Accured Qual Assur (2000) 5:441–445

GENERAL PAPER

Adolf Zschunke

The role of reference materials

Received: 17 March 2000
Accepted: 15 August 2000

Presented at 3rd EURACHEM Workshop "Status of Traceability in Chemical Measurement", 6–8 September 1999, Bratislava, Slovak Republic

A. Zschunke
Bundesanstalt für Materialforschung und -prüfung (BAM),
Richard-Willstätter-Strasse 11,
12489 Berlin, Germany
e-mail: adolf.zschunke@bam.de
Tel.: +49-30-81 04 58 00
Fax: +49-30-81 04 59 72

Abstract In this article the role of reference materials is confined to chemical measurements only. Recognized reference materials are one of the tools to obtain comparability of analytical results. Recognition demands confidence in the reference materials and in the reference material producers. A reference material producer is a technical competent body that is fully responsible for the certified or other property values of the reference material. The "analyte" has to be specified in relation to the selectivity of analytical procedure. The full range of reference materials can be presented as a three-dimensional space of the coordinates: analyte, matrix and application. If reference materials are used for calibration or correction of calibrations they establish the traceability of results of chemical measurements. The traceability is only valid within a stated range of uncertainty. Pure substances can represent the unit of amount of substance. A precondition is the microscale specification of the analyte and the accurate determination of the main component and/or the impurities.

Key words Reference materials · Traceability · Chemical identification · Amount of substance

Introduction

A role is an acting part in a play which consists of teamwork with other actors. Similarly, the role of reference materials in chemical measurements is important but should be described in context with uncertainty, traceability, comparability.

Chemical measurements are a special part of the scientific discipline "Analytical Chemistry". They are also applied in many other testing fields and other scientific disciplines, such as biology, physics and medicine. The results of chemical measurements become more and more important for decisions in economy, trade, science, medical care, environmental protection, consumer protection, sports, jurisdiction and politics. Comparability is needed on different levels, beginning at the laboratory and ending in a global exchange of analytical results.

Global comparability of analytical results

More and more decisions based on chemical measurement are having global effects. Reference materials are important tools to obtain global comparability of results of chemical measurement. However, the use of validated analytical methods and the proof of personal skills by proficiency testing are other tools of the same rank (Fig. 1) [1].

A prerequisite for global comparability is the mutual recognition of reference materials provided in different countries. Reference materials have to fulfill certain requirements to become accepted (Fig. 2).

Certification of reference materials according to the requirements of ISO Guides 34 and 35 [2] or Bureau Communautaire de Reference (BCR) guidelines [3] is an important mean to establish international acceptance. The certificate has to prove the traceability as an

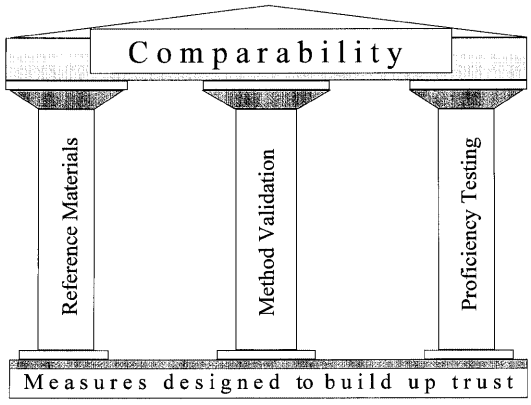

Fig. 1 Components of comparability

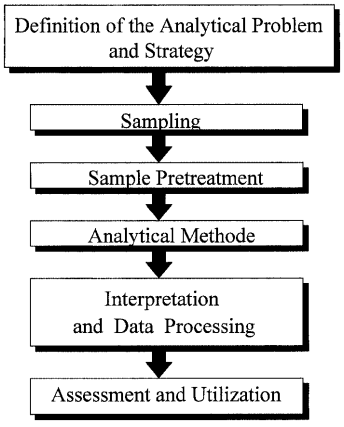

Fig. 3 Steps of analytical procedure

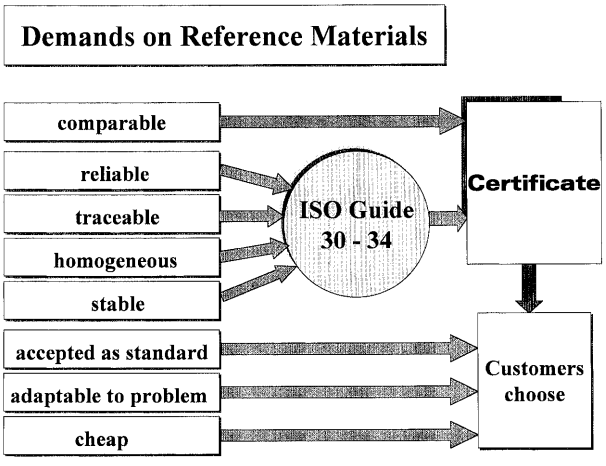

Fig. 2 Requirements of reference materials

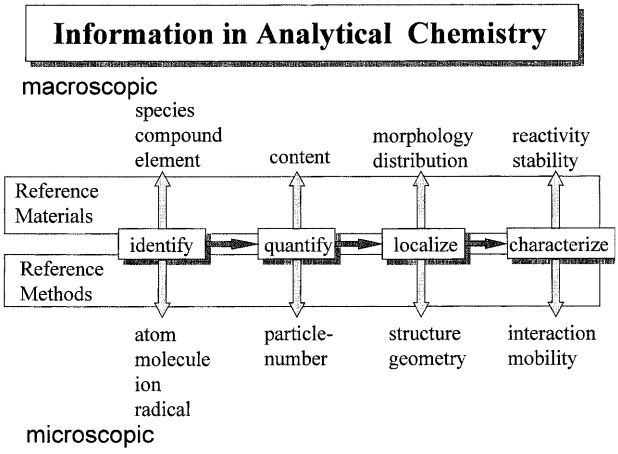

Fig. 4 Information gain in analytical chemistry

additional authorization. Another aspect of international recognition is the creation of confidence in reference materials by third-party assessment of the producer (bodies who are responsible for preparation, homogeneity and stability assessment, testing, assignment of property values and their uncertainties, packing, labelling and distribution of a reference material). The International Laboratory Accreditation Co-operation (ILAC) [4] is preparing a worldwide system of third-party assessment of reference materials producers in co-operation with ISO-REMCO, EURACHEM, EUROLAB and EA.

Range of reference materials

The term chemical measurement emphasizes the measuring aspect of chemical analysis. However, chemical measurements are always embedded in an analytical step by step procedure, which also has to consider many chemical problems (reactivity, chemical equilibrium, etc.) (Fig 3).

Reference materials often allow the assessment of the whole analytical procedure. Analytical chemistry can be defined as a scientific discipline which develops and applies methods, instruments and strategies to obtain information on the composition and nature of matter in space and time [5]. During the course of this information gain special entities are determined on a macroscopic or microscopic scale.

The term chemical measurement can cover all these determinations, including identification [6]. Identification defines the so called "analyte" by means of chemical, electrochemical, spectroscopical and other physical properties. In most cases identification is done by measurements. Identification is valid only in a reference system. The terms describing the analytical problem (see Fig. 4), the measuring system used, the reference methods and the reference materials, belong together as the reference system.

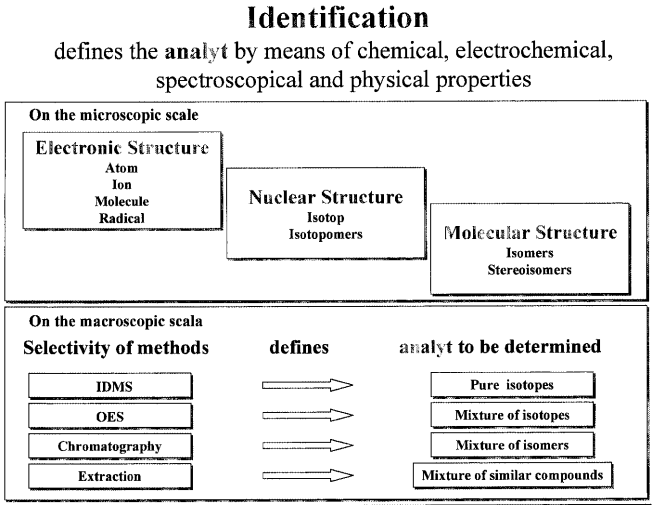

Fig. 5 Identification on the microscopic and macroscopic scale

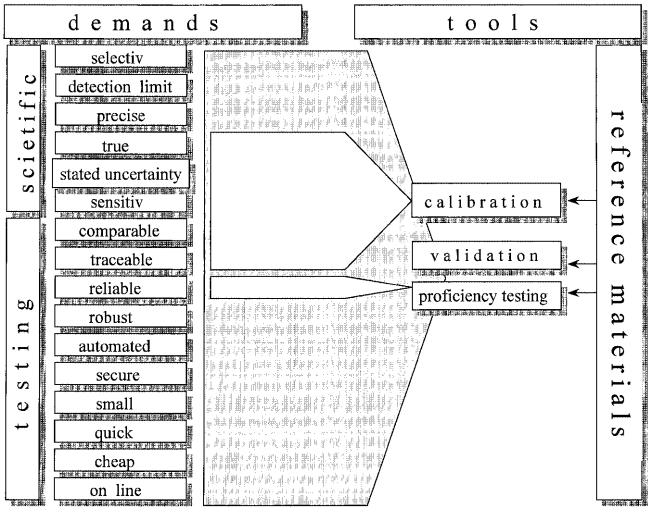

Fig. 6 Demand of customers on analytical chemistry

On the microscopic scale, the identity can be defined by considering the electronic, nuclear and molecular structures (Fig. 5).

On the macroscopic scale, in most cases, only groups of identities can be identified (isotope mixtures, isotopomer mixtures, stereoisomer mixtures). The definition of the "analyte" depends on the selectivity of the analytical method including sample pretreatment, e.g. extraction (see Fig. 3). In a complex composition sometimes only classes of compounds (e.g. fat, polycyclic aromatic hydrocarbons) are identified. In these cases the analyte is designated as a sum parameter.

All quantities and properties on the macroscopic scale of analytical chemistry can be represented by standards. In many cases the standards are divisible without changing the properties. Then they are called reference materials. Reference materials can be:

- Pure chemical substances
- Blends or synthetic mixtures
- Simulates or artifacts
- Spiked and unspiked real life samples

The range of reference materials covers a three-dimensional space of co-ordinates:

- Analytes
- Matrices
- Applications

Systems of classification very often follow the application fields, e.g. the catalogues of the Institute for Reference Materials and Measurements (IRMM), the National Institute for Standards and Technology (NIST), Laboratory of the Government Chemist (LGC), etc. or the database for certified reference materials COMAR. In all application fields like food and agriculture, environment, health and safety, industry and services, etc., reference materials are used for:

- Calibration of measuring systems
- Assessment of analytical procedures
- Performance test of instruments
- Definition of measurement scales
- Interlaboratory comparisons
- Qualitative analysis.

The selection of a suitable reference material is determined by the following viewpoints:

- The analytical task, considering the reference systems
- The definition of "analytes", considering the analytical procedure
- The intended use.

The demands on analytical chemistry differ to some extend depending on whether they come from purely scientific sources or arise in the field of testing. In the latter case the customer defines the demand. Fitness for purpose determines the quality of the reference material. The gathered demands (see Fig. 6) have partly overlapping meanings and are not independent of each other. Other reference materials have to meet all demands.

Reference materials as the base of traceability

If reference materials are used for calibration or correction of calibration they establish traceability of chemical measurements. Traceability is the link or the "vertical comparison" between an analytical result and a national or international accepted standard, preferable a realization of the SI unit (see Fig. 7).

The certificate of a reference material is only proof of traceability if the certified values are accompanied by uncertainties. The certified reference material

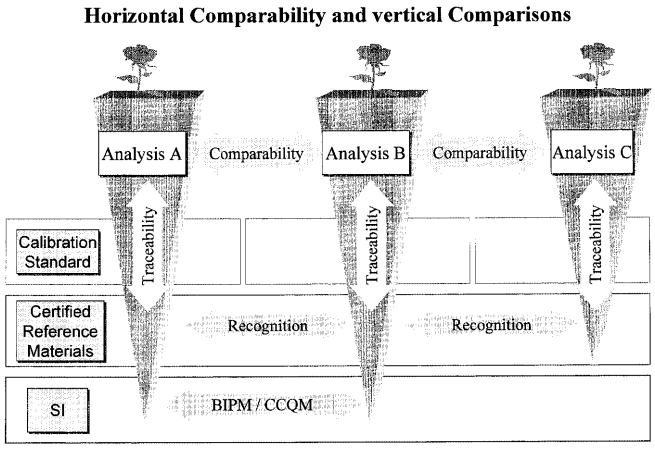

Fig. 7 Horizontal comparability and vertical comparisons

should be the end-point of the traceability chain for the user.

The producer (certifier) of certified reference materials is responsible for the link to the SI or, if this is not possible, for mutual recognition of the reference materials within the respective sphere of validity. For global comparability a global recognition is needed.

Traceability has an additional confidence building aspect: traceability is the proof of trueness and the proof of the reliability of an analytical result. Traceability is only valid in connection with an uncertainty range. Every reference material has to be traceable to a stated reference independent of the intended use. But use defines the needed uncertainty range.

Representation of the unit amount of substance

If the reference materials are pure substances and can be specified on the microscopic level, then they represent the unit amount of substance. Because there are no absolute pure substances the representation is in all cases an approximation. The degree of approximation is given by the accuracy of the contents of the main component. In case of pure elements, e.g. metals Fe, Cu, Zn the determination of the main component by coulometry is limited by an uncertainty of 0.01%. The determination of all impurities needs completeness and requires a great deal of analytical equipment. However, a combination of inductively coupled plasma-mass spectrometry (ICP-MS), atomic absorption spectrometry (AAS) and isotope dilution mass spectrometry (ID-MS) covering all elements of the periodic table allows a decrease of total uncertainty to 0.0032% (Cu, see Fig. 8).

Many elements are specified on the isotopic level because the natural isotopic ratio is well known. The best characterized pure element is the best approximation of the unit.

In the case of pure compounds, the specification can become a problem when isotopomers, stereoisomers and other species are possible. Because of its structural

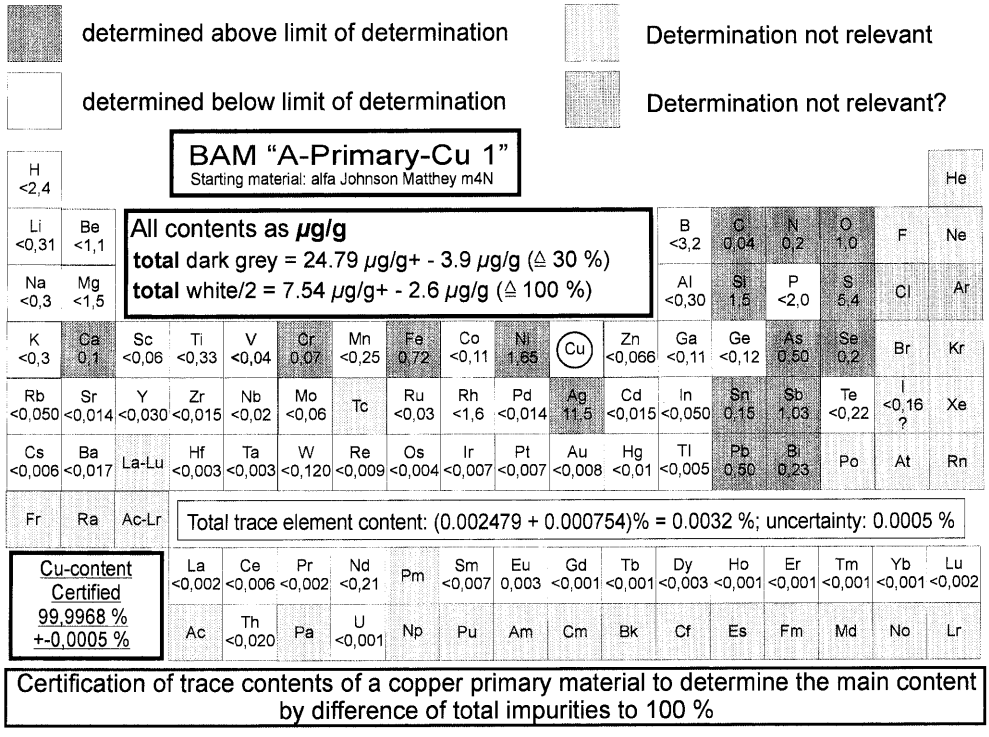

Fig. 8 Multielement characterization of m4 N copper

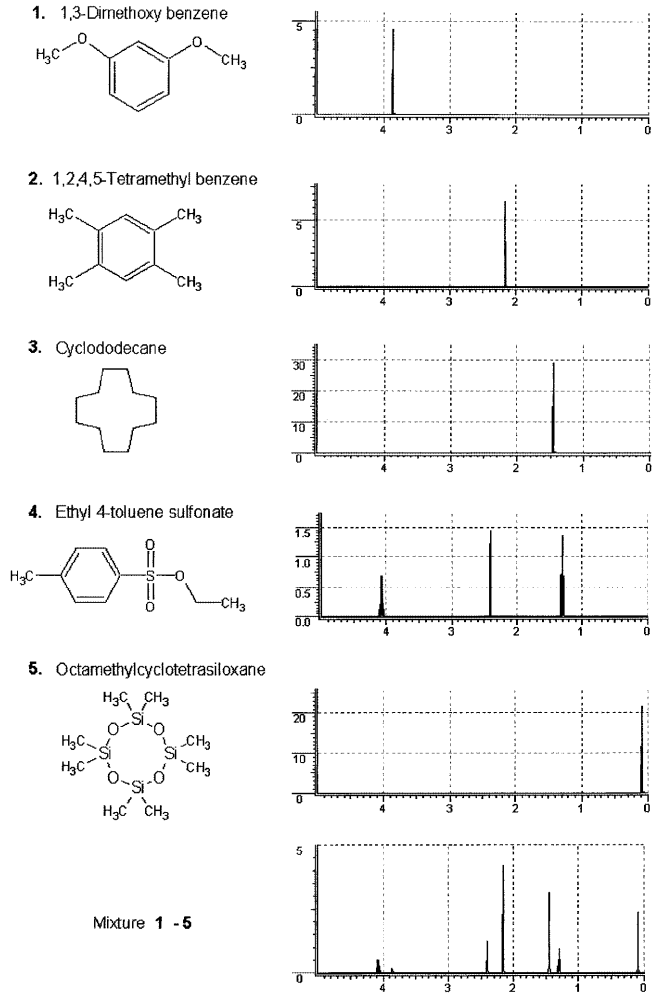

Fig. 9 Composition of organic compounds for a quantitative nuclear magnetic resonance comparison experiment

and isotopic selectivity nuclear magnetic resonance (NMR) spectroscopy is the most promising method to characterize representations of amount of substance. The high isotopic and structural selectivity of NMR spectroscopy is supplemented by the primary character of the quantification.

In the NMR spectrum integrated signals are exactly proportional to the number of contributing nuclei. The Comité Consultatif pour la Quantité de Matière (CCQM) has started international comparison of quantitative NMR experiments. In the first round the possible reproducibility should be established. The composition of a mixture of organic compounds has been determined by integration of the NMR signals. Already the first experiments (Fig. 9) have shown the problems arising by isomerization (ethyl-4-toluene sulphonate), decomposition (1,3-dimethoxybenzene), purity of standard compound and superimposition of isotopic satellites. Additional experiments with a new composition are necessary.

References

1. Zschunke A (1998) Accred Qual Assur 3:393 – 397
2. ISO Guide 34 (1996) Quality system guidelines for the production of reference materials; ISO Guide 35 (1989) Certification of reference materials – general and statistical principles. ISO, Geneva
3. European Commission Doc BCR /48/ 93 (1993) Guidelines for the production and certification of BCR reference materials. European Commission, Brussels
4. ILAC-G12:2000 (2000) Guidelines for the requirements for the competence of reference material producers. International Laboratory Accreditation Cooperation (ILAC see www.ilac.org)
5. IUPAC, Analytical Chemistry Division (1999) Division's aims; http://www.iupac.org/divisions/V/index.html
6. Karpov YA (1999) Accred Qual Assur 4:174 – 176
7. De Bièvre P, Taylor PDP (1997) Metrologia 34:67–75