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TURKAK Principles for Estimation of Uncertainty of Measurement in Testing / Analysis Results

FOREWORD

As laid down in TS EN ISO/IEC 17025 standard that includes requirements for accredited testing laboratories and TS EN ISO 15189 standard with which accredited medical laboratories must comply; the best estimate of uncertainty must be made for testing / analysis results, and the procedures used for estimating uncertainty must be documented. In some cases, the nature of testing method makes it impossible to make a rigorous estimation of measurement uncertainty that is valid metrologically and statistically. In such cases the laboratory should at least attempt to define all components of the uncertainty, make a reasonable estimation and ensure that the form of reporting the results does not give a wrong impression.

There are various approaches for calculating measurement uncertainty. This document aims to provide guidelines to testing laboratories, medical laboratories and assessment teams.

1. PURPOSE

This Guidance describes TURKAK principles on the calculation, estimation and statement of uncertainties included in testing / analysis results

2. POLICY

Policies on measurement uncertainty jointly established by EUROLAB, EURACHEM, CLSI and EA are defined in ILAC-G17 [1]:

a. The statement of uncertainty of measurement should contain sufficient information for comparative purposes.

b. The GUM [2], TS EN ISO/IEC 17025 [3] and TS EN ISO 15189 [4] form the basic documents. However, sector specific interpretations may be needed.

c. Only uncertainty of measurement in quantitative testing shall be considered. A strategy on handling results from qualitative testing has to be developed by the scientific committee.

d. When using a standard test method there are three cases:

- When using a standardised test method, which contains guidance to the uncertainty evaluation, testing laboratories are not expected to do more than to follow the uncertainty evaluation procedure as given in the standard.
- If a standard gives a typical uncertainty of measurement for test results, laboratories are allowed to quote this figure. In this case however, the laboratory should demonstrate full compliance with the test method.
- If a standard implicitly includes the uncertainty of measurement in the test results there is no further action necessary. In this case too, the laboratory should demonstrate full compliance with the test method.

e. The required depth of the uncertainty estimations may be different in different technical fields.

f. In certain cases it can be sufficient to report the reproducibility standard deviations at multiple levels of operation as the combined uncertainty.

g. In addition, it is appropriate to use fit-for-purpose / sector-specific sources published at national / international level.

3. IMPLEMENTATION

3.1 APPROACHES FOR ESTIMATING UNCERTAINTY OF MEASUREMENT

Testing laboratories should adhere to documents issued by the national or international organizations for the estimation of uncertainty of measurement in testing results. The references for this purpose are provided in the Annexes.

EURACHEM/CITAC [5] and EA 4/16 [6] guides describe two possible approaches to estimating uncertainty of measurement:

a. Formulating a model function with a defined measurand, defining each source of uncertainty individually which influences the results and calculating the contribution of each source to uncertainty of measurement: This approach is also known as "bottom-up" approach. In some cases, it is also called "classical GUM" or "component-component approach or model approach".

b. Use of method performance data: This is called "top-down approach" or "empirical approach".

3.2 GUM APPROACH

The GUM method is based on sound theory and provides a consistent evaluation of measurement uncertainty and metrological traceability.

BIPM's recommendation INC-1 on uncertainties [7] recommends that the components of uncertainty of measurement be grouped in two categories as Type A calculated by statistical methods and Type B which is derived by non-statistical methods and the components of which are expressed in terms of variance, then the two be combined to give a single variance value on the basis of mathematical probability theory. The resultant standard deviation is an expression of the uncertainty of measurement. The details of a view on Uncertainty Approach are provided in GUM [2] which assumes that the measurand can be expressed as a single quantity and treats the uncertainty of measurement mathematically through a model of measurement.

3.3 USE OF VALIDATION AND METHOD PERFORMANCE DATA

The GUM approach can be very useful if each component of uncertainty is individually identified or studied. It is reported however that in many testing measurements, this approach has yielded figures lower than the actual uncertainty of measurement [8], [9]. It is difficult for the GUM approach to include all possible components of uncertainty. By the use of validation and method performance data, the highest likelihood is arrived to include all components of uncertainty. In the GUM approach however, the uncertainty of measurement may be smaller than what it should be due to the difficulties in identifying and calculating all components of uncertainty.

Information on test method performance may be obtained from:

- Data accumulated during validation and verification
- Interlaboratory studies
- Internal quality control data (quality control cards etc.)
- External quality assessment data (proficiency testing / interlaboratory studies).

3.3.1 Data accumulated during validation and verification

In practice, the fitness for purpose of test methods applied for routine testing is frequently checked through method validation and verification studies. The data so accumulated can inform the evaluation of

uncertainty for test methods [5], [6]. The following parameters can be considered for quantitative measurements:

Precision: This is the degree of proximity between independent test results obtained under agreed upon conditions [10], and expressed in standard deviation derived under repeatability conditions, intermediate conditions, and reproducibility conditions within and in-between laboratory. When the uncertainty of measurement is derived from method validation, the precision data should be taken as the standard deviation value called intermediate precision or reproducibility within laboratory obtained using different operators, different test items over time ideally in the same laboratory using the same sample and method.

Precision studies should take into account the measurement range of and matrices covered by the test method. Methods covering a wide measurement range should consider matrix differences (if any), involve studies at various levels (e.g. low, medium, and high concentration levels), and investigate the relation between standard deviations and testing levels. The lower level studies should include the limit of quantification (LOQ) and legitimate limit values if applicable. Based on the results, matrix and level differences should be taken into account when calculating uncertainty of measurement as necessary. Precision data are the basic component of uncertainty of measurement of a method.

Trueness: The degree of proximity between the average value obtained of a large series of testing results and an agreed reference value is defined as trueness [10]. Trueness may be named differently based on the item studied. When trueness study is held with the reference material, it is called “bias”, and if with a standard item, then “regain”. The most important aim is to eliminate bias or reduce it to insignificant levels. Bias/regain data are the basic component of uncertainty of measurement of a method.

Linearity: Linearity is the most important indication of the measurement range of the method. Where there is significant deviation from linearity, correction should be made by the use of non-linear calibration functions. Alternatively, the study range may be restricted. Data derived from precision include normally the deviations from linearity. If these deviations are negligible compared with the uncertainties associated with calibration, additional uncertainty evaluation is not required.

LOD*: LOD value is not directly associated with uncertainty of measurement

** “Limit of Detection” may be variously referred to by laboratories e.g. limit of observability, limit of determination, limit of measurement etc. Therefore, this abbreviation is preferred.*

Sensitivity (Selectivity): Since these parameters are important for chemical analyses and not directly associated with uncertainty of measurement, they need not be taken into account as a component of uncertainty of measurement.

3.3.2 Interlaboratory studies

ISO 5725 TS 5822 series standards [10] that are taken as basis in interlaboratory studies give necessary definitions for repeatability standard deviation sr, reproducibility standard deviation sR and the estimation of trueness. Where the repeatability and reproducibility values obtained in interlaboratory studies based on these standards are included in the testing method and if the laboratory demonstrates that the method is under control through its internal and external quality control work and fully complies with the method, the laboratory may use the reproducibility standard deviation given in the testing method in the calculation of uncertainty of measurement. The use of such data in estimation of uncertainty of measurement is detailed in ISO TS 21748 [11] and Eurachem/CITAC: 2012 [5].

3.3.3 Internal quality control data

The laboratory should undertake regular internal quality control activities to check whether the performance in validation studies is maintained. Such activities may be conducted by the use of control cards and/or other internal quality control methods. The values of intermediate precision / within

laboratory reproducibility and the results of trueness studies (bias/regain) shall be used in estimation of uncertainty of measurement [8], [9].

3.3.4 External quality assessment data (proficiency testing / interlaboratory studies)

The laboratory should participate in regular external quality assessment schemes to verify its performance. The results from the participated schemes may be used in estimation of uncertainty of measurement. A laboratory must have successfully participated in at least 6 schemes before the systematic error resulting from the external quality assessment can be considered in estimation of uncertainty of measurement. All these 6 schemes should involve the same conditions of participation [5], [6], [7].

3.3.5 Other

When estimating uncertainty of measurement, a laboratory should refer in priority to the standard method or the sources referred by the standard method. However, if the standard method makes no description of uncertainty of measurement, other available sources are listed in [12]. Therefore, it is appropriate to use fit-for-purpose / sector-specific sources published at national / international level which are not listed in this guide.

3.4 CALCULATION OF COMPONENTS OF MEASUREMENT UNCERTAINTY

Not all components of uncertainty of measurement contribute equally to uncertainty. In practice, only few uncertainty components are expected to add significantly to the uncertainty. If components contributing to the uncertainty of measurement are less than 1/3 of the largest uncertainty component and the number of such components is few, they need not be included in estimation of uncertainty of measurement. However, it should be demonstrated that they are insignificant.

To that end, the contribution of each component should be estimated in preliminary studies or uncertainty components should be combined. Resultant ones which are still insignificant should be eliminated [5].

Following the calculation of all standard uncertainties, the Combined Uncertainty u(y) is estimated as follows:

$$u(y) = \sqrt{u_1^2 + u_2^2 + u_3^2 + \ldots.}$$

As a last step; the Expanded Uncertainty U(y) is estimated by multiplying the combined uncertainty value by the coverage factor (k) determined based on the confidence interval:

$$U(y)=k.u(y)$$

As a general approach, the preferred confidence level is 95%, for which the coverage factor is 2. For a confidence level of 99%, the coverage factor is 3.

3.5 REPORTING UNCERTAINTY OF MEASUREMENT

The uncertainty of measurement shall be reported:

- Where the result of a test / analysis exceeds a certain pre-established tolerance or limit when the relevant uncertainty is applied (e.g. legal limit values);
- Where the client ordering the test / analysis so requests;

- Where it is necessary for the validity or application of results of a test / analysis, along with the test results.

In the absence of a specific reason or unless otherwise noted in the testing method, the expanded uncertainty (U) value for a measurement result (y) should be stated in the confidence level of 95% as follows:

$$y \pm U$$

along with its unit of measurement.

4. REFERENCES

[1] ILAC-G17:2002. Introducing the Concept of Uncertainty of Measurement in Testing in Association with the Application of the Standard ISO/IEC 17025

[2] BIPM, IEC, IFCC, ISO, IUPAC, IUPAP, OIML JCGM 100:2008. Evaluation of measurement data - Guide to the expression of uncertainty in measurement (GUM 1995 with minor corrections) (www.bipm.org). (Printed as ISO/IEC Guide 98-3:2008. (www.iso.org))

[3] TS EN ISO/IEC 17025:2012. General requirements for the competence of testing and calibration laboratories

[4] TS EN ISO 15189:2014 Medical laboratories – Requirements for quality and competence

[5] Eurachem/CITAC: 2012. Quantifying uncertainty in analytical measurement, 3 Edition, ISBN 978-0-948926-30-3 (www.eurachem.org)

[6] EA 4/16 G:2003. EA guidelines on the expression of uncertainty in quantitative testing (www.european-accreditation.org)

[7] KAARLS, R. (1981), BIPM Proc.-Verb. Com. Int. Poids et Mesures 49, A1-A12 (in French); Giacomo, P. (1981), Metrologia 17, 73 -74 (in English)

[8] ISO 11352:2012. Water quality -- Estimation of measurement uncertainty based on validation and quality control data (www.iso.org)

[9] Nordtest Report TR 537-Approved 2012 Edition 3.1 Handbook for calculation of measurement uncertainty in environmental laboratories, (www.nordtest.info)

[10] ISO 5725 TS 5822 series

- ISO 5725-1 TS 5822 -1 Ölçme metotlarının ve sonuçlarının doğruluğu (gerçeklik ve kesinlik) bölüm 1: Genel prensipler ve tarifler [Accuracy (trueness and precision) of measurement methods and results - Part 1: General principles and definitions (and Corrigendum 1:1998). (www.iso.org)]
- ISO 5725-2 TS 5822 -2 Ölçme metotlarının ve sonuçlarının doğruluğu (gerçeklik ve kesinlik) bölüm 2: Standard bir ölçme metodunun tekrarlanabilirliğinin ve uyarlığın tayini için temel metot [Accuracy (trueness and precision) of measurement methods and results - Part 2: Basic method for the determination of repeatability and reproducibility of a standard measurement method (and Technical Corrigendum 1:2002). (www.iso.org)
- ISO 5725-3 TS 5822 -3 TS 5822-3 ISO 5725-3 Ölçme metotlarının ve sonuçlarının doğruluğu (gerçeklik ve kesinlik) - Bölüm 3: Standard bir ölçme metodunun kesinliğinin ara ölçmeleri [Accuracy (trueness and precision) of measurement methods and results - Part 3: Intermediate measures of the precision of a standard measurement method (and Corrigendum 1:2001). (www.iso.org)]
- ISO 5725-4 TS 5822 -4 Ölçme metotlarının ve sonuçlarının doğruluğu (gerçeklik ve kesinlik)-Bölüm 4: Standard bir ölçme metodunun gerçekliğini belirlemek için temel metotlar [Accuracy (trueness and precision) of measurement methods and results - Part 4: Basic methods for the determination of the trueness of a standard measurement method. (www.iso.org)]
- ISO 5725-5 TS 5822 -5 Ölçme metotlarının ve sonuçlarının doğruluğu (gerçeklik ve kesinlik)-Bölüm 5: Standard bir ölçme metodunun kesinliğini belirlemek için alternatif metotlar [Accuracy (trueness and precision) of measurement methods and results - Part 5: Alternative methods for the determination of the precision of a standard measurement method (and Corrigendum 1: 2005). (www.iso.org)]

- ISO 5725-6 TS 5822 -6 Ölçme metotlarının ve sonuçlarının doğruluğu (gerçeklik ve kesinlik)-Bölüm 6: Doğruluk değerlerinin pratikte kullanılması [Accuracy (trueness and precision) of measurement methods and results - Part 6: Use in practice of accuracy values (and Corrigendum 1: 2001). (www.iso.org)

[11] ISO 21748:2010. Guidance for the use of repeatability, reproducibility and trueness estimates in measurement uncertainty estimation. (www.iso.org)

[12] Other References:

- JCGM 200:2012 VIM, International Vocabulary of Basic and General Terms in Metrology
- ISO/TS 21749:2005. Measurement uncertainty for metrological applications -- Repeated measurements and nested experiments. (www.iso.org)
- The expression of uncertainty and confidence in measurement, M3003, Edition 3, UKAS, 2012 (www.ukas.com)
- Policy on Estimating Measurement Uncertainty for Medical Testing Laboratories, (A2LA - The American Association for Laboratory Accreditation) (www.a2la.com)
- Technical Guide 4 A Guide on Measurement Uncertainty in Medical Testing (http://www.sac-accreditation.gov.sg)
- N. Majcen, P. Taylor, T. Martisius, A. Menditto, M. Patriarca, Practical examples on traceability, measurement uncertainty and validation in chemistry Vol 2, 2011, (European Commission, Joint Research Centre)
- Measurement uncertainty revisited: Alternative approaches to uncertainty evaluation, Technical report No. 1/2007, EUROLAB, 2007 (www.eurolab.org)
- Guide to the evaluation of measurement uncertainty for quantitative tests results, Technical report No. 1/2006, EUROLAB, 2006 (www.eurolab.org)
- K. Jewell, Microbiological measurement uncertainty: A practical guide, CCFRA, 2004, ISBN 0 905942 66 3 (www.campdenbri.co.uk)
- CLSI EP29-A. Expression of Measurement Uncertainty in Laboratory Medicine; Approved Guideline
- Uncertainty of Measurement in Quantitative Medical Testing, A Laboratory Implementation Guide, AACB Uncertainty of Measurement Working Group, November 2004
- ISO/TS 19036:2006. Microbiology of food and animal feeding stuffs - Guidelines for the estimation of measurement uncertainty for quantitative determinations
- ISO 14956:2002. Air quality - Evaluation of the suitability of a measurement procedure by comparison with a required measurement uncertainty
- ISO 11222:2002. Air quality - Determination of the uncertainty of the time average of air quality measurements
- ISO 20988:2007. Air quality - Guidelines for estimating measurement uncertainty
- ISO/TR 12134:2010. Rubber - Estimation of uncertainty for test methods - Non- functional parameters
- ISO/ASTM 51707:2015. Guide for estimation of measurement uncertainty in dosimetry for radiation processing
- ISO/TR 24498:2006. Paper, board and pulps -- Estimation of uncertainty for test methods
- ISO 29201:2012. Water quality - The variability of test results and the uncertainty of measurement of microbiological enumeration methods
- ISO 3822-1:1999. Acoustics - Laboratory tests on noise emission from appliances and equipment used in water supply installations - Part 1: Method of measurement .Amd 1:2008. Measurement uncertainty
- SANCO/12571/2013. Guidance Document on analytical quality control and validation procedures for pesticide residues analysis in food and feed.