IOP Publishing Metrologia

Metrologia **45** (2008) 335–341 doi:10.1088/0026-1394/45/3/011

Essential for metrology in chemistry, but not yet achieved: truly internationally understood concepts and associated terms

Paul De Bièvre

Independent Consultant on Metrology in Chemistry (MiC), Duineneind 9, B-2460 Kasterlee, Belgium

E-mail: paul.de.bievre@skynet.be

Received 18 June 2007
Published 16 May 2008
Online at stacks.iop.org/Met/45/335

Abstract

Unambiguous and consistent concepts and associated terms should govern the description of the results of chemical measurements. This is not yet the case as numerous international workshops have shown over the last decade and as the chemical literature amply and continuously demonstrates. A number of concepts and associated terms in measurement are discussed, which are used ambiguously in the daily work of field laboratories, in the chemical literature, in ISO Guides and Standards, in regulatory documents, etc. They illustrate the need for clarification of their definitions. The consistent use of the recently revised edition of the 1993 '*International Vocabulary of Basic and General Terms in Metrology*', henceforth (2007) called the ISO/IEC Guide 99:2007, '*International Vocabulary of Metrology—Basic and General Concepts and Associated Terms (VIM)*', is a step in the direction of achieving this goal.

(Some figures in this article are in colour only in the electronic version)

1. Introduction

Metrology is the 'science of measurement and its application' [VIM3, 2.2] [1], and '... includes all theoretical and practical aspects of measurement, whatever the measurement uncertainty and field of application' [*idem*] where measurement is understood as a 'process of experimentally obtaining one or more quantity values that can reasonably be attributed to a quantity' [VIM3, 2.1] [1].

These definitions set the scene for thinking about concepts and terms used in all measurements, including any chemical measurement. All measurements have fundamentally identical conceptual foundations. The use of the results may be located in many and very different applications. It is useful to think about the reasons why one performs measurements:

(a) to assist in moving from qualitative knowledge (something is larger, taller, bigger, ... than something else) to quantitative knowledge (something is so many times larger, taller, bigger, ... than something else) which carries much more information and

(b) to *communicate* the magnitude of the quantities[1] we use in
   - – describing our observations of nature and in
   - – carrying out our scientific experiments using measurements.

In communication between parties, a language is needed as a vehicle for the ideas we want to exchange. When the measurement results are described in such a language, concepts about measurement are needed which are understood in the same way by the communicating parties. Commonly agreed terms in one language are therefore necessary for *labelling* these concepts. In addition, having a set of *internationally*

---

[1] The concept with the associated term 'quantity' is used here in its metrological meaning, not in the meaning 'amount'. An unfortunate language evolution has taken place: the original French term '*quantité*' (meaning 'amount') was borrowed by the English language to mean 'amount'. However, the term which is used in French to mean the things we measure, '*grandeur*' (concentration, volume, time, mass, temperature), had no corresponding term in the English language. Thus, 'quantity' started to be used in English to also be the translation for '*grandeur*'. This is a recipe for confusion. Hence, 'quantity' is a term covering two different concepts in English. This illustrates a potential problem that awaits translators.
In measurement, it would be good to reserve 'quantity' exclusively for the things we measure and not use it (any longer) to mean 'amount'.

0026-1394/08/030335+07$30.00

We have several means available for the communication of measurement results

languages:	languages need tools:
mathematical equations	symbols
pictures	pictograms
sentences	terms

We have to attach the same meaning to the same tools.

Figure 1. Means of communication.

agreed terms in one language is the necessary basis for any translation of these terms and their use in other languages. Consistent terminology is essential for clarity in understanding when speaking to each other as well as in reading and in writing. Conversely, a lack of clarity in our writings is known to affect unwillingly the clarity of our thinking.

We have several means available for communication about measurements and their results: mathematical equations, pictures and sentences. See figure 1. All three need adequate tools to carry out that task: symbols, pictograms and terms. These tools must mean the same thing to all those working in the same or similar field. From these tools, pictures are the most readily understood. Symbols are also understood rather well, especially in mathematics, physics and chemistry. Terms and their relation to well-defined concepts hidden behind them have always been more of a problem. This was recognized at an early stage, and, indeed, some of the oldest commissions of the International Union of Pure and Applied Chemistry (IUPAC) and the International Union of Pure and Applied Physics (IUPAP) aim at a common understanding of symbols (as well as of nomenclature, units and terms):

- the SUNAMCO (Symbols, Units, Nomenclature, and Atomic Mass Committee) of the IUPAP,
- the ICTNS (Interdivisional Committee for Terminology, Nomenclature and Symbols) of the IUPAC.

The basic and general terms for measurement have been systematically addressed in the '*International Vocabulary of Basic and General Terms in Metrology*', in its first edition VIM1[2] [2], in its second edition VIM2 [3] and in its thoroughly revised edition VIM3 [1], henceforth called 'ISO/IEC Guide 99:2007, *International Vocabulary of Metrology—Basic and General Concepts and Associated Terms* (VIM)'. On the global scene at the start of the 21st century, agreement is needed on the definitions of the common concepts (with their associated terms) we use in communicating science and technology worldwide. VIM3 aims at assisting in this task.

'Objects, concepts, designations, and definitions are fundamental to terminology…' [4] and 'concepts are not to be confused with abstract or imagined objects (i.e. we observe concrete, abstract or imagined objects in a given context, conceptualise them in our minds and then attribute a *designation* to the concept rather than to the objects themselves' [4]). The best way to achieve this is to define a concept in an international vocabulary and assign a specific term to each concept. Such an international vocabulary in metrology has been available, in a first edition for 23 years [2] and in a second edition [3] for 13 years. It has been little used in the chemical measurement community at large with the exception of the clinical measurement field (which, in matters of consistent concepts and associated terms, is probably 10–15 years ahead of any other domain in chemistry), as well as in more refined physico-chemical and purely 'metrological' measurement laboratories. They were thought to be applicable only in 'high level metrology' where more significant digits are being pursued in a measurement result in the framework of fundamental research, rather than being pushed by daily practice.

The statement that 'the concept of measurement covers a wide range of activities and purposes' [5] is certainly true in chemistry: many new measurement methods have been developed in the chemical field during the last few decades, and some of them have a profound societal impact, such as advanced biochemical, clinical and DNA measurements. A common vocabulary for all of them is essential for worldwide communication. Such a vocabulary is defined in ISO 1087-1:2000 as a 'terminological dictionary that contains designations and definitions from two or more subject fields' [6].

At the end of the 20th century, several reasons became apparent for a fundamental revision of VIM2:

(a) our thinking about chemical measurement had evolved because of better understanding of the process of measurement; this required the definition of basic and general concepts to be widened to accommodate these improved understandings such as
  - the 'measurement uncertainty' being an intrinsic part of any 'measurement result',
  - 'measurand' is the quantity which we *intend* to measure and
  - there is no such thing as a true value in nature, only—and conventionally—in the concepts developed in our minds to describe nature,

(b) the need for a VIM to fully encompass chemical measurement; VIM1 and VIM2 were mostly written with physics and engineering in mind,

(c) the development in the last 20 years of biochemical measurements and their various applications such as the measurement of 'biological activity' had to be covered by the definitions of basic concepts in measurement,

(d) ISO Guides and Standards were—and still are—not written using a consistent common vocabulary; this requires an up-to-date edition in which chemical measurement is also fully covered,

(e) VIM2 [3] was 'neither fully coherent nor terminologically quite satisfactory' [7],

(f) the publication, after 15 years of work, in 1993/1995 of the ISO *Guide to the Expression of Uncertainty in Measurement* (GUM) [8], initiated by the CIPM; it constituted a fundamental change in the thinking about a

---

[2] VIM is an acronym derived from '*Vocabulaire de Métrologie*', the '*International Vocabulary of Basic and General Concepts in Metrology*'. Both English and French languages are official languages in this matter.

‘measurement result’ and its ‘measurement uncertainty’; this had to be reflected in the definition of the concepts involved; it is to be noted that the GUM is still not fully understood and applied in the chemical measurement community 15 years after its inception[3].

(g) clarity in important documents for global use has become of paramount importance in, for example, settlement of disputes in global trade by the World Trade Organisation (WTO), in the drafting and implementation of European Commission (EC) Directives governing global trade and in mutual acceptability of measurement results across borders in areas such as clinical chemistry, greenhouse gas measurements and in the CIPM Mutual Recognition Arrangements [9].

Thus, the preparation of a third edition (‘VIM3’) was initiated in 1997. It was published in 2007 [1], under the authority of the Joint Committee for Guides in Metrology (JCGM) representing the Bureau International des Poids et Mesures (BIPM), the International Electrotechnical Commission (IEC), the International Federation of Clinical Chemistry (IFCC), the International Laboratory Accreditation Cooperation (ILAC), the International Organisation for Standardization (ISO), the International Union for Pure and Applied Chemistry (IUPAC), the International Union for Pure and Applied Physics (IUPAP) and the Organisation Internationale pour la Métrologie Légale (OIML).

‘Ideally, every term in a vocabulary should designate only one concept, in order to minimize confusion’, but, ‘constructing a single vocabulary of metrology that is able to unambiguously encompass and harmonize all of the approaches is difficult’ [5]. Thus, an ideal vocabulary proved to be elusive, the main reason being that much laboratory jargon has gained so much ‘civil rights’ by frequent usage, that the measurement community wants to find it recognized in a vocabulary to support their position in case they are involved in discussions and settlement of disputes or, simply, to see *their* interpretation and use of terms confirmed, regardless of whether these terms are consistent with each other or not. In VIM3, the consistency between concepts was considered to be of overriding importance, rather than the consecration of jargon into official use, as frequently demanded. Unfortunately, a few exceptions to the rule of consistency had to be made under high pressure from acquired ‘civil rights’ of laboratory jargon.

The clarification given by VIM3 by delivering a more consistent set of concepts will now be illustrated by way of a few examples of revised concept definitions with their associated terms (the labels of concepts).

A central concept in measurement is ‘measurand’. The definition of ‘measurand’ in VIM2 is a ‘particular quantity subject to measurement’ [VIM2, 2.6] [3]. This definition has probably contributed to a paradoxical situation. Chemists can argue that they comply with the definition of ‘measurand’ when they deliver as ‘measurement uncertainty’ of a result of a chemical measurement some form of uncertainty of the electric current measurement of their instrument[4] consisting of a repeatability or a reproducibility statement (or the performance specification by the manufacturer of the instrument), whereas chemical measurements usually have chemical steps involved such as a chemical preparation of the sample prior to the electric measurement. In many cases, these chemical operations have much larger variabilities than the instrumental measurement. Hence, on formal grounds (i.e. the VIM2 definition of the ‘measurand’) the major contribution to the final ‘measurement uncertainty’ of the ‘measurement result,’ i.e. the variability of the chemical operations prior to the electric current measurement, could be ignored. Hence, the definition of ‘measurand’ might have been at the origin of the frequent observation in the past that a pair of measurement results obtained for the same measurand in the same material appear to show differences which are significant, not because they are real, but because the measurement uncertainties of each of the measurement results are underestimated (i.e. the so-called ‘error bars’ indicated are too small) since they reflect only the measurement uncertainty of the electric measurement. See figure 2. The revised VIM3 definition of ‘measurand’ as the ‘quantity intended to be measured’ makes any chemical pre-treatment of the sample carrying the measurand an intrinsic

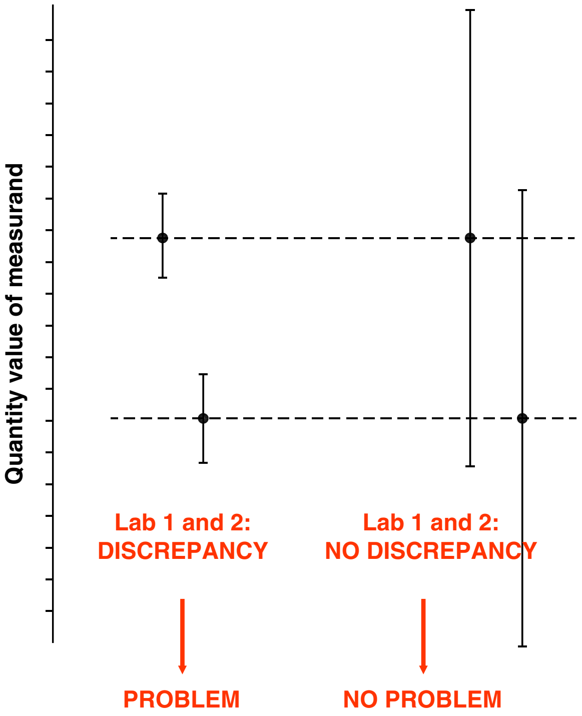

Figure 2. The same measurand in the same sample: discrepancy problems are mostly caused by lack of full (= ‘GUM’) evaluation of measurement uncertainty (not so much by undetected systematic errors).

---

[3] Over the period 1998–2005, I made a systematic sounding in my audiences for lectures and seminars on ‘Metrology in Chemistry’ worldwide. Less than 5% of the attendants in many tens of audiences knew about the existence of a VIM or GUM, let alone used them, with one single exception where the percentage rose to 10% (due to the presence in the audience of . . . historians in chemistry).

[4] Most of the measuring systems of the modern chemist make use of the impressive array of electric measurement instrumentation which measures electric currents after atoms and molecules have been converted into charged particles (ions).

part of the process of measurement. Thus, the variability unavoidably associated with each such chemical operation in the process of measurement becomes an integral part of the final measurement uncertainty of the measurement result.

A further point about the concept 'measurand': it is quite current to use the identification of the analyte (component, chemical compound, such as atoms of Cd or molecules of a dioxin) as 'measurand' whereas in chemical measurement—as in any other measurement—*quantities* are measured; for example, in spectrometric measurements, the quantity 'intended to be measured' is 'concentration' (amount-of-substance per volume, unit: mol/litre) or 'mass fraction' (mass per mass, unit: kg/kg) or content (amount-of-substance per mass, unit: mol/kg) or amount fraction (amount-of-substance per amount-of-substance, unit: mol/mol). The new definition clarifies this by defining measurand as a 'quantity intended to be measured' (VIM3, 2.3) [1].

The new definition also enables us to settle the old—and ongoing—discussion about the uncertainty of sampling being part of the measurement uncertainty: if the measurand is defined before the measurement to be the concentration in the sample submitted, then the sampling of a material is not part of the measurement and therefore cannot contribute to the measurement uncertainty of the measurement result. On the other hand, if the analyst has accepted that a particular measurand is a concentration of a specified chemical compound in, for example, a large geological layer or sediment, a sampling plan will have to be developed by a suitable sampling method. This then becomes a part of the whole process of measurement and the resulting sampling uncertainty will have to be an inherent part of the measurement uncertainty of the final measurement result, consistent with the definition of the measurand.

There has always been a problem with incompletely defined measurands. Another example is the measurement of the amount of, for example, *leachable Cd* in the measurement of a ceramic plate rather than the amount of *total Cd* in the plate. In such a definition, the measurement procedure ('detailed description of a measurement...' [VIM3, 2.6] [1]) describes an empirical procedure suitable for obtaining the intended measurement result. It is of great practical importance for the intended use of the measurement result and has, therefore, to be included in the definition of the measurand. Thus, it is useful to have a concept of measurand which accommodates an operationally defined measurand, i.e. a measurand defined by its very measurement procedure.

A 'measurement' entails the concept of the 'measurement result'. Traditionally, few chemical measurement results encompassed a form of measurement uncertainty, sometimes not at all. The goal and the end of the operation 'measurement' is to make an estimate of a value (or a value range), for a 'measurand', e.g. 'concentration'. This encompasses the *evaluation* of some form of possible error or uncertainty at the end of the operation called 'measurement' and raises the question whether the 'measurement uncertainty' is a part of the 'measurement result'. In the VIM2 definition (VIM2, 3.1) [3], this was not the case, at least not unambiguously. Yet the usefulness of a result or even the ability to compare it with another result or even the fitness for an intended use all depend on the 'measurement uncertainty' of the result. See again figure 2. Whether two results are equivalent to each other, or are simply interchangeable for a specified use, depends, in the first place, on their respective measurement uncertainties, not so much on the magnitude of their quantity values. Thus, a complete (in the GUM sense of the term) measurement uncertainty must be a part of the measurement result, in order for this result to be meaningful. If a definition of the 'measurement result' thus revised is combined with a revised definition of 'measurand' ('quantity intended to be measured') in the case of 'concentration', it again follows that the variability of the chemical operation needed on a chemical sample in order to perform the *intended* measurement ('concentration') becomes a component of the combined measurement uncertainty of the measurement result, notably making it larger. The definition of 'measurand' influences the construction of the measurement budget. In VIM3, 2.9, [1] this is taken care of by defining the measurement result as a 'set of quantity values being attributed to a measurand together with any other available relevant information' accompanied by an explanatory note saying that 'a measurement result is generally expressed as a single measured quantity value and a measurement uncertainty' (VIM3, 2.9] [1].

This change in the definition of the 'measurement result' requires a clearer definition of the 'measurement uncertainty'. The new insight in the 'measurement uncertainty' (GUM) (end of the 20th century thinking), as a measure of doubt [8], is basically different from the older, pre-GUM concept confidence (in a true value/error) accompanied by a confidence level (19th–20th century thinking). The GUM approach to the measurement uncertainty provides a more refined means than the classical approach for describing the perceived quality of a measurement result. Because of this large change in approach, 'there is not always a clear demarcation between approaches, but rather a blending of concepts and terminologies from one new approach to another' [5]. It is worth noting that the measurement uncertainty is first evaluated to identify the potential sources of measurement uncertainties, then calculated by combining the values of the various contributions from all possible measurement uncertainty sources to the full measurement uncertainty budget. This GUM approach fits much better the needs of the chemical measurement through the requirement that the measurement uncertainty be obtained through Type A and Type B evaluations [8]. The GUM evaluation of the measurement uncertainty requires the evaluation of all possible uncertainty sources and recognizes that 'the quality and utility of the uncertainty quoted for the result of a measurement therefore ultimately depends on the understanding, critical analysis, and integrity of those who contribute to the assignment of its value' [8]. The chemical literature is awash with a large variety of 'error' statements, which in most cases are just a measure of the spread of results of replicate measurements, i.e. repeatability or reproducibility, evaluated by Type A evaluation. These are only a part of the full measurement uncertainty budget (A + B). VIM3, 2.9, in its definition of measurement uncertainty [1] contributes to an important clarification of the meaning of all these terms. It is interesting to note that the 'measurement uncertainty' can only be evaluated after the measurement since it is only generated during the very measurement and by the very process of measuring.

Determination of the 'fitness-for-purpose' of a measurement result is a current expression in the chemical literature (in many cases without detailing the purpose). It is useful that this purpose is formulated unambiguously *before* the measurement and that it is *quantified*. One or both are sometimes missing. It is more clarifying to use the expression 'fitness for intended use' as the verb 'intend' thereby enters the description of a property of the measurement result in a similar way as is the case in the definition of 'measurand'.

What is also needed is the concept of 'target measurement uncertainty'. Missing, but required to establish fitness for intended use in VIM1 and VIM2, was the definition of a concept corresponding to a *pre-set* measurement uncertainty, based on grounds which are *external* to the measurement system. For example, a pre-set measurement uncertainty for the measured amount of U or Pu is needed to avoid the possibility that a critical amount of U and Pu (potentially sufficient to make an atomic bomb) is hidden in the measurement uncertainty of the measured U or Pu amount declared to the international nuclear inspectors of the International Atomic Energy Agency.

I therefore coined the concept of 'target for measurement uncertainty' (TMU) in 1976, which was only truly accepted for publication some years later [10–12]. It is a goal for which nuclear measurement laboratories must aim in order to underpin with a sufficiently small uncertainty their declarations of possession of nuclear materials. It is a measurement uncertainty required to be achieved in order to avoid the possibility that a critical amount of nuclear material can be accumulated within a declared measurement uncertainty and could therefore be systematically hidden from the international nuclear material control (by the IAEA).

The comparison of an actually achieved measurement result with a TMU determines the (degree of) quality of the measurement result. Previous VIMs did not contain this concept. In judging a measurement result, or when 'validating' it, the concept 'maximum permissible error' is often used, a concept unclear by itself as no criterion for 'permissible' is usually given. In addition, the use of the term 'error' is ambiguous. Often performance characteristics of a measurement method were used as criteria for deciding the 'fitness-for-purpose', which is a circular reasoning. The formal inclusion of the concept target measurement uncertainty in VIM3, 2.34 [1], settles these ambiguities, especially if combined with a definition of measurand.

Of overriding importance is the concept of 'metrological traceability'. In any measurement, the measurement result must show proof of its scientific authority as opposed to being a mere declaration of an isolated figure. This requires that a 'trace' must be visible between the measurement result up to the definition of a measurement unit (through the realization or embodiment of this unit in a material). Yet, in practical work and in current parlance, a measurement result is often considered as 'traceable' to a measuring system, or to an instrument, or to a process, or to a material (or sample) or to an institute. In measurement, we are interested in the 'traceability' of a measurement result to another value, commonly accepted as *stated reference*, ultimately, but not necessarily, to (the definition of) the chosen measurement unit, e.g. an SI or other unit. In order to distinguish this particular form of traceability from the more general 'traceability', VIM3, 2.41 [1], defines the 'metrological traceability' as a 'property of a measurement result whereby the result can be related to a reference through a documented unbroken chain of calibrations, each contributing to the measurement uncertainty'.

If the measurand in a chemical measurement is defined as a 'particular quantity subject to measurement' [VIM2, 2.6] [3], and that is interpreted as an electric current measurement[4] only, or as a measurement of a ratio of electric currents in the classical sample-to-standard sequence, what is the ultimate 'reference'? Maybe (the definition of) the ampere. With a revised definition of 'measurand as the 'quantity intended to be measured' [VIM3, 2.3] [1] and of the 'measurement result' (encompassing measurement uncertainty) [VIM3, 2.9] [1], the (ultimate) reference for metrological traceability of an 'amount-of-substance concentration' (amount-of-substance per volume) is the definition of the unit mol/L through its *realization* by a 'primary reference measurement procedure' [VIM3, 2.8] [1] (which includes a *primary preparation procedure* as possibility). 'Quantity values' are carried by (or embodied in) references such as a 'calibrator' (a specific form of a 'measurement standard' taking the form of a 'certified reference material' CRM) or they can be produced by a device (e.g. an atomic clock, which is also a CRM) or they can be obtained by using a 'reference measurement procedure' [VIM3, 2.7] [1]. In the latter case, the measurand is operationally defined.

Since 'measurement' requires the choice of a 'measurement standard' or 'calibrator' which—for obvious reasons—is made *before* the actual measurement is started, a (short or longer) 'calibration hierarchy' is thereby conceived and established consisting of by its very nature a reference for the planned calibration. Such a calibration hierarchy can be very short (the end-user's measuring system calibrated by means of a calibrator purchased from a CRM producer) or very long (several consecutive measuring systems with their respective calibrators). This depends on the level in the calibration hierarchy which was designated to be necessary for the intended use of the measurement result. The calibration hierarchy goes down from the chosen reference to the measured quantity value. 'Metrological traceability' (i.e. traceability of a measurement result) goes up from the measured quantity value to the chosen reference. It is the inverse of any chosen 'calibration hierarchy'. The path of the 'metrological traceability' of the 'measurement result' *after* the measurement is the inverse of the calibration hierarchy chosen *before* the measurement is carried out. Hence, a predictable 'metrological traceability

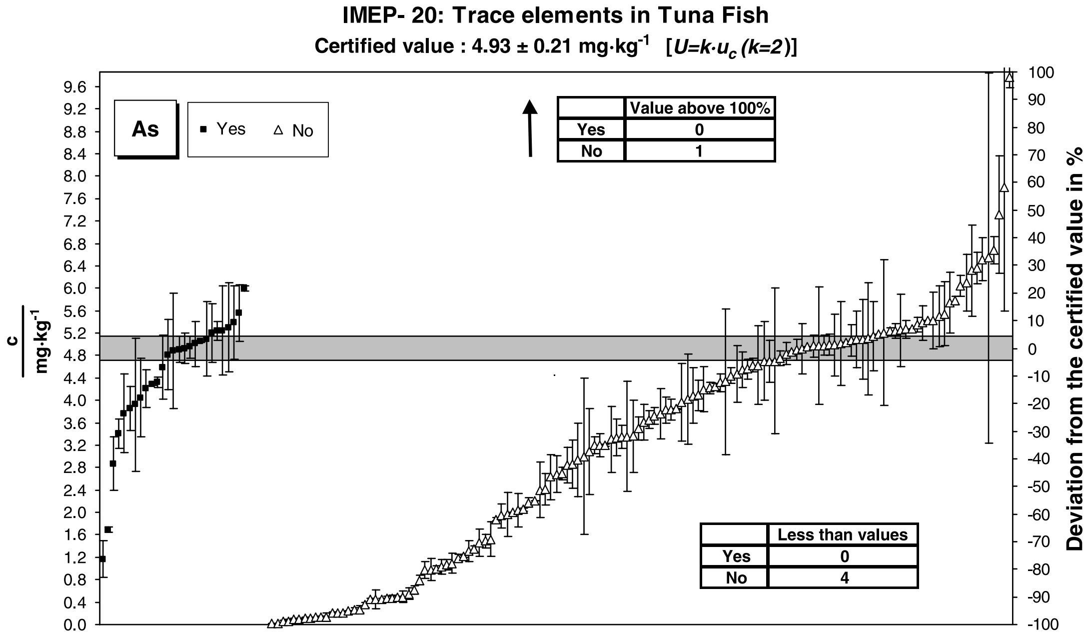

Figure 3. Results from all participants on the use of certified reference materials (CRMs). It cannot be ‘assumed’ automatically that results of chemical measurements are always normally distributed.

chain’ [VIM3, 2.42] [1] *a posteriori* to the measurement is the inverse of a ‘calibration hierarchy’ decided *a priori* to the measurement.

A very useful consequence of ‘metrological traceability’ is ‘comparability of measurement results’. Comparability is directly related to the term comparison. It is useful to remember that *any* measurement is a comparison with a measurement standard and, ultimately, with a measurement unit. Comparability of two measurement results is generated by both results being traceable to the same stated reference, e.g. through a documented unbroken chain of calibrations, to a realization of that unit. Thus, a common reference for the two results is established. A measurement unit[5] is a quantity value fixed and agreed to be the unit on a measurement scale for the same quantity as the measurand and either given the value ‘1’ or, sometimes, another value by common agreement. A simple example is the duration of a fixed number of stated energy transitions in a ^{133}Cs atom, first measured, then fixed by agreement and conveniently named ‘1 second’). In common parlance, comparability is mostly used to indicate that the quantity values are of the same magnitude, a very different meaning. Only one is acceptable on the truly international scene and that must be fixed in a common vocabulary. This is now done and the metrological comparability of measurement results is defined in VIM3, 2.46, as the ‘comparability of measurement results, for quantities of a given kind, that are metrologically traceable to the same reference’ [1]. Two ‘comparable’ values need not be of the same magnitude. The correct translation of the definition of comparability in other languages may be one of the most important and most difficult tasks in the near future.

Further examples of lack of truly international understanding. It is not widely understood that the almost automatic assumption of a ‘normal distribution’ of chemical measurement results is questionable unless proven otherwise since

(a) the number of results is usually too small (well under the 30–50 required as a minimum for the assumption to be fulfilled) and hence unsuitable as the basis for valid conclusions and
(b) they rarely belong to a homogeneous population, a condition for ‘normal distribution’, as is the case, e.g. in so-called interlaboratory comparisons, where they are usually obtained by different measurement methods and/or different measurement techniques and/or different operators yielding numerous documented cases where the distribution around a ‘reference value’ does not seem normal; see figure 3 [13], IMEP-20; the applicability of the concept ‘normal distribution’ to chemical measurement results must be clearly understood worldwide in the same way; also the question must be asked whether it is indicated or even permissible to automatically assume the normal distribution of chemical measurement results when no time or money is available to perform a large enough number of measurements or to perform them by the same measurement method, technique or operator.

2. The translation problem

Correct translation is known to be very difficult. It is even doubted whether it can be done exactly. In any language, each term covers a ‘field’, resulting from its history and the context in which it is used. It follows that a common concept must be truly internationally understood—and a common definition of

---

[5] A unit is mostly—and by convention—given the value 1, but other values for a unit can be *defined*.

that concept truly internationally accepted—before any valid translation of a term can be attempted, as this must be based on a truly common understanding of the underlying concept. With VIM3, the possibility of such a translation will become a reality for chemical measurements as soon as VIM3 is freely available on the website of BIPM (agreed at the Joint Committee for Guides in Metrology, JCGM, chaired by the director of BIPM (it is already available for sale as hard copy from the website of ISO, Geneva)).

The use of VIM3 should go further. There is a need to implement a commonly agreed metrological language in ISO Guides and Standards, ILAC Multilateral Agreements within ILAC, Mutual Recognition Arrangements under CIPM and its Consultative Committees, EC Directives, WTO documents and probably many others. This would ensure consistency and compliance worldwide with common truly internationally understood concepts and associated internationally agreed terms in one language, presumably English. Only then can consistent and compliant translations be made in other languages. The VIM3 makes this now also possible for chemical measurement results.

3. Conclusions

On the global scene, clear border-crossing agreements are needed. Such agreements can only last if they are based on common understanding. Good understanding can only be based on clarity in the communication tools used. Proper communication presupposes commonly understood concepts with associated terms. Common and truly internationally understood concepts and associated terms are the necessary tools in languages where measurements are involved. Unambiguous terms describing concepts are needed in at least one language in order to achieve coherence and clarity before the needed translation into other languages is meaningful.

References

[1] BIPM, IEC, IFCC, ILAC, ISO, IUPAC, IUPAP and OIML 2007 *International Vocabulary of Metrology—Basic and General Concepts and Associated Terms (VIM)* ISO/IEC Guide 99:2007 (Geneva: ISO)

[2] BIPM, IEC, IFCC, ISO, IUPAC, IUPAP and OIML 1987 *International Vocabulary of Basic and General Terms in Metrology* (Geneva: ISO) (1983, amended)

[3] BIPM, IEC, IFCC, ISO, IUPAC, IUPAP and OIML 1993 *International Vocabulary of Basic and General Terms in Metrology* 2nd edn (Geneva: ISO)

[4] ISO/DIS 704 1999 *Terminology Work—Principles and Methods* ISO/TC 37/SC 1 (Geneva: ISO)

[5] Ehrlich C, Dybkaer R and Woeger W 2007 Evolution of philosophy and description of measurement result (preliminary rationale for VIM3) *Accred. Qual. Assur.* **12** 201–18 *presented at NCSLI (National Conf. of Standards Laboratories Int.) Symp. (Nashville, TN, USA, August 2006)*

[6] ISO 1087-1:2000 *Terminology Work – Vocabulary, Part 1: Theory and Application* (Geneva: ISO)

[7] Dybkaer R 2004 *An Ontology on Property for Physical, Chemical and Biological Systems* (*APMS Suppl. No* 117) vol 112 p 17

[8] BIPM, IEC, IFCC, ISO, IUPAC, IUPAP and OIML 1993/1995 *Guide to the Expression of Uncertainty in Measurement (GUM)* (Geneva: International Organization for Standardization)

[9] CIPM and BIPM 1999 *Mutual Recognition Arrangements* www.bipm.org

[10] De Bièvre P *et al* 1987, 1987 Target Values for uncertainty components in fissile isotope and element assay *Proc. IAEA Symp. Nucl. Safeguards Technol. (Wien, 1986)* pp 649–62

[11] Deron S *et al* 1994, 1993 International Target Values for uncertainty components in measurements of nuclear materials for Safeguards purposes *ESARDA Bulletin* 23 (Joint Research Centre ISPRA)

[12] Kuhn E *et al* 1994, 1993 International Target Values for uncertainty components in fissile isotope and element assay for the effective safeguarding of nuclear materials *IAEA STR-294 (Wien)*

[13] http://www.imep.ws