

## Analysis of Residual Ethylene Oxide in Medical Devices by Headspace Gas Chromatography (Water Extraction)

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### User Benefits

- ◆ Regarding the JIS T 0993-7:2012, the analysis conditions of residual ethylene oxide (EO) in medical devices were established by headspace gas analysis of solvent extract using water as an extraction solvent.
- ◆ The use of water as an extraction solvent has made it possible to perform environmentally friendly, safe, and inexpensive analyses.

### Introduction

Ethylene oxide gas (EOG) is a flammable and colorless gas commonly used in medical device sterilization. Its permitted maximum residual levels are set by a range of international and local organizations, including the International Organization for Standardization (i.e., ISO 10993-7:2008) and Japanese Industrial Standards (i.e., JIS T 0993-7:2012).

In these standards, extraction can be either exhaustive or simulated-use. The exhaustive extraction entails a solvent extraction using both gas chromatography (GC) and headspace (HS). The choice of extraction solvent depends on the sample and its intended use. The use of water as the extraction solvent is attracting attention as an environmentally friendly analysis.

In this article, extraction of residual EO using water as extraction solvent by the HS-GC was performed in reference to the JIS and ISO section K.4.4 "Exhaustive Extraction with Ethanol Followed by Headspace Gas Analysis of the Ethanol Extract."

### Instrument Configuration and Analytical Conditions

In this experiment, the headspace gas sampler HS-20 was connected to the Nexis GC-2030 for effective sample introduction. The analytical conditions for GC and HS were in reference to JIS T 0993-7:2012 as listed in Tables 1 and 2.

**Table 1 GC Analytical Conditions**

Model	: Nexis GC-2030
Detector	: FID-2030 flame ionization detector
Headspace Sampler	: HS-20
Analytical Column	: SH-Stabilwax™ (30 m × 0.53 mm I.D., d.f.= 2.00 μm)
Column Temperature	: 40 °C (5 min) – 30 °C/min – 200 °C (20 min) Total 30.33 min
Injection Mode	: Split
Split Ratio	: 20
Carrier Gas Controller	: Constant Linear Velocity
Linear Velocity	: 30 cm/sec (N <sub>2</sub> )
Detector Temperature	: 250 °C
Detector Gas	: H <sub>2</sub> 32 mL/min, Air 200 mL/min
Make up Gas	: N <sub>2</sub> 24 mL/min
Injection Volume	: 1 mL

**Table 2 HS-20 Analytical Conditions**

Oven Temperature	: 70 °C
Sample Line Temperature	: 75 °C
Transfer Line Temperature	: 75 °C
Vial Volume	: 10 mL
Vial Shaking Level	: 3
Vial Equilibrating Time*1	: Standard) 30 min Sample) 180 min
Vial Pressurizing Time	: 1 min
Vial Pressure	: 100 kPa
Loading Time	: 1 min
Needle Flush Time	: 8 min

\*1 The vial equalizing time listed in the Table 2 is an example only and varies depending on the type of samples.

### Preparation of Standards and Samples

The standards and the samples used in this experiment were prepared in reference to JIS T 0993-7:2012.

For the standards, a 100 μg/mL EO solution and a 100 μg/mL propylene oxide (PO) internal standard solution were prepared. Five calibrator points were prepared by diluting the 100 μg/mL EO stock solution with water to 0.4, 0.8, 1.2, 1.6, and 2.0 μg/mL. Each calibrator solution also contained PO internal standard at 0.5 μg/mL. For a calibration curve, 5 mL of a calibrator solution was aliquoted into a 10 mL HS vial and hermetically sealed before analysis.

For the samples, EOG-sterilized bandage and suction catheter were selected to represent sheet and tube types of samples, respectively. The extraction solution was prepared by diluting the 100 μg/mL PO stock solution with water to 0.5 μg/mL. The bandage was cut into 10 mm square pieces while the suction catheter was trimmed into 5 mm long pieces. Ca. 0.5 g of sample pieces were placed in a 10 mL HS vial along with 5 mL of the 0.5 μg/mL PO extraction solution and hermetically sealed for analysis.

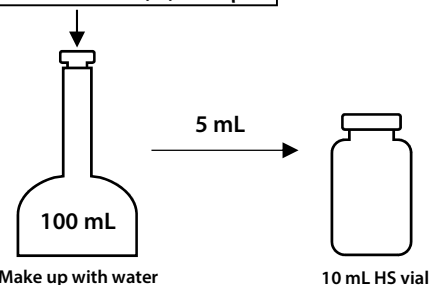
※ It should be noted that all the above-mentioned solutions and lab apparatus (e.g., volumetric flasks) used to handle those solutions were kept at a sub-ambient temperature during the preparation to suppress an evaporative loss of EO.

#### <Standards>

100 μg/mL EO solution: 400 - 2000 μL

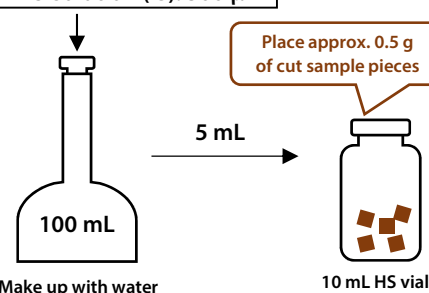
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100 μg/mL PO solution (IS): 500 μL



#### <Samples>

100 μg/mL PO solution (IS): 500 μL



**Fig. 1 Sample Preparation Method**

## System Requirements Test (Water Extraction)

JIS T 0993-7:2012 contains the following statements with respect to system requirements.

- Resolution between EO and PO be not less than 2.0
- Tailing factor for EO be not more than 1.8
- Relative deviation of the standard curve (RSD) does not exceed 5 % for the range of standards used
- %RSD of the EO peak area does not exceed 5% for the range of the standards used
- Correlation coefficient of the calibration curve be greater than 0.95.

The results obtained in this experiment satisfied all the above five criteria.

The detailed analytical results are summarized in Table 3. The chromatograms and a calibration curve are shown below in Figs. 2 and 3, respectively.

※ In the case of water extraction, the possibility of conversion of EO to ethylene glycol (EG) or ethylene chlorohydrin (ECH) should be evaluated, but not evaluated in this article. For simultaneous analysis of EO, ECH, and EG, please refer to Application News 01-00139-EN.

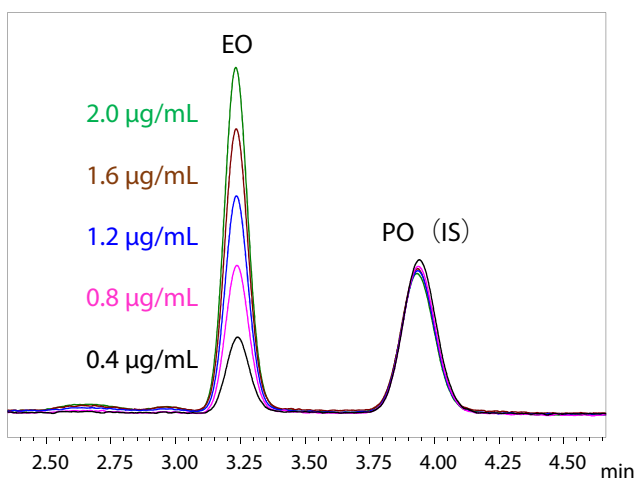


Fig. 2 Standard Chromatograms

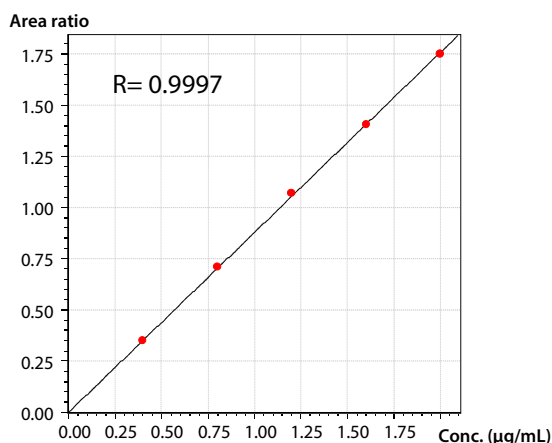


Fig. 3 Calibration Curve

Table 3 System Requirements Test Results (n=6) \*3

Concentration (µg/mL)	0.4	0.8	1.2	1.6	2.0
Mean area value	3197	6178	9025	11803	14058
Area value %RSD	3.341	0.965	0.950	0.474	4.683
Mean area ratio	0.359	0.717	1.079	1.402	1.735
Area ratio %RSD	2.200	1.402	0.842	0.747	1.268
Resolution	3.325	3.325	3.328	3.330	3.324
Tailing factor	1.095	1.072	1.063	1.060	1.058
Limit of detection (µg/mL) <sup>*2</sup>	0.030	0.030	0.031	0.030	0.033
Limit of quantification (µg/mL) <sup>*2</sup>	0.099	0.100	0.105	0.100	0.110

\*2 The limit of detection and the lower limit of quantification were calculated at S/N=3 and S/N=10, respectively.

\*3 The chromatograms and quantitative results are for reference purposes only and should not be regarded as guaranteed values.

## Sample Results (Water Extraction)

Fig. 4 are the overlaid chromatograms of the bandage and the suction catheter. The quantitative results are listed in Table 4.

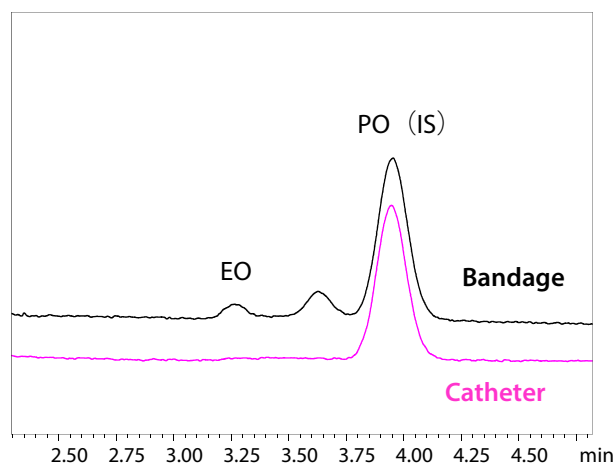


Fig. 4 Sample Chromatograms

Table 4 Quantitative Values of EO in 0.5 g of Samples (µg/0.5 g)<sup>\*3</sup>

	Bandage	Catheter
Data 1	0.480	ND
Data 2	0.400	ND
Data 3	0.425	ND
Mean	0.435	—

## Conclusion

In reference to JIS T 0993-7:2012 and ISO 10993-7:2008, quantitation of residual ethylene oxide in bandages and suction catheters was conducted by HS-GC using water as extraction solvent.

The Shimadzu GC-2030 + HS-20 system satisfied the system requirements and is considered an excellent instrument for measuring residual ethylene oxide in a medical device.

For ethanol extraction results, please refer to Application News No. G 336.

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