Application Note 43141

Total and speciation analysis of Mercury in contact lens solutions by ICP-MS

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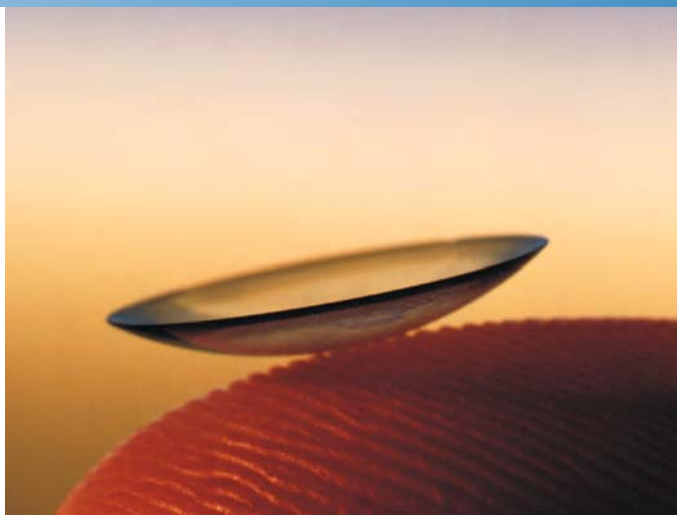
Key Words

iCAP Q, ICP-MS, ICS-5000, ion chromatography, Thiomersal, Hg, speciation

Goal

To develop a fully quantitative method for the determination of both total Hg and Hg species in contact lens solutions.



Introduction

While there is continual awareness regarding exposure to mercury (Hg) sources in general and $MeHg^+$ in particular due to its presence in food samples such as fish, less interest is paid to the potential risk from ethylmercury ($EtHg^+$ or EtHgX). One of the main reasons for this is the faster degradation and consequently excretion of $EtHg^+$ in the human body that results in considerably lower chronic toxicity. There remain however potential sources where acute intake of $EtHg^+$ can occur, for example as a consequence of exposure to thiomersal. Thiomersal is used as a bactericide in multi-dose (typical concentration 0.001 to 0.01 %)[1] and in other health related products such as eye drops or contact lens solutions. The compound hydrolyzes in aqueous solution to form $EtHg^+$ and thiosalycilate which is an effective bactericide. Although no direct correlation between thiomersal usage and potential health risks has been established[2], the use of thiomersal has been reduced in both Germany and the USA. Its use is still permitted in multidose vaccines and contact lens solutions at concentrations of up to 100 and 70 mg/kg respectively.

Sample and Calibration Solution Preparation

Three different commercially available contact lens solutions were prepared for total Hg and Hg speciation analysis. For total mercury analysis, the contact lens solutions were analyzed after a 2000-fold dilution in 2% HNO_3/0.5% HCl. However, as no detectable signal for mercury was found, a lower dilution factor (20-fold) was employed. For Hg speciation analysis, calibration standards were prepared in a matrix solution containing 0.5% NaCl and 0.01% EDTA to mimic the matrix of the contact lens solutions and to promote the formation of the same mercury complexes as in the sample matrix (such as $[HgCl_4]^{2-}$). The standards and the contact lens solutions were then diluted 2000-fold with ultra high purity water prior to injection.

For total Hg determination, gold was added to the samples and the rinse solution to minimize memory effects from the sample introduction system.

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Instrument Configuration

The Thermo Scientific iCAP Qc quadrupole ICP-MS was used for both total mercury and mercury speciation measurements. The iCAP Qc ICP-MS was equipped with a Peltier cooled cyclonic quartz spray chamber and a PFA-LC nebuliser (Elemental Scientific, Omaha, NE, USA). The PFA-LC nebulizer has a very low dead volume and is compatible with common chromatographic fittings making it ideal for LC or IC analyses. A demountable torch equipped with a 2 mm I.D. quartz injector was used throughout. Chromatographic separations were carried out using the Thermo Scientific Dionex ICS-5000 ion chromatography system. Due to its completely metal-free solvent pathway, this system is perfectly suited for elemental speciation studies. The Thermo Scientific Dionex CS5A cation exchange column (2 mm ID x 250 mm length) was used for the separation of the mercury species. During total elemental analyses, a Teflon probe was attached to the LC nebuliser and for speciation analyses the column outlet from the ICS-5000 was directly connected to the PFA-LC nebulizer.

Qtegra Software Platform

Full control of the complete IC-ICP-MS system and synchronisation between both instruments was achieved using the Thermo Scientific Qtegra software platform. Qtegra's unique modular design employs a series of 'plug-ins' to control individual instruments. Components of an analytical configuration (whether it is IC-ICP-MS, LC-ICP-MS, GC-ICP-MS or LA-ICP-MS etc) are then controlled via Qtegra's single user interface. The ICS-5000 system in this application was controlled via the Chromeleon plug-in from within the Qtegra platform. Using this modular approach, the entire chromatographic system, including all devices such as pumps, autosampler or column compartments, were controlled by Qtegra without the need for an independently operating software suite or a trigger cable. Figures 1 and 2 show the user interface for control of the ICS-5000 system within Qtegra.

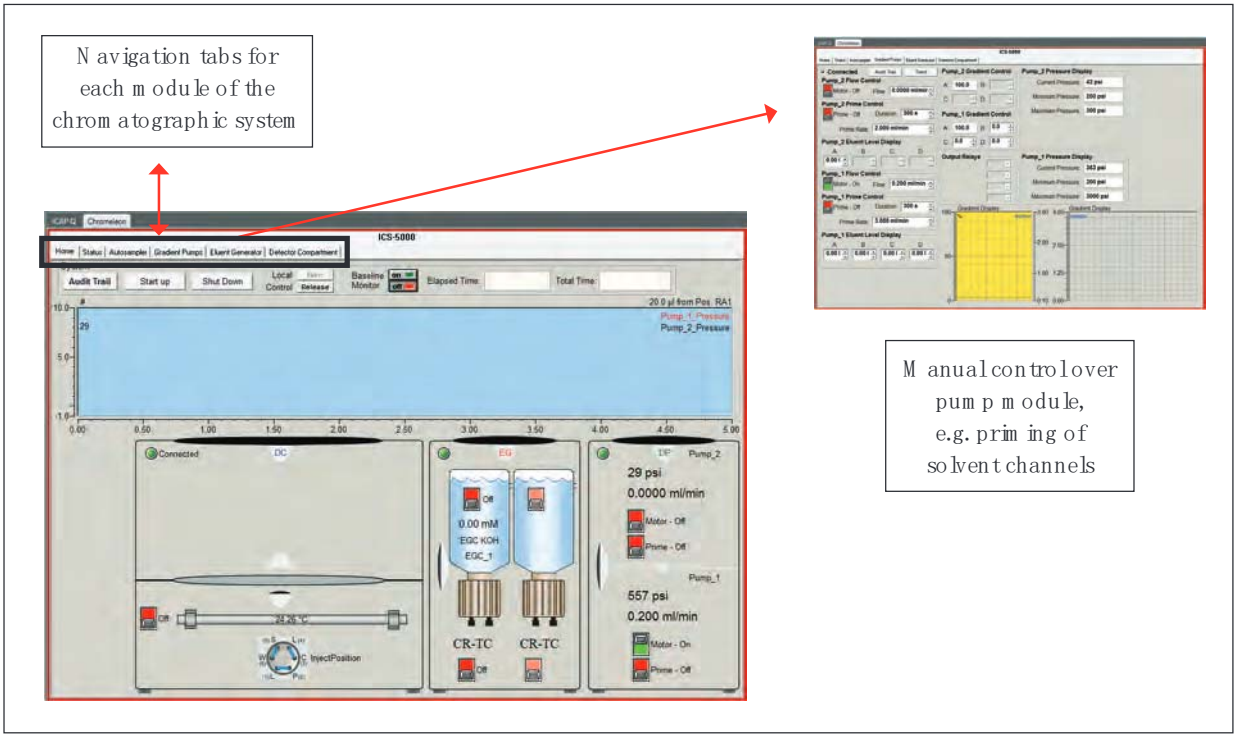

Figure 1: Screenshots of the Qtegra user interface showing complete, native control of the ICS-5000.

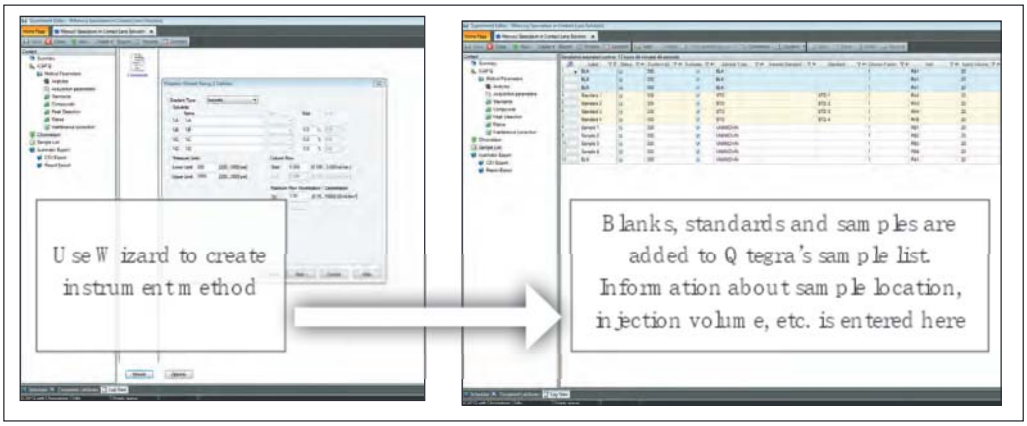

Figure 2: Creation of chromatographic methods via Wizards from within the Qtegra platform.

General Analytical Conditions

The iCAP Qc was operated using the following parameters (different settings for speciation analysis are indicated):

Table 1: iCAP Qc operating parameters.

Parameter	Value
Forward power	1550 W
Nebulizer gas	1.05 L/min
Injector	2 mm I.D., quartz
Interface	Ni sampler and skimmer
Dwell time per isotope	10 ms, 100 ms for speciation analysis
Analysis mode	Standard (no cell gas)

After total Hg analysis the outlet from the IC column was connected directly to the LC nebulizer body without switching the plasma off and speciation analyses could begin without the need to re-optimize the system.

Chromatographic separations were carried out on the ICS-5000 using the parameters summarized in Table 2. Cysteine was added to the mobile phase to complex Hg^{2+} and $EtHg^{+}$ minimizing memory effects in the chromatographic system.

Table 2: ICS-5000 operating parameters.

Parameter	Value
Column	Dionex CS5A (2 mm I.D. x 250 mm)
Elution	Isocratic, 0.5 mL/min
Mobile phase	10 mmol/L $NaClO_4$, 10 mmol/L Acetic Acid, 10 mmol/L in Cysteine
Injection volume	20 µL
Duration	5 minutes

Results and Discussion

The limit of detection for total Hg determination is 1 pg/g. As indicated by the manufacturers labels, no Hg above this level was detected in the 20-fold diluted contact lens solutions.

To show the applicability and the potential of the speciation method, one of the three solutions was spiked with different levels of thiomersal (approximately 10 and 20 mg/kg) and analyzed to assess spike recovery.

In Figure 3 an example chromatogram of ethylmercury (at a concentration of 10 µg/kg after dilution) from the hydrolysis of thiomersal is shown. A single sharp peak is seen after 90 s.

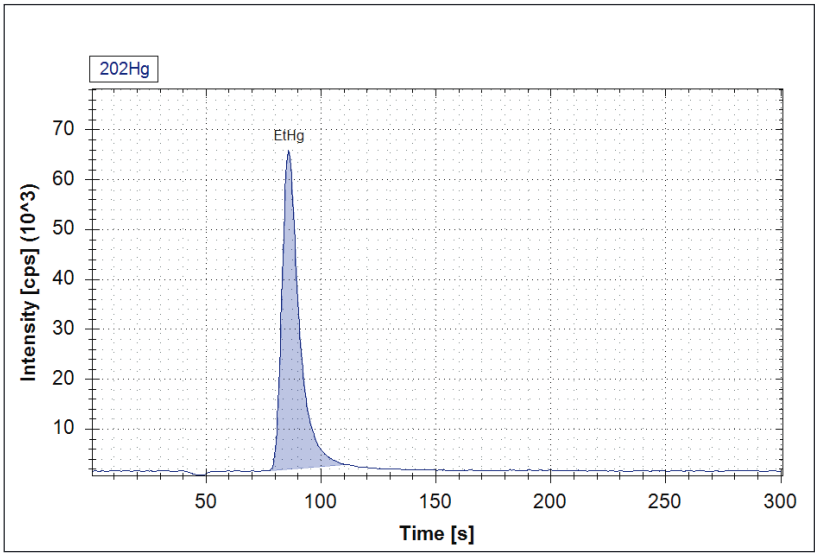

Figure 3: Chromatographic separation of $EtHg^{+}$ derived from thimerosal hydrolysis.

After external calibration between 1 and 20 µg/kg, spike recovery was determined for the two thiomersal spiked contact lens solutions (each diluted 2000-fold prior to analysis). The obtained results can be seen in Table 3. From the obtained calibration graph an instrumental detection limit of 30 pg/kg was calculated, which corresponds to a method detection limit of 60 ng/kg in contact lens solutions or other pharmaceutical preparations. This value is well below the typical concentrations of thiomersal found in vaccines, that contain only trace amounts of the compound, e.g. 1 µg per 0.5 mL dose.[1]

Table 3: Spike recovery of thiomersal in contact lens solution.

Sample #	Amount spiked [mg/kg]	Amount recovered [mg/kg]	Spike recovery [%]
1	10.2	10.9 ± 0.04	108
2	18.1	18.8 ± 0.07	104

In order to determine the presence of (contaminating) inorganic mercury in a sample, the chromatographic separation of the two species was assessed. For example, Hg^{2+} can be found as a trace impurity in the NaCl salt used to prepare the standards. Whereas EtHg^{+} elutes as previously shown after 90 s, Hg^{2+} is observed after approximately 130 s (Figure 4). For this analysis the solution was injected without dilution and contained 0.5% of NaCl, which explains the drop in signal intensity after elution of Hg^{2+}.

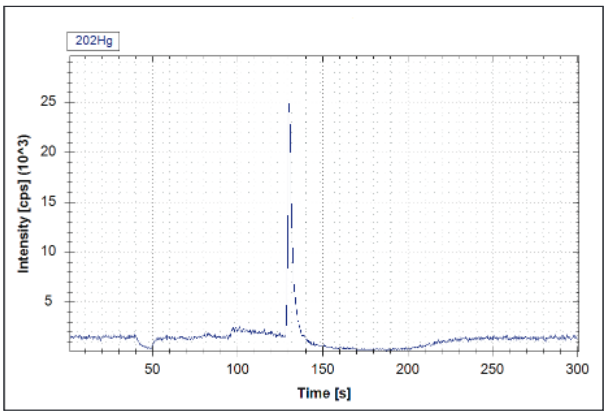

Figure 4: 0.5% NaCl solution with a 1.3 ng/g thiomersal spike.

Conclusion

The iCAP Qc ICP-MS is shown to be an ideal tool for both total Hg determination and speciation of Hg. The Dionex ICS-5000 system and the iCAP Q ICP-MS is an ideal combination for the determination of thiomersal in contact lens solutions and other pharmaceutical preparations. Seamless control of the IC-ICP-MS instrument is achieved using the Qtegra software platform thus enabling routine, unattended operation. The data evaluation features of Qtegra, including dedicated chromatographic integration, compound specific quantification and compound specific QC, facilitate the data handling and ensure accurate and valid speciation results.

Products Used in this Note:

Product	Fisher Scientific Catalogue Number
Dionex CS5A (2 mm I.D. x 250 mm)	046100
$NaClO_4$	10775341
Acetic Acid	10216494
Cysteine	10325460

References

1. Thimerosal in Vaccines Questions and Answers, US Food and Drug Administration; http://www.fda.gov/BiologicsBloodVaccines/Vaccines/QuestionsaboutVaccines/UCM070430

2. Statement on thiomersal, World Health Organisation; http://www.who.int/vaccine_safety/topics/thiomersal/statement_jul2006/en/index.html

3. Thimerosal in Vaccines, US Food and Drug Administration; http://www.fda.gov/BiologicsBloodVaccines/SafetyAvailability/VaccineSafety/UCM096228

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