# Traceability and uncertainty of qualitative analysis results

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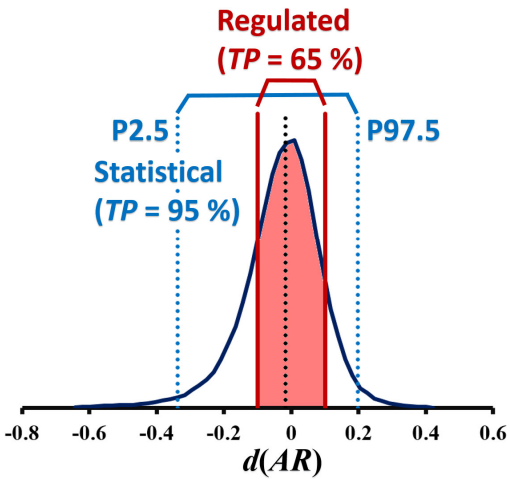


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## Outline

1. Qualitative analyses specificities
2. Qualitative analysis traceability
3. Qualitative analysis uncertainty
4. Eurachem/CITAC Guide
5. Final remarks

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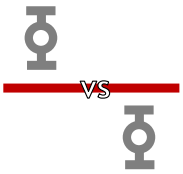
## 1. Qualitative analyses specificities

**The chemical characterization of an item can involve:**

- **the quantification of a chemical parameter (measurement[1])**
- **the determination of a qualitative property (examination[1,2])**
  - **Compliance/non-compliance with a quantitative limit**
  - **Presence/absence of a property**





1 - JCGM 200, International Vocabulary of Metrology - Basic and General Concepts and Associated Terms (VIM 3rd edition), BIPM, 2012.
2 - G. Nordin, R. Dybkaer, U. Forsum, X. Fuentes-Arderiu, F. Pontet, Vocabulary on nominal property, examination, and related concepts for clinical laboratory sciences (IFCC-IUPAC Recommendations 2017), Pure Appl. Chem. 90 (2018) 913-935.

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## 1. Qualitative analyses specificities

**Quantitative parameter:**

- **Measurement[1]:**

**2.41** (6.10)
**metrological traceability**
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**

→ Define the reference for the measurement

**2.26** (3.9)
**measurement uncertainty**
uncertainty of measurement
uncertainty
non-negative parameter characterizing the dispersion of the **quantity values** being attributed to a **measurand**, based on the information used

→ Quantify measurement quality *(confidence interval for the measurand)*

1 - JCGM 200, International Vocabulary of Metrology - Basic and General Concepts and Associated Terms (VIM 3rd edition), BIPM, 2012.

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## 1. Qualitative analyses specificities

**Qualitative parameter:**

- **Examination[2]:**

**3.21 examination traceability** → Define the reference for the examination

property of an *examination result* (3.4) whereby it can be related to a reference through a documented unbroken chain of *examination calibrations* (4.3), each contributing to the *examination uncertainty* (3.9)

**3.9 examination uncertainty** → Quantify examination quality *(probability of result being correct)*

fraction of *examined values* (3.5) that is different from a *reference nominal property value* (3.3) among all the examined values provided

2 - G. Nordin, R. Dybkaer, U. Forsum, X. Fuentes-Arderiu, F. Pontet, Vocabulary on nominal property, examination, and related concepts for clinical laboratory sciences (IFCC-IUPAC Recommendations 2017), Pure Appl. Chem. 90 (2018) 913-935.

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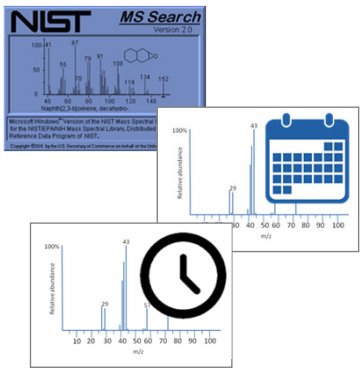
## 2. Qualitative analysis traceability

**Example of references types:**

**The identification of trace levels of compounds can be performed by GC-MS using:**

- **Ref. 1: Mass spectrum obtained on other equipment and ionization conditions**
- **Ref. 2: Mass spectrum obtained in the used equipment in another day**
- **Ref. 3: Mass spectrum obtained immediately before sample analysis**

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## 2. Qualitative analysis traceability

**The reference for a nominal property is also a nominal property:**

**Ref. 1: Result is traceable to mass spectrum X of the library Y**

**Ref. 2: Result is traceable to mass spectrum X obtained from reference substance Y in conditions A and day B**

**Ref. 3: Result is traceable to mass spectrum X obtained from reference substance Y in equivalent conditions.**

**Mass spectra collection conditions and used reference substance must be described with adequate detail.**

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## 3. Qualitative analysis uncertainty

**The most trivial way of reporting qualitative analysis uncertainty:**

**Positive result:**

- **True positive result rate (*TP*)**
- **False positive result rate (*FP*)**

**Negative result:**

- **True negative result rate (*TN*)**
- **False negative result rate (*FN*)**

$$TP + FN = 1$$

$$TN + FP = 1$$

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## 3. Qualitative analysis uncertainty

The most trivial way of reporting qualitative analysis uncertainty:
**These metrics can be combined in likelihood ratios, *LR*:**

**Positive result:**

- True positive result rate (*TP*)
- False positive result rate (*FP*)

$$LR(+) = \frac{TP}{FP}$$

**Negative result:**

- True negative result rate (*TN*)
- False negative result rate (*FN*)

$$LR(-) = \frac{TN}{FN}$$

***Express method performance***

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## 3. Qualitative analysis uncertainty

**ENFSI defined verbal equivalents to *LR*(+) values to make the reporting of evidence strength easier [3].**

| Likelihood ratio | Verbal equivalent |
|---|---|
| 1 | Findings do not support one proposition over the other |
| 2 - 10 | Weak support for the first proposition relative to the alternative |
| 10 - 100 | Moderate support (…) |
| 100 - 1000 | Moderately strong support (…) |
| 1000 - 10 000 | Strong support (…) |
| 10 000 - 1 000 000 | Very strong support (…) |
| > 1 000 000 | Extremely strong support (…) |

3 - European Network of Forensic Science Institutes, ENFSI Guideline for evaluative reporting in forensic science, ENFSI, 2015.

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## 3. Qualitative analysis uncertainty

**(…) if it is known the prevalence of positive cases, *P*(+):**

**Prevalence of cocaine doping in elite athletes of 0.1% estimated between 2000 and 2009.**

4 - S. Rossi and F. Botrè, J Sports Sci . 29 (2011) 471-476.

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## 3. Qualitative analysis uncertainty

**(…) if it is known the prevalence of positive cases, *P*(+):**

**The probability of a positive result being correct, *P*, can be estimated [5,6]:**

$$P = \frac{\frac{P(+)}{1-P(+)} LR(+)}{\frac{P(+)}{1-P(+)} LR(+) + 1}$$

***Express analysed item characteristics***

**In many cases, it is difficult to have sound estimates of *P*(+).**

5 - S. L. R. Ellison, S. Gregory, W. A. Hardcastle, Analyst 123 (1998) 1155-1161.
6 - R. B. Silva, Talanta 150 (2016) 553-567.

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## 3. Qualitative analysis uncertainty

**Performance determination:**

**When identification criteria are probabilistic, the confidence level, *cl*, defines the *TP* (e.g. retention time confidence interval for 95% *cl*):**

$$TP = cl$$

**If *FP* is estimated experimentally, many analyses of negative cases need to be performed.**

**About 1000 tests must be performed for a reliable estimate of an *FP* = 1 %.**

7 - Eurachem/CITAC Guide: Assessment of performance and uncertainty in qualitative chemical analysis. First Edition, Eurachem, 2021.

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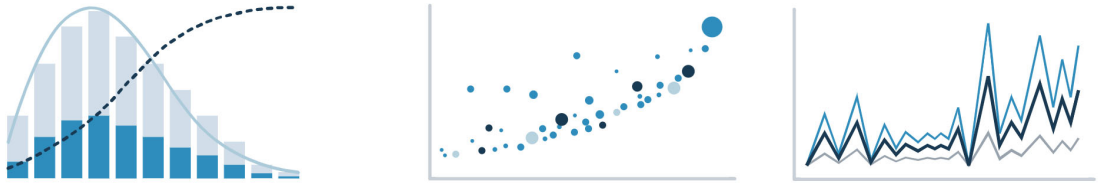
## 3. Qualitative analysis uncertainty

**Alternative to the experimental determination of *FP*:**

- **Data simulation**



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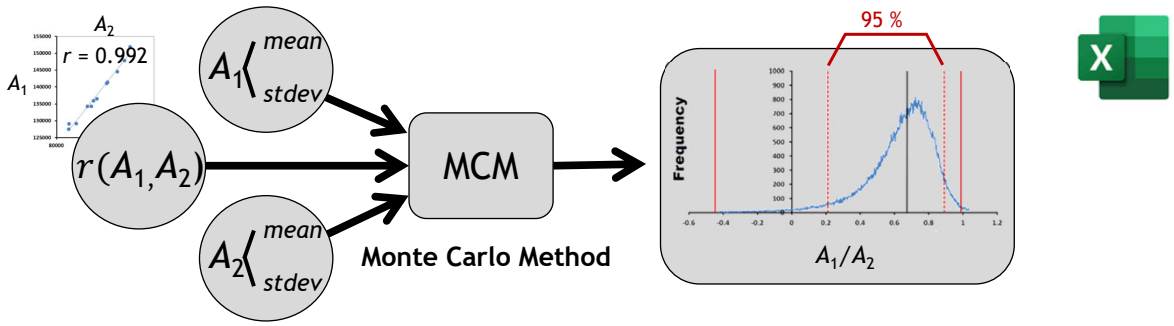
## 3. Qualitative analysis uncertainty

**Example A1: Simulation of identification criteria (*TP*)**

- **Criteria for identification by mass spectrometry:**

**The ratio of characteristic ion abundances of a mass spectra has an asymmetric distribution[6,8] (…)**




6 - R. B. Silva, Talanta 150 (2016) 553-567.
8 - J. Narciso, S. Luz, R. B. Silva, Anal. Chemi. 91 (2019) 6638-6644.

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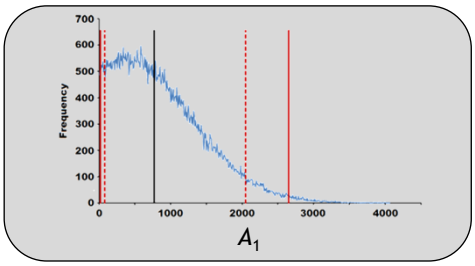
## 3. Qualitative analysis uncertainty

**Example A2: *FP* simulation**

**The simulation of blank signals (i.e. negative cases) by taking the mean and standard deviation of the signal noise truncated below zero: (…)**




**(…) allow estimating the change of signal noise producing a false positive (…)**

6 - R. B. Silva, Talanta 150 (2016) 553-567.
8 - J. Narciso, S. Luz, R. B. Silva, Anal. Chemi. 91 (2019) 6638-6644.

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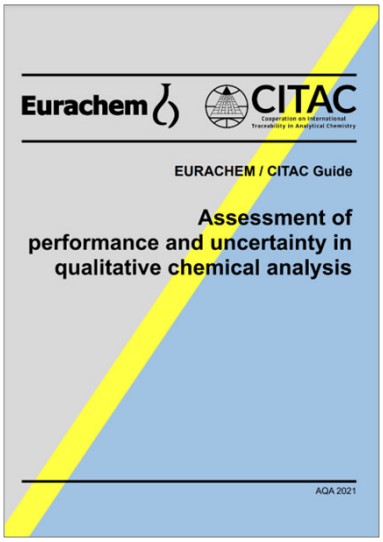
## 4. Eurachem/CITAC Guide




| | | | |
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7 - Eurachem/CITAC Guide: Assessment of performance and uncertainty in qualitative chemical analysis. First Edition, Eurachem, 2021.

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## 4. Eurachem/CITAC Guide


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**7 - Eurachem/CITAC Guide: Assessment of performance and uncertainty in qualitative chemical analysis. First Edition, Eurachem, 2021.**

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## 5. Final remarks

- **The performance of qualitative analyses should be monitored**
- **Qualitative analyses should be based on adequate references**
- **If sound estimates of false results rates are available, it is useful to report qualitative analysis results with uncertainty**

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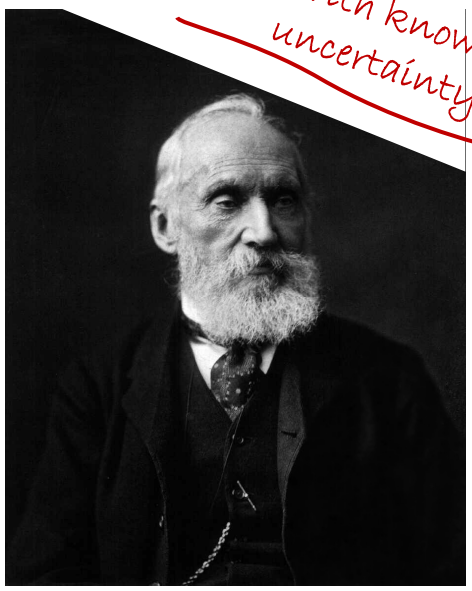

With known uncertainty

To measure or to examine
is to know.
If you can not or to examine
measure it,
you can not
improve it.

- Lord Kelvin -

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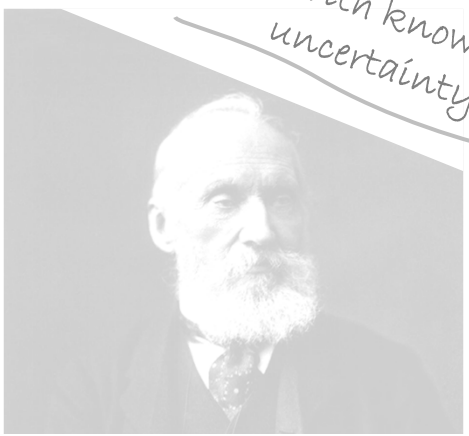

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Thank you for your attention!

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