ESTIMATION OF UNCERTAINTY OF MEASUREMENT USING AIS LIMS DATA (BASED ON NORDTEST TR537 AND ISO 11352:2012)

1. Introduction

1.1 This procedure which is used for the estimation of uncertainty of measurement for quantitative tests employed in the chemistry section at TSS is effective from April 1st 2018 whereupon it will replace procedure PP019. It has an advantage over procedure PP019 in that it has provision for the calculation of the uncertainty component due to bias from proficiency testing results and also from up to 4 certified reference materials. The procedure will not estimate the uncertainty component of any external factors such as that of sampling.

1.2 The procedure outlines a method that can be employed for estimating uncertainty of measurement (UoM) from data held in the LIMS 'AQC' table. Data is exported from LIMS and pasted into cells in an Excel workbook titled "UOMNORDTESTV4.xlsm" where the master copy is held in the UoM_Calcs\Nordtest directory on the quality drive. Uncertainty due to precision and bias is calculated in the workbook. The combined relative standard uncertainty will be derived and on application of the coverage factor the expanded relative standard uncertainty derived. The value derived can then be copied into the 'Relative' field in the LIMS 'Dets' table and consequently shall be applied to results entered into LIMS.

1.3 The workbook contains 6 main calculation spreadsheets that can accept data from LIMS. The spreadsheets contain enough calculation cells to accept the last 60 (or fewer) results from LIMS except spreadsheet bias_PT where up to the last 24 PT results can be used. Cells shaded in gold are available for the acceptance of data. A minimum of 6 sets of results are required, for each sheet, with more results than this being preferable. (Fewer results could be used, for example if there are less than 6 proficiency test results available, but any uncertainty estimate derived in such a scenario would need to be carefully considered as to the confidence that could be placed in the result). The first 2 spreadsheets (precision_AQCSTANDARD and precision_AQCDUPDIFF) are used for estimating the relative standard uncertainty due to precision using LIMS AQC Standard or LIMS AQC Duplicate / Difference data respectively. The following 4 sheets (bias_CRM, bias_CRMx, bias_PT and bias_Spikes) are used for calculating the relative standard uncertainty due to bias. The bias_Spikes sheet contains cells where uncertainty in the concentration of the spiking solution and in the volume of spiking solution dispensed may be added. The last sheet (Combined) takes the combined estimate for uncertainty due to precision and combines this value with the highest estimate for uncertainty due to bias (if more than one spreadsheet has been used) to derive the combined relative standard uncertainty. On applying the coverage factor of 2 (to give 95 % confidence) the expanded relative standard uncertainty for the method is obtained.

1.4 Data can be conveniently exported from LIMS into Excel using a SQL script of the form:

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SELECT * FROM AQC
WHERE [AQC].[DET] LIKE 'FSCD%' AND ([AQC].[EXCLUDE] = 0 OR
[AQC].[EXCLUDE] IS NULL)
ORDER BY AQC_NAME
```

where FSCD is the determinand being examined.

1.5 The data chosen should be validated against the criteria given in section 10 (below) to ensure it is suitable for use.

2. Background

2.1 Uncertainty of measurement is defined as "a parameter, associated with the result of a measurement, that characterises the dispersion of the values that could be reasonably attributed to the measurand" or more simply the part of the result which follows the ± sign. It is useful as it allows for the assessment of the reliability of a test result, allows assessment of the confidence that can be placed in the result and allows comparisons to be made between test results.

2.2 Traditionally, uncertainty of measurement has been estimated using the approach outlined in the Eurachem[1] document (GUM) where a list of all potential sources of uncertainty would be listed and grouped (usually in cause and effect diagrams) and then an estimation of each source of uncertainty would be derived by experiment (type A) or from other sources such as calibration certificates (type B). This approach although comprehensive is time consuming and relies heavily on the person making the estimation incorporating all the relevant factors.

2.3 Nordtest[2] have produced a document which took an approach similar to the Eurachem document in that it required the sources of uncertainty to be identified and quantified but instead of considering factors individually considered that factors which would affect the uncertainty should be reflected in the precision and bias data obtained from the use of the method. This approach was suitable for use in the laboratory as in taking the precision and bias data for a method from the LIMS 'AQC' table the data used would be covering the whole scope of the laboratory's method. The data in the 'AQC' table will have been gathered with good variation in many of the factors affecting uncertainty of measurement in that it will have probably been gathered over a long time period, by differing analysts, using different items of equipment, differing equipment calibrations, differing calibration solutions, differing temperatures, differing analyte concentration levels, differing matrices etc.

2.4 ISO published ISO 11352:2012 (Water quality – Estimation of measurement uncertainty based on validation and quality control data) with reference made in the introduction of the ISO that the Nordtest document had been used as a basis for developing the ISO document.

2.5 Council Directive 98/83/EC was amended in 2015 by Commission Directive (EU) 2015/1787 to include performance characteristics for uncertainty of measurement. A 'blue book' document[3] was published by the Standard Committee of Analysts in January 2018 titled 'Estimation of Uncertainty of Measurement for Chemical and Physico-chemical Determinands in Drinking Water 2018' along with 2 accompanying spreadsheets. The calculations outlined in the document have been incorporated within spreadsheet "UOMNORDTESTV4.xlsm" and as such the spreadsheet should also be suitable for determining the uncertainty of measurement of the laboratory's water section methods.

3. Precision_AQCSTANDARD

3.1 Initially, an estimation of method uncertainty due to precision using the two sheets designed for this purpose in the Excel spreadsheet needs to be made. The first of these is precision_AQCSTANDARD. This sheet must always be used (the second spreadsheet, precision_AQCDUPDIFF, needs only be used if the sample matrices used in the employment of the method is not similar to that used for the control). This sheet is based on the requirements of section 4.2 of the Nordtest document. The AQC Standard results (for **only** the aqc standard in current use) are exported from LIMS and pasted, as values, into cells B5:B65 of the sheet. The AQC Standard used does not have to be a certificated standard – the purpose of this sheet is to determine the uncertainty component due to precision only. The AQC Standard does, however, need to be stable in composition. The spreadsheet will then calculate the uncertainty due to method precision, which is in this case the standard deviation. This value is then converted to a relative standard uncertainty by dividing by the mean of the

results followed by multiplication by 100. (All final results produced during the procedure will be expressed relatively to produce a combined relative value on the final combined spreadsheet).

3.2 The control sample chosen (the AQC Standard) would normally be in the concentration range of normal laboratory samples but you may have 2 or more controls at differing concentration levels. If this is so, calculate the relative standard deviation at each level and if they are similar it would indicate that concentration was proportional to precision and the relative standard deviations could be pooled together to provide one estimate of uncertainty due to precision. If there was no correlation then separate uncertainty budgets at the 2 concentration levels would need to derived – an example of this is catered for in the Nordtest document (section 4.2) using 2 separate control solutions. A similar procedure should be followed if using differing matrices as controls in the same method. (Neither of these scenarios are likely to be employed in the TSS laboratory and as such these are not catered for directly).

4. Precision_AQCDUPDIFF

The second spreadsheet used for estimating uncertainty due to precision is provided on spreadsheet precision_AQCDUPDIFF and is based on the requirements of section 4.3 of the Nordtest document. Use this spreadsheet, in combination with spreadsheet precision_AQCSTD, when the matrix of the control solution used in spreadsheet precision_AQCSTD, is not similar to that used for routine laboratory samples. In this case we export AQC Duplicate or AQC Difference data for typical laboratory samples from LIMS and paste, as values, into cells within the range B5:C65 of the spreadsheet. Duplicate results which have a zero result with a non zero result should not be included. This spreadsheet provides a measure of the overall run to run variability. To obtain the repeatability standard deviation for single determinations, the mean of the absolute normalised difference data is taken and divided by 1.128 as of Appendix 8 of the Nordtest document. This value is then combined with the uncertainty obtained from spreadsheet Precision_AQCSTANDARD as required in section 4.3 of the Nordtest document to produce the final standard uncertainty due to method precision.

5. Bias_CRM

The next 4 sheets (bias_CRM, bias_CRMx, bias_PT and bias_Spikes) are used for estimating uncertainty due to bias. The preferred sheet to use for estimating bias is the Bias_PT sheet although it is noted that this will not always be possible due to numbers of results gathered or availability of an EQA scheme.

The bias_CRM sheet is based on section 5.1 of the Nordtest document and the cells B10:B70 are populated with AQC Standard data exported from the LIMS ‘AQC’ table. Note that this differs from spreadsheet precision_AQCSTANDARD in that the data on this occasion must be data from a material which has an assigned target and derivable standard uncertainty attributable to the assigned value (for example ISO Guide 34 CRM, CRM, RM etc.). This information can be found on the certificate or report supplied with the material. Fill cells D2 and E3 with the assigned target value and standard uncertainty value from the control’s certificate. On occasion, the data may need to be manipulated beforehand – often expanded uncertainties, U, are provided on certificates instead of standard uncertainties, u_c. [For example, if the data has been expressed as an expanded uncertainty with a rectangular distribution the value must be divided by $\sqrt{3}$, or if it has been expressed as a 95% confidence interval divide by 1.96 etc – the Eurachem document provides information on these procedures]. The spreadsheet will then calculate the uncertainty component for bias using the equation in step 4 of section 5.1 of the Nordtest document.

6. Bias_CRMx

The bias_CRMx sheet is also based on section 5.1 of the Nordtest document in the part marked for the use of 'several CRM's'. Cells A8:B68 (for CRM1), E8:F68 (for CRM2), I8:J68 (for CRM3) and M8:M68 (for CRM4) are populated with AQC Standard data exported from the LIMS 'AQC' table for each CRM available. Note again that this must be data from a material which has an assigned target and derivable standard uncertainty of the assigned value. Fill cells C2 and C3 (for CRM1), G2 and G3 (for CRM2), K2 and K3 (for CRM3) and O2 and O3 (for CRM4)) with the assigned target value and standard uncertainty value from the material's certificate bearing in mind the guidance given to the derivation of the standard uncertainty outlined above. Note the (sbias/√n) parameter is not included in the calculation of the mean relative uncertainty due to bias, ubias. Only use this sheet when you have at least 2 materials – the bias_CRM sheet should be used if the results for only 1 material is available.

7. Bias_PT

The bias_PT sheet is based on section 5.2 of the Nordtest document and the cells A5:C28, E5:E28 and G5:G28 are populated with data received from proficiency test rounds. (The required data can be stored in the LIMS table 'PT_UOM' or be entered directly into the spreadsheet. A SQL script can be used to extract the required data if it has been stored in the 'PT_UOM' table). On the spreadsheet the nominal value is the value assigned by the scheme provider, the lab result is the result reported by the laboratory, the S_R value is the reproducibility standard deviation indicating the standard deviation found from all results used in the proficiency testing round (this can go under several names, for example it is called σ_p by FAPAS and SDPA by Aquacheck) and the number of labs is the number of participants in the round. If the S_R value is not provided (unlikely) it can be derived from the Horwitz equation (for example a PT round with assigned value of 378 ug/kg will have a S_R value of 69.9 ug/kg [(2 x 0.000000378^-0.15)/100) x 378].

Cells D5:D28 and F5:F28 will be used to calculate the bias (%) and S_R (%) values respectively.
Input the value '1.25' in cell D30 if a robust mean or median value has been used by the PT scheme organisers. If neither of these apply then insert the value '1.00'. (Note the Nordtest document uses a value of 1.23 and the ISO uses 1.25 - for consistency always use 1.25 when this applies). The spreadsheet will then calculate the uncertainty component for bias, u(Bias).

8. Bias_Spikes

The bias_Spikes sheet is based on section 5.3 of the Nordtest document. Data from the LIMS 'AQC' table is exported for AQC Spikes and pasted as values into cells B9:D69. The uncertainty estimate for the concentration of the spiking solution (u(conc)) and the uncertainty of the volume dispensed for spiking (u(vol)) needs to be added to the spreadsheet. The u(conc) value can usually be derived from the certificated value provided with the solution – for example a stock metal solution of certified value 1000 ± 5 mg/L should have the value of 0.5% added into the cell for u(conc) [(5/1000) x 100]. A stock value of 1.0% should be used in the cell for u(vol) – this is derived from ISO 8655-2:2002 (Table 1) whereupon any automatic pipette, of volume greater than 20µL, should have a maximum permissible bias of ± 1% and a maximum repeatability error of ± 0.5% (these are combined as of the equation given in section 5.3 of the Nordtest document). Any automatic pipette not satisfying ISO 8655-2:2002 would be withdrawn from use and thus the value used for u(vol) should be the worst case scenario likely to be encountered. Individual estimates can be derived with further guidance provided with the spreadsheets issued with the 'blue book' method. The spreadsheet will then calculate the uncertainty component for bias, u(Bias).

9. Combined

9.1 The final sheet takes the relative standard uncertainty derived for precision and combines it with the highest value obtained for the standard uncertainty due to bias to produce the relative standard uncertainty. (The highest value is chosen as it is preferable to over-estimate rather than under-estimate the measurement uncertainty). A coverage factor (k = 2) is then applied to produce the expanded estimate of uncertainty (with a 95 % confidence interval). The lower portion of the sheet provides a few examples and charts the factors contributing to the overall uncertainty.

9.2 The sheets can then be printed, as pdf files, for storing using the macro on the introduction sheet for filing. Prior to printing the default printer should be set to be the 'AIS PDF Writer' printer driver. On printing save the pdf file, for the relevant section, in the T:\UoM_Calcs\Nordtest directory, using the format 'UOM Test Det Date' where the date should be in the format Month YYYY. An example filename thus would be 'UoM PF052 FOODNa September 2019'. There is no requirement to print out copies of the files but superseded files should be retained in the Archive directory (T:\UoM_Calcs\Nordtest\Archive). Only senior staff have access to the T:\ drive.

9.3 The LIMS Dets.Relative field value should then be updated using the value derived from the spreadsheet.

10. Reference sources:

1. Eurachem: "Quantifying Uncertainty in Analytical Measurement"
http://www.measurementuncertainty.org/mu/guide/index.html

2. "Nordtest Project 1589-02 Handbook for Calculation of Measurement Uncertainty in Environmental Laboratories", Version 3.1 (May 2012) (Magnusson et al)
http://www.nordtest.info/images/documents/nt-technical-reports/nt_tr_537_ed3_1_English_Handbook%20for%20Calculation%20of%20Measurement%20uncertainty%20in%20environmental%20laboratories.pdf

3. Estimation of Uncertainty of Measurement for Chemical and Physico-chemical Determinands in Drinking Water 2018, Standard Committee of Analysts.