Estimating measurement uncertainty in chemical measurements: difficulties and misconceptions

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https://analytical.chem.ut.ee/poznan-2026/

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Outline

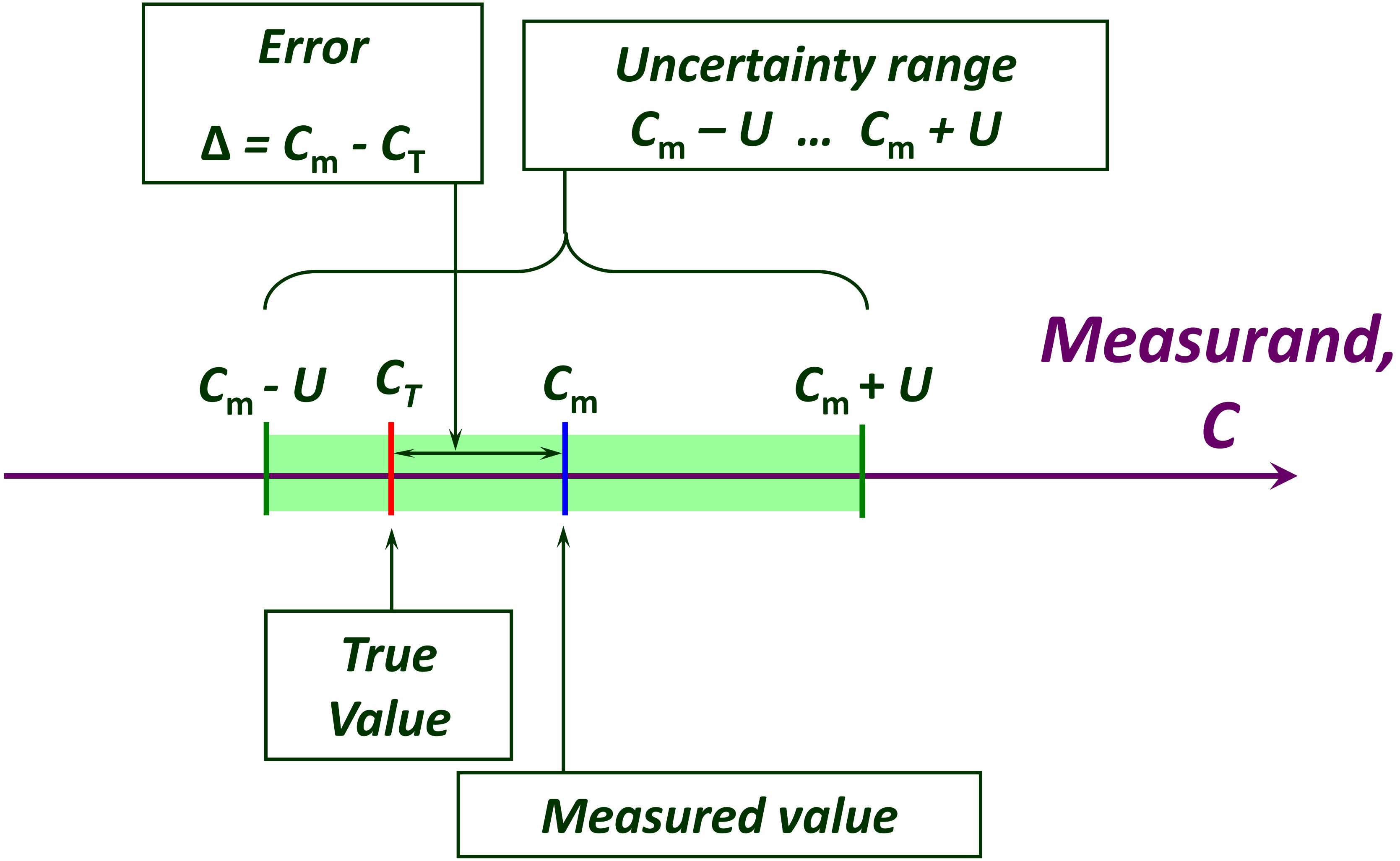
- **Main concepts**
  - What is measurement uncertainty
- **Difficulties**
  - in estimating uncertainty of chemical measurements
- **Some misconceptions**
  - leading to underestimating measurement uncertainty
- **A pragmatic approach**
  - for estimating uncertainty of chemical measurements

Materials:

https://analytical.chem.ut.ee/poznan-2026/

In many cases I generalise and simplify

What are error and uncertainty?



Simplified definitions:

Error is the difference between the measured value (C_m) and the true value (C_T)

Uncertainty (U) is the half-width of a range around measured value (C_m) within which the true (C_T) value lies with a high probability

The probability is called **coverage probability**

What influences measurement result?

Random effects

Influence on measurement result:

- Cause **scatter**
  - in random direction
  - with random magnitude

Examples?

Systematic effects

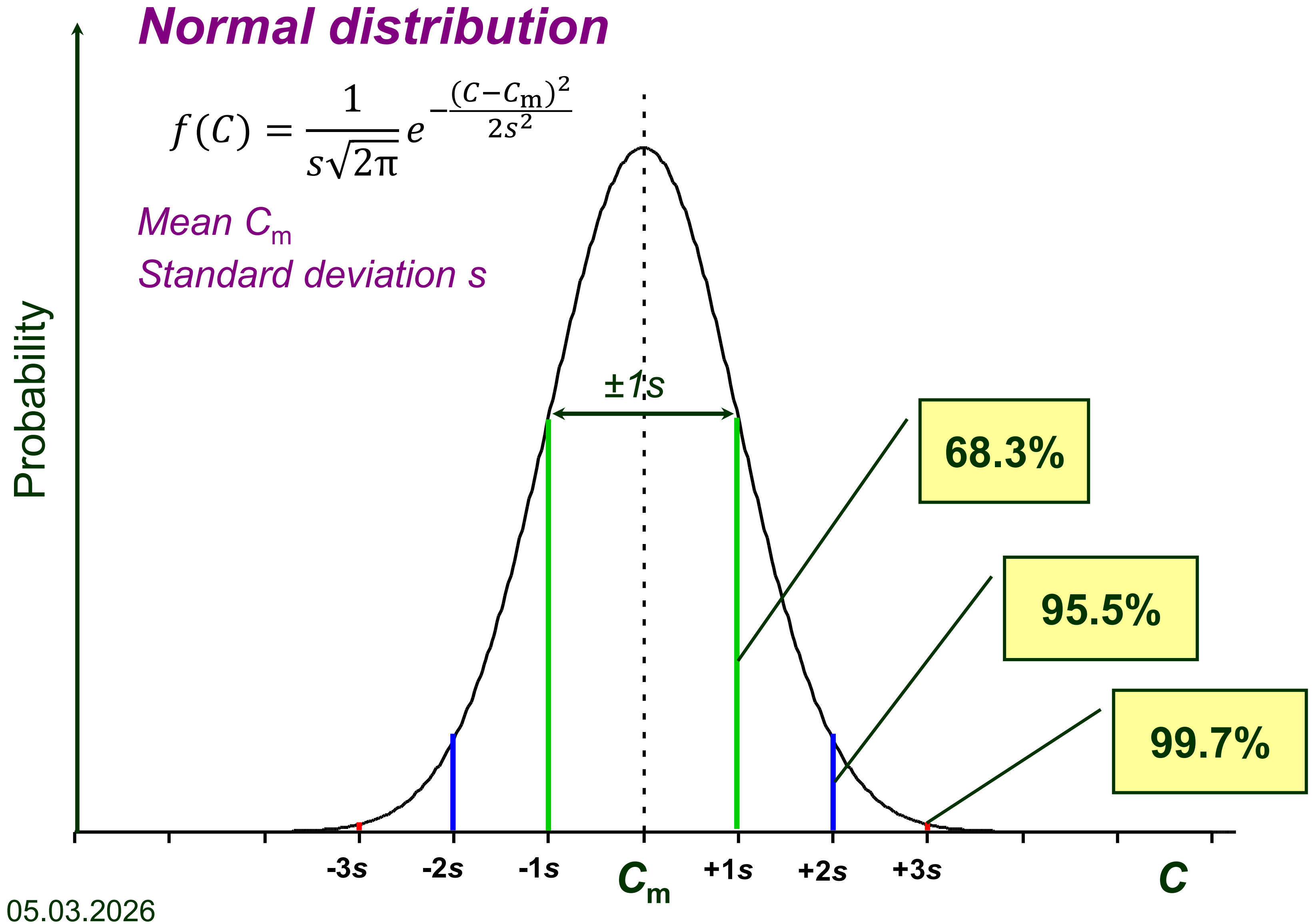
Influence on measurement result:

- Cause **bias**
  - in the same direction
  - with constant (or proportional) magnitude

Examples?

Collectively: **Uncertainty sources**

What about the probability?



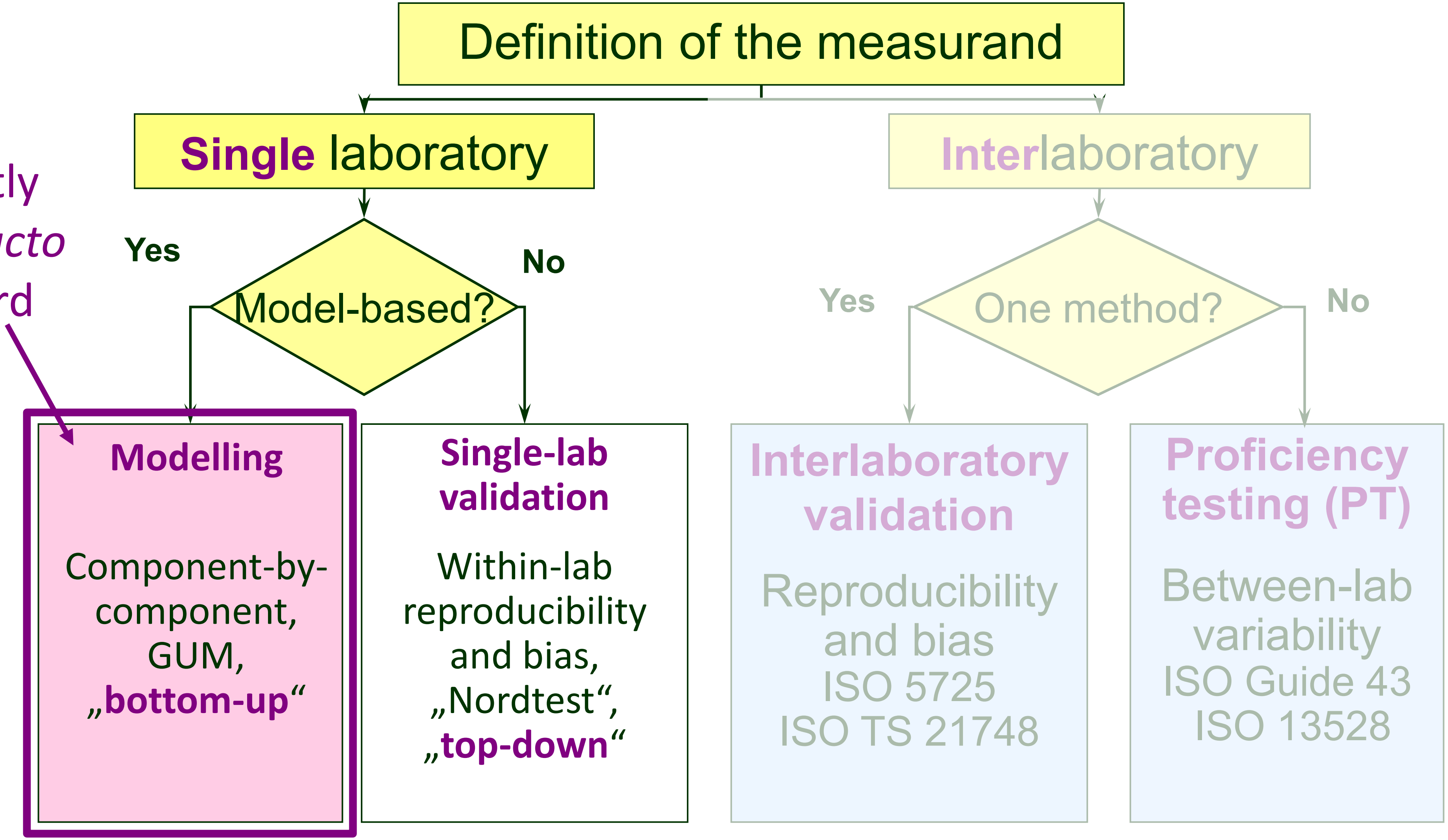
Simplified definitions:

Standard uncertainty (u, u_c): uncertainty expressed as standard deviation, i.e. with coverage proability ≈68%

Expanded uncertainty (at k = 2 level) (U): uncertainty with coverage proability ≈95%

$U = k \cdot u_\mathrm{c}$

Uncertainty estimations approaches



Definition of the measurand

Single laboratory

Model-based?

Yes

No

Modelling

Component-by-component, GUM, „**bottom-up**“

Single-lab validation

Within-lab reproducibility and bias, „Nordtest“, „**top-down**“

Interlaboratory

One method?

Yes

No

Interlaboratory validation

Reproducibility and bias
ISO 5725
ISO TS 21748

Proficiency testing (PT)

Between-lab variability
ISO Guide 43
ISO 13528

Currently the *de facto* standard

Eurolab Technical Report No 1/2007 Available from: http://www.eurolab.org/

Challenges with Chemical Measurements

- Often **not readily modeled**
  - E.g. complex sample preparation
- Uncertainty contributions not readily **quantified**
  - Analyte losses during **sample preparation**
  - Interferences from other components of the sample
  - Contamination
  - Sample carryover
- Significant time and effort is often needed

Quantification is often the most difficult thing with chemical analysis!

Danger to underestimate uncertainty!

Misconception 1

Misconception 1

Uncertainty is primarily determined by the accuracy of the instrument

Misconception 1

Gravimetry

- "Normal" uncertainty of weighing with a 0.0001g balance is 0.0003 .. 0.0005 g ($k = 2$)
- This holds only for **"well-behaving" objects**!
- **Does not** hold, if:
  - The object is hygroscopic
  - If there is electrostatic charge
  - If the object is volatile
  - Some other cause for unstable reading

In such cases the uncertainty can well be 10 times higher!

Example: Moisture content determined by loss on drying

Misconception 1

- The model:

$$Q_{\mathrm{moisture}} = \frac{m_{\mathrm{sample}} - m_{\mathrm{sample\_after\_heating}}}{m_{\mathrm{sample}}} \times 100\%$$

- Substituting typical balance data yields:
- $Q_{\mathrm{moisture}} = (5.525 \pm 0.022)\ \%\ (k = 2)$
  - moisture in % by mass

S. Pawade et al *Biofuels, Bioprod. Bioref.* **2026**. doi.org/10.1002/bbb.70124

Misconception 1

Modified model

$$Q_{\text{moisture}} = \frac{m_{\text{sample}} - m_{\text{sample\_after\_heating}}}{m_{\text{sample}}} \times 100\% \times f$$

- f takes into account
  - sample inhomogeneity
  - possibly incomplete drying
  - other sources of variability
- Value: $f = 1$
- Uncertainty: $u(f) = s(Q_{\text{moisture}})/\text{mean}(Q_{\text{moisture}})$

Example: Moisture Content

Misconception 1

- If in addition to the balance we try to take into account:
  - Sample inhomogeneity
  - Possibly incomplete drying
  - Other sources of variability
- Then, substituting more realistic data, we get:
- $Q_{\text{moisture}} = (5.53 \pm 0.56)\ \%\ (k = 2)$

S. Pawade et al *Biofuels, Bioprod. Bioref.* **2026**. doi.org/10.1002/bbb.70124

Example: Moisture Content

Misconception 1

The difference between 0.022% and 0.56% is around ***25 times*** *!*

The intrinsic balance uncertainty sources are almost insignificant in this case!

Photometric absorbance

Misconception 1

- Photometers are quite accurate instruments
- The main **instrument-related** uncertainty sources are:
  - Repeatability of the reading, $\boldsymbol{u}_{\mathbf{rep}}$
  - Drift of the photometer parameters during the day, $\boldsymbol{u}_{\mathbf{drift}}$
  - Deviation of the photometer reading from the Lambert-Beer law, $\boldsymbol{u}_{\mathbf{nonlin}}$
  - (Uncertainty due to the rounding of the last digit)

L. Sooväli et al *Accred. Qual. Assur.* **2006**, *11*, 246-255. doi.org/10.1007/s00769-006-0124-x

Photometric absorbance

Misconception 1

- In chemical measurements there are usually additional **chemical** or **object-related** uncertainty contributions:
  - Absorbance change (either overlap or interference with reaction) caused by interfering compounds, u_{interf}
  - Uncertainty caused by mismatch between sample solution and calibration solution, u_{mismatch}
  - Limited stability of the color of the complex, $u_{\mathrm{chem\_drift}}$

L. Sooväli et al *Accred. Qual. Assur.* **2006**, *11*, 246-255. doi.org/10.1007/s00769-006-0124-x

Photometric absorbance

Misconception 1

- Uncertainty of absorbance with typical uncertainty contributions:
  - (at aborbance value 0.40)

$$u_c(A) = \sqrt{u^2_{\text{rep}}(A) + u^2_{\text{drift}}(A) + u^2_{\text{nonlin}}(A) + u^2_{\text{interf}}(A) + u^2_{\text{mismatch}}(A) + u^2_{\text{chem\_drift}}(A)}$$

„Ideal“ case:

$u_c(A)$ = **0.005** 0.0001 0.002 0.002 **0.003** 0.0 **0.003**

(**0.0042** with only chemical sources)

Difficult case (nitrite determination ISO 6777 if unstable color):

$u_c(A)$ = **0.030** 0.0001 0.002 0.002 **0.010** 0.0 **0.028**

(**0.030** with only chemical sources)

Instrumental

Chemical

L. Sooväli et al *Accred. Qual. Assur.* **2006**, *11*, 246-255. doi.org/10.1007/s00769-006-0124-x

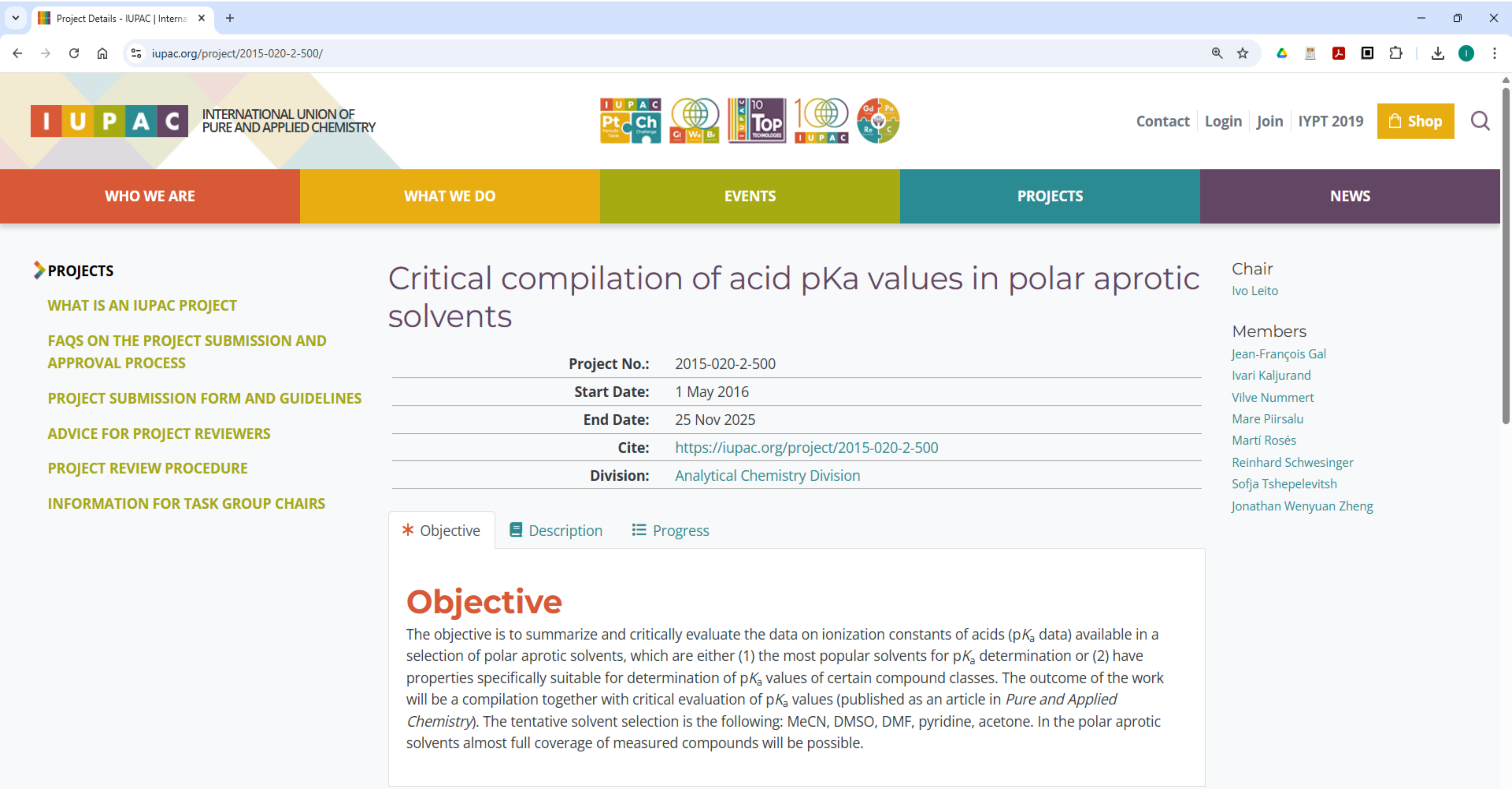
Conclusion:

- **Even in „ideal“ case instrument uncertainty sources are less important!**
- **In difficult case instrument uncertainty sources are irrelevant!**

In chemistry, uncertainty mostly comes
***from the object*,**
not from the instrument!

Misconception 2

Uncertainty is quantitatively expressed by (dis)agreement between results of repeated measurements



Critical compilation of acid pKa values in polar aprotic solvents

Project No.:	2015-020-2-500
Start Date:	1 May 2016
End Date:	25 Nov 2025
Cite:	https://iupac.org/project/2015-020-2-500
Division:	Analytical Chemistry Division

Chair
Ivo Leito

Members
Jean-François Gal
Ivari Kaljurand
Vilve Nummert
Mare Piirsalu
Martí Rosés
Reinhard Schwesinger
Sofja Tshepelevitsh
Jonathan Wenyuan Zheng

Objective

The objective is to summarize and critically evaluate the data on ionization constants of acids (pK_a data) available in a selection of polar aprotic solvents, which are either (1) the most popular solvents for pK_a determination or (2) have properties specifically suitable for determination of pK_a values of certain compound classes. The outcome of the work will be a compilation together with critical evaluation of pK_a values (published as an article in *Pure and Applied Chemistry*). The tentative solvent selection is the following: MeCN, DMSO, DMF, pyridine, acetone. In the polar aprotic solvents almost full coverage of measured compounds will be possible.

https://iupac.org/project/2015-020-2-500/

05.03.2026

Critical compilation of acid pK_a values in polar aprotic solvents

- More than **9000** pK_a values
- Around to **5000** acids
- In **DMSO, acetonitrile, DMF, pyridine, acetone, propylene carbonate, THF**
- **Critical evaluation**
  - Around **2700** pK_a values flagged as „doubtful“ or „unreliable“
  - **Corrected**, where possible: around **2400** pK_a values
- Published in *Pure and Applied Chemistry*, **2025**, *97*, 973-998. https://doi.org/10.1515/pac-2024-0276
- Data is freely available in Zenodo

Out of **9713** values:

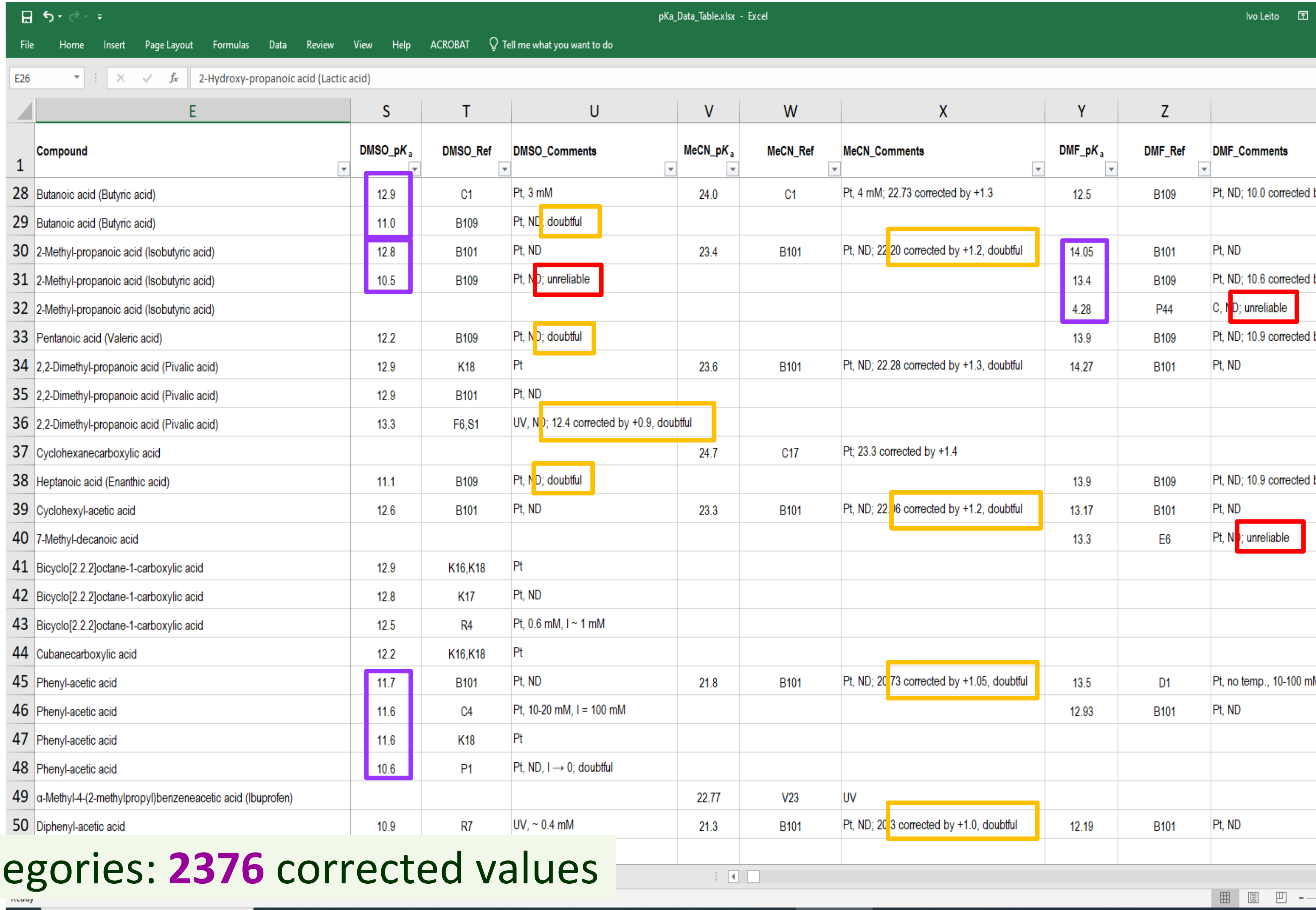
Critical evaluation

„Preferred“ **542**

Unflagged **6426**

„Doubtful“ **1932**

„Unreliable“ **813**



2-Hydroxy-propanoic acid (Lactic acid)

	E	S	T	U	V	W	X	Y	Z	
1	Compound	DMSO_pK_a	DMSO_Ref	DMSO_Comments	MeCN_pK_a	MeCN_Ref	MeCN_Comments	DMF_pK_a	DMF_Ref	DMF_Comments
28	Butanoic acid (Butyric acid)	12.9	C1	Pt, 3 mM	24.0	C1	Pt, 4 mM; 22.73 corrected by +1.3	12.5	B109	Pt, ND; 10.0 corrected
29	Butanoic acid (Butyric acid)	11.0	B109	Pt, ND doubtful						
30	2-Methyl-propanoic acid (Isobutyric acid)	12.8	B101	Pt, ND	23.4	B101	Pt, ND; 22 20 corrected by +1.2, doubtful	14.05	B101	Pt, ND
31	2-Methyl-propanoic acid (Isobutyric acid)	10.5	B109	Pt, ND; unreliable				13.4	B109	Pt, ND; 10.6 corrected
32	2-Methyl-propanoic acid (Isobutyric acid)							4.28	P44	C, ND; unreliable
33	Pentanoic acid (Valeric acid)	12.2	B109	Pt, ND; doubtful				13.9	B109	Pt, ND; 10.9 corrected
34	2,2-Dimethyl-propanoic acid (Pivalic acid)	12.9	K18	Pt	23.6	B101	Pt, ND; 22.28 corrected by +1.3, doubtful	14.27	B101	Pt, ND
35	2,2-Dimethyl-propanoic acid (Pivalic acid)	12.9	B101	Pt, ND						
36	2,2-Dimethyl-propanoic acid (Pivalic acid)	13.3	F6,S1	UV, ND; 12.4 corrected by +0.9, doubtful						
37	Cyclohexanecarboxylic acid				24.7	C17	Pt; 23.3 corrected by +1.4			
38	Heptanoic acid (Enanthic acid)	11.1	B109	Pt, ND; doubtful				13.9	B109	Pt, ND; 10.9 corrected
39	Cyclohexyl-acetic acid	12.6	B101	Pt, ND	23.3	B101	Pt, ND; 22.06 corrected by +1.2, doubtful	13.17	B101	Pt, ND
40	7-Methyl-decanoic acid							13.3	E6	Pt, ND; unreliable
41	Bicyclo[2.2.2]octane-1-carboxylic acid	12.9	K16,K18	Pt						
42	Bicyclo[2.2.2]octane-1-carboxylic acid	12.8	K17	Pt, ND						
43	Bicyclo[2.2.2]octane-1-carboxylic acid	12.5	R4	Pt, 0.6 mM, I ~ 1 mM						
44	Cubanecarboxylic acid	12.2	K16,K18	Pt						
45	Phenyl-acetic acid	11.7	B101	Pt, ND	21.8	B101	Pt, ND; 20 73 corrected by +1.05, doubtful	13.5	D1	Pt, no temp., 10-100 m
46	Phenyl-acetic acid	11.6	C4	Pt, 10-20 mM, I = 100 mM				12.93	B101	Pt, ND
47	Phenyl-acetic acid	11.6	K18	Pt						
48	Phenyl-acetic acid	10.6	P1	Pt, ND, I → 0; doubtful						
49	α-Methyl-4-(2-methylpropyl)benzeneacetic acid (Ibuprofen)				22.77	V23	UV			
50	Diphenyl-acetic acid	10.9	R7	UV, ~ 0.4 mM	21.3	B101	Pt, ND; 20 3 corrected by +1.0, doubtful	12.19	B101	Pt, ND

In the lowest three categories: **2376** corrected values

Misconception 2

Some examples

Acid	Ref	pK_a	Uncer-tainty	Reported meaning of uncertainty	Best available pK_a	Absolute difference
Acetic acid	B101	21.57	**0.05**	Std dev of replicates	23.5	**1.9**
Acetic acid	B165	22.23	**0.02**	Std dev of mean	23.5	**1.3**
4-Methylbenzoic acid	L12	20.86	**0.07**	St dev of 4 values	22.0	**1.1**
Benzenesulfonamide	L1	24.61	**0.03**	St dev of 3 values	26.63	**2.0**
9-Cyanofluorene	S19	20.8	**0.1**	St dev of 3 values	21.35	**0.5**

- Repeatability is a minor uncertainty source
- More important uncertainty sources: calibration (reference values), impurities (H_2O and others) in solutions, side-processes

Pure and Applied Chemistry **2025**, *97*, 973-998.
https://doi.org/10.1515/pac-2024-0276

Conclusion:

In chemistry, uncertainty usually comes mainly
***from systematic effects**,*
not from (within-day) random effects

Misconception 3

Misconception 3

„Simple“ measurements are simple

(pH, dissolved oxygen, ...)

pH, dissolved oxygen, etc are easy to measure accurately, right?

Misconception 3

- The meter shows the value
- Easy, no?
- What can go wrong here?

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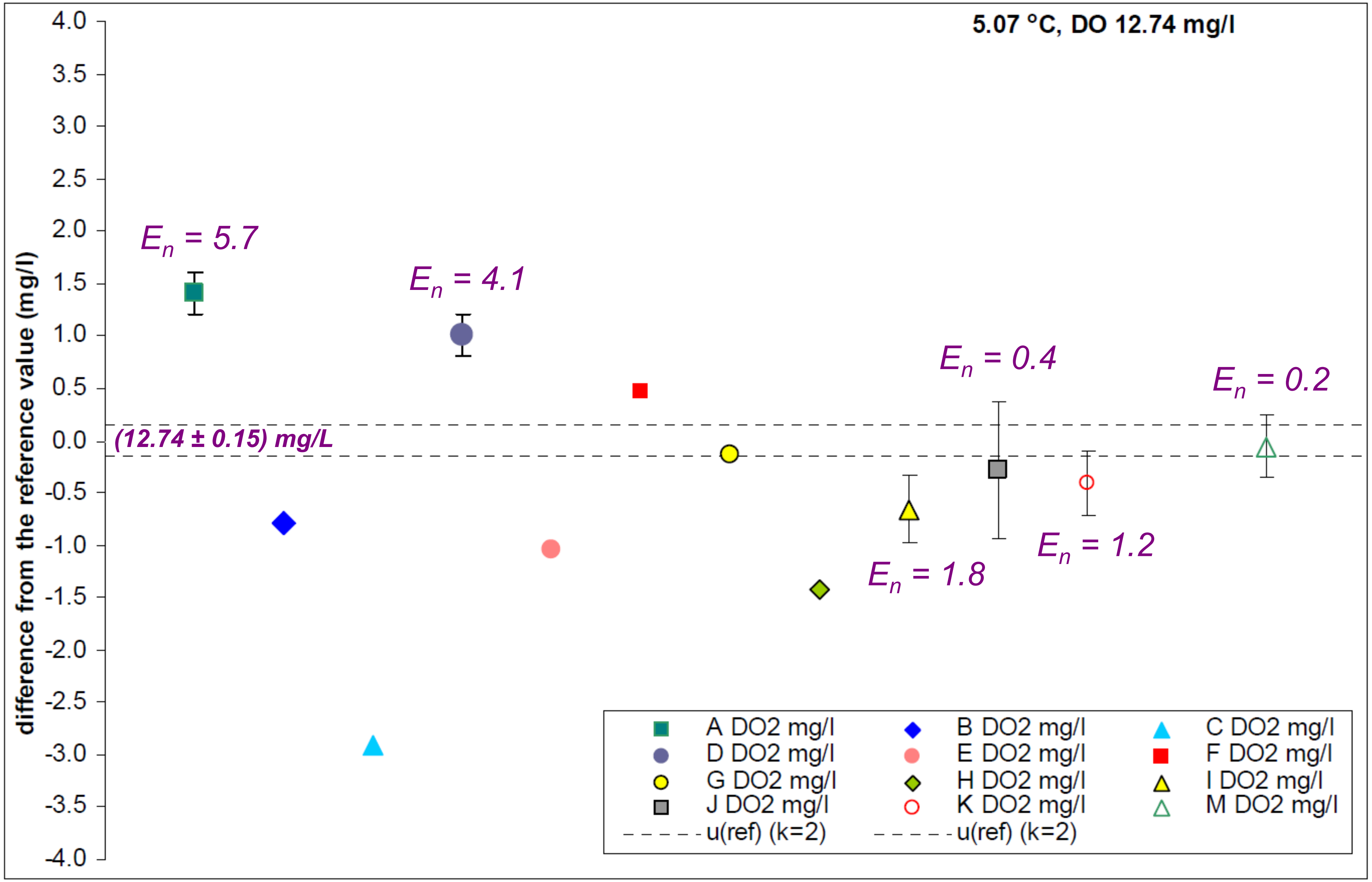
Dissolved oxygen intercomparison

Misconception 3



https://sisu.ut.ee/wp-content/uploads/sites/131/estdo-2012_final_report.pdf

How simple is this measurement?

Misconception 3

- Measurement model:

$$C_{\text{result}} = \frac{C_{\text{read\_meas}} + \Delta C_{\text{stir}} + \Delta C_{\Delta t} + \Delta C_{\text{drift}} + \Delta C_{\text{linearity}}}{\gamma \cdot b_1} - \frac{b_0}{b_1}$$

$$b_0 = \frac{C_{\text{read\_cal\_0}} \cdot C_{\text{cal}} - C_{\text{cal\_0}} \cdot C_{\text{read\_cal}}}{C_{\text{cal}} - C_{\text{cal\_0}}}$$

$$b_1 = \frac{C_{\text{read\_cal}} - C_{\text{read\_cal\_0}}}{C_{\text{cal}} - C_{\text{cal\_0}}}$$

I. Helm et al *Environ. Monit. Assess.* **2018**, 190. https://doi.org/10.1007/s10661-018-6692-5

How simple is this measurement?

Misconception 3

- **18 individual uncertainty components to quantify!**
- Related to:
  - Calibration
  - Instrument drift
  - Temperature effect
  - Liquid flow rate
  - ...

Table 2 Values of uncertainty components expressed as standard uncertainties (unless stated otherwise) and comments about their calculations

Input quantities	Uncertainty contributors	WTW-340i	HACH-HQ30d	Comment
C_{read_meas}	$u(C_{meas\_Rep})$	0.051 mg/L	0.069 mg/L	Intermediate precision was evaluated from the same data that were used for evaluating drift (Fig. 1) as the pooled standard deviation (from two different data series) of the differences from reference values. This is an acceptable approach if we consider that the measurement procedure involves calibration once a month.
	$u(C_{meas\_res})$	0.0029 mg/L	0.0029 mg/L	Resolution of the instrument reading. Calculated as $\frac{0.01}{2\cdot\sqrt{3}}$ mg/L
C_{read_cal}	$u(C_{cal\_rep})$	0.020 mg/L	0.0039 mg/L	Uncertainty of analyzer's reading during calibration is estimated as the pooled repeatability standard deviation of the reading at stirring rate 120 rpm (used during calibration).
	$u(C_{cal\_res})$	0.0029 mg/L	0.0029 mg/L	Resolution of the instrument reading. Calculated as in the case of $u(C_{meas\_res})$.
$C_{read\_cal\_0}$	$u(C_{cal\_0\_rep})$	0.020 mg/L	0.0049 mg/L	Uncertainty of analyzer's reading during calibration is estimated as the repeatability of the reading at stirring rate of 120 rpm.
	$u(C_{cal\_0\_res})$	0.0029 mg/L	0.0029 mg/L	Resolution of the instrument reading. Calculated as in the case of $u(C_{meas\_res})$.
C_{cal}	$u(C_{cal})$	0.031 mg/L	0.031 mg/L	Estimated as average uncertainty of saturation value found by Helm et al. (2012).
C_{cal_0}	$u(C_{cal\_0})$	0.0058 mg/L	0.0058 mg/L	Estimated as ± 0.01 mg/L (rectangular distribution).
γ	$u(\gamma)$	$u(\gamma) = \frac{(\gamma-1)\cdot 0.5}{\sqrt{3}}$		Estimated as ± half of the activity coefficient difference from 1 (rectangular distribution).
ΔC_{stir}	$u(\Delta C_{stir})$	$u(\Delta C_{stir}) = \frac{b_{1\_stir}\cdot\Delta v_{stir}\cdot C_{read\_meas}}{\sqrt{3}\cdot 100\%}$		Δv_{stir}—stirring rate at measurement from calibration (%)
	b_{1_stir}	0.0146	− 0.00094	b_{1_stir}—the slope of the plot in Fig. 5 that shows measurement systematic relative deviation (%) when stirring rate at measurement is 1% different from flow rate at calibration.
$\Delta C_{\Delta t}$	$u(\Delta C_{\Delta t})$	$u(\Delta C_{\Delta t}) = \frac{b_{1\_\Delta t}\times\Delta t\times C_{read\_meas}}{\sqrt{3}\times 100\%}$		C_{read_meas}—the reading of the analyzer at measuring; Δt—the difference of the temperatures between the calibration and the measurement;
	$b_{1\_\Delta t}$	− 0.078%/°C	0.024%/°C	$b_{1\_\Delta t}$—the slope of the graph in Fig. 2 that presents the systematic deviation (%) of measurement device reading when the difference between calibration and measurement temperatures 1 °C.
ΔC_{drift}	$u(\Delta C_{drift})$	$u(\Delta C_{drift}) = \frac{(b_{1\_drift}+s(b_{1\_drift}))\cdot\Delta day}{\sqrt{3}}$		Δday—the number of days between calibration and measurement.
	b_{1_drift} $s(b_{1\_drift})$	0.0038 mg/L 0.0009 mg/L	0.0079 mg/L 0.0008 mg/L	b_{1_drift}—absolute value of the change of analyzer reading during 1 day (mg/L) that is established with drift test. $s(b_{1\_drift})$—standard deviation of slope
$\Delta C_{linearity}$	$u(\Delta C_{linearity})$	$u(\Delta C_{linearity}) = \frac{(C_{read\_meas}-11)\cdot b_{1\_linearity}}{\sqrt{3}}$		Is used in case of optical sensor when reading of the sample is higher than 11 mg/L.
	$b_{1\_linearity}$	0^{a}	0.028	$b_{1\_linearity}$—slope of the line presented in Fig. 4 at concentrations higher than 11 mg/L.

[a] Applies only in the case of optical sensor. In the case of the amperometric sensor, linearity over a wide range is assumed

I. Helm et al *Environ. Monit. Assess.* **2018**, 190
https://doi.org/10.1007/s10661-018-6692-5

Conclusion:

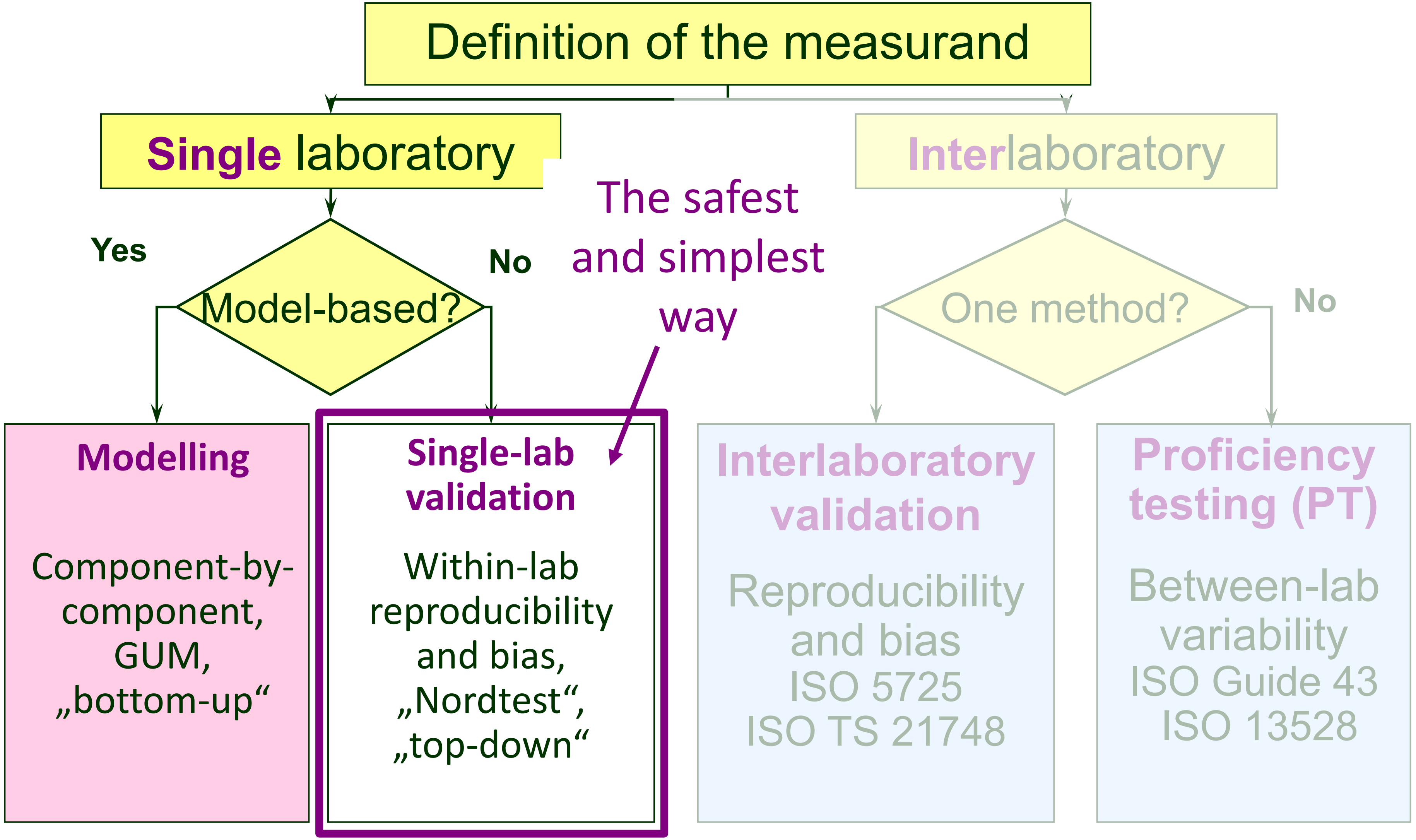
Misconception 3

In chemistry, even for „simple“ measurement,

adequate modeling and evaluation of individual uncertainty components is usually challenging

Uncertainty estimations approaches

Pragmatic approach



Definition of the measurand

Single laboratory

Interlaboratory

Model-based?

Yes

No

One method?

No

The safest and simplest way

Modelling

Component-by-component, GUM, „bottom-up“

Single-lab validation

Within-lab reproducibility and bias, „Nordtest“, „top-down“

Interlaboratory validation

Reproducibility and bias
ISO 5725
ISO TS 21748

Proficiency testing (PT)

Between-lab variability
ISO Guide 43
ISO 13528

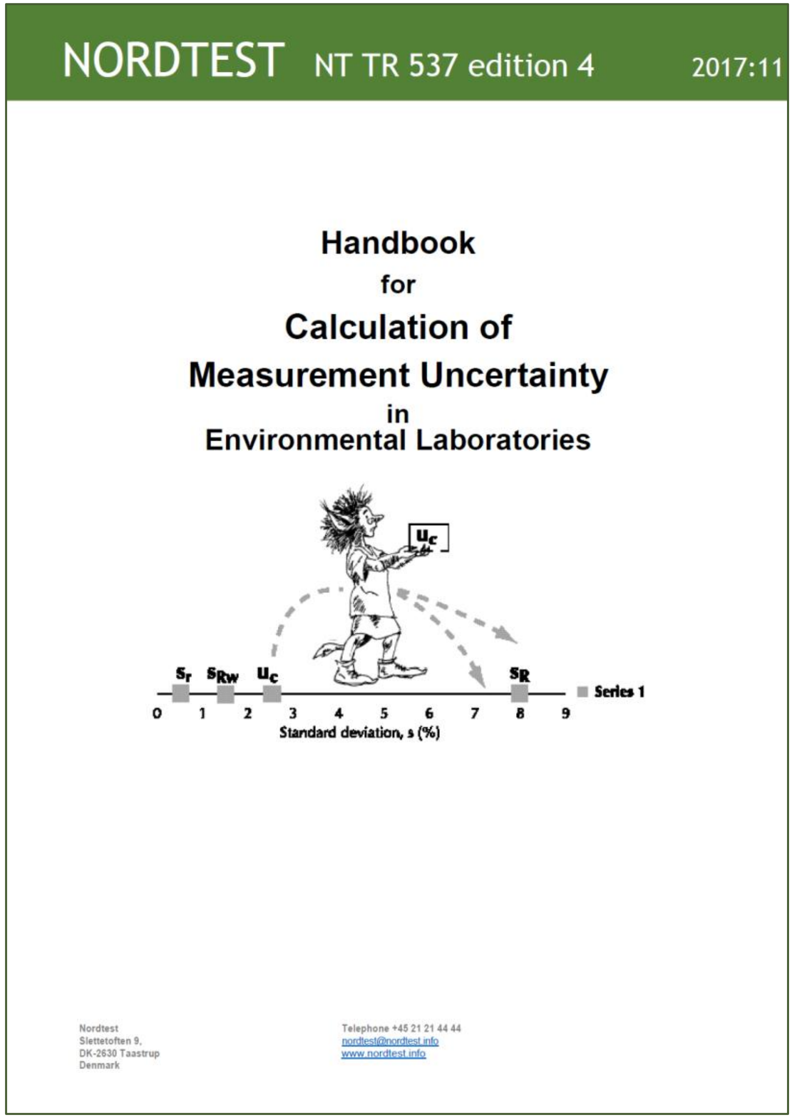
Eurolab Technical Report No 1/2007 Available from: http://www.eurolab.org/

Pragmatic approach

„Single-lab validation“ approach

aka “the Nordtest approach„

based on validation and Quality Control Data



NORDTEST NT TR 537 edition 4 2017:11

Handbook
for
Calculation of
Measurement Uncertainty
in
Environmental Laboratories

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Nordtest Technical Report 537, ed 4 (2017)
http://www.nordtest.info/

Single-laboratory validation approach

Pragmatic approach

Effects contributing to uncertainty

Random

Systematic

- The two groups of uncertainty contributions are quantified separately and then combined:

$$u_{\mathrm{c}} = \sqrt{{u_1}^2 + {u_2}^2}$$

Uncertainty arising from random effects

Uncertainty accounting for *possible* bias

Long-term!

Simplified definition:

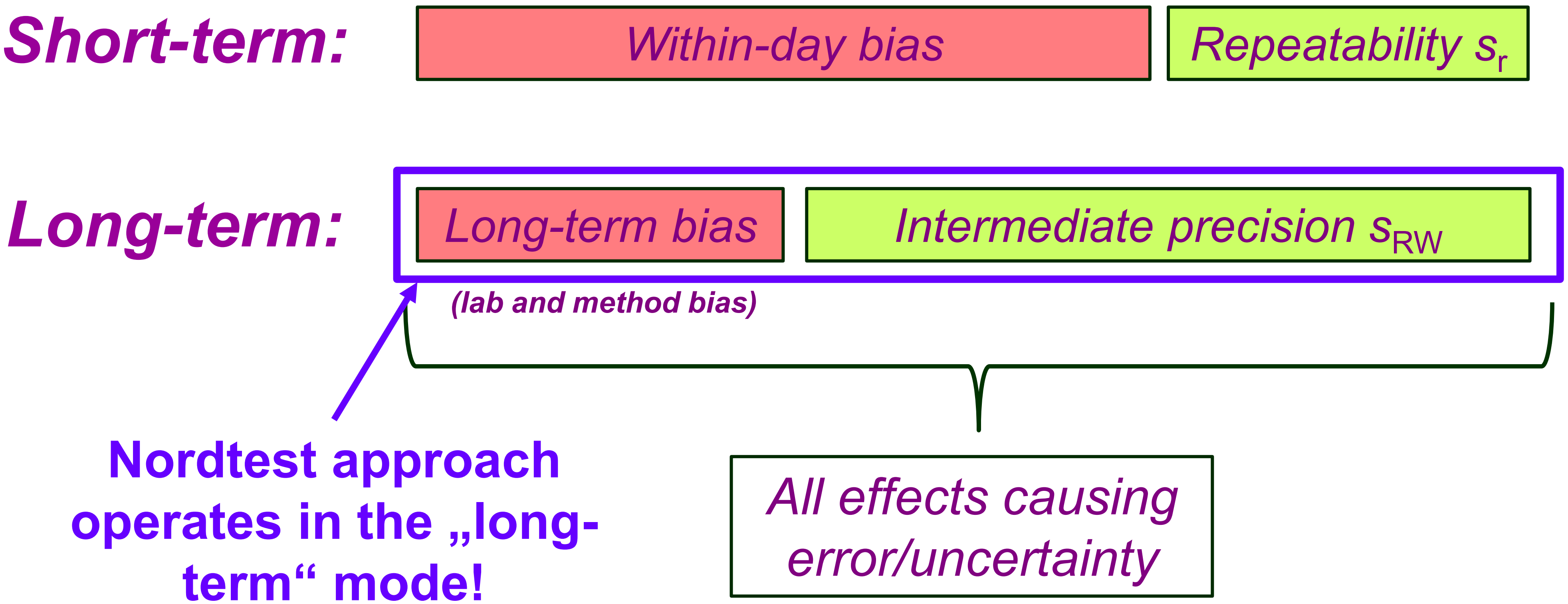
Bias: estimate of **systematic** error.

Bias can be obtained as difference between the mean of a number of measurements with a reference sample and the respective reference value

Systematic and random effects

Pragmatic approach

- *Random and systematic effects can be grouped differently:*



Short-term: *Within-day bias* | *Repeatability s_r*

Long-term: *Long-term bias* | *Intermediate precision s_{RW}*

(lab and method bias)

All effects causing error/uncertainty

Nordtest approach operates in the „long-term“ mode!

The longer is the time frame the more effects change their „status“: systematic ⟶ random

Single lab validation approach: in practice

Pragmatic approach

- The main equation:

$$u_\mathrm{c} = \sqrt{u(R_\mathrm{w})^2 + u(bias)^2}$$

Within-laboratory reproducibility

This component accounts for the long-term random effects

Uncertainty of the estimate of the possible laboratory bias and the possible method bias

This component accounts for the possible long-term systematic effects

No need to investigate individual uncertainty sources!

Nordtest Technical Report 537, ed 4 (2017)
http://www.nordtest.info/

Systematic effects, u(bias)

Pragmatic approach

- The *possible* **bias** of lab's results from the best estimate of true value is taken into account

Including sample preparation!

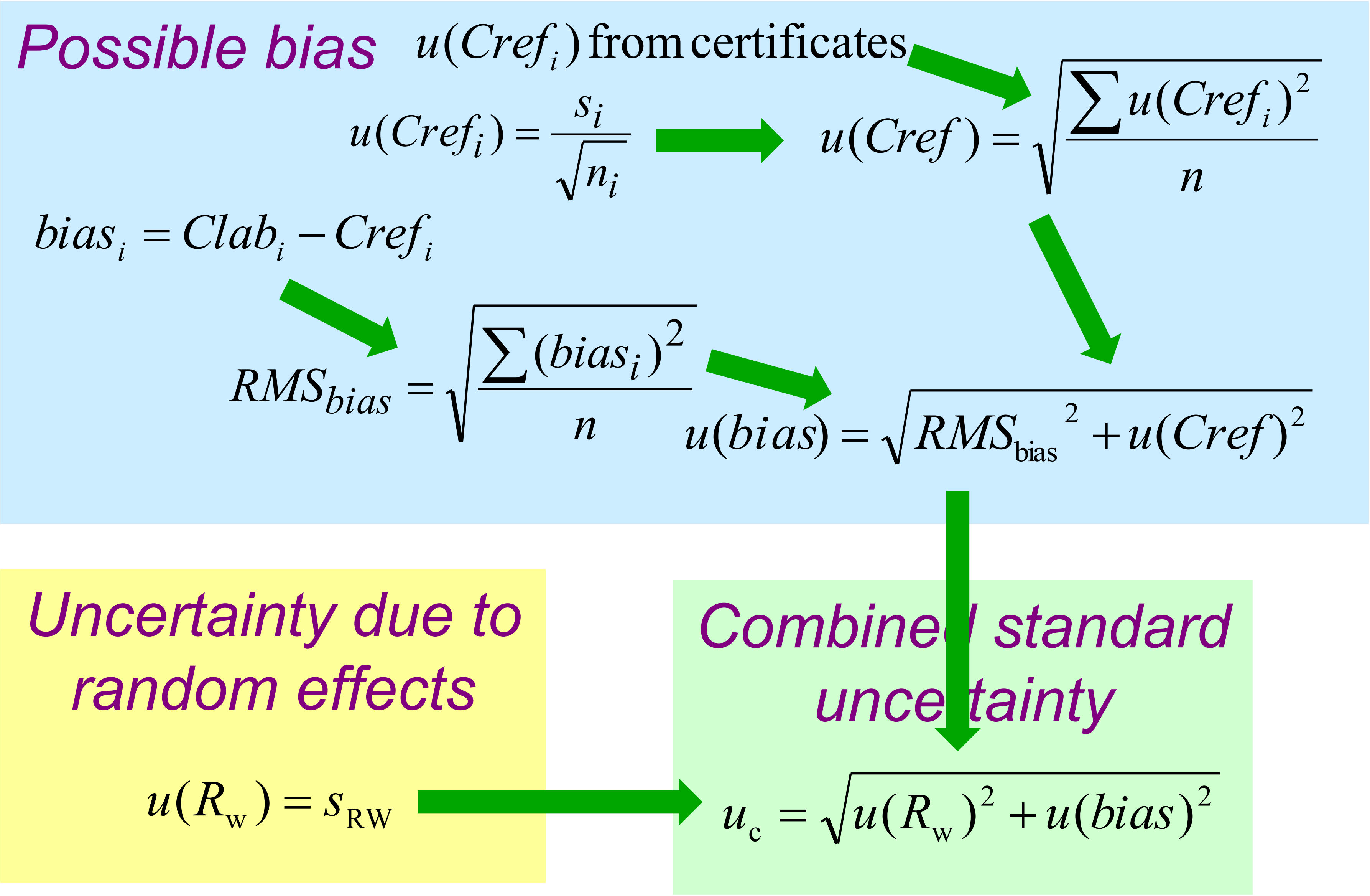
- **Reference value is needed!**
- Reference value and *u*(*bias*) can be found:
  - From the analysis of the same samples with a reference method
  - From the analysis of certified reference materials (CRMs)
  - From interlaboratory comparison measurements
  - From spiking experiments

Replicate measurements!

Ideally: several reference materials, several PTs because the bias will in most cases vary with matrix and concentration range

Roadmap:

Pragmatic approach



Possible bias

$u(Cref_i)$ from certificates

$$u(Cref_i) = \frac{s_i}{\sqrt{n_i}}$$

$$u(Cref) = \sqrt{\frac{\sum u(Cref_i)^2}{n}}$$

$$bias_i = Clab_i - Cref_i$$

$$RMS_{bias} = \sqrt{\frac{\sum (bias_i)^2}{n}}$$

$$u(bias) = \sqrt{RMS_{\mathrm{bias}}{}^2 + u(Cref)^2}$$

Uncertainty due to random effects

$$u(R_{\mathrm{w}}) = s_{\mathrm{RW}}$$

Combined standard uncertainty

$$u_{\mathrm{c}} = \sqrt{u(R_{\mathrm{w}})^2 + u(bias)^2}$$

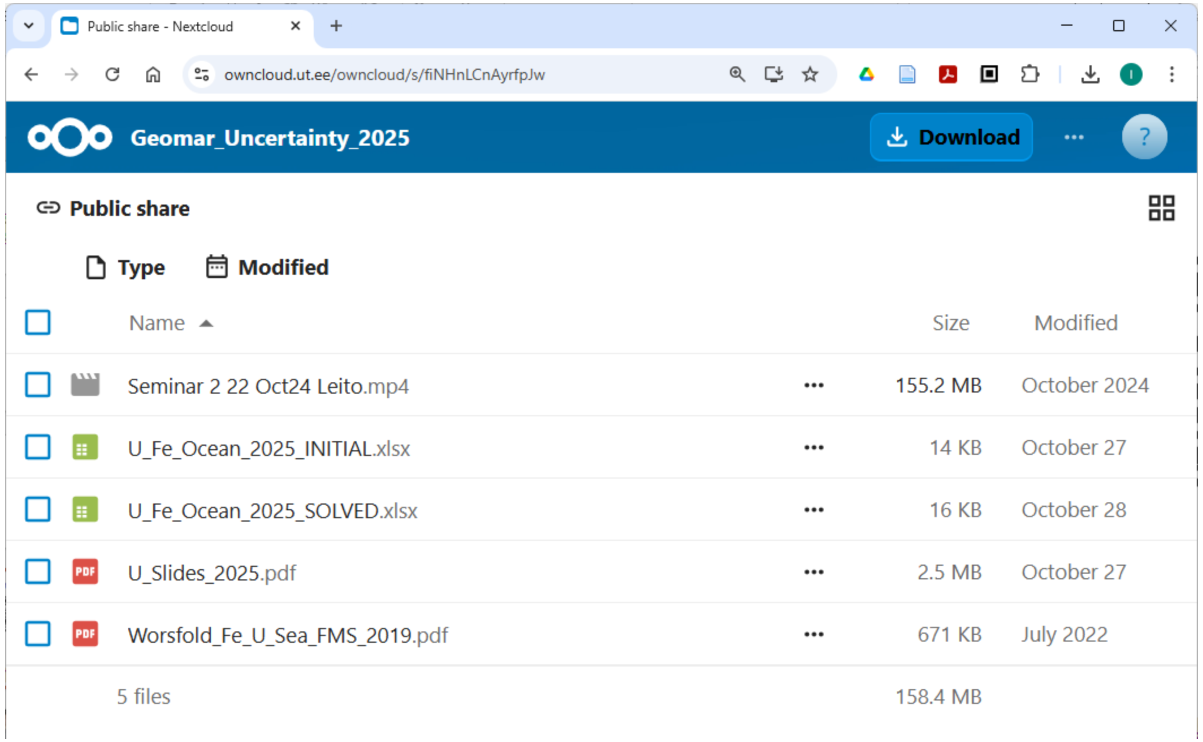
Example: uncertainty estimation of iron content in seawater

Pragmatic approach

Materials:

https://analytical.chem.ut.ee/poznan-2026/

Link „Example: uncertainty estimation of iron content in seawater “



Geomar_Uncertainty_2025

☐	Name		Size	Modified
☐	Seminar 2 22 Oct24 Leito.mp4	•••	155.2 MB	October 2024
☐	U_Fe_Ocean_2025_INITIAL.xlsx	•••	14 KB	October 27
☐	U_Fe_Ocean_2025_SOLVED.xlsx	•••	16 KB	October 28
☐	U_Slides_2025.pdf	•••	2.5 MB	October 27
☐	Worsfold_Fe_U_Sea_FMS_2019.pdf	•••	671 KB	July 2022
	5 files		158.4 MB	

Worsfold PJ, Achterberg EP, Birchill AJ, Clough R, Leito I, Lohan MC, Milne A and Ussher SJ Estimating Uncertainties in Oceanographic Trace Element Measurements. *Front. Mar. Sci*. 2019, 5, 515. https://doi.org/10.3389/fmars.2018.00515

Thanks
to all these
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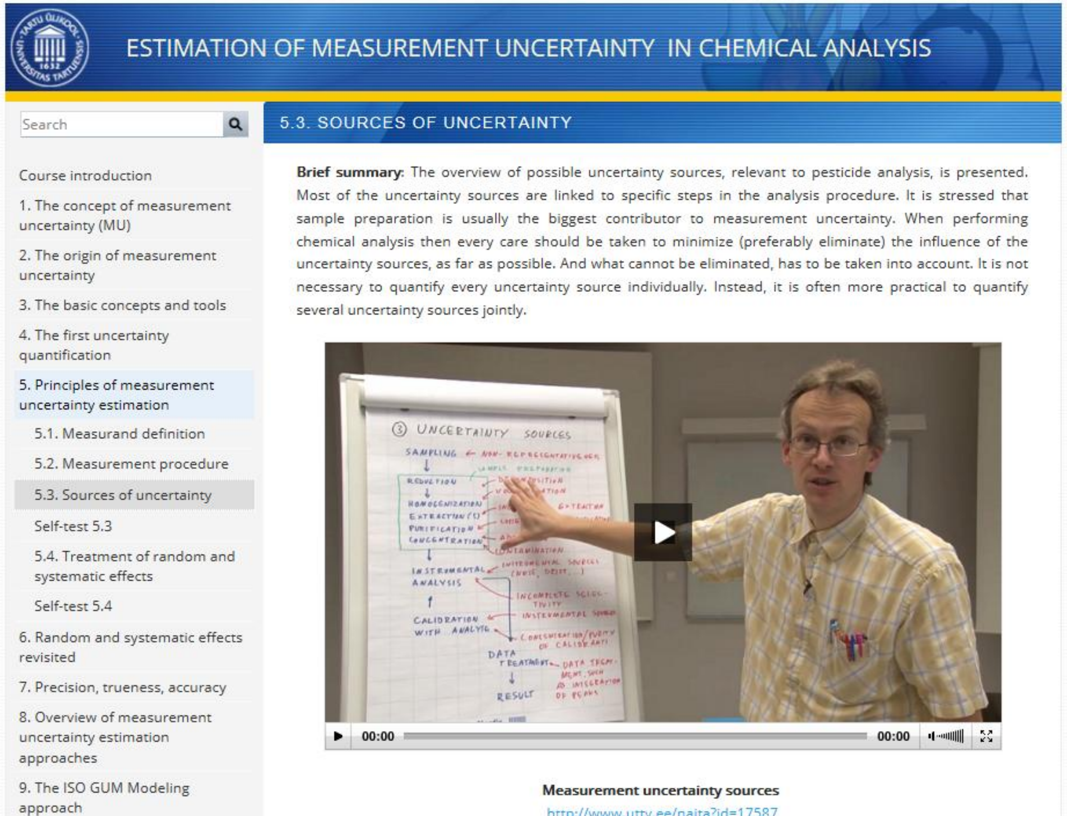
Thank you for your attention!

Materials: https://analytical.chem.ut.ee/poznan-2026/

Do you wish to learn more?

- Feel free to **contact me** with any measurement uncertainty issues
  - Allow some time to reply
- Web course **Estimation of measurement uncertainty in chemical analysis** (1 ECTS)
  - registration link is at https://sisu.ut.ee/measurement/
  - Mar 24 – May 6, 2026



ESTIMATION OF MEASUREMENT UNCERTAINTY IN CHEMICAL ANALYSIS

Course introduction
1. The concept of measurement uncertainty (MU)
2. The origin of measurement uncertainty
3. The basic concepts and tools
4. The first uncertainty quantification
5. Principles of measurement uncertainty estimation
  5.1. Measurand definition
  5.2. Measurement procedure
  5.3. Sources of uncertainty
  Self-test 5.3
  5.4. Treatment of random and systematic effects
  Self-test 5.4
6. Random and systematic effects revisited
7. Precision, trueness, accuracy
8. Overview of measurement uncertainty estimation approaches
9. The ISO GUM Modeling approach

5.3. SOURCES OF UNCERTAINTY

Brief summary: The overview of possible uncertainty sources, relevant to pesticide analysis, is presented. Most of the uncertainty sources are linked to specific steps in the analysis procedure. It is stressed that sample preparation is usually the biggest contributor to measurement uncertainty. When performing chemical analysis then every care should be taken to minimize (preferably eliminate) the influence of the uncertainty sources, as far as possible. And what cannot be eliminated, has to be taken into account. It is not necessary to quantify every uncertainty source individually. Instead, it is often more practical to quantify several uncertainty sources jointly.

Measurement uncertainty sources

http://www.uttv.ee/naita?id=17587