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Breath Alcohol Instrument Calibration Uncertainty Estimation Problem Example 2

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Uncertainty Estimation
Problem Example 2

Assume there are four principle components that contribute to the total uncertainty when calibrating and certifying a breath test instrument: (1) bias in the Toxicology Lab preparing simulator solutions, (2) the analytical component, (3) the instrument scale resolution and (4) traceability.

Assume that the maximum bias observed in the Toxicology Lab on their gas chromatograph when measuring controls was 0.002 g/100ml at a mean concentration of 0.1030 g/100ml.

Assume that when performing n=10 simulator measurements on the breath test instrument the mean was 0.0825 g/210L with a standard deviation of 0.0009 g/210L.

Assume that the digital display on the breath test instrument shows three decimal places.

Assume that the combined uncertainty for traceability (including the uncertainty in the simulator partition coefficient) is 0.0025 g/100ml at a reference concentration of 0.1045 g/100ml.

Determine the bias of the breath test instrument and report the unbiased mean results along with an expanded combined uncertainty (k=2). Determine the vapor ethanol concentration using the constant of C = 1.23. Determine also the percent that each of the four components contributes to the total uncertainty. Assume that the standard deviation is equivalent to the standard uncertainty.

Solution

We first determine the uncertainty component due to the maximum observed bias of 0.002 g/100ml. To do so we employ the uniform distribution.

$$S_{Bias} = \frac{a}{\sqrt{3}} = \frac{0.002}{\sqrt{3}} = 0.0012\, g/100ml \qquad Eq.1$$

We are given that the replicate tests on the breath test instrument yields: $\overline{Y} = 0.0825\ g/210L \quad S_Y = 0.0009\ g/210L \quad n = 10$

For the digital display of three digits we assume the uncertainty to be half of the least significant digit which would be 0.0005 g/210L. We employ the uniform distribution to convert this to a standard deviation (standard uncertainty) estimate according to:

$$S_{Scale} = \frac{a}{\sqrt{3}} = \frac{0.0005}{\sqrt{3}} = 0.00029\, g/210L \qquad Eq.2$$

Finally, we are given that the unbiased reference value for the simulator solution is 0.1045 g/100ml with a combined uncertainty due to traceability and the partition coefficient of 0.0025 g/100ml.

We first find the vapor ethanol equivalent for the solution according to:

$$Vapor = \frac{0.1045}{1.23} = 0.08496 = 0.0850\ g/210L$$

Next, we find the bias in the breath test instrument according to:

$$bias = \left[\frac{\overline{Y} - R}{R}\right] \bullet 100 = \left[\frac{0.0825 - 0.0850}{0.0.0850}\right] \bullet 100 = -2.9\% \qquad Eq.3$$

We now combine the four sources of uncertainty according to:

$$\frac{S_Y}{\overline{Y}} = \sqrt{CV^2_{Bias} + CV^2_{Analytical} + CV^2_{Scale} + CV^2_{Traceability}} \qquad Eq.4$$

$$\frac{S_Y}{0.0850} = \sqrt{\left[\frac{0.0012}{0.1030}\right]^2 + \left[\frac{\frac{0.0009}{\sqrt{10}}}{0.0825}\right]^2 + \left[\frac{0.00029}{0.0850}\right]^2 + \left[\frac{0.0025}{0.1045}\right]^2} \Rightarrow \frac{S_C}{0.0850} = 0.0270$$

$$S_C = 0.0023\,g/210L$$

Notice that since we incorporated the n=10 measurements within the square root sign, we will obtain an estimate of the standard deviation of the mean. We now report our unbiased estimate along with the combined expanded uncertainty as:

$$0.0850\ g/210L \pm 2(0.0023) \Rightarrow 0.0850\ g/210L \pm 0.0046\,g/210L$$

The proportion that each component contributes to the total uncertainty is:

Bias	19%
Analytical	2%
Scale Resolution	1%
Traceability	78%

10/30/2009 RGG