CODEX ALIMENTARIUS COMMISSION

Food and Agriculture Organization of the United Nations

World Health Organization

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CL 2020/31/OCS-MAS
May 2020

TO: Codex Contact Points
Contact Points of international organizations having observer status with Codex

FROM: Secretariat, Codex Alimentarius Commission,
Joint FAO/WHO Food Standards Programme

SUBJECT: **Request for comments: (i) the proposed revised *Guideline on Measurement Uncertainty* (ii) Information document on procedures for the estimation of measurement uncertainty; and (iii) criteria to select Type II methods from multiple Type III methods**

DEADLINE: **30 June 2020**

BACKGROUND

1. Following the rescheduling of CCMAS41 due to the COVID-19 pandemic, the chair of CCMAS, the host Secretariat, Hungary, and the Codex Secretariat are encouraging continued discussion on work currently on the agenda of CCMAS to facilitate progress or completion of work at CCMAS scheduled for May 2021.

2. In light of this, comments are being sought on the (i) revised proposed *Guideline on Uncertainty* (CXG 54-2004); (ii) information document on procedures for the estimation of measurement uncertainty to support the revision and implementation of CXG 54-2004; and (iii) the criteria for the selection of Type II methods from multiple Type III methods to support the CCMAS work on consideration and endorsement of methods. Comments submitted will allow further development of the papers for discussion and finalization at CCMAS41. Background information is available in CX/MAS 20/41/8 and CX/MAS 20/41/10.

3. A revised version of the *Guideline on Measurement Uncertainty* (CXG 54-2004) based on the comments received at Step 6 in response to CL 2019/80/OCS and published as CX/MAS 20/41/7 has been prepared by Germany and is available as an Appendix to this CL for comment and to inform comments on the information document.

REQUEST FOR COMMENTS

4. Codex members and observers are invited to submit comments on:

   (i) the revised *Guideline on Uncertainty* (CXG 54-2004) taking into account the comments submitted at Step 6 and published in CX/MAS 20/41/7;

   (ii) the information document taking into account the revised CXG 54-2004. Comments should also indicate if the information document serves the purpose of supporting the revision of CXG54 and their implementation once the revised CXG54 is adopted by CAC;

   (iii) the criteria for the selection of Type II methods from multiple Type III methods, in particular their suitability to support the CCMAS work on consideration and endorsement of methods. The documents are uploaded to the Codex Online Commenting System (OCS): https://ocs.codexalimentarius.org/, as per the guidance below.

5. In submitting comments on the above, Codex members and observers are invited to consider the background information and conclusions provided in CX/MAS 20/41/8, the revised version of CXG54 (Appendix I of this CL), including comments compiled in CX/MAS 20/41/7, and CX/MAS 20/41/10, respectively.

GUIDANCE ON THE PROVISION OF COMMENTS

6. Comments should be submitted through the Codex Contact Points of Codex members and observers using the OCS.

7. Contact Points of Codex members and observers may login to the OCS and access the document open for comments by selecting “Enter” in the “My reviews” page, available after login to the system.

8. Contact Points of Codex members and observers organizations are requested to provide proposed changes and relevant comments/justifications and/or at the document level (general comments or

summary comments). Additional guidance on the OCS comment categories and types can be found in the OCS Frequently Asked Questions (FAQs).

9. Other OCS resources, including the user manual and short guide, can be found at the following link: http://www.fao.org/fao-who-codexalimentarius/resources/circular-letters/en/.

10. For questions on the OCS, please contact Codex-OCS@fao.org.

APPENDIX I

REVISED DRAFT REVISION OF THE *GUIDELINES ON MEASUREMENT UNCERTAINTY* (CXG 54 – 2004)

(Revised proposal prepared by Germany based on comments received at Step 6 and compiled in CX/MAS 20/41/7. Changes are indicated in **bold/underlined** or in strikethrough format)

1. **Physical and** analytical measurement results in food control are used to assess whether food products meet relevant specifications. The accuracy of measurement results is affected by various error components, and it is important to ensure these errors are properly considered. Since the true value of the quantity being measured is unknown, errors cannot be known exactly. The focus thus shifts to an evaluation of the uncertainty associated with a measurement result. All measurement results have an associated uncertainty; the non-estimation of measurement uncertainty does not mean that there is no uncertainty. ~~The estimation of measurement uncertainty is required to establish the metrological traceability of the measurement results.~~ Accordingly, measurement uncertainty is of utmost importance in **physical and** analytical testing and subsequent decision-making.

2. ~~It should be noted that~~ **The present document does not provide guidance for** ~~, in this guideline,~~ the evaluation of **the contribution to total uncertainty due to** sampling~~uncertainty is not included.~~

3. The present document does not provide guidance as to how to take measurement uncertainty into account in the specification of sampling plans for acceptance sampling in connection with lot inspection.

4. The Codex Alimentarius Commission has developed *Guidelines for the Assessment of the Competence of Testing Laboratories Involved in the Import and Export Control of Foods* (CXG 27-1997). They recommend that laboratories involved in food control for import/export should adopt the general criteria set forth in ISO/IEC 17025 (ISO, 2017). This standard ~~requires that where necessary for the interpretation of the test results and where applicable measurement uncertainty shall be included in the test report. The ISO/IEC 17025 standard also requires that the measurement uncertainty and its level of confidence must be made available to the user (customer) of the results, on request. The use of measurement uncertainty in establishing decision rules must be documented. In summary, the ISO/IEC 17025 standard~~ requires that information regarding measurement uncertainty must be provided in test reports insofar as it is relevant to the validity or application of the test results, in response to a customer's request, or when the uncertainty affects compliance to a specification limit.

Scope

5. This guideline covers general aspects of measurement uncertainty for quantitative analysis, gives definitions of measurement uncertainty and related terminology and clarifies the role of measurement uncertainty in the interpretation of test results **in conformity assessment** and ~~the relationship between measurement uncertainty and~~in **specifying** sampling plans **for the inspection of lots**. This guideline does not address the uncertainty component associated with sampling and focuses on uncertainty contributions which arise in connection with obtaining a test sample from the laboratory sample, taking a test portion from a test sample (i.e. the errors due to the heterogeneity[1] between test portions) and the analysis of a test portion in the laboratory.

6. ~~While the role of~~Physical **measurement and** chemical **analysis** in food control ~~often involves~~ **is often** *quantitative* ~~analytical measurement results~~, **but** *qualitative* **test** results are also relevant. **While an evaluation or estimation of measurement uncertainty is not required for qualitative results, it is recommended that laboratories identify factors which have an influence on such test results and establish quality assurance procedures to control relevant** effects.~~For the estimation of the measurement uncertainty associated with qualitative results, a different approach should be applied than for quantitative results.~~

[1] The heterogeneity between test portions is composed of compositional heterogeneity (CH) and distributional heterogeneity (DH). Both of these lead to random errors when selecting a test portion, known as Fundamental Sampling Error – also called Fundamental Variability – and Grouping and Segregation Error. Fundamental variability results from CH ~~and is the variability between test portions that remains even under the best achievable degree of particle size reduction. The fundamental variability~~ **and** has a dominant effect on total variability when the "target compound" is predominantly located in a specific fraction of the particles (there is a low number of particles with relatively high concentrations of the target compound). The fundamental variability can be controlled by collecting a sufficient test portion mass. Grouping and segregation error results from DH and is the non-random distribution (spatial or temporal) of the "target compound" within the material from which a test portion is selected. The grouping and segregation error can be controlled through the collection of a sufficient number of random increments to comprise a test portion.

Prerequisites

~~7.~~ Laboratories which perform physical measurements or~~in~~ chemical analysis should have effective quality assurance procedures in place (properly trained staff, equipment maintenance, calibration of equipment, reference materials and standards, documentation, participation in proficiency tests, quality control charts etc.), which can be used for the evaluation of measurement uncertainty. Furthermore, sufficient statistical knowledge either by qualified staff or external consultants is recommended, in order to ensure that statistical methods, mathematical formulas and decision rules are correctly applied, and that criteria for producer and consumer risks are met **(JCGM 106:2012 and ISO 10576).** ~~**Examples and explanations of decision rules can be found in ISO 10576 and JCGM 106:2012.**~~

Terms and definitions

8. For the purposes of this guideline, the terms and definitions of the following documents apply.

9. Guidelines on analytical terminology (CXG 72-2009)

JCGM 200:2012 International vocabulary of metrology – Basic and general concepts and associated terms (VIM)

ISO 3534-1:2006 Statistics – Vocabulary and symbols – Part 1: General statistical terms and terms used in probability

ISO 3534-2:2006 Statistics – Vocabulary and symbols – Part 2: Applied statistics

ISO 2859-1:2014 Sampling procedures for inspection by attributes – Part 1: Sampling schemes indexed by acceptance quality limit (AQL) for lot-by-lot inspection

ISO 3951-1:2016 Sampling procedures for inspection by variables – Part 1: Specification of single sampling plans indexed by acceptance quality limit (AQL) for lot-by-lot inspection for a single quality characteristic and a single AQL

ISO 6498:2012 Animal feeding stuffs -- Guidelines for sample preparation

ISO 10725:2000 Acceptance sampling plans and procedures for the inspection of bulk materials

ISO 17025:2017 General requirements for the competence of testing and calibration laboratories

10. For convenient reference, the following definitions are provided here:

inspection by variables

inspection by measuring the magnitude of a characteristic of an item

increment

quantity of material drawn at one time from a larger quantity of material to form a sample

item

that which can be individually described and considered

laboratory sample

sample as prepared (from the lot) for sending to the laboratory and intended for inspection or testing

lot

a lot is a definite quantity of some commodity manufactured or produced under conditions, which are presumed uniform for the purpose of these Guidelines.

measurement uncertainty

parameter, associated with the result of a measurement, that characterizes the dispersion of the values that could reasonably be attributed to the measurand

sample

set of one or more items taken from a lot and intended to provide information on the lot

sampling plan

specified sample size, methodology for the selection of samples and lot acceptability criteria

sample size

number of items in the sample

test sample

subsample or sample prepared from the laboratory sample and from which test portions will be taken

test portion

quantity of material drawn from the test sample (or from the laboratory sample if both are the same)

~~**sample**~~

~~set of one or more items taken from a lot and intended to provide information on the lot~~

~~**sample size**~~

~~number of items in the sample~~

~~**sampling plan**~~

~~combination of sample size(s) to be used and associated lot acceptability criteria~~

~~**sampling increment**~~

~~amount of bulk material taken in one action by a sampling device~~

~~**composite sample**~~

~~aggregation of two or more sampling increments taken from a lot for inspection of the lot~~

General considerations

11. When a measurement is performed, it is generally assumed that a "true value" of the quantity being measured exists. However, this true value is unknown and is thus only available as a reference value or a conventional true value. For this reason, measurement error cannot be reliably estimated and the focus shifts to the evaluation of measurement uncertainty. Measurement uncertainty is expressed as an interval within which values which can reasonably attributed to the measured quantity will lie with a stated coverage probability. ~~It is assumed that any necessary bias correction has been correctly performed.~~ Since all measurement results are subject to error, laboratories are expected to estimate and, if necessary, report the measurement uncertainty associated with every result.

12. Measurements are affected by many influences – e.g. effects which arise in connection with changes in temperature, pressure, humidity, matrix variability or with the judgement of the analyst. These errors can be classified as either *systematic* or *random*. The term *bias* is often used to refer to a systematic error. Even if all *systematic* error components could be evaluated and corrected for, measurement results would remain subject to random errors which cannot be corrected for, leading to an uncertainty range. An example of the manner in which a random error manifests itself is the dispersion of measurement results observed when measurements are performed within one laboratory under near-identical, i.e. repeatability, conditions. **Both systematic and random components of measurement uncertainty should be summarily quantified, respectively.** ~~The individual components of measurement uncertainty should be identified and estimated. Some of these~~ Components **of measurement uncertainty** can be evaluated from the statistical distribution of a series of measurement results and characterized by standard deviations. The other components, which can also be characterized by standard deviations, are evaluated on the basis of distributional assumptions derived from experience or other information. All components of uncertainty, including those arising from systematic effects such as the uncertainty of bias corrections and reference standards, contribute to the dispersion.

13. It is important to note that time and financial resources do not allow for the evaluation and correction of all measurement errors. For this reason, the focus lies on the identification and evaluation of the *main* components of measurement uncertainty. **However it is for utmost importance to identify and evaluate systematic components of measurement uncertainty since these cannot be reduced by repeated measurements. Whenever possible test methods should be used that have been validated by collaborative studies. In case that there are two methods with identical measurement uncertainty, the method with lower systematic error should be preferred.**

Uncertainty components

14. While performing a measurement, it is important to consider all possible uncertainty components which will influence the result of the measurement. Typical uncertainty components include effects associated with instrumental equipment, analyst, sample matrix, method, calibration, time and environment. These sources may not be independent, in which case the respective correlations should be taken into account in the

uncertainty budget – i.e. in the computation of the total uncertainty. Moreover, under certain circumstances, the effect associated with a particular uncertainty component may change over time and a new estimation of measurement uncertainty may be necessary as a result. For more information on this subject, please refer to the EURACHEM / CITAC Guide CG 4.

Procedures for estimating measurement uncertainty

15. There are many ~~procedures~~**approaches** available for estimating the uncertainty of a measurement result, notably those described in ISO/IEC Guide 98-3:2008 and EURACHEM / CITAC Guide CG 4. The Codex guidelines do not recommend a particular approach for estimating measurement uncertainty, but it is important that whatever approach is used be scientifically acceptable[2]. **Among such scientifically acceptable approaches, none may be said to be better than any other – i.e. there is no "hierarchy" among such approaches**. Choosing the appropriate ~~procedure~~**approach** depends on the type of **measurement or** analysis, the method used, the required level of reliability, and the urgency of the request for an estimate of measurement uncertainty. In general, procedures are based either on a "bottom-up" approach or on a "top-down" approach, with the latter using data from collaborative ~~trials~~**studies**, proficiency studies, validation studies, ~~or~~ intra-laboratory quality control samples, or a combination of such data.

16. Most common approaches for the evaluation of measurement uncertainty:

- Modelling (Classical ISO GUM)
  - Bottom-up component-by-component evaluation according to ISO GUM
- Single-lab validation
  - Top-down approach e.g. according to Nordtest TR 537, NMKL procedure No. 5, EURACHEM / CITAC Guide CG 4 (uncertainty of results obtained using the same procedure in a single laboratory varying conditions as described above)
- Interlaboratory validation
  - Top-down approach using the reproducibility standard deviation (**ISO 5725 and** ISO 21748) (uncertainty of results obtained using the same procedure in different laboratories)
- Proficiency testing (PT)
  - Top-down approach using the target reproducibility standard deviation (uncertainty of results obtained by analysing the same sample(s) in different laboratories)

17. These procedures are not equivalent and may produce different estimates of the measurement uncertainty. In the top-down approach, the reproducibility standard deviation obtained from collaborative studies is often used ~~as a measure of~~**an estimate of** measurement uncertainty. The matrix mismatch uncertainty component should be adequately taken into account during the estimation of measurement uncertainty. To overcome this deficiency different matrices and concentration levels – depending on the scope of the method – could be used. In the case of a single-lab validation study, intermediate precision (within-lab reproducibility) is used for the estimation of the uncertainty and the laboratory bias is therefore missing with the result that the uncertainty may have been underestimated. Depending on the case, this can be addressed e.g. by estimating and correcting for the bias via a recovery experiment (with the uncertainty of the recovery correction duly taken into account in the uncertainty) or by simulating the laboratory bias by varying influencing effects like analytical instruments, analysts, time span, equipment for sample preparation etc. **Certified reference materials can also be used to estimate bias and its uncertainty.**

18. In addition to the fact that these procedures may vary with regard to the influencing effects included there is also often considerable variation due to random variability of the standard deviation figures (intermediate precision (within-lab reproducibility), reproducibility, repeatability). Therefore, both the chosen approach for estimating measurement uncertainty (in-house validation, collaborative study, bottom up etc.) and the estimated level of confidence of the measurement uncertainty should be provided.

19. Almost all uncertainty data are expressed as standard deviations or functions of standard deviations. If a standard deviation is calculated using a small amount of data there is considerable uncertainty in the estimate of measurement uncertainty obtained.

20. If the estimate of a standard deviation is obtained from a low number of tests run by a single laboratory or from a collaborative study conducted by a low number of laboratories each with a single measurement, the true standard deviation can be up to 2-3 times the estimated standard deviation. **The exact** factor **by which the estimate should be multiplied** can be calculated with the following Excel formula: SQRT((N-

[2] The expression "scientifically acceptable" is used here to mean either that the approach has been previously described in an international standard or guideline or that, upon expert scrutiny, it would be agreed that the approach is appropriate.

1)/CHISQ.INV(0.05,N-1**)), where N is the number of laboratories or the number of tests inside the single laboratory.** The~~is uncertainty~~ **reliability** of measurement uncertainty components should be taken into account in the design of experimental studies and the evaluation of measurement uncertainty.

21. It is recommended that laboratories which perform food testing with quantitative methods should always evaluate measurement uncertainty. ~~In cases where a rigorous evaluation~~**Even if some components of measurement uncertainty** cannot be ~~made~~**evaluated**, ~~measurement uncertainty should~~ **such components can often** at least be estimated on the basis of principles, experience and "state of the art" knowledge based e.g. on results from comparable laboratories, concentration levels, matrices, analytical methods or analytes.

22. In order to demonstrate that a laboratory is competent in the application of a validated method, there are two possible approaches:

a. the laboratory uses a validated in-house test method with established limits regarding the major measurement uncertainty components along with the exact manner in which relevant quantities must be calculated

b. the laboratory uses an official and/or standardized method with established method performance characteristics and verifies that it can meet and/or exceed the within laboratory performance parameters in accordance with the official standardized method and that all the critical influences are under control

23. Most of the methods used in food testing and recommended in Codex documents are well-recognized methods which have been reliably validated. As long as the laboratory's competence in the application of a validated method has been demonstrated following either one of the two approaches described, the measurement uncertainty evaluation/estimation is considered to have been successfully performed and any requirements regarding the measurement uncertainty are considered to have been met.

24. **ISO/IEC 17025** ~~The *Guidelines for the Assessment of the Competence of Testing Laboratories involved in the Import and Export Control of Food* (CXG 27-1997)~~ requires laboratories involved in the import/export of foods to ~~comply with the general criteria set forth in ISO/IEC 17025. This standard requires laboratories to~~use validated methods; ~~it is~~ thus, ~~usually recommendable to use~~ data from the interlaboratory or single-lab validation study ~~rather than another approach such as the bottom-up approach~~ **can be used for the estimation of measurement uncertainty following the top-down approach.** In Section 7.6.2 of the EURACHEM / CITAC Guide CG 4 ~~EURACHEM / CITAC Guide CG 4~~, a procedure for evaluating measurement uncertainty using collaborative study data is provided. The EURACHEM / CITAC Guide CG 4 ~~EURACHEM / CITAC Guide CG 4~~also references ISO 21748 as the primary source for the estimation of uncertainty on the basis of "collaborative study data acquired in compliance with ISO 5725".

Uses of measurement uncertainty

25. Measurement uncertainty has several uses including:

- Reporting of measurement results (see ISO/IEC 17025):

  Typically, the measurement uncertainty is reported as the expanded measurement uncertainty U, i.e. as the standard uncertainty u multiplied by a coverage factor $k = 2$, which for a normal (Gaussian) distribution corresponds to a coverage probability of approximately 95 %. Note: The higher the uncertainty of the standard deviation used for the calculation of the measurement uncertainty, the lower the coverage probability of the latter. In such cases it may be sensible to increase the coverage factor k by taking the corresponding factor of the Student t distribution.
- **For conformity assessment, to assess whether the true value of the tested sample complies with a specification (see paragraphs 26 and 27). This is different from sampling inspection where the conformity of a lot is assessed. Examples and explanations of decision rules can be found in JCGM 106:2012 and ISO 10576.**
- Assessing the performance of laboratories (see ISO 13528)
- For the design of acceptance sampling **plans based on inspection by variables**~~(see ISO 3951 and GL50):~~
- The determination of ~~sample size and acceptance number for inspection by attributes, and of~~ sample size and acceptability constant for inspection by variables is based on the procedures and the sampling plans provided in ISO standards and/or Codex guidelines **(e.g. ISO 3951 and GL50). When large in relation to the process standard deviation, measurement uncertainty should be taken into consideration in these** ~~This calculation has to take into account the components of measurement uncertainty.~~
- **For the characterization of certified reference materials**

- For comparison between measurement results and true/reference values (ISO 5725-6)

How to report measurement uncertainty in test results

26. In accordance with ISO/IEC 17025 measurement uncertainty should be reported to allow for a decision as to whether a *laboratory sample* meets a specification on the basis of an analytical result.

27. However, ISO/IEC 17025 does not ~~state~~**specify exactly which information should be reported**. ~~how measurement uncertainty should be taken into account.~~ It is clear, however, that it ~~is not sufficient to consider measurement uncertainty only, but it is necessary~~ **would be useful** to include information ~~on~~ **as to whether a correction for method bias was applied and whether the contribution corresponding to uncertainty of bias correction is included in the reported measurement uncertainty**~~and on whether or not a correction was applied.~~ **The reader is also referred to the relevant sections in the Codex Alimentarius Commission's Procedure Manual (27th edition, 2019).**

Examples of situations occurring when measurement uncertainty is considered

28. ~~The~~Figure 1~~below~~ illustrates how measurement uncertainty can affect decisions whether the true values **of the samples tested** conform to specification limits. ~~However~~ **Figure 1 is intended to illustrate the basic principle only.**~~ve purposes of the principle~~ Measurement uncertainty intervals such as those in Figure 1 cannot be used as a valid ~~product~~**conformity** assessment procedure.

29. The decision whether the *laboratory sample* meets the specification or not depends on the rules which the different parties involved have agreed to apply.

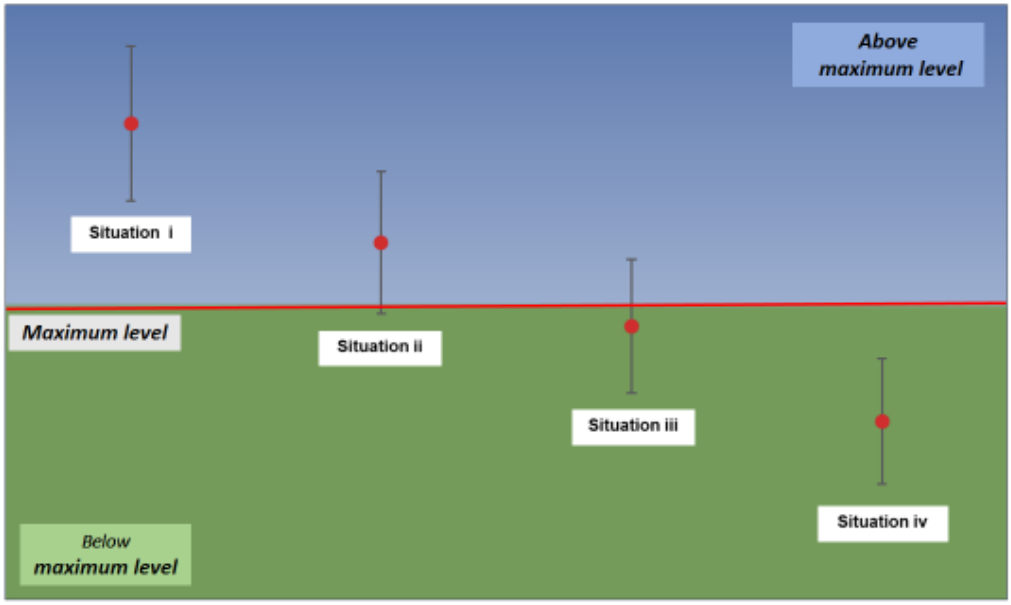

Figure 1: Taking into account the expanded measurement uncertainty in the comparison of test results with a Maximum Level. For each situation, the red point represents an individual test result and the vertical bar represents the associated measurement uncertainty interval.

Situation i

The analytical result minus the expanded measurement uncertainty exceeds the maximum level. The conclusion is that it lies above the specification.

Situation ii and iii

The analytical result differs from the maximum level by less than the expanded measurement uncertainty. The standard interpretation here is the outcome is inconclusive. Action on this result depends on existing agreements between the trading partners.

Situation iv

The analytical result is below the maximum level by more than the expanded measurement uncertainty. The decision is that it lies below the specification.

Note: The measurement uncertainty interval used in Figure 1 and its comparison to the maximum level is not intended to be used for lot acceptance sampling or conformity assessment but to illustrate the interrelation of the analytical test result and its measurement uncertainty with regard to a maximum level.

Note: The implications of situations i to iii in the case of testing MRL compliance are extensively discussed in the *Guidelines on estimation of uncertainty of results* (CXG 59-2006). If, as in situations ii and iii, it cannot be concluded beyond reasonable doubt (in relation to the consumer and producer risks involved) that the MRL **or maximum level** is exceeded or that a compliant test result has been obtained, the decision will depend on national practices and on existing agreements between the trading partners, which may thus have a considerable impact on the acceptance of trade consignments. This question is addressed in the guideline CXG 83-2013 “Principles for the Use of Sampling and Testing in International Food Trade”. It is stated that “the exporting country and the importing country should agree on how the analytical measurement uncertainty is taken into account when assessing the conformity of a measurement against a legal limit”.