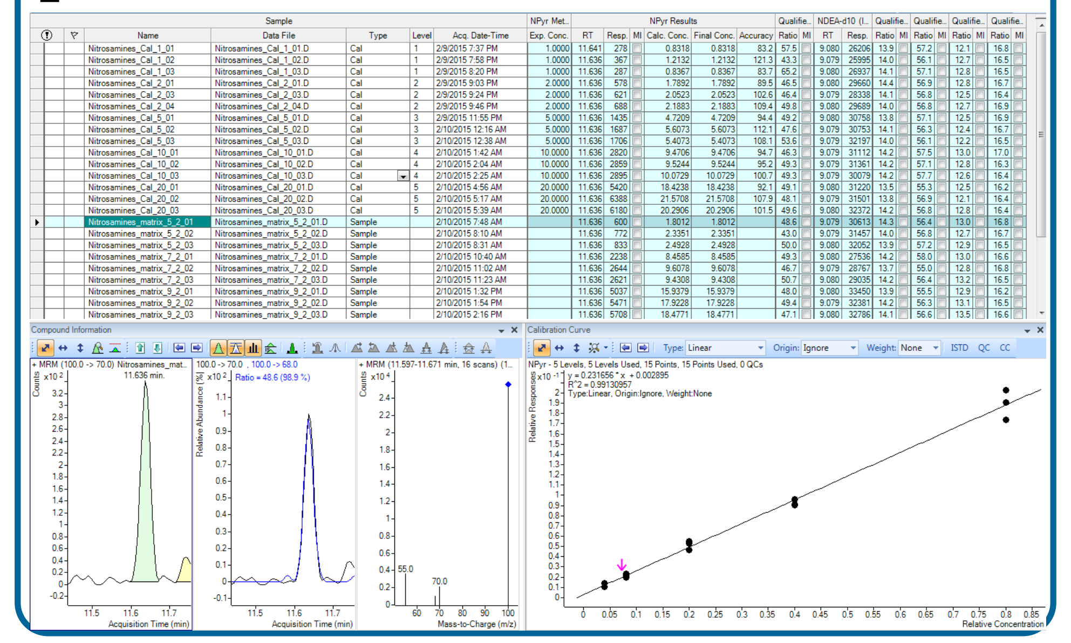


Figure 6. NPYR results
Calibration from 1.0 to 20 ng L^{-1}



Results and Discussion

Figure 7. NPIP results
Calibration from 1.0 to 20 ng L^{-1}

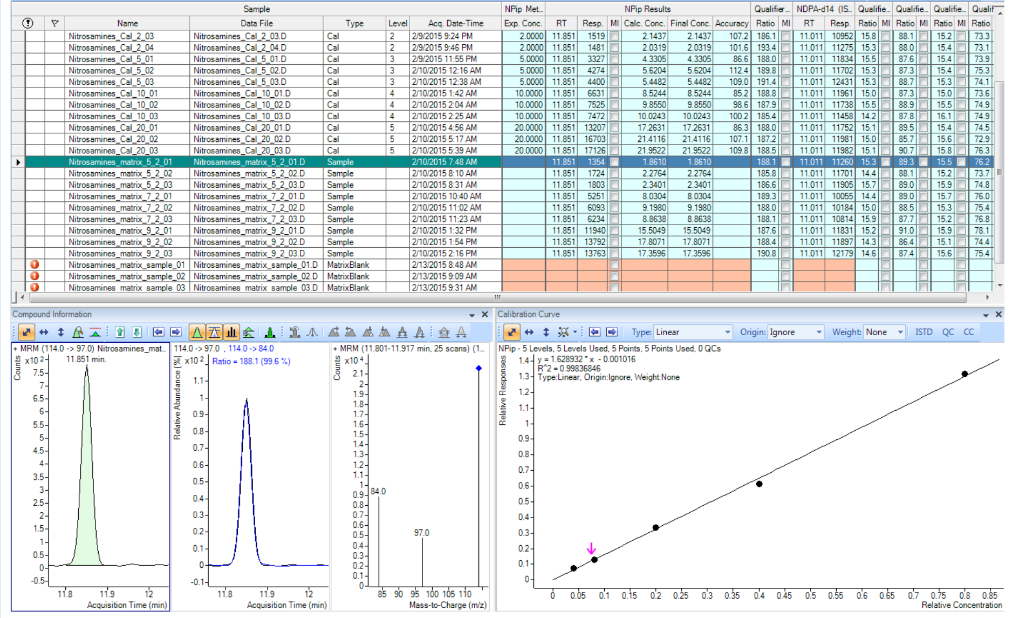


Figure 8. NDBA results Calibration from 1.0 to 20 ng L^{-1}

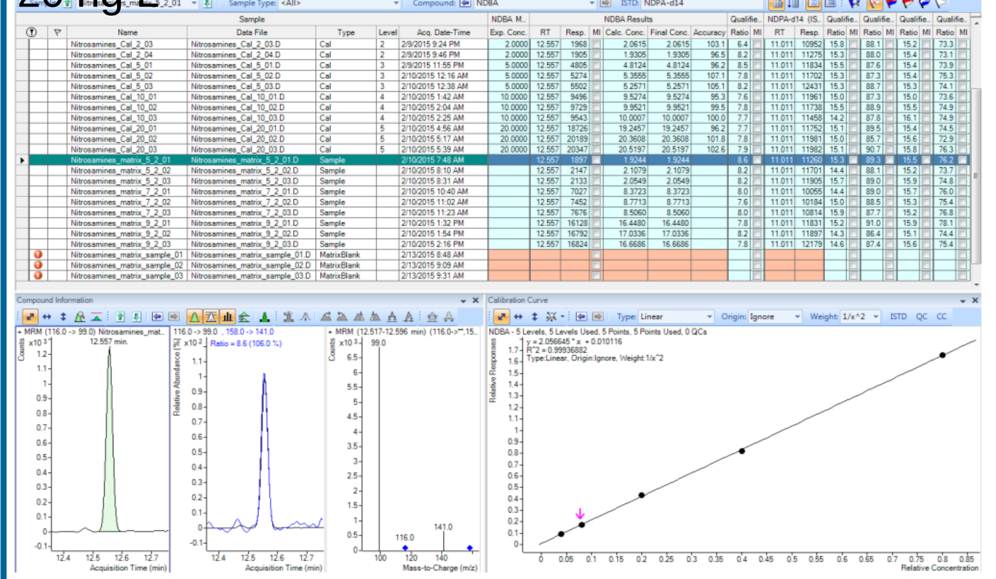


Table 2. Recovery Results
Average of 3 replicates of 2 ppt Matrix spike

Compound	Conc	Ave. Calc. Conc.	Ave. Recovery	Limits
NDMA	2	2.36	118.20	70-130
NMEA	2	2.23	111.65	70-130
NDEA	2	2.06	102.92	70-130
NDPA	2	1.99	99.70	70-130
NMOR	2	1.94	97.12	70-130
Npyr	2	2.24	111.92	70-130
Npip	2	2.16	107.83	70-130
NDBA	2	2.03	101.55	70-130

Table 3. MDL/LOQ/LOD; at 95% confidence calculated from 8 replicates at 1.25 ng L^{-1} using 0.5 µL injections (all concentrations in ng L^{-1})

Name	TS	RT	Avg. Conc.	Std. Dev.	MDL	LOQ	LOD	EPA MRLs	Noise	S/N	Avg. Resp	Resp. RSD(%)
NDMA	1	7.15	1.62	0.0471	0.141	0.471	0.141	1.6	5	228	3275	3.9
NMEA	2	8.28	1.48	0.0287	0.086	0.287	0.086	1.5	3	258	2073	4.1
NDEA	3	9.13	1.43	0.0579	0.174	0.579	0.174	2.1	3	Inf.	1347	5.3
NDPA	4	11.08	1.29	0.1423	0.427	1.423	0.427	1.2	10	214	238	8.9
NMOR	5	11.47	1.19	0.0411	0.123	0.412	0.123		3	1912	2478	3.9
NPyr	5	11.64	1.32	0.124	0.372	1.240	0.372	1.4	1	1525	375	7.5
NPip	6	11.85	1.41	0.045	0.135	0.450	0.135	1.4	3	216	1206	3.5
NDBA	7	12.56	1.47	0.0595	0.178	0.595	0.178	1.4	8	Inf.	928	3.8

Matrix blanks were interspersed during the calibration and MDL injection sequence to verify there was no carryover.
All calibration levels were performed using three replicates.
Matrix blanks were spiked at three levels (2, 8, and 15 ppt) to verify recovery. Results at the 2ppt level are listed in Table 2.

Conclusions

The enhanced EI sensitivity of the HES ion source of new generation GC-MS/MS systems meets and exceeds the detection requirements of EPA Method 521, providing a good alternative to the now unavailable PCI MS/MS Ion Trap systems. The rapid EI/MS/MS method was applied to the analysis of samples over several days to validate the application and confirm the stability of the method. The generated results established that EI/MS/MS mode has excellent detection levels ranging from 0.08 – 0.4 ng L^{-1} with only a 0.5 µL sample injection, well below the required levels. The small injection volume led to less sample on column, less concentration of the sample and less maintenance on the total system. Results of calibration in the 1-20ng L^{-1} range and recoveries at multiple levels all demonstrated highly sensitive, accurate and reliable performance.