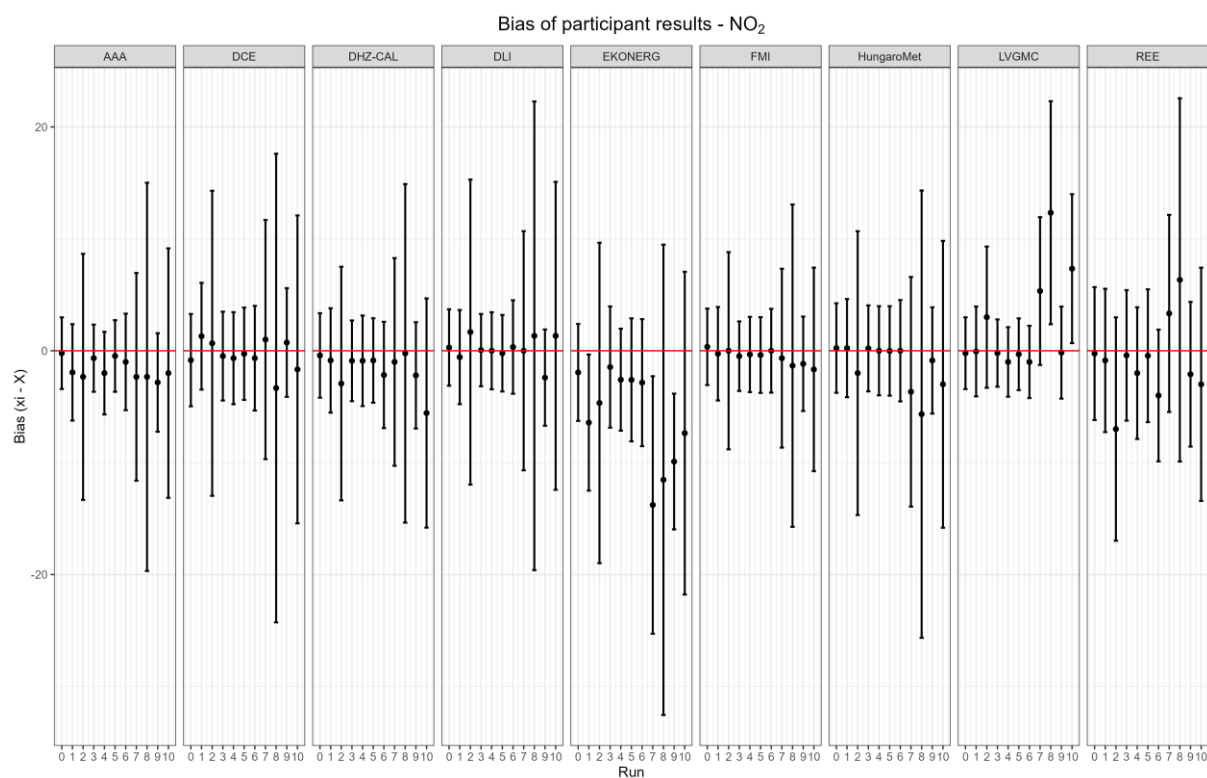


Proficiency testing scheme Measurement of inorganic gaseous pollutants in filtered ambient air, 20-23 April 2026 Ispra - Italy

European Commission harmonisation programme for
Air Quality Measurements

Barbieri, M., Tarricone, C., Borowiak, A.

2026



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PROFICIENCY TESTING SCHEME



EUROPEAN REFERENCE LABORATORY FOR AIR POLLUTION - ERLAP

Proficiency testing scheme
Measurement of inorganic gaseous pollutants in
filtered ambient air,
20-23 April 2026 Ispra - Italy

Tarricone, C., Barbieri, M., Borowiak, A.



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Abstract

Within the harmonisation programme of air-quality monitoring in Europe, as required by European air policy, the European Reference Laboratory of Air Pollution (ERLAP) organises proficiency tests (PTs) for inorganic gaseous air pollutants for the National air quality reference laboratories. This report evaluates the proficiency of participating laboratories for SO₂, CO, O₃, NO and NO₂ using the z or z' score and En score performance indicators. Based on the z or z' score evaluation, 99.1 % of the reported results were satisfactory. Considering the En score, 93.5 % of the reported values were satisfactory. These results are in line with previous exercises. The En score calculation uses the expanded uncertainty of the assigned value provided by the ERLAP that includes the contribution as well from homogeneity of the test-gas.

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1. Introduction

Directive (EU) 2024/2881 [1] on ambient air quality and cleaner air for Europe, sets the framework for harmonised air-quality assessment across Europe. The Directive establishes reference methods for measurements and Data Quality Objectives (DQOs) for the accuracy of measurements of sulphur dioxide (SO₂), nitrogen dioxide (NO₂) and nitrogen monoxide (NO), carbon monoxide (CO), ozone (O₃) and particulate matter. The European Commission has supported the development and publication of reference measurement methods for CO [4], SO₂ [5], NO–NO₂ [6] and O₃ [7] as European standards methods. Appropriate calibration methods [8], [9] and [10] have been standardised by the International Organization for Standardization (ISO). As foreseen in the Air Quality Directive, the European Reference Laboratory of Air Pollution (ERLAP) of the Directorate for Energy, Mobility and Climate at the Joint Research Centre (JRC) organises Proficiency Testing exercises (PT) to assess and improve the comparability of measurements of National Reference Laboratories (NRLs) of the Member States of the European Union.

Since 1990 ERLAP has organised Proficiency Testing exercises (PT) to evaluate the comparability of measurements carried out by NRLs and promote information exchange among expert laboratories. In agreement with the Network of National Reference Laboratories for Air Quality (AQUILA) [11], a systematic approach was adopted, to fulfil two main objectives: providing an alert mechanism for European Commission (EC) legislation and supporting the NRLs in implementing quality assurance schemes.

ERLAP is accredited under ISO 17043:2023 [16] to organise PT for the pollutants and EN standard methods used during this proficiency test (EN 14626:2024 — CO) [4], EN 14212:2024 — SO₂ [5], EN 14211:2024 — NO/NO₂ [6], EN 14625:2024 — O₃ [7].

The evaluation scheme implements the z or z' score method [12] as performance indicator. Participants' results (measurement values and uncertainties) are also compared to the reference values applying the difference D and the En score method [12]. Participants are requested to submit also their measurement uncertainty in the unit requested in the protocol for each value reported.

According to AQUILA position paper N37 [11], NRLs are required to repeat their participation in the subsequent proficiency test to demonstrate corrective measures if a given parameter yields either more than 20 % unsatisfactory results or more than 40 % questionable results. Additionally, participation is considered valid only if at least 80 % of the requested values per pollutant are successfully submitted.

2. Exercise organization

In July 2025 the PT was announced via email to the members of the AQUILA network. Registration was opened and closed according to the schedule communicated to participants. Every participant, together with the registration confirmation, received a detailed protocol with all the necessary information about the PT. Each laboratory was required to bring their own measurement instruments, data acquisition equipment and travelling standards (to be used for calibrations or checks during the PT).

The participants were invited to arrive on Monday, 20 of April 2026, for their equipment installation. The calibration of NO_x and O_3 analysers was carried out the morning of the following day and the generation of NO_x and O_3 gas mixtures started at 11:00 on Tuesday. The calibration of SO_2 and CO analysers was carried out on Wednesday afternoon and the generation of CO and SO_2 gas mixtures started at 20:00 of the same day. The test gases generation and measurements finished on Thursday at 9:00.

3. Participants and instrumentation

All participants were organisations dealing with the routine ambient air monitoring or institutions involved in environmental or public health protection. The national representatives came from Croatia, Cyprus, Denmark, Finland, Hungary, Latvia, Lithuania, United Kingdom and the European Commission's ERLAP laboratory participated as well.

Table 1: Participating laboratories.

Acronym	Laboratory	Country
DHZ-CAL	Meteorological and Hydrological Service - CALIBRATION	Croatia
EKONERG	Energy and Environmental Protection Institute	Croatia
DLI	Dept. of Labour Inspection	Cyprus
DCE	National Environmental Research Institute	Denmark
FMI	Finnish Meteorological Institute	Finland
HungaroMet	HungaroMet - Hungarian Meteorological Service	Hungary
ERLAP	European Reference Laboratory for Air Pollution	European Commission
LVGMC	Latvian Environment, Geology and Meteorology Centre	Latvia
AAA	Environmental Protection Agency	Lithuania
REE	Ricardo Energy & Environment	United Kingdom

Source: JRC 2026

The following Table 2 reports the manufacturer and model of the instrumentations used by every participant during the proficiency test, including those used in the calculation of the reference values. The list contains technical information and cannot be considered as an implicit or explicit endorsement by the PT provider of any specific instrumentation. This list is used to identify the presence of cluster during the data evaluation.

Table 2: Instrumentation reported by the participating laboratories.

Lab.	Analyser SO ₂	Analyser CO	Analyser NO	Analyser O ₃
DHZ-CAL	Teledyne - APIT100		Teledyne - APIT200U	Teledyne - APIT400
EKONERG	Horiba - APSA370	Horiba - APMA370	Horiba - APNA370	Horiba - APOA370
DLI	Serinus - Serinus50	Serinus - 30	Serinus - 40	Thermo - 49i
DCE	Teledyne - APIT100	Teledyne - APIT300	Teledyne - APIT200	Teledyne - APIT400
FMI	Thermo - 43i	Horiba - APMA370	Horiba - APNA360	Thermo - 49i
HungaroMet	Thermo - 43i	Thermo - 48i	Horiba - APNA370	Thermo - 49i
ERLAP	Thermo - 43i	Horiba - APMA370	Horiba - APNA370	Horiba - APOA370
LVGMC	Teledyne - APIT100		Teledyne - APIT200	
AAA	Horiba - APSA370	Horiba - APMA370	Horiba - APNA370	Horiba - APOA370
REE	Thermo - 43i	Horiba - APMA370	Thermo - 42i	Thermo - 49i

Source: JRC 2026

4. Preparation of test mixtures

ERLAP PT facility has been described in several reports [13], [14]. During this PT, gas mixtures were prepared for SO₂, CO, O₃, NO and NO₂ at concentration levels around limit values, critical levels and assessment thresholds set by the European Air Quality Directive [1].

Table 3: Sequence of generated test mixtures.

Day	Start time	Duration	Pollutant	NO	NO ₂	O ₃	CO	SO ₂
		h		µg/m ³	µg/m ³	µg/m ³	mg/m ³	µg/m ³
1st	09:00						Installation	
2nd	08:00						Calibration	
2nd	11:00	1	NO-NO ₂ -O ₃	Zero air				
2nd	12:00	2	NO-NO ₂	250	6.5			
2nd	14:00	2	NO-NO ₂	100	235			
2nd	16:00	2	O ₃			240		
2nd	18:00	2	NO-NO ₂	40	0.50			
2nd	20:00	2	NO-NO ₂	30	15			
2nd	22:00	2	O ₃			145		
3rd	00:00	2	NO-NO ₂	80	0.30			
3rd	02:00	2	NO-NO ₂	45	45			
3rd	04:00	2	O ₃			165		
3rd	06:00	2	NO-NO ₂	455	170			X
3rd	08:00	2	NO-NO ₂	320	375			X
3rd	10:00	2	O ₃			380		
3rd	12:00	2	NO-NO ₂	345	7.0			X
3rd	14:00	2	NO-NO ₂	200	235			X
3rd	16:00	2	O ₃			240		
3rd	18:00	2					Calibration	
3rd	20:00	1	CO-SO ₂					Zero air
3rd	21:00	2	CO-SO ₂				0.80	340
3rd	23:00	2	CO-SO ₂				10	115
4th	01:00	2	CO-SO ₂				1.0	30
4th	03:00	2	CO-SO ₂				2.3	75
4th	05:00	2	CO-SO ₂				6.0	155
4th	07:00	2	CO-SO ₂					Zero air
4th	09:00	End						

Source: JRC 2026

Table 3 details the requested sequence of generated test concentrations. Additionally, by agreement with the participants, the proficiency test (PT) provider included specific SO₂ concentrations—marked with an ‘X’ in Table 3—during the NO generation phase to evaluate SO₂ interference.

To prepare the test mixtures, high-concentration cylinders of NO, SO₂, and CO were diluted using thermal mass flow controllers [10]. Ozone (O₃) was introduced using an ozone generator, while NO₂ was either sourced directly from NO₂ present within the NO cylinders or produced via the gas-phase titration method [15] under NO-excess conditions. However, because these cylinders and mass flow controllers are not certified, the preparation process itself does not determine the assigned values for the proficiency test. Instead, the assigned values are established directly through ERLAP's measurements using instruments calibrated against Primary Reference Materials (PRMs) and Standard Reference Photometer (SRP) for ozone. To ensure calibration accuracy, ERLAP relies on a system, which calculates mass flow of PRMs by evaluating the pressure drop across a laminar flow element in combination with precise temperature and pressure readings.

To assess the repeatability of their standardized measurement methods, participants were required to report three half-hour mean measurements for each concentration level, referred to as a "run." For zero-concentration levels, which were generated for one hour, participants only needed to report a single half-hour mean measurement; as a result, repeatability was not calculated for these specific runs.

5. The evaluation of laboratory's measurement proficiency

σ_{pt} (sigma PT) is the **standard deviation for proficiency assessment**. In a Proficiency Test (PT), it represents the acceptable level of variability (or the performance target) established by the provider for a specific measurement. It is used to evaluate the performance of participating laboratories, serving as the denominator in the *z score* calculation.

In summary, σ_{pt} defines the width of the tolerated error margin. It determines how far a laboratory's result can deviate from the reference value before its performance is judged as "satisfactory", "questionable" or "unsatisfactory".

More details about σ_{PT} are given in paragraph 5.1. To evaluate the participant's measurement proficiency, the methodology described in ISO 13528:2022 [12] was applied and measurement results of ERLAP were used as the reference values [12]. The traceability of ERLAP's measurement results and the reference values list are presented in paragraph 5.2. In the following proficiency evaluations, the uncertainty of test gas homogeneity (par. 5.2.1) was added to the uncertainties of ERLAP's measurement results.

As described in the AQUILA document 37 [11], the proficiency of the participants was assessed using *z* or *z'* score as performance indicator. The performance indicators *z* or *z'* score verify if the difference between the participants measured value and the assigned value remains within the limits of a common criterion. The selection of the appropriate indicator, *z* score or *z'*-score, depends on whether the uncertainty of the assigned value (u_{ref}) meets the criterion $u_{ref} < 0,3 \sigma_{PT}$ from ISO 13528:2022 [12]. When the criterion is met the *z* score value is applied, in the other case *z'* score is used. Other informative indicators (*D* and *En* score) were calculated in order to verify if the difference between the participants measured values and assigned value remains within the limits of a criterion calculated, from the uncertainty of the participant measurement result and the uncertainty of the assigned value.

As a first step, a process of detection of exceptional errors (typing error, slip in performing the measurement or the calculation, wrong averaging interval, malfunction of instrumentation, etc.) is applied. In this procedure a data consistency evaluation is carried out as described in ISO 13528:2022 [12]. Laboratories showing clear blunders are requested to investigate the cause of discrepancies and are allowed to correct their results in case of identification of exceptional errors. After blunders removal, data are considered definitive. In Annex A for each participant and for each run, the values of measurement submitted, the mean value, the uncertainties, σ_{PT} calculated, measurement error (*D*), *z* score or *z'*-score and *En* score are reported. The data are reported in a table and a graphical format, with all values plotted against the established assigned value.

5.1. Standard deviation for proficiency assessment (σ_{PT})

Over the whole measurement range, σ_{PT} is calculated by linear interpolation between the uncertainty of 2.5 % at the calibration point (75 % of certification range) and the uncertainty at zero-level concentration. The parameters have been discussed and agreed with the AQUILA network through document N37 [10]. The standard deviation for this proficiency assessment is calculated with equation 1 applying the parameters (*a*, *b*) in table 4 and the concentration levels (*X*) generated during the PT.

$$\text{Equation 1} \\ \sigma_{PT} = aX + b$$

where:

- *a* = slope
- *b* = intercept
- *X* = concentration level

Table 4: Parameters for the fitness-for-purpose standard deviation.

Pollutant	a	b	Unit (b)
SO ₂	0.022	2.664	µg/m ³
CO	0.024	0.116	mg/m ³
O ₃	0.020	1.996	µg/m ³
NO	0.024	1.248	µg/m ³
NO ₂	0.028	2.678	µg/m ³

Source: N 37 on ILC organisation [11]

5.2. Assigned values

ERLAP results are used as assigned values. For each pollutant and run, the assigned value is obtained from the ERLAP measurement, corrected by the instrument calibration curve determined for that PT round. ERLAP's analysers are calibrated against certified assigned values of CRMs and are traceable to international standards. In this perspective the assigned values are defined as described in the ISO 13528:2022 [12]. To foster its reference function ERLAP is participating regularly to key comparisons of the Gas Analysis Working Group within the framework of BIPM's CCQM and it is yearly confirming the compliance to standard to ISO 17043:2023 [16], through an annual audit run by the competent Italian accreditation body (see par. 9). During this PT ERLAP's SO₂, CO and NO analysers were calibrated according to the methodology described in the standard ISO 6143:2025 [8].

The assigned values and their uncertainties are computed by the dedicated ERLAP R software, whose calculation model is documented and validated separately.

Calibration gas mixtures were produced from the primary reference materials (produced and certified by NMI Van Swinden Laboratorium) by dynamic dilution method using mass flow controllers [10]. All flows were verified with a certified Molbox/molbloc system. For O₃ measurements, the analysers were calibrated using the JRC SRP42 primary standard (constructed by NIST), which has been compared to the BIPM primary standard [17]. The photometer absorption cross section uncertainty was included in the uncertainty budget [18]. To extend calibration from the NO to NO₂ channel of NOX analyser, the GPT test was performed to establish the efficiency of NO₂-converter, and its contribution is added to the uncertainty. In the following table all assigned values are reported together with their uncertainties.

The calibration curve is fitted with an Errors-in-Variables Generalized Least Squares (EIV-GLS) model that accounts for the uncertainty of both the assigned values and the instrument readings. The combined standard uncertainty of each assigned value is calculated as:

Equation 2

$$u(X) = \sqrt{u_{\text{cal}}^2 + u_{\text{drift}}^2 + u_{\text{hom}}^2}$$

where u_{cal} combines the calibration-curve coefficient uncertainty and the propagated PT-reading uncertainty, u_{drift} is the rectangular contribution from the instrument drift between the pre-PT calibration and the post-PT verification, and u_{hom} is the test-mixture homogeneity contribution.

The expanded uncertainty of the assigned value is calculated using a coverage factor of $k = 2$, which provides a coverage probability of approximately 95 %.

Traceability is ensured through the certified cylinder concentrations, the molbloc flow calibration certificates and the SRP reference.

Table 5: Assigned values, uncertainties and σ_{pt} values used for the proficiency evaluation.

Pollutant	Run	Unit	Assigned value	Standard u	Expanded U	σ_{pt}
SO ₂	0	$\mu\text{g}/\text{m}^3$	0.10	1.9	4.0	2.7
	1		342	2.5	5.0	10
	2		114	2.0	4.0	5.2
	3		29	1.9	4.0	3.3
	4		74	2.0	4.0	4.3
	5		154	2.1	4.0	6.1
CO	0	mg/m^3	0.00	0.006	0.012	0.12
	1		0.69	0.008	0.016	0.13
	2		10.2	0.050	0.100	0.36
	3		1.04	0.008	0.016	0.14
	4		2.19	0.013	0.026	0.17
	5		5.64	0.027	0.060	0.25
O ₃	0	$\mu\text{g}/\text{m}^3$	0.04	1.2	2.4	2.0
	1		244	1.0	1.9	6.9
	2		143	0.6	1.2	4.9
	3		164	0.7	1.3	5.3
	4		383	1.5	3.0	9.6
	5		241	1.0	2.0	6.8
NO	0	$\mu\text{g}/\text{m}^3$	0.20	1.0	2.0	1.3
	1		246	1.4	2.9	7.2
	2		96	1.0	2.1	3.6
	3		38	1.0	1.9	2.2
	4		28	1.0	2.0	1.9
	5		75	1.0	2.0	3.0
	6		45	1.0	1.9	2.3
	7		453	2.1	4.0	12
	8		318	1.6	3.0	8.9
	9		347	1.7	3.0	9.6
	10		196	1.2	2.5	6.0
NO ₂	0	$\mu\text{g}/\text{m}^3$	0.22	1.6	3.0	2.7
	1		6.4	2.0	4.0	2.9
	2		237	2.1	4.0	9.3
	3		0.67	1.5	3.0	2.7
	4		16	1.5	3.0	3.1
	5		0.47	1.6	3.0	2.7
	6		46	1.5	3.0	4.0
	7		169	2.8	6.0	7.4
	8		378	3.0	6.0	13
	9		7.8	2.0	4.0	2.9
	10		239	2.2	4.0	9.4

Source: JRC 2026

5.2.1. Homogeneity

The homogeneity of the test gas distribution system was verified before the start of the PT by comparing the response of a sample analyser at each bench position against a reference analyser connected to the reference port.

The criterion for acceptable homogeneity is that the difference between sample and reference does not exceed 0.5 % of the generated concentration. Table below reports the results of the homogeneity test.

Table 6: Homogeneity test results for the gas distribution system.

Bench position	Sample Analyzer SN14	Ref Analyzer SN15	Diff. in nmol/mol	<0.5 % passed?
20a/b	447.0	436.0	0.0	Yes
1a	446.0	436.0	-1.0	Yes
1b	446.0	435.0	0.0	Yes
2a	447.0	436.0	0.0	Yes
2b	447.5	436.0	0.5	Yes
3a	449.0	437.0	1.0	Yes
3b	449.0	437.0	1.0	Yes
4a	448.0	436.2	0.8	Yes
4b	449.0	437.7	0.3	Yes
5a	449.0	437.4	0.6	Yes
5b	449.0	437.6	0.4	Yes
6a	448.0	438.1	-1.1	Yes
6b	448.0	438.0	-1.0	Yes
7a	448.0	438.0	-1.0	Yes
7b	449.5	438.3	0.2	Yes
8a	449.0	438.4	-0.4	Yes
8b	449.0	438.4	-0.4	Yes
9a	450.0	438.6	0.4	Yes
9b	450.0	438.6	0.4	Yes
10a	449.0	438.4	-0.4	Yes
10b	449.0	438.5	-0.5	Yes
11a	449.0	438.5	-0.5	Yes
11b	450.0	438.5	0.5	Yes
12a	450.0	438.6	0.4	Yes
12b	450.0	438.6	0.4	Yes
13a	450.0	438.7	0.3	Yes
13b	450.0	438.7	0.3	Yes
14a	450.0	438.8	0.2	Yes
14b	450.0	438.8	0.2	Yes
15a	450.5	438.5	1.0	Yes
15b	450.0	438.6	0.4	Yes
16a	450.0	438.6	0.4	Yes
16b	449.0	438.3	-0.3	Yes
17a	451.0	438.3	1.7	Yes
17b	451.0	438.7	1.3	Yes
18a	450.0	438.7	0.3	Yes
18b	450.0	438.5	0.5	Yes
19a	451.0	438.7	1.3	Yes
19b	450.0	438.7	0.3	Yes
20a	450.5	438.8	0.7	Yes
20b	451.0	438.6	1.4	Yes
21a	451.5	439.5	1.0	Yes
21b	451.0	439.4	0.6	Yes
22a	450.0	439.4	-0.4	Yes
22b	450.0	438.8	0.2	Yes
22c	450.0	438.6	0.4	Yes
22d	449.0	438.6	-0.6	Yes
23a	448.0	439.0	-2.0	Yes
23b	450.0	438.0	1.0	Yes
23c	449.0	439.1	-1.1	Yes
23d	449.0	438.5	-0.5	Yes

Source: JRC 2026

5.3. z or z' score evaluation

The z-score and z'-score performance indicators are calculated according to ISO 13528:2022 [12] as follows:

$$\text{Equation 3}$$

$$z = \frac{x_i - X}{\sqrt{\sigma_{pt}^2}}$$

$$\text{Equation 4}$$

$$z' = \frac{x_i - X}{\sqrt{\sigma_{pt}^2 + u_X^2}}$$

Where:

- z = z score
- z' = z' score
- x_i = participant average values
- X = the assigned value
- u_X = uncertainty of the assigned value
- σ_{pt} = standard deviation for proficiency assessment

The selected z or z' score is calculated using the ISO 13528:2022 [12] criterion: z score is used when the standard uncertainty of the assigned value is smaller than $0.3 \sigma_{PT}$; otherwise, z' score is used.

The assessment of results is made according to the following criteria:

- $|z \text{ or } z'| \leq 2$ is considered satisfactory.
- $2 < |z \text{ or } z'| < 3$ are considered questionable.
- $|z \text{ or } z'| \geq 3$ are considered unsatisfactory.

Scores falling in this range are very unusual and are taken as evidence that an anomaly has occurred that should be investigated and corrected.

All calculations use unrounded values; rounding is applied only in reporting columns.

Table 7 summarizes the overall performance of the participating laboratories based on the z and z' scores.

Table 7: Overall z or z' score evaluation summary.

indicator	evaluation	n	percent
z or z'	satisfactory	333	99.1
z or z'	questionable	3	0.9

Source: JRC 2026

Out of 336 total evaluations, 99.1 % were satisfactory, 0.9 % questionable and none unsatisfactory. This outcome is in line with the historical average performance of the NRL network in these exercises.

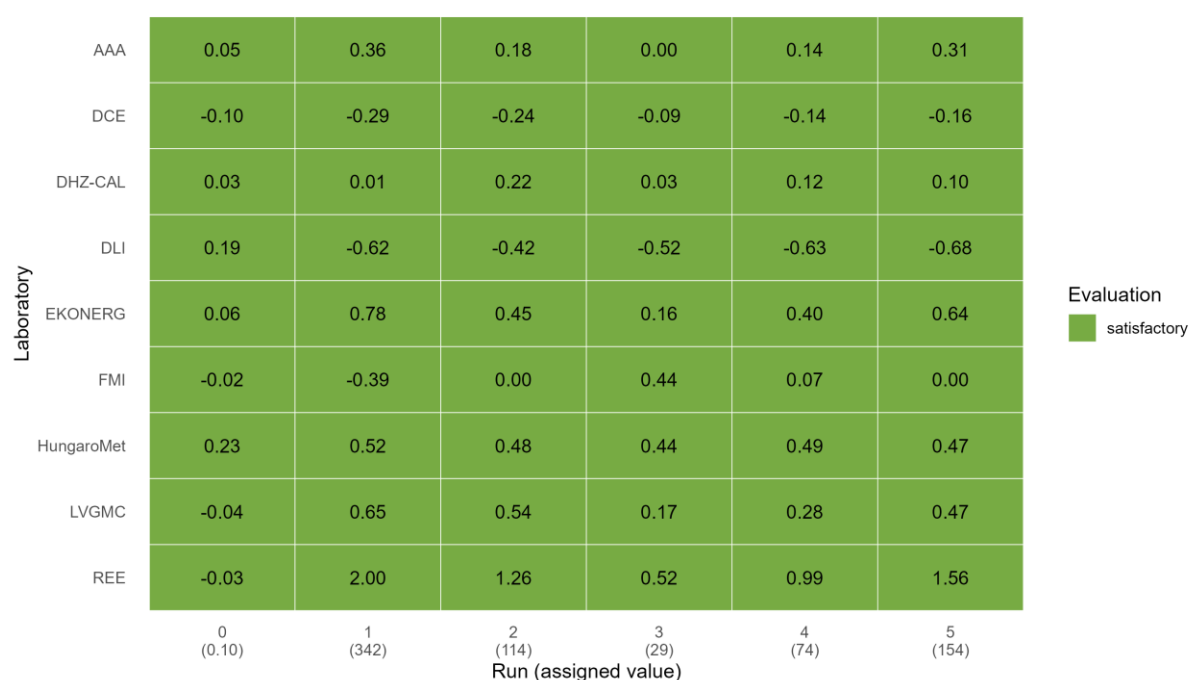
Table 8: z or z' score evaluation summary by pollutant.

Pollutant	z_evaluation	n	percent
CO	satisfactory	42	100.0
NO	satisfactory	97	98.0
NO	questionable	2	2.0
NO ₂	satisfactory	98	99.0
NO ₂	questionable	1	1.0
O ₃	satisfactory	42	100.0
SO ₂	satisfactory	54	100.0

Source: JRC 2026

The summary results of the z and z' score evaluations (Table 8) present an overall picture of the participants' performance by pollutant.

Parameters with excellent performance (≥ 95 % satisfactory): **CO** (100 % satisfactory), **O₃** (100 % satisfactory), **SO₂** (100 % satisfactory), **NO₂** (99 % satisfactory, 1 questionable), **NO** (98 % satisfactory, 2 questionable). These results indicate excellent mastery of the analytical methods. The results of z score evaluation are presented in coloured graphic matrix charts (Figure 1 to 5) that displays for each pollutant each candidate (rows) against the statistical indicator used to summarise the performance. Each column is referring to the tested concentration level generated during the PT. Each cell is filled with the value and a colour that describes the score obtained by the participant. The colour coding provides a quick visual summary: a candidate whose row is predominantly green has performed well across both indicators, whereas a row with more than 40 % yellow or 20 % red cells flags require remediation.

Figure 1: z or z' score matrix for SO₂. Scores are shown for each participant and run.
z or z' score evaluation - SO₂

Source: JRC 2026

For **SO₂**, 54 out of 54 results were satisfactory (100 %).

Figure 2: z or z' score matrix for CO. Scores are shown for each participant and run.
z or z' score evaluation - CO

Laboratory	AAA	0.09	0.15	0.83	0.45	0.06	0.65
	DCE	-0.45	-0.33	0.28	-0.38	-0.53	0.25
	DHZ-CAL	n.i.	n.i.	n.i.	n.i.	n.i.	n.i.
	DLI	-0.16	-0.23	0.18	-0.24	-0.53	-0.15
	EKONERG	-0.10	0.01	0.47	0.03	0.07	0.24
	FMI	0.00	0.00	-0.83	-0.17	-0.53	-0.54
	HungaroMet	-0.22	-0.08	0.28	-0.26	0.06	0.25
	LVGMC	n.i.	n.i.	n.i.	n.i.	n.i.	n.i.
	REE	-1.12	-0.93	-0.55	-0.90	-0.53	-0.15
		0 (0.00)	1 (0.69)	2 (10)	3 (1.0)	4 (2.2)	5 (5.6)
		Run (assigned value)					

Evaluation

- n.i.: no instrument for this gas
- satisfactory

Source: JRC 2026

For **CO**, 42 out of 42 results were satisfactory (100 %).

Figure 3: z or z' score matrix for O₃. Scores are shown for each participant and run.
z or z' score evaluation - O₃

Laboratory	AAA	-0.02	-0.58	0.14	0.19	-0.14	0.15
	DCE	n.r.	n.r.	n.r.	n.r.	n.r.	n.r.
	DHZ-CAL	0.84	0.28	0.73	0.59	0.17	0.37
	DLI	0.14	-0.53	-0.41	-0.32	-0.48	-0.44
	EKONERG	-0.06	-0.60	-0.42	-0.26	-0.25	-0.36
	FMI	-0.27	-0.15	-0.07	0.00	-0.07	-0.15
	HungaroMet	-0.02	-0.15	-0.14	0.00	-0.14	-0.20
	LVGMC	n.i.	n.i.	n.i.	n.i.	n.i.	n.i.
	REE	-0.79	0.00	0.21	0.25	0.24	0.15
		0 (0.04)	1 (244)	2 (143)	3 (164)	4 (383)	5 (241)
		Run (assigned value)					

Evaluation

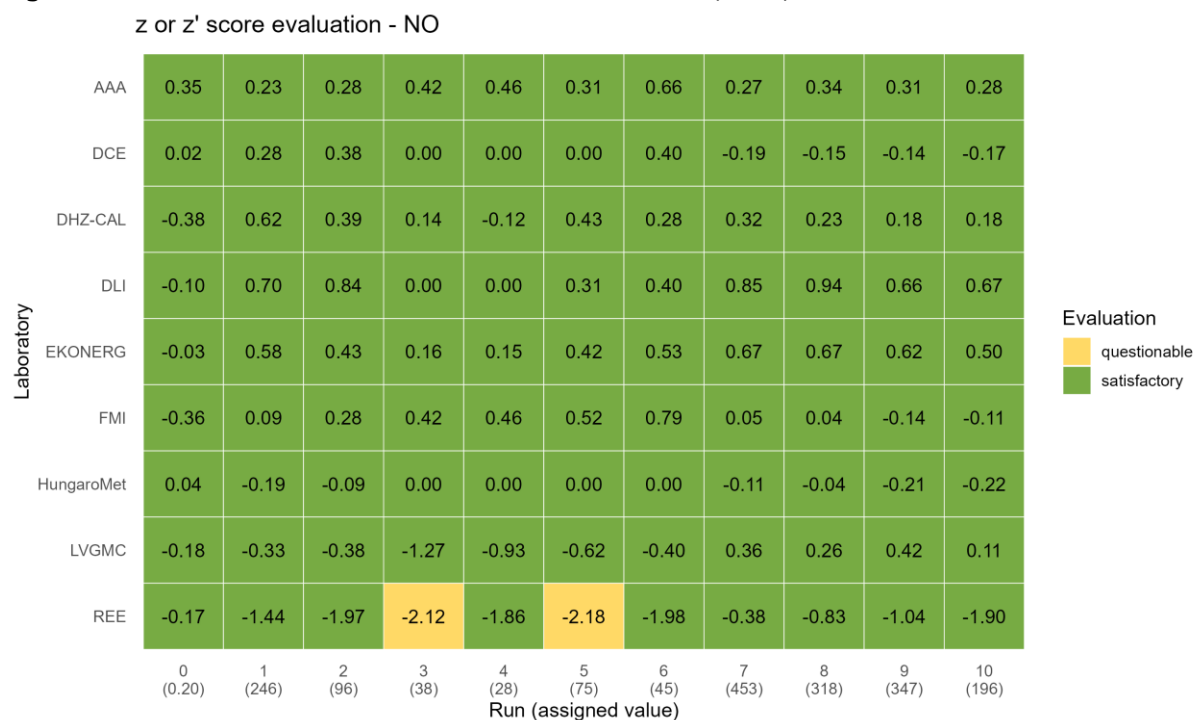
- n.i.: no instrument for this gas
- n.r.: value not reported
- satisfactory

Source: JRC 2026

For **O₃**, 42 out of 42 results were satisfactory (100 %). Laboratory DCE did not report O₃ results.

During pre-test installation, the participant reported an anomalous response from their O₃ analyzer. Despite an attempted on-site repair, the issue persisted. **Subsequent investigation revealed that the ozone monitor's UV-drive board assembly had failed**, which explains the participant's missing data.

Figure 4: z or z' score matrix for NO. Scores are shown for each participant and run.



Source: JRC 2026

For **NO**, 97 out of 99 results were satisfactory (98 %), 2 questionable (2 %) and 0 unsatisfactory. Questionable results (without unsatisfactory) were observed for REE. The majority of laboratories (8 out of 9) achieved fully satisfactory results.

Figure 5: z or z' score matrix for NO₂. Scores are shown for each participant and run.
z or z' score evaluation - NO₂

Laboratory	AAA	-0.07	-0.55	-0.25	-0.22	-0.58	-0.15	-0.24	-0.29	-0.18	-0.81	-0.21
	DCE	-0.27	0.37	0.07	-0.16	-0.19	-0.09	-0.16	0.13	-0.25	0.21	-0.18
	DHZ-CAL	-0.13	-0.25	-0.31	-0.29	-0.26	-0.28	-0.51	-0.13	-0.02	-0.63	-0.59
	DLI	0.09	-0.16	0.18	0.02	0.00	-0.07	0.08	0.00	0.10	-0.68	0.14
	EKONERG	-0.62	-1.84	-0.50	-0.47	-0.75	-0.83	-0.67	-1.74	-0.87	-2.81	-0.79
	FMI	0.11	-0.08	0.00	-0.16	-0.10	-0.12	0.00	-0.08	-0.10	-0.33	-0.18
	HungaroMet	0.08	0.07	-0.21	0.07	0.00	-0.01	0.00	-0.46	-0.43	-0.25	-0.32
	LVGMC	-0.07	-0.02	0.32	-0.07	-0.29	-0.10	-0.24	0.67	0.93	-0.05	0.78
	REE	-0.08	-0.25	-0.75	-0.14	-0.58	-0.14	-0.94	0.42	0.48	-0.60	-0.32
		0 (0.22)	1 (6.4)	2 (237)	3 (0.67)	4 (16)	5 (0.47)	6 (46)	7 (169)	8 (378)	9 (7.8)	10 (239)
		Run (assigned value)										

Evaluation

questionable

satisfactory

Source: JRC 2026

For **NO₂**, 98 out of 99 results were satisfactory (99 %), 1 questionable (1 %) and 0 unsatisfactory. Questionable results (without unsatisfactory) were observed for EKONERG. The majority of laboratories (8 out of 9) achieved fully satisfactory results.

5.4. En score evaluation

To evaluate the participants' ability to have results close to the assigned values within their reported uncertainties, the E_n -score parameters (E_n) were calculated as follows:

$$\text{Equation 5} \\ E_n = \frac{x_i - X}{\sqrt{U_{x_i}^2 + U_X^2}}$$

where X is the assigned value with its associated expanded uncertainty U_X and x_i is the participant's mean value with its associated expanded uncertainty U_{x_i} .

The E_n score evaluates the difference between the participant result and the assigned value relative to the corresponding combined expanded uncertainty. Results with $|E_n| < 1$ are considered satisfactory whereas results with $|E_n| \geq 1$ are considered unsatisfactory.

Table 9: Overall E_n score evaluation summary.

indicator	evaluation	n	percent
En	satisfactory	314	93.5
En	unsatisfactory	22	6.5

Source: JRC 2026

Table 9 summarizes the overall En score evaluation. Most of the submitted values (93.5 %) were found to be satisfactory.

Table 10: En score evaluation summary by pollutant.

Pollutant	En_evaluation	n	percent
CO	satisfactory	37	88.1
CO	unsatisfactory	5	11.9
NO	satisfactory	91	91.9
NO	unsatisfactory	8	8.1
NO ₂	satisfactory	94	94.9
NO ₂	unsatisfactory	5	5.1
O ₃	satisfactory	42	100.0
SO ₂	satisfactory	50	92.6
SO ₂	unsatisfactory	4	7.4

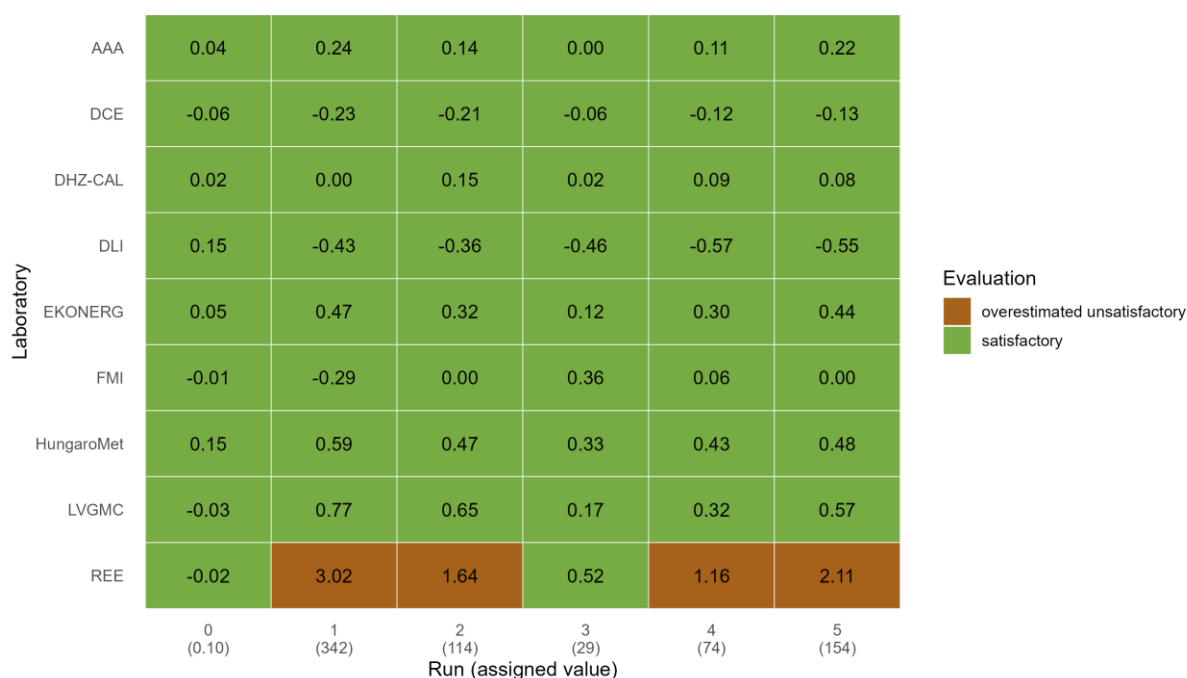
Source: JRC 2026

The 22 unsatisfactory evaluations (6.5 %) were distributed across various parameters and concentration levels, as reported in Table 10. This table highlights a lower performance rate for NO, which recorded 8 unsatisfactory evaluations (8.1 %). Laboratories LVGMC and REE reported satisfactory z or z' scores but unsatisfactory En scores, suggesting that the reported measurement uncertainty may be underestimated relative to the observed bias. This pattern indicates that the underperformance is mainly due to inadequate uncertainty budgets rather than measurement errors.

The overall performance of all participants in terms of the En score is shown in Figures 6 to 10 as colour-coded graphical matrices. The x-axis represents the runs (concentration levels), while the y-axis represents the participants. Through this two-dimensional graphical representation, the figures use different colours to indicate the En score obtained by each participant at each concentration level analysed during the PT.

The En score calculated for each participant is reported in the corresponding matrix cell. In each figure, the legend uses different colours to classify the results: red indicates underestimated unsatisfactory results, green indicates satisfactory results, and brown indicates overestimated unsatisfactory results.

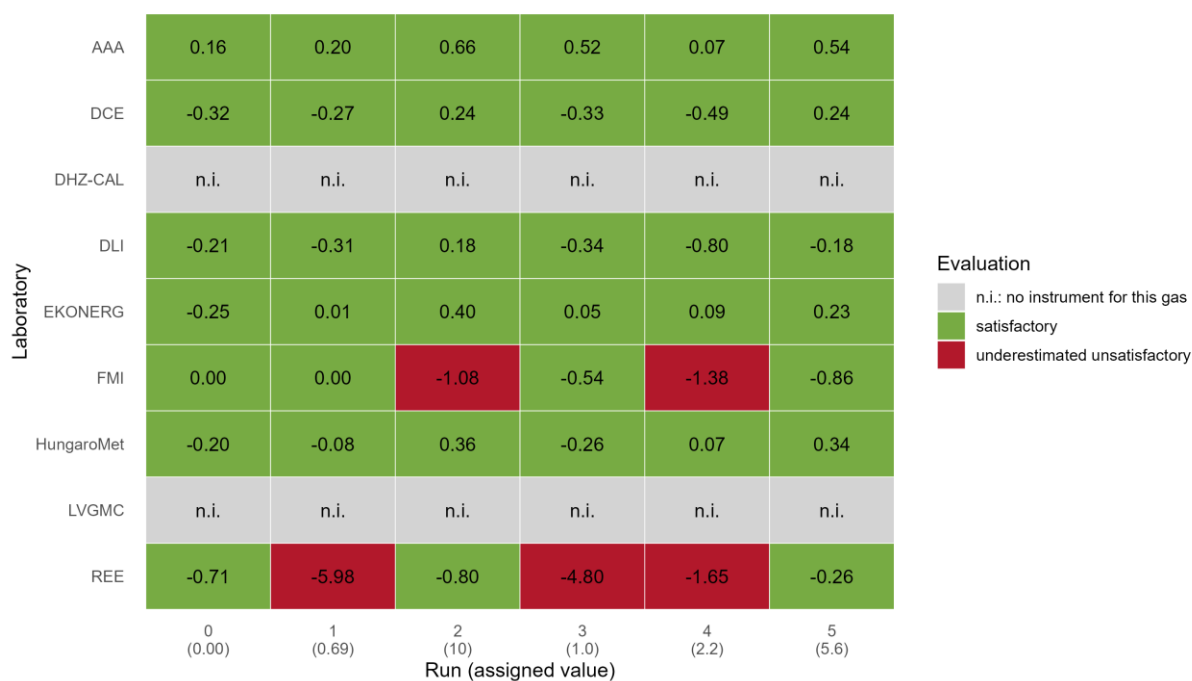
Figure 6: En score matrix for SO₂. Scores are shown for each participant and run.
En score evaluation - SO₂



Source: JRC 2026

For **SO₂**, 50 of 54 En evaluations were satisfactory (92.6 %) and 4 unsatisfactory. Unsatisfactory En scores were recorded for REE.

Figure 7: En score matrix for CO. Scores are shown for each participant and run.
En score evaluation - CO

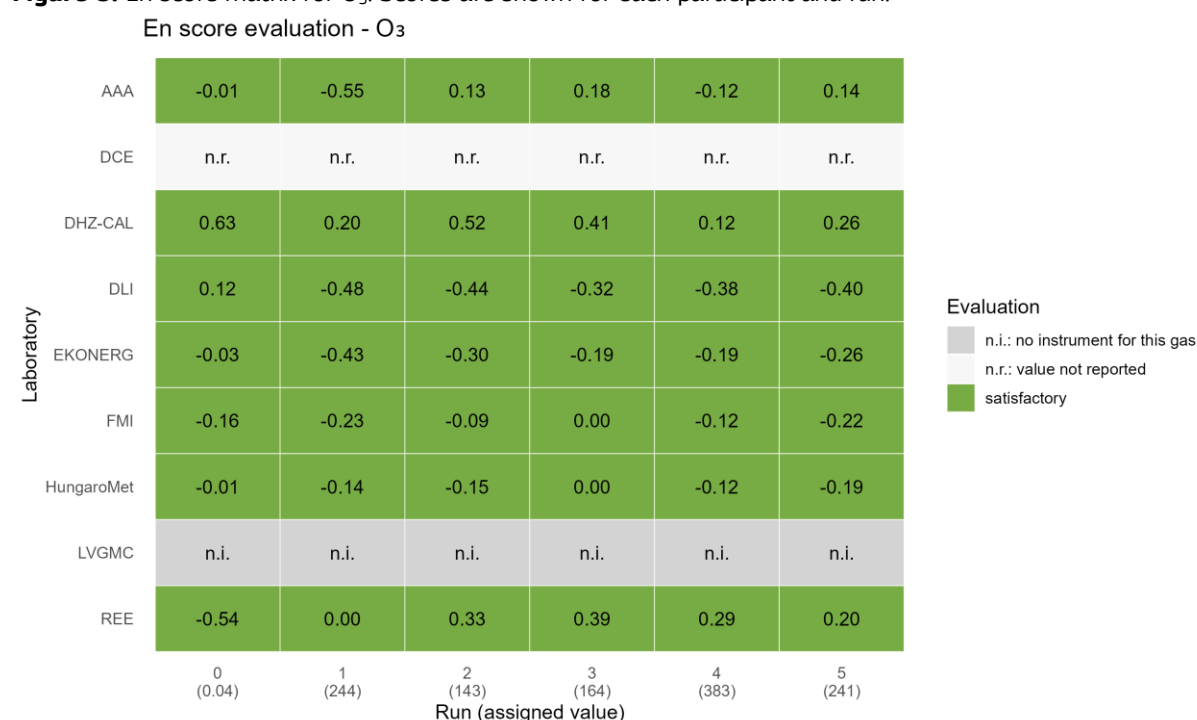


Source: JRC 2026

For **CO**, 37 of 42 En evaluations were satisfactory (88.1 %) and 5 unsatisfactory. Unsatisfactory En scores were recorded for FMI and REE. FMI and REE reported satisfactory z or z' scores but unsatisfactory En scores, suggesting that the reported measurement uncertainty may be

underestimated. AAA, DCE, DLI, EKONERG, and HungaroMet maintained satisfactory En scores across all runs.

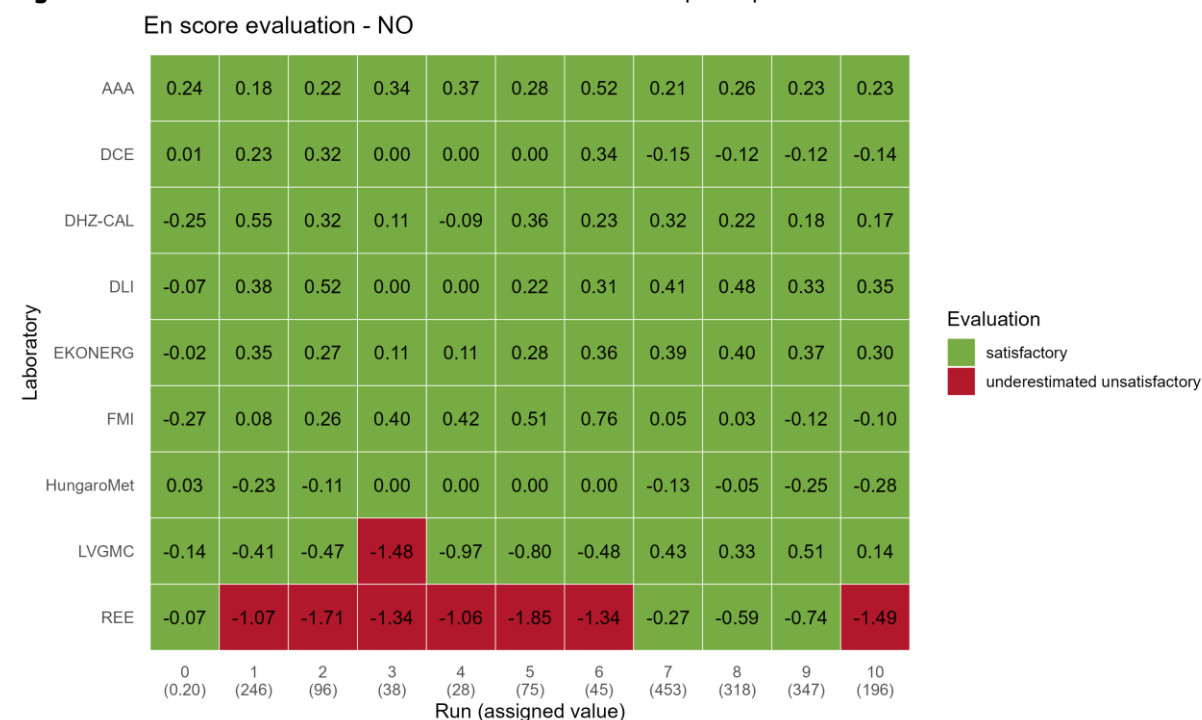
Figure 8: En score matrix for O₃. Scores are shown for each participant and run.



Source: JRC 2026

For O₃, 42 of 42 En evaluations were satisfactory (100 %) and 0 unsatisfactory. DCE didn't report value for this pollutant.

Figure 9: En score matrix for NO. Scores are shown for each participant and run.



Source: JRC 2026

For **NO**, 91 of 99 of the E_n evaluations were satisfactory (91.9 %). The remaining 8 unsatisfactory E_n scores belonged to LVGMC (1 value) and REE (7 values). LVGMC's satisfactory z or z' scores contrast with their unsatisfactory E_n scores, pointing to an underestimated measurement uncertainty. Conversely, REE produced questionable z or z' scores in runs 3 and 5, with other values remaining satisfactory, which points to a combination of measurement bias and uncertainty underestimation.

Figure 10: E_n score matrix for NO₂. Scores are shown for each participant and run.



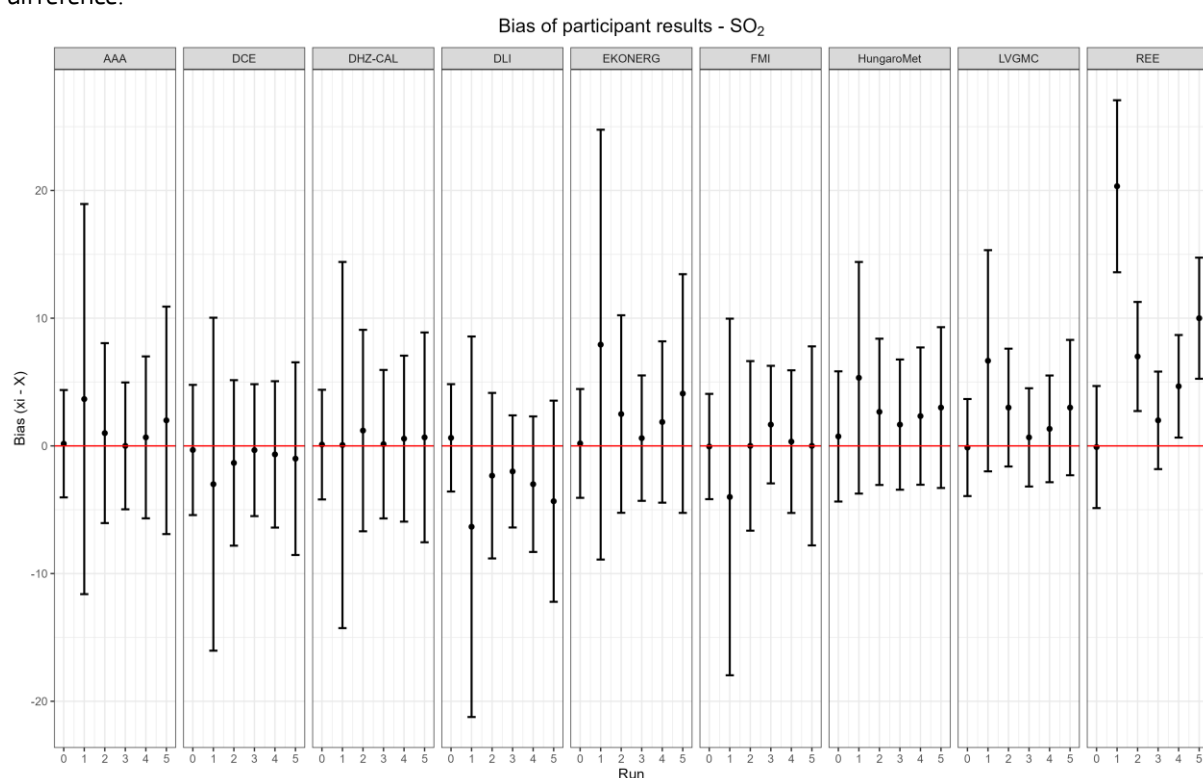
Source: JRC 2026

For NO₂, 94 out of 99 E_n evaluations (94.9 %) were satisfactory. The five unsatisfactory E_n scores were recorded by EKONERG and LVGMC. LVGMC achieved satisfactory z or z' scores despite their unsatisfactory E_n results, suggesting that their reported measurement uncertainty may be underestimated. Similarly, EKONERG's z or z' scores were generally satisfactory (with the exception of a questionable value in run 9), indicating that their unsatisfactory E_n scores also point to an uncertainty calculation that requires review.

5.5. Estimates of deviation - measurement error (D)

The following figures show the participant error ($x_i - X$) for each run indicated as a dot. The error bars represent the combined expanded uncertainty of the difference, $\sqrt{(U_X^2 + U_{x_i}^2)}$. Results with error bars touching or crossing the x-axis (red line) are satisfactory.

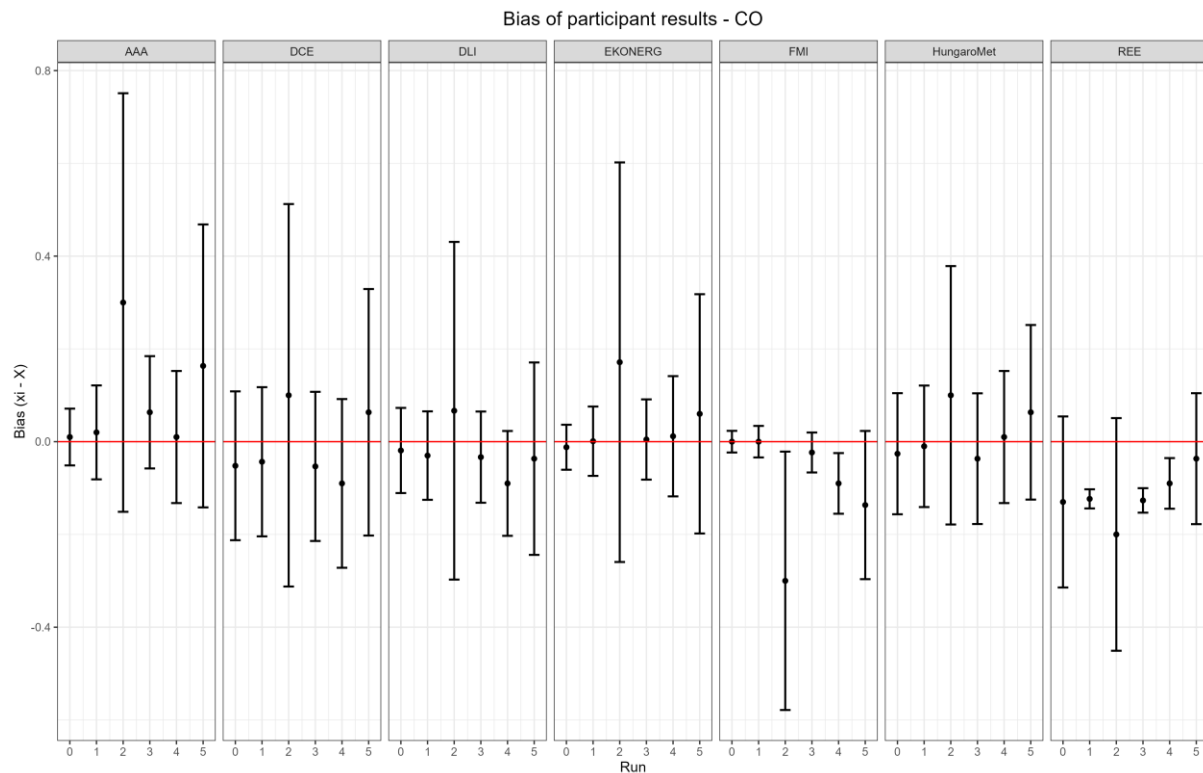
Figure 11: D of participant SO₂ measurement results. Error bars: combined expanded uncertainty of the difference.



Source: JRC 2026

For **SO₂**, the bias analysis reveals the following patterns. EKONERG, HungaroMet, LVGMC, and REE showed a systematic positive bias (results above the assigned value). DLI showed a systematic negative bias (results below the assigned value). AAA, DCE, DHZ-CAL, and FMI demonstrated near-zero mean bias, indicating good agreement with the assigned value.

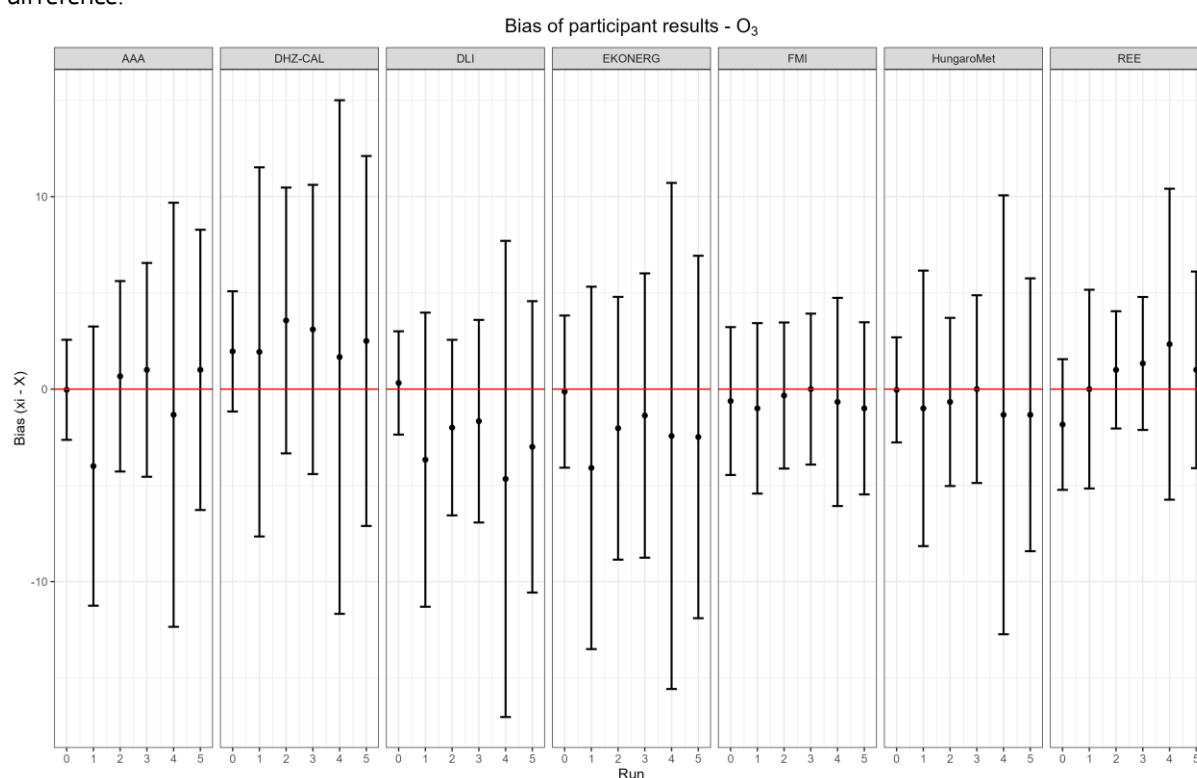
Figure 12: D of participant CO measurement results. Error bars: combined expanded uncertainty of the difference.



Source: JRC 2026

For **CO**, the bias analysis reveals the following patterns. AAA showed a systematic positive bias (results above the assigned value). FMI and REE showed a systematic negative bias (results below the assigned value). DCE, DLI, EKONERG, and HungaroMet demonstrated near-zero mean bias, indicating good agreement with the assigned value.

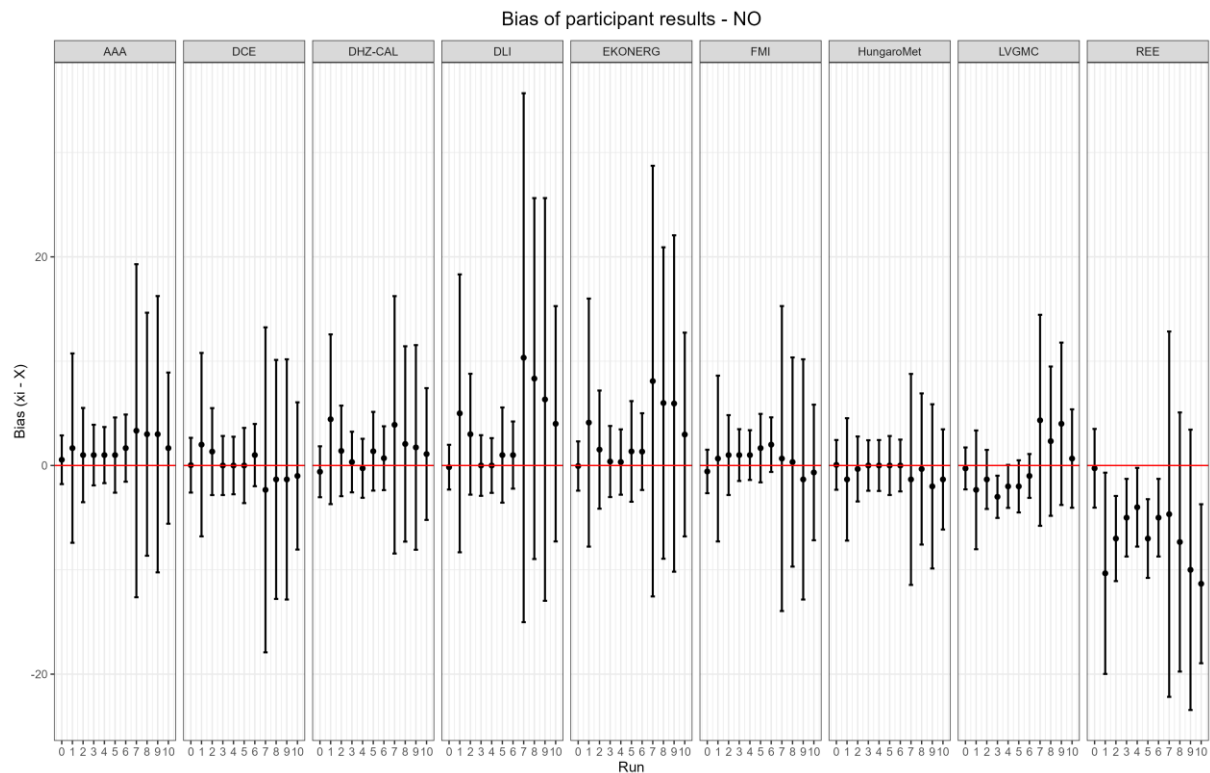
Figure 13: D of participant O₃ measurement results. Error bars: combined expanded uncertainty of the difference.



Source: JRC 2026

For O₃, the bias analysis reveals the following patterns. DHZ-CAL showed a general positive bias (results above the assigned value). DLI and EKONERG showed a negative bias (results below the assigned value). AAA, FMI, HungaroMet, and REE demonstrated near-zero mean bias, indicating good agreement with the assigned value.

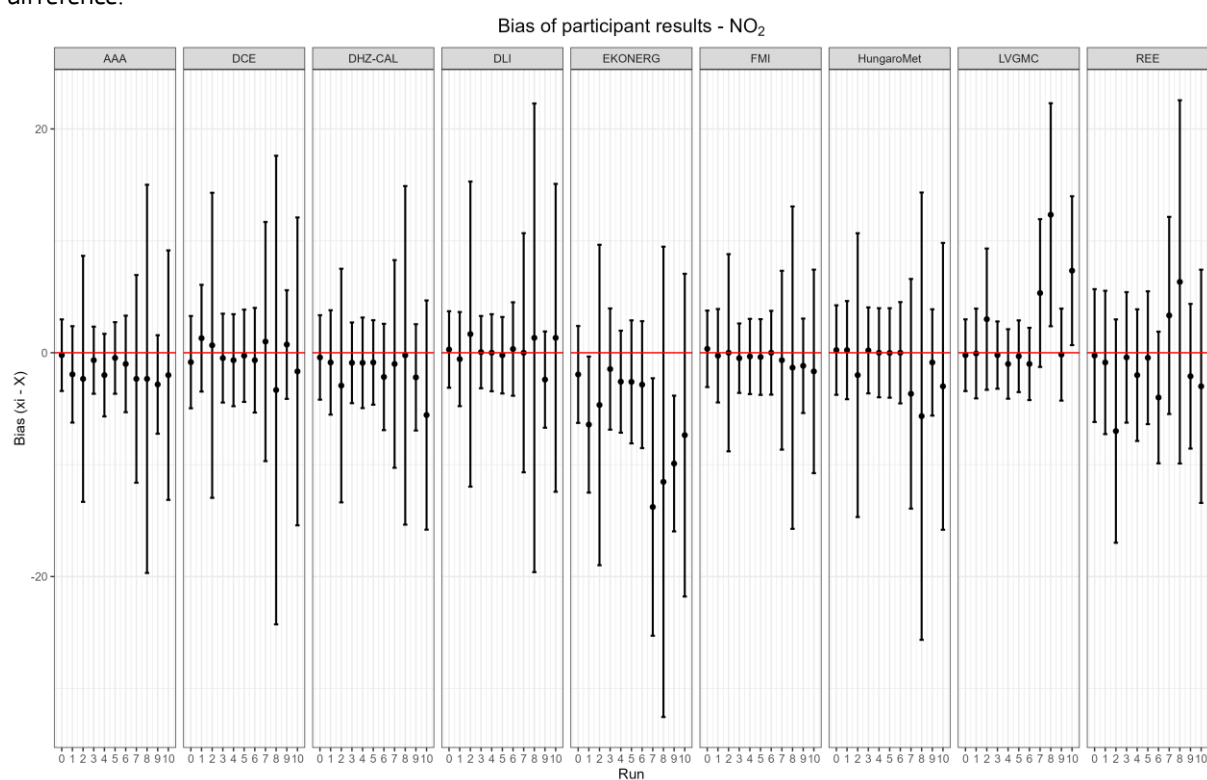
Figure 14: D of participant NO measurement results. Error bars: combined expanded uncertainty of the difference.



Source: JRC 2026

For **NO**, the bias analysis reveals the following patterns. DLI and EKONERG showed a positive bias (results above the assigned value). REE showed a systematic negative bias (results below the assigned value).

Figure 15: D of participant NO₂ measurement results. Error bars: combined expanded uncertainty of the difference.



Source: JRC 2026

For **NO₂**, the bias analysis reveals the following patterns. AAA, DHZ-CAL, and EKONERG showed a negative bias (results below the assigned value).

5.6. Quality result general assessment - decision categories

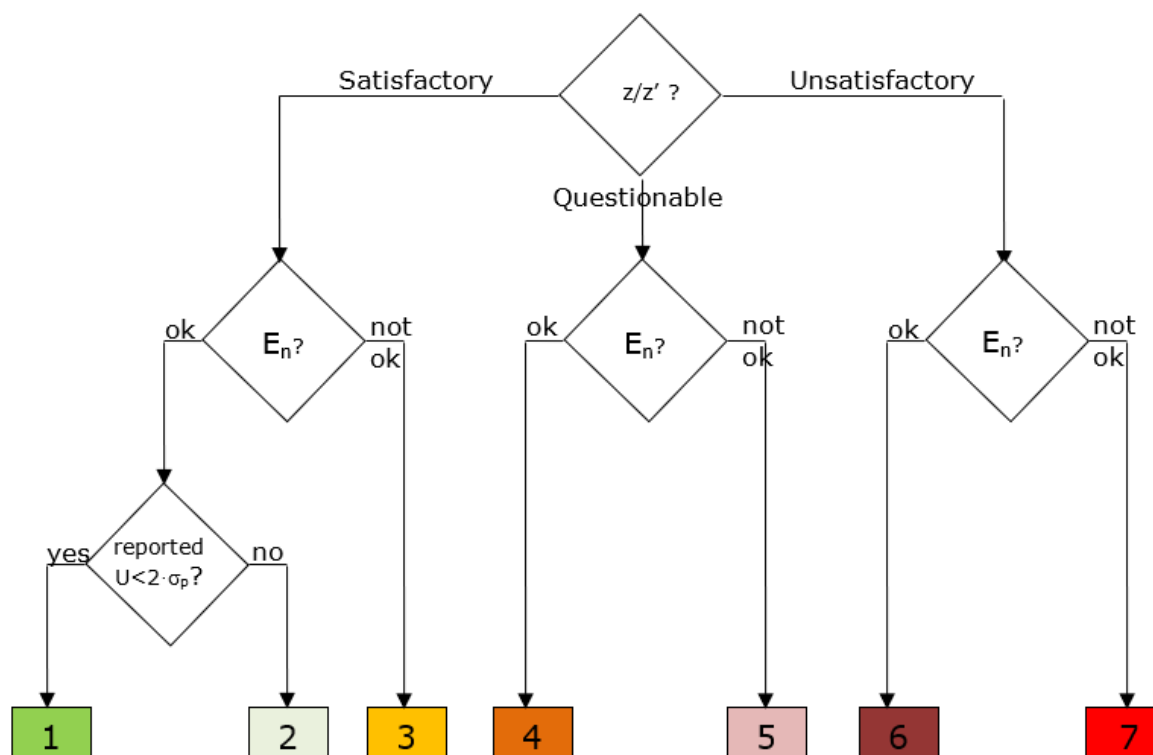
A decision diagram was developed for a general assessment of the quality of each result. It combines the z or z' score evaluation with the E_n score evaluation and, where both are satisfactory, checks whether the reported uncertainty is proportionate to the fitness-for-purpose standard deviation. The assessment results in seven categories (1 to 7):

Table 11: Decision categories for general assessment of proficiency results.

Category	z / z'	E_n	Reported u	Interpretation
1	Satisfactory	OK	Proportionate	Completely satisfactory result
2	Satisfactory	OK	Too high	Result satisfactory, but uncertainty is overestimated
3	Satisfactory	Not OK	—	Measured value satisfactory, but uncertainty is underestimated
4	Questionable	OK	High enough to account for deviation	Questionable z/z' , the result is compatible with the reference value when the reported uncertainty is taken into account
5	Questionable	Not OK	—	Questionable result
6	Unsatisfactory	OK	High enough to account for deviation	Unsatisfactory z/z' , but the result is compatible with the reference value when the reported uncertainty is taken into account
7	Unsatisfactory	Not OK	—	Unsatisfactory result

Source: JRC 2026

Figure 16: Decision diagram for general assessment of proficiency results.



Source: JRC 2026

Table 12: General assessment of quality: decision categories per participant and run.

Pollutant	Run	Ref. conc.	AAA	DCE	DHZ-CAL	DLI	EKONERG	FMI	HungaroMet	LVGMC	REE
SO ₂ (µg/m ³)	0	0.10	1	1	1	1	1	1	1	1	1
	1	342	1	1	1	1	1	1	1	1	3
	2	114	1	1	1	1	1	1	1	1	3
	3	29	1	1	1	1	1	1	1	1	1
	4	74	1	1	1	1	1	1	1	1	3
	5	154	1	1	1	1	1	1	1	1	3
CO (mg/m ³)	0	0.00	1	1	n.i.	1	1	1	1	n.i.	1
	1	0.69	1	1	n.i.	1	1	1	1	n.i.	3
	2	10.2	1	1	n.i.	1	1	3	1	n.i.	1
	3	1.04	1	1	n.i.	1	1	1	1	n.i.	3
	4	2.19	1	1	n.i.	1	1	3	1	n.i.	3
	5	5.64	1	1	n.i.	1	1	1	1	n.i.	1
O ₃ (µg/m ³)	0	0.04	1	n.r.	1	1	1	1	1	n.i.	1
	1	244	1	n.r.	1	1	1	1	1	n.i.	1
	2	143	1	n.r.	1	1	1	1	1	n.i.	1
	3	164	1	n.r.	1	1	1	1	1	n.i.	1
	4	383	1	n.r.	1	1	1	1	1	n.i.	1
	5	241	1	n.r.	1	1	1	1	1	n.i.	1
NO (µg/m ³)	0	0.20	1	1	1	1	1	1	1	1	2
	1	246	1	1	1	1	1	1	1	1	3
	2	96	1	1	1	1	1	1	1	1	3
	3	38	1	1	1	1	1	1	1	3	5
	4	28	1	1	1	1	1	1	1	1	3
	5	75	1	1	1	1	1	1	1	1	5
	6	45	1	1	1	1	1	1	1	1	3
	7	453	1	1	1	2	1	1	1	1	1
	8	318	1	1	1	1	1	1	1	1	1
	9	347	1	1	1	1	1	1	1	1	1
NO ₂ (µg/m ³)	10	196	1	1	1	1	1	1	1	1	3
	0	0.22	1	1	1	1	1	1	1	1	1
	1	6.4	1	1	1	1	3	1	1	1	1
	2	237	1	1	1	1	1	1	1	1	1
	3	0.67	1	1	1	1	1	1	1	1	1
	4	16	1	1	1	1	1	1	1	1	1
	5	0.47	1	1	1	1	1	1	1	1	1
	6	46	1	1	1	1	1	1	1	1	1
	7	169	1	1	1	1	3	1	1	1	1
	8	378	1	1	1	1	1	1	1	3	1
	9	7.8	1	1	1	1	5	1	1	1	1
	10	239	1	1	1	1	1	1	1	3	1

Source: JRC 2026

n.i.= no instrument, the participant did not take part in the proficiency testing for this pollutant.
n.r. = not reported values

Table 13: Summary of decision categories across all results.

Category	Description	N results	%
1	Completely satisfactory	312	92.9
2	Satisfactory, U overestimated	2	0.6
3	Satisfactory value, U underestimated	19	5.7
5	Questionable (En not ok)	3	0.9

Source: JRC 2026

The decision category analysis provides an integrated assessment combining both performance indicators. Out of 336 results, 92.9 % were completely satisfactory (**category 1**) and 93.5 % had correct measurement values (**categories 1 and 2** combined).

The uncertainty estimation remains the dominant issue: 6.2 % of all results show a mismatch between the reported uncertainty and the observed performance. Specifically, 2 results (**category 2**) reported uncertainties exceeding $2 \cdot \sigma_{PT}$ despite satisfactory values, while 19 results (**category 3**) reported uncertainties that were too small relative to the observed bias.

Underestimated uncertainties (**category 3**) were most frequent for REE (12 results), LVGMC (3 results). These laboratories are encouraged to review their uncertainty budgets, as the observed deviations from the assigned values are not fully covered by the declared expanded uncertainty. A total of 3 results (0.9 %) fall in the most critical **categories (5 and 7)**, where both the z or z' score and the En score indicate unsatisfactory performance. These are distributed across: NO (2), NO₂ (1). The laboratories concerned are: REE (2), EKONERG (1).

6. Discussion

The proficiency evaluation scheme assessed participants' measured values and their evaluated uncertainties through one assessment indicator (z or z' score). Other performance indicators were calculated to have a more complete overview of the quality of the results reported (En score and D).

In this exercise 99.1 % of results in the z or z' score evaluation are satisfactory. Regarding the En score, 93.5 % of results are found satisfactory.

The z or z' score evaluates the difference between the participant result and the assigned value relative to the common fitness-for-purpose standard deviation σ_{PT} . The En score, on the other hand, is driven by the participant's own reported uncertainty. A satisfactory z or z' score combined with an unsatisfactory En score indicates that the measured value is acceptable, but the reported uncertainty is underestimated. Conversely, a questionable z or z' score with a satisfactory En score can occur when a laboratory reports a large uncertainty that compensates for a biased result. The following laboratories obtained satisfactory z or z' scores but unsatisfactory En scores, suggesting underestimated uncertainties:

- EKONERG (NO₂): 2 result(s)
- FMI (CO): 2 result(s)
- LVGMC (NO): 1 result(s)
- LVGMC (NO₂): 2 result(s)
- REE (CO): 3 result(s)
- REE (NO): 5 result(s)
- REE (SO₂): 4 result(s)

These laboratories are encouraged to review their uncertainty budgets.

6.1. Laboratory overall evaluation (AQUILA N37 criterion)

According to the AQUILA document N37 [11], the overall z or z' score assessment per laboratory and per parameter is considered satisfactory provided that:

- no more than or equal to 20 % of the results are unsatisfactory.
- fewer than 40 % of the results are questionable.
- participation is considered valid only if a minimum of 80 % of the requested values per pollutant are successfully submitted.

Should a laboratory fail at least one of these requirements, the NRL must repeat the exercise for the concerned parameter in the subsequent Proficiency Test to verify the successful implementation of corrective actions.

The following laboratory/parameter combinations have an **unsatisfactory evaluation** for a **O₃** and are required to repeat participation:

- DCE — O₃: data capture 0% (submitted 0 out of 5 expected runs) (reason: insufficient data capture)

No data was submitted by the participant DCE due to a hardware failure in their O₃ analyzer showed already during pre-test installation.

The measurement error plots ($D = x_i - X$, Figures 11 to 15) provide a visual assessment of the bias of each participant relative to the assigned value. Overall, 93.3 % of the error bars (combined expanded uncertainty) cross or touch the zero line, confirming satisfactory agreement with the reference for the majority of results.

The component with the lowest agreement rate is CO (85.7 % of error bars crossing zero), consistent with the higher proportion of unsatisfactory En scores observed for this pollutant.

Systematic positive biases (results consistently above the assigned value) are visible for:

AAA (CO and NO),
DHZ-CAL (O₃),
EKONERG (SO₂),
HungaroMet (SO₂),
LVGMC (SO₂),
REE (SO₂).

Systematic negative biases (results consistently below the assigned value) are visible for:

AAA (NO₂),
DCE (SO₂),
DHZ-CAL (NO₂),
DLI (O₃ and SO₂),
EKONERG (NO₂ and O₃),
FMI (CO and O₃),
HungaroMet (O₃),
REE (CO and NO).

Laboratories showing a consistent bias direction across multiple concentration levels should investigate potential calibration offsets or drift in their measurement systems.

The overall performance of the participating laboratories can be considered particularly good. Statistical unsatisfactory results obtained are not considered as extraordinary errors but may be due to significant differences in participants' standard operating procedures or underestimated uncertainty budgets or its calculation procedure.

7. Conclusions

7.1. Overall performance

This proficiency test involved 9 National Reference Laboratories measuring 5 gaseous pollutants (SO_2 , CO, O_3 , NO, NO_2), producing a total of 336 individual results.

Based on the z or z' score evaluation, 99.1 % of the reported results were satisfactory, 0.9 % were questionable and none were unsatisfactory. Considering the En score, 93.5 % of the reported values were satisfactory and 6.5 % were unsatisfactory.

The stability and reproducibility of the ERLAP test-gas generation and reference measurement system are documented in the Technical Quality Report (ISO/IEC 17043:2023 [16]), available among the documents on the PT-DAP web platform, which demonstrates that the standard deviation of the assigned values across the three consecutive PT rounds of this campaign is well below $0.3 \times \sigma_{\text{PT}}$ for all pollutants and concentration levels, and that the assigned values are compatible with the robust consensus of participant results ($\text{En} < 1$ for all runs).

7.2. Per-component assessment

Excellent performance (z/z' satisfactory rate ≥ 99 %) was achieved for NO_2 and CO and O_3 and SO_2 . The most critical component was NO, with a z/z' satisfactory rate of 98 % and an En satisfactory rate of only 88.1 %. This indicates that some laboratories face challenges in accurately measuring this pollutant and/or in estimating their measurement uncertainty.

7.3. Measurement uncertainty assessment

The En score unsatisfactory rate (6.5 %) is considerably higher than the z/z' unsatisfactory rate (0 %), indicating that the primary issue is not measurement bias but rather the **adequacy of the reported measurement uncertainties**. According to the decision category analysis, 5.7 % of all results fall in category 3 (satisfactory value but underestimated uncertainty), confirming that several laboratories should revise their uncertainty budgets.

7.4. Bias patterns

Among the 22 unsatisfactory En results, 16 were due to underestimation of the measurand and 6 to overestimation. The predominance of negative biases suggests that calibration drift or insufficient converter efficiency may affect some laboratories.

7.5. Follow-up actions

According to the AQUILA position paper [11], one laboratory (DCE) didn't submit some valid results for O_3 requiring follow-up action. DCE: insufficient data capture (O_3). This laboratory is requested to demonstrate satisfactory performance in the next PT round for this pollutant. During pre-test installation, the participant reported an anomalous response from their O_3 analyzer. Despite an attempted on-site repair, the issue persisted which explains the participant's missing data.

7.6. General conclusion

With 99.1 % satisfactory z/z' scores, the overall performance of the NRL network is good and confirms the measurement capability of the participating laboratories for the assessed pollutants. The 92.9 % completely satisfactory results (decision category 1) demonstrate that the majority of laboratories produce accurate measurements with appropriately estimated uncertainties.

Each participant's individual results are reported in Annex A.

8. Confidentiality

The results of the Proficiency Testing are published non-anonymously in agreement with the National Reference Laboratories (NRLs) reported in the AQUILA-N37 document [11], which has received unanimous consent from all NRL members within the AQUILA network.

ERLAP is committed to preserving the confidentiality of laboratory data through the following measures:

- Any administrative information supplied by a laboratory remains confidential and will not be shared with third parties.
- Access to ERLAP facilities is strictly limited to members of JRC Unit C5 and authorized personnel.
- A confidential password permits to access the web application for all phases of the PT exercise.
- By expressing interest in participating, each applicant agrees with these privacy and confidentiality policies. To ensure permanent and public access to the PT results, a Digital Object Identifier (DOI) is associated with the report.

As part of their initial PT engagement with ERLAP, participants are required to sign a Confidentiality Involvement Form during their first participation to a PT organized by ERLAP.

9. Accreditation

ERLAP is formally accredited to the ISO/IEC 17043:2023 standard [16] as a Proficiency Testing Provider. This accreditation specifically covers the organization of PT schemes for the pollutants and EN standard methods evaluated in this exercise, using spiked filtered ambient air as the test matrix. To achieve and maintain this status, ERLAP has implemented a quality management system compliant to ISO/IEC 17043:2023 [16] requirements. This quality system serves as the foundation of ERLAP's operations, ensuring that all internal processes and procedures are under control, well-documented, and highly effective. Ultimately, this accreditation is a formal recognition of the laboratory's technical competence, which is verified annually by an independent Accreditation Body to guarantee the consistent and reliable production of valid proficiency tests.

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11. List of abbreviations and definitions

Abbreviations	Definitions
AQUILA	Network of National Reference Laboratories for Air Quality
CEN	European Committee for Standardization
CO	Carbon monoxide
CRM	Certified Reference Material
DQO	Data Quality Objective
ERLAP	European Reference Laboratory for Air Pollution
EC	European Commission
GPT	Gas Phase Titration
ILC	Inter-Laboratory Comparison Exercise
ISO	International Organization for Standardization
JRC	Joint Research Centre
NO	Nitrogen monoxide
NO ₂	Nitrogen dioxide
NO _x	The oxides of nitrogen, the sum of NO and NO ₂
NRL	National Reference Laboratory
O ₃	Ozone
PT	Proficiency Test
PTP	Proficiency Test Provider
SO ₂	Sulphur dioxide
VDI	Verein Deutscher Ingenieure

12. Mathematical Symbols

- D: measurement error, defined as the difference between the participant (i) result and the assigned value, $D = x_i - X$ (ISO 13528:2022)
- En: En-score statistic used to assess the compatibility of the participant result with the assigned value, taking their associated uncertainties into account (ISO 13528:2022)
- (r): repeatability limit (ISO 5725-6:1994)
- (R): reproducibility limit (ISO 5725-6:1994)
- σ_{PT} : standard deviation for proficiency assessment, representing the fitness-for-purpose criterion used for the evaluation of participant performance (ISO 13528:2022)
- x^* : robust average calculated from participant results (Annex C, ISO 13528:2022)
- s^* : robust standard deviation calculated from participant results (Annex C, ISO 13528:2022)
- sr: repeatability standard deviation (ISO 5725-6:1994)
- sR: reproducibility standard deviation (ISO 5725-6:1994)
- X: assigned value for a given pollutant and concentration level (ISO 13528:2022)
- U(X): standard uncertainty associated with the assigned value (X) (ISO 13528:2022)
- U(X): expanded uncertainty associated with the assigned value (X) (ISO 13528:2022)
- $\bar{x}_i$: arithmetic mean of the replicate values reported by participant (i) for a given pollutant and concentration level
- U($\bar{x}_i$) expanded uncertainty associated with the result ($\bar{x}_i$) reported by participant (i)
- z: z-score statistic used to assess the deviation of a participant result from the assigned value relative to the standard deviation for proficiency assessment (ISO 13528:2022)
- z' : z'-score statistic, which additionally considers the standard uncertainty associated with the assigned value (ISO 13528:2022)

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Annex A: Participant's results

The following pages present, for each participating laboratory, a summary table and diagnostic plots. In the table: the step-level results, mean value, uncertainties, assigned value and its expanded uncertainty, σ_{PT} , D, z or z' score with selection, and En score. In the plots, from left to right for each pollutant:

- (D) the submitted measurement result compared to the assigned value,
- the z or z' score compared with the ± 2 and ± 3 criteria,
- the En score compared with the ± 1 criterion.

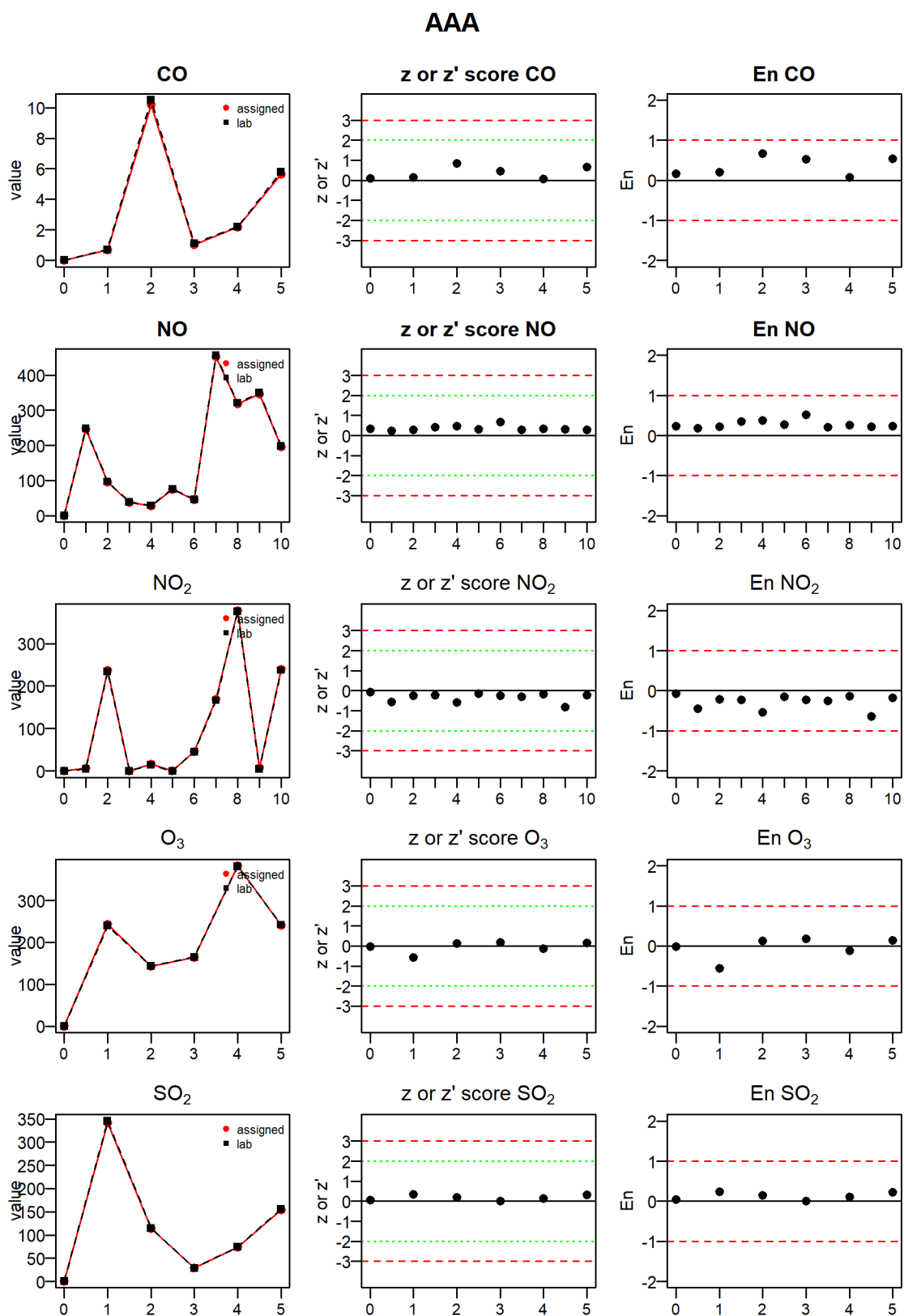
AAA

Table 14: Results for laboratory AAA. Units: CO in mg/m³, NO in µg/m³, NO₂ in µg/m³, O₃ in µg/m³, SO₂ in µg/m³.

Lab values								Assigned value					
Pollutant	Run	Avg	Step 1	Step 2	Step 3	Std u	Exp U	Avg.	Exp U.	σPT	D	z or z' score	En score
CO	0	0.01	0.01			0.03	0.06	0.00	0.01	0.12	0.01	0.09 (z)	0.16
CO	1	0.71	0.71	0.71	0.71	0.05	0.10	0.69	0.02	0.13	0.02	0.15 (z)	0.20
CO	2	10	10	10	10	0.22	0.44	10	0.10	0.36	0.30	0.83 (z)	0.66
CO	3	1.1	1.1	1.1	1.1	0.06	0.12	1.0	0.02	0.14	0.06	0.45 (z)	0.52
CO	4	2.2	2.2	2.2	2.2	0.07	0.14	2.2	0.03	0.17	0.01	0.06 (z)	0.07
CO	5	5.8	5.8	5.8	5.8	0.15	0.30	5.6	0.06	0.25	0.16	0.65 (z)	0.54
NO	0	0.75	0.75			0.60	1.2	0.20	2.0	1.3	0.55	0.35 (z')	0.24
NO	1	248	247	248	248	4.3	8.6	246	2.9	7.2	1.7	0.23 (z)	0.18
NO	2	97	97	97	97	2.0	4.0	96	2.1	3.6	1.00	0.28 (z)	0.22
NO	3	39	39	39	39	1.1	2.2	38	1.9	2.2	1.00	0.42 (z')	0.34
NO	4	29	29	29	29	0.90	1.8	28	2.0	1.9	1.00	0.46 (z')	0.37
NO	5	76	76	76	76	1.5	3.0	75	2.0	3.0	1.00	0.31 (z')	0.28
NO	6	47	46	47	47	1.3	2.6	45	1.9	2.3	1.7	0.66 (z')	0.52
NO	7	457	456	457	457	7.7	15	453	4.2	12	3.3	0.27 (z)	0.21
NO	8	321	321	321	322	5.6	11	318	3.2	8.9	3.0	0.34 (z)	0.26
NO	9	350	350	350	350	6.4	13	347	3.4	9.6	3.0	0.31 (z)	0.23
NO	10	198	198	198	198	3.4	6.8	196	2.5	6.0	1.7	0.28 (z)	0.23
NO ₂	0	0.00	0.00			0.00	0.00	0.22	3.2	2.7	-0.22	-0.07 (z')	-0.07
NO ₂	1	4.5	4.9	4.5	4.1	0.80	1.6	6.4	4.0	2.9	-1.9	-0.55 (z')	-0.45
NO ₂	2	235	234	235	235	5.1	10	237	4.1	9.3	-2.3	-0.25 (z)	-0.21
NO ₂	3	0.00	0.00	0.00	0.00	0.00	0.00	0.67	3.0	2.7	-0.67	-0.22 (z')	-0.22
NO ₂	4	14	14	14	14	1.00	2.0	16	3.1	3.1	-2.0	-0.58 (z')	-0.54
NO ₂	5	0.00	0.00	0.00	0.00	0.00	0.00	0.47	3.2	2.7	-0.47	-0.15 (z')	-0.15
NO ₂	6	45	45	45	45	1.5	3.0	46	3.1	4.0	-1.00	-0.24 (z')	-0.23
NO ₂	7	166	166	166	167	3.7	7.4	169	5.6	7.4	-2.3	-0.29 (z')	-0.25
NO ₂	8	376	376	376	375	8.1	16	378	6.2	13	-2.3	-0.18 (z)	-0.13
NO ₂	9	4.9	5.0	4.8	5.0	0.80	1.6	7.8	4.1	2.9	-2.8	-0.81 (z')	-0.64
NO ₂	10	237	238	237	237	5.1	10	239	4.5	9.4	-2.0	-0.21 (z)	-0.18
O ₃	0	0.00	0.00			0.50	1.00	0.04	2.4	2.0	-0.04	-0.02 (z')	-0.01
O ₃	1	240	238	240	241	3.5	7.0	244	1.9	6.9	-4.0	-0.58 (z)	-0.55
O ₃	2	144	143	144	144	2.4	4.8	143	1.2	4.9	0.67	0.14 (z)	0.13
O ₃	3	165	165	165	165	2.7	5.4	164	1.3	5.3	1.00	0.19 (z)	0.18
O ₃	4	381	381	381	382	5.3	11	383	3.0	9.6	-1.3	-0.14 (z)	-0.12
O ₃	5	242	242	242	242	3.5	7.0	241	2.0	6.8	1.00	0.15 (z)	0.14
SO ₂	0	0.27	0.27			0.90	1.8	0.10	3.8	2.7	0.17	0.05 (z')	0.04
SO ₂	1	345	345	345	346	7.2	14	342	5.1	10	3.7	0.36 (z)	0.24
SO ₂	2	115	115	115	115	2.9	5.8	114	4.0	5.2	1.00	0.18 (z')	0.14
SO ₂	3	29	29	29	29	1.6	3.2	29	3.8	3.3	0.00	0.00 (z')	0.00
SO ₂	4	74	74	74	75	2.5	5.0	74	3.9	4.3	0.67	0.14 (z')	0.11
SO ₂	5	156	156	156	156	3.9	7.8	154	4.3	6.1	2.0	0.31 (z')	0.22

Source: JRC 2026

Figure 17: Diagnostic plots for laboratory AAA. Left: measured value vs assigned value. Centre: z or z' score (limits at 2 and 3). Right: En score (limit at 1).



Source: JRC 2026

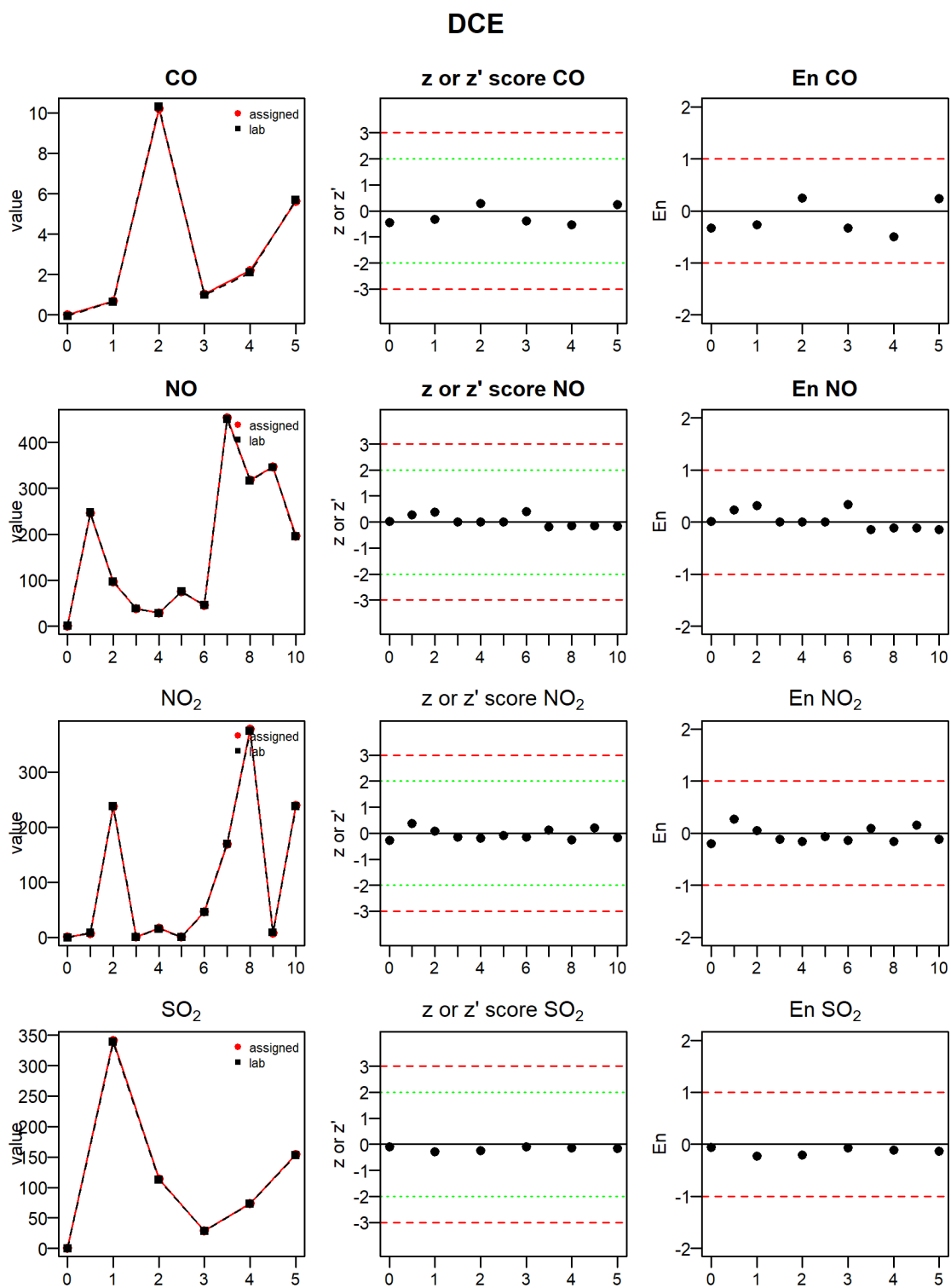
DCE

Table 15: Results for laboratory DCE. Units: CO in mg/m³, NO in µg/m³, NO₂ in µg/m³, SO₂ in µg/m³.

Lab values								Assigned value					
Pollutant	Run	Avg	Step 1	Step 2	Step 3	Std u	Exp U	Avg.	Exp U.	σPT	D	z or z' score	En score
CO	0	-0.05	-0.05			0.08	0.16	0.00	0.01	0.12	-0.05	-0.45 (z)	-0.32
CO	1	0.65	0.65	0.65	0.64	0.08	0.16	0.69	0.02	0.13	-0.04	-0.33 (z)	-0.27
CO	2	10	10	10	10	0.20	0.40	10	0.10	0.36	0.10	0.28 (z)	0.24
CO	3	0.98	1.00	0.97	0.98	0.08	0.16	1.0	0.02	0.14	-0.05	-0.38 (z)	-0.33
CO	4	2.1	2.1	2.1	2.1	0.09	0.18	2.2	0.03	0.17	-0.09	-0.53 (z)	-0.49
CO	5	5.7	5.7	5.7	5.7	0.13	0.26	5.6	0.06	0.25	0.06	0.25 (z)	0.24
NO	0	0.23	0.23			0.84	1.7	0.20	2.0	1.3	0.03	0.02 (z')	0.01
NO	1	248	248	248	248	4.1	8.3	246	2.9	7.2	2.0	0.28 (z)	0.23
NO	2	97	98	97	97	1.8	3.6	96	2.1	3.6	1.3	0.38 (z)	0.32
NO	3	38	38	38	38	1.00	2.1	38	1.9	2.2	0.00	0.00 (z')	0.00
NO	4	28	28	28	28	0.96	1.9	28	2.0	1.9	0.00	0.00 (z')	0.00
NO	5	75	75	75	75	1.5	3.0	75	2.0	3.0	0.00	0.00 (z')	0.00
NO	6	46	46	46	46	1.1	2.3	45	1.9	2.3	1.00	0.40 (z')	0.34
NO	7	451	451	451	451	7.4	15	453	4.2	12	-2.3	-0.19 (z)	-0.15
NO	8	317	316	317	318	5.3	11	318	3.2	8.9	-1.3	-0.15 (z)	-0.12
NO	9	346	345	346	346	5.7	11	347	3.4	9.6	-1.3	-0.14 (z)	-0.12
NO	10	195	195	195	196	3.3	6.6	196	2.5	6.0	-1.00	-0.17 (z)	-0.14
NO ₂	0	-0.62	-0.62			1.3	2.6	0.22	3.2	2.7	-0.84	-0.27 (z')	-0.20
NO ₂	1	7.7	8.1	8.4	6.7	1.3	2.6	6.4	4.0	2.9	1.3	0.37 (z')	0.27
NO ₂	2	238	237	238	238	6.3	13	237	4.1	9.3	0.67	0.07 (z)	0.05
NO ₂	3	0.19	0.12	0.19	0.25	1.3	2.6	0.67	3.0	2.7	-0.48	-0.16 (z')	-0.12
NO ₂	4	15	16	15	15	1.4	2.7	16	3.1	3.1	-0.67	-0.19 (z')	-0.16
NO ₂	5	0.20	0.02	0.55	0.02	1.3	2.6	0.47	3.2	2.7	-0.27	-0.09 (z')	-0.07
NO ₂	6	45	45	45	46	1.7	3.5	46	3.1	4.0	-0.67	-0.16 (z')	-0.14
NO ₂	7	170	169	170	170	4.6	9.1	169	5.6	7.4	1.00	0.13 (z')	0.09
NO ₂	8	375	375	375	374	9.8	20	378	6.2	13	-3.3	-0.25 (z)	-0.16
NO ₂	9	8.5	8.9	9.1	7.5	1.3	2.6	7.8	4.1	2.9	0.73	0.21 (z')	0.15
NO ₂	10	238	238	238	237	6.3	13	239	4.5	9.4	-1.7	-0.18 (z)	-0.12
SO ₂	0	-0.22	-0.22			1.7	3.4	0.10	3.8	2.7	-0.32	-0.10 (z')	-0.06
SO ₂	1	339	339	338	339	6.0	12	342	5.1	10	-3.0	-0.29 (z)	-0.23
SO ₂	2	113	113	112	113	2.6	5.1	114	4.0	5.2	-1.3	-0.24 (z')	-0.21
SO ₂	3	29	28	29	29	1.8	3.5	29	3.8	3.3	-0.33	-0.09 (z')	-0.06
SO ₂	4	73	73	73	73	2.1	4.2	74	3.9	4.3	-0.67	-0.14 (z')	-0.12
SO ₂	5	153	153	153	153	3.1	6.2	154	4.3	6.1	-1.00	-0.16 (z')	-0.13

Source: JRC 2026

Figure 18: Diagnostic plots for laboratory DCE. Left: measured value vs assigned value. Centre: z or z' score (limits at 2 and 3). Right: En score (limit at 1).



Source: JRC 2026

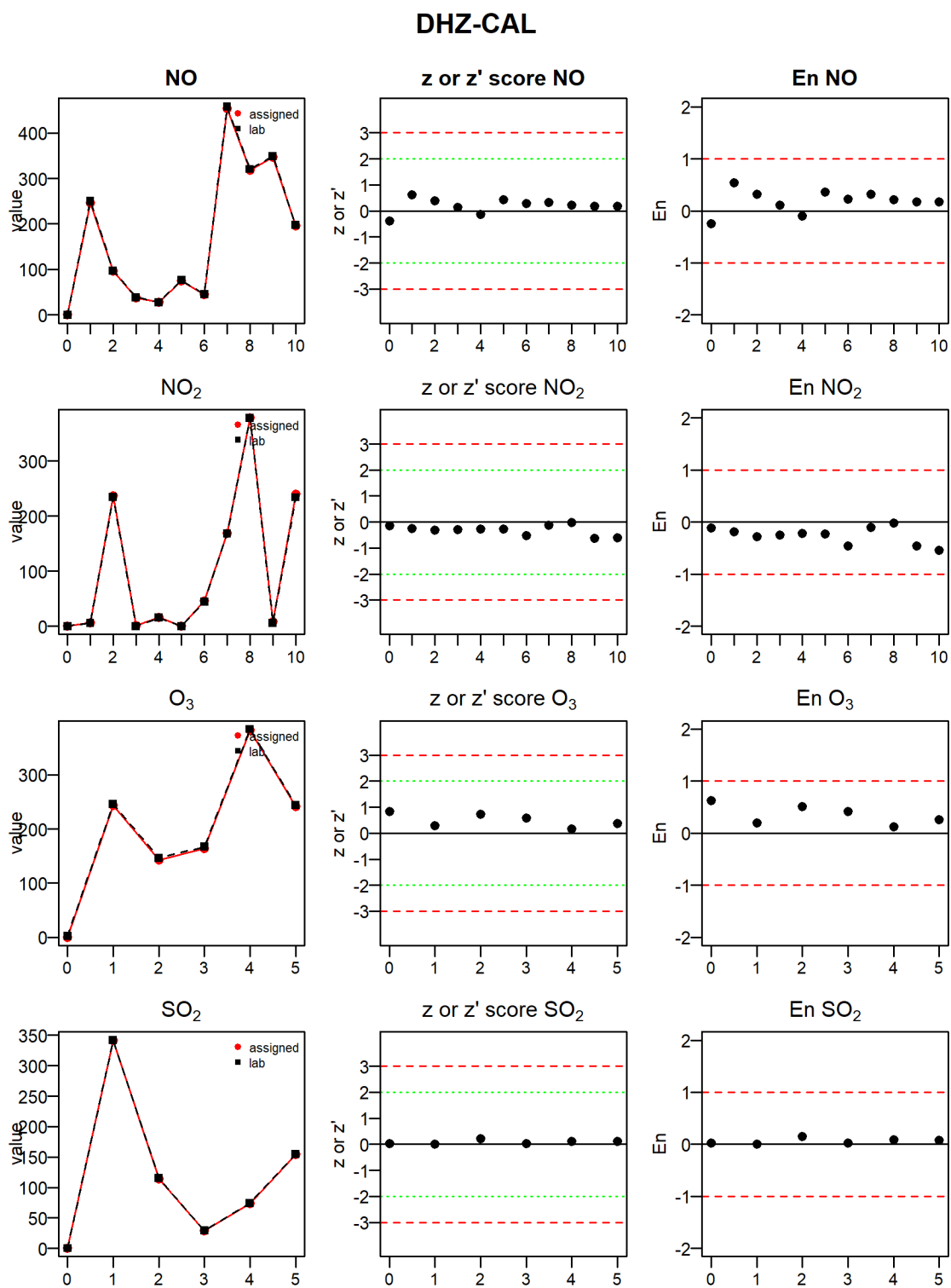
DHZ-CAL

Table 16: Results for laboratory DHZ-CAL. Units: NO in $\mu\text{g}/\text{m}^3$, NO₂ in $\mu\text{g}/\text{m}^3$, O₃ in $\mu\text{g}/\text{m}^3$, SO₂ in $\mu\text{g}/\text{m}^3$.

Lab values								Assigned value					
Pollutant	Run	Avg	Step 1	Step 2	Step 3	Std u	Exp U	Avg.	Exp U.	σ_{PT}	D	z or z' score	En score
NO	0	-0.40	-0.40			0.70	1.4	0.20	2.0	1.3	-0.60	-0.38 (z')	-0.25
NO	1	250	250	251	251	3.8	7.6	246	2.9	7.2	4.4	0.62 (z)	0.55
NO	2	97	98	97	97	1.9	3.8	96	2.1	3.6	1.4	0.39 (z)	0.32
NO	3	38	38	38	38	1.1	2.2	38	1.9	2.2	0.33	0.14 (z')	0.11
NO	4	28	28	28	28	1.00	2.0	28	2.0	1.9	-0.27	-0.12 (z')	-0.09
NO	5	76	76	76	76	1.6	3.2	75	2.0	3.0	1.4	0.43 (z')	0.36
NO	6	46	46	46	46	1.2	2.4	45	1.9	2.3	0.70	0.28 (z')	0.23
NO	7	457	457	457	457	5.8	12	453	4.2	12	3.9	0.32 (z)	0.32
NO	8	320	320	321	320	4.4	8.8	318	3.2	8.9	2.1	0.23 (z)	0.22
NO	9	349	348	349	349	4.6	9.2	347	3.4	9.6	1.7	0.18 (z)	0.18
NO	10	197	197	197	198	2.9	5.8	196	2.5	6.0	1.1	0.18 (z)	0.17
NO ₂	0	-0.20	-0.20			1.00	2.0	0.22	3.2	2.7	-0.42	-0.13 (z')	-0.11
NO ₂	1	5.6	6.2	5.8	4.7	1.2	2.4	6.4	4.0	2.9	-0.87	-0.25 (z')	-0.19
NO ₂	2	234	233	234	235	4.8	9.6	237	4.1	9.3	-2.9	-0.31 (z)	-0.28
NO ₂	3	-0.23	-0.10	-0.20	-0.40	1.00	2.0	0.67	3.0	2.7	-0.90	-0.29 (z')	-0.25
NO ₂	4	15	15	15	15	1.3	2.6	16	3.1	3.1	-0.90	-0.26 (z')	-0.22
NO ₂	5	-0.40	-0.50	-0.40	-0.30	1.00	2.0	0.47	3.2	2.7	-0.87	-0.28 (z')	-0.23
NO ₂	6	44	44	44	44	1.8	3.6	46	3.1	4.0	-2.2	-0.51 (z')	-0.46
NO ₂	7	168	168	168	167	3.7	7.4	169	5.6	7.4	-1.00	-0.13 (z')	-0.11
NO ₂	8	378	379	378	376	6.9	14	378	6.2	13	-0.23	-0.02 (z)	-0.02
NO ₂	9	5.6	5.5	5.5	5.7	1.2	2.4	7.8	4.1	2.9	-2.2	-0.63 (z')	-0.46
NO ₂	10	234	234	234	233	4.6	9.2	239	4.5	9.4	-5.6	-0.59 (z)	-0.54
O ₃	0	2.0	2.0			1.00	2.0	0.04	2.4	2.0	2.0	0.84 (z')	0.63
O ₃	1	246	245	246	246	4.7	9.4	244	1.9	6.9	1.9	0.28 (z)	0.20
O ₃	2	147	146	147	146	3.4	6.8	143	1.2	4.9	3.6	0.73 (z)	0.52
O ₃	3	167	167	167	167	3.7	7.4	164	1.3	5.3	3.1	0.59 (z)	0.41
O ₃	4	384	384	385	384	6.5	13	383	3.0	9.6	1.7	0.17 (z)	0.12
O ₃	5	244	243	244	244	4.7	9.4	241	2.0	6.8	2.5	0.37 (z)	0.26
SO ₂	0	0.20	0.20			1.00	2.0	0.10	3.8	2.7	0.10	0.03 (z')	0.02
SO ₂	1	342	341	342	342	6.7	13	342	5.1	10	0.07	0.01 (z)	0.00
SO ₂	2	115	115	115	115	3.4	6.8	114	4.0	5.2	1.2	0.22 (z')	0.15
SO ₂	3	29	29	29	29	2.2	4.4	29	3.8	3.3	0.13	0.03 (z')	0.02
SO ₂	4	74	74	74	74	2.6	5.2	74	3.9	4.3	0.57	0.12 (z')	0.09
SO ₂	5	155	155	155	154	3.5	7.0	154	4.3	6.1	0.67	0.10 (z')	0.08

Source: JRC 2026

Figure 19: Diagnostic plots for laboratory DHZ-CAL. Left: measured value vs assigned value. Centre: z or z' score (limits at 2 and 3). Right: En score (limit at 1).



Source: JRC 2026

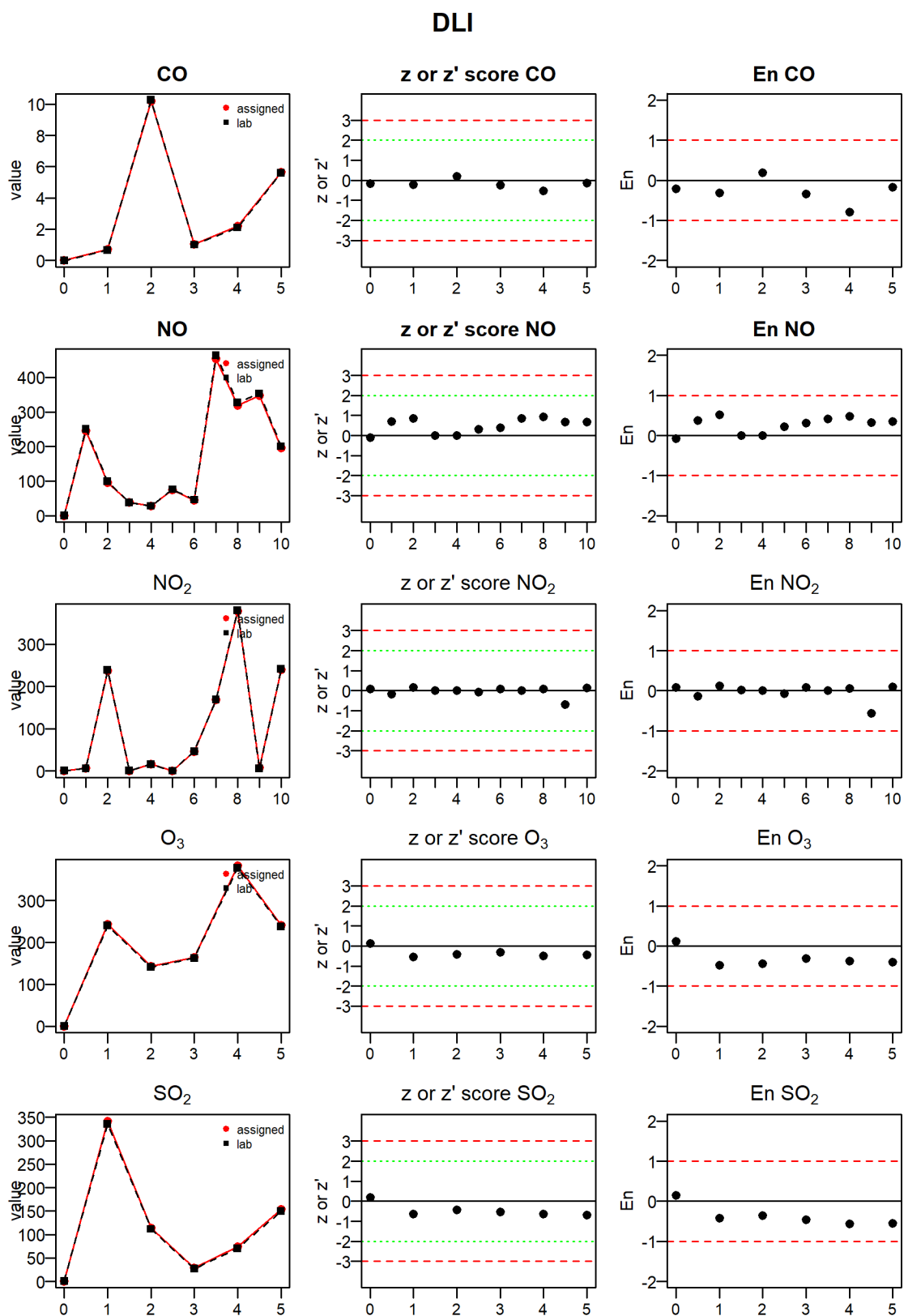
DLI

Table 17: Results for laboratory DLI. Units: CO in mg/m³; NO in µg/m³; NO₂ in µg/m³; O₃ in µg/m³; SO₂ in µg/m³.

Lab values								Assigned value					
Pollutant	Run	Avg	Step 1	Step 2	Step 3	Std u	Exp U	Avg.	Exp U.	σPT	D	z or z' score	En score
CO	0	-0.02	-0.02			0.05	0.09	0.00	0.01	0.12	-0.02	-0.16 (z)	-0.21
CO	1	0.66	0.66	0.66	0.66	0.05	0.09	0.69	0.02	0.13	-0.03	-0.23 (z)	-0.31
CO	2	10	10	10	10	0.18	0.35	10	0.10	0.36	0.07	0.18 (z)	0.18
CO	3	1.0	1.0	1.00	1.00	0.05	0.10	1.0	0.02	0.14	-0.03	-0.24 (z)	-0.34
CO	4	2.1	2.1	2.1	2.1	0.06	0.11	2.2	0.03	0.17	-0.09	-0.53 (z)	-0.80
CO	5	5.6	5.6	5.6	5.6	0.10	0.20	5.6	0.06	0.25	-0.04	-0.15 (z)	-0.18
NO	0	0.04	0.04			0.39	0.78	0.20	2.0	1.3	-0.16	-0.10 (z')	-0.07
NO	1	251	251	251	251	6.7	13	246	2.9	7.2	5.0	0.70 (z)	0.38
NO	2	99	99	99	99	2.7	5.4	96	2.1	3.6	3.0	0.84 (z)	0.52
NO	3	38	38	38	38	1.1	2.2	38	1.9	2.2	0.00	0.00 (z')	0.00
NO	4	28	28	28	28	0.86	1.7	28	2.0	1.9	0.00	0.00 (z')	0.00
NO	5	76	76	76	76	2.0	4.1	75	2.0	3.0	1.00	0.31 (z')	0.22
NO	6	46	46	46	46	1.3	2.6	45	1.9	2.3	1.00	0.40 (z')	0.31
NO	7	464	463	464	464	12	25	453	4.2	12	10	0.85 (z)	0.41
NO	8	327	326	327	327	8.7	17	318	3.2	8.9	8.3	0.94 (z)	0.48
NO	9	353	353	353	354	9.4	19	347	3.4	9.6	6.3	0.66 (z)	0.33
NO	10	200	200	200	201	5.3	11	196	2.5	6.0	4.0	0.67 (z)	0.35
NO ₂	0	0.51	0.51			0.60	1.2	0.22	3.2	2.7	0.29	0.09 (z')	0.08
NO ₂	1	5.9	6.6	5.7	5.3	0.64	1.3	6.4	4.0	2.9	-0.57	-0.16 (z')	-0.13
NO ₂	2	239	239	238	239	6.4	13	237	4.1	9.3	1.7	0.18 (z)	0.12
NO ₂	3	0.72	0.46	0.60	1.1	0.60	1.2	0.67	3.0	2.7	0.05	0.02 (z')	0.02
NO ₂	4	16	16	16	16	0.76	1.5	16	3.1	3.1	0.00	0.00 (z')	0.00
NO ₂	5	0.24	-0.14	0.30	0.57	0.60	1.2	0.47	3.2	2.7	-0.22	-0.07 (z')	-0.07
NO ₂	6	46	46	47	46	1.4	2.8	46	3.1	4.0	0.33	0.08 (z')	0.08
NO ₂	7	169	170	169	167	4.5	9.1	169	5.6	7.4	0.00	0.00 (z')	0.00
NO ₂	8	379	380	379	379	10.0	20	378	6.2	13	1.3	0.10 (z)	0.06
NO ₂	9	5.4	4.8	5.9	5.4	0.64	1.3	7.8	4.1	2.9	-2.4	-0.68 (z')	-0.56
NO ₂	10	241	241	240	241	6.4	13	239	4.5	9.4	1.3	0.14 (z)	0.10
O ₃	0	0.36	0.36			0.58	1.2	0.04	2.4	2.0	0.32	0.14 (z')	0.12
O ₃	1	240	240	240	240	3.7	7.4	244	1.9	6.9	-3.7	-0.53 (z)	-0.48
O ₃	2	141	141	141	141	2.2	4.4	143	1.2	4.9	-2.0	-0.41 (z)	-0.44
O ₃	3	162	162	162	163	2.5	5.1	164	1.3	5.3	-1.7	-0.32 (z)	-0.32
O ₃	4	378	378	378	378	5.8	12	383	3.0	9.6	-4.7	-0.48 (z)	-0.38
O ₃	5	238	238	238	238	3.7	7.3	241	2.0	6.8	-3.0	-0.44 (z)	-0.40
SO ₂	0	0.73	0.73			0.90	1.8	0.10	3.8	2.7	0.63	0.19 (z')	0.15
SO ₂	1	335	335	336	335	7.0	14	342	5.1	10	-6.3	-0.62 (z)	-0.43
SO ₂	2	112	112	112	111	2.6	5.1	114	4.0	5.2	-2.3	-0.42 (z')	-0.36
SO ₂	3	27	27	27	27	1.1	2.2	29	3.8	3.3	-2.0	-0.52 (z')	-0.46
SO ₂	4	71	71	71	70	1.8	3.6	74	3.9	4.3	-3.0	-0.63 (z')	-0.57
SO ₂	5	150	150	149	150	3.3	6.6	154	4.3	6.1	-4.3	-0.68 (z')	-0.55

Source: JRC 2026

Figure 20: Diagnostic plots for laboratory DLI. Left: measured value vs assigned value. Centre: z or z' score (limits at 2 and 3). Right: En score (limit at 1).



Source: JRC 2026

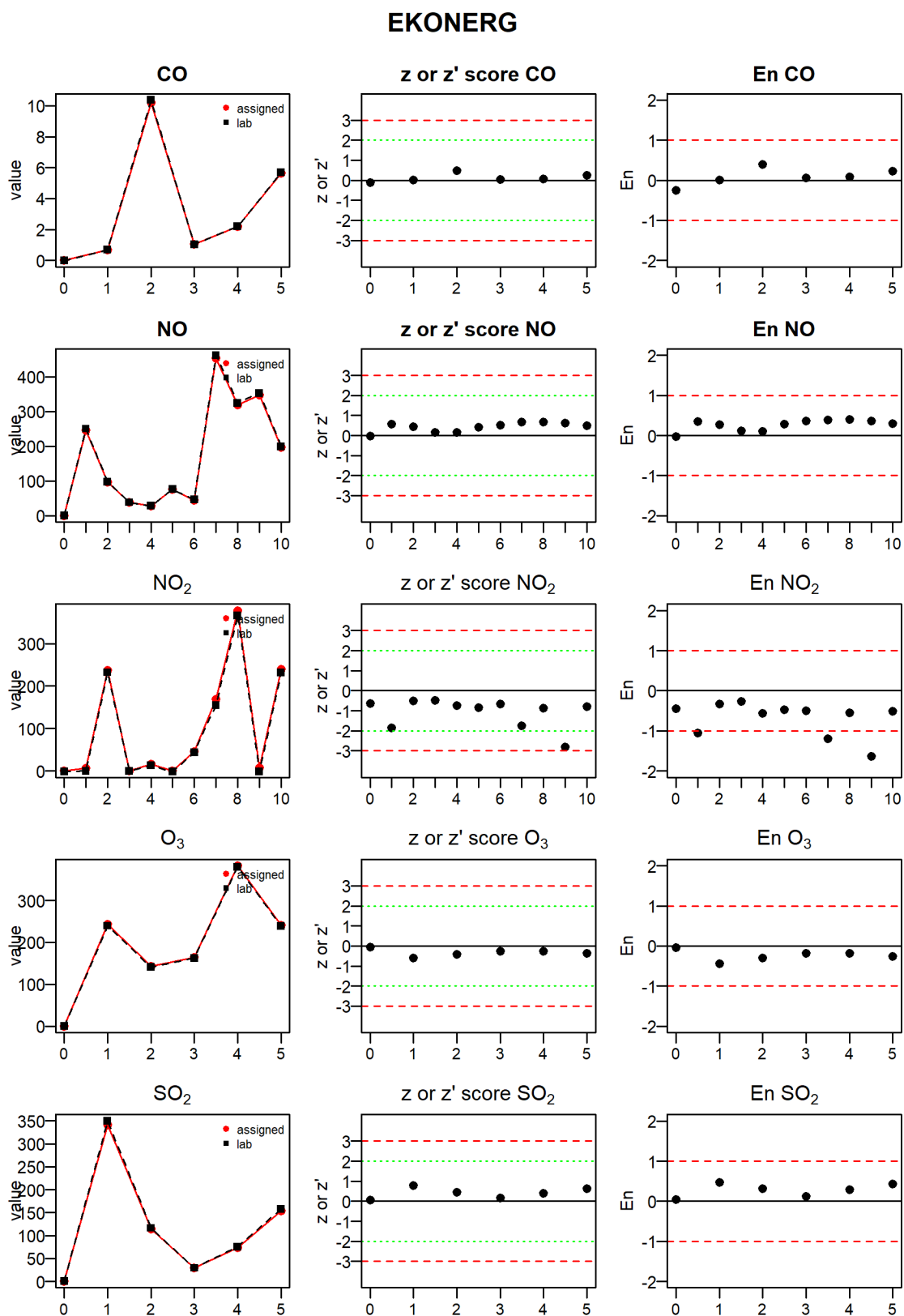
EKONERG

Table 18: Results for laboratory EKONERG. Units: CO in mg/m³; NO in µg/m³; NO₂ in µg/m³; O₃ in µg/m³; SO₂ in µg/m³.

Lab values								Assigned value					
Pollutant	Run	Avg	Step 1	Step 2	Step 3	Std u	Exp U	Avg.	Exp U.	σPT	D	z or z' score	En score
CO	0	-0.01	-0.01			0.02	0.05	0.00	0.01	0.12	-0.01	-0.10 (z)	-0.25
CO	1	0.69	0.69	0.69	0.69	0.04	0.07	0.69	0.02	0.13	0.00	0.01 (z)	0.01
CO	2	10	10	10	10	0.21	0.42	10	0.10	0.36	0.17	0.47 (z)	0.40
CO	3	1.0	1.0	1.0	1.0	0.04	0.08	1.0	0.02	0.14	0.00	0.03 (z)	0.05
CO	4	2.2	2.2	2.2	2.2	0.06	0.13	2.2	0.03	0.17	0.01	0.07 (z)	0.09
CO	5	5.7	5.7	5.7	5.7	0.13	0.25	5.6	0.06	0.25	0.06	0.24 (z)	0.23
NO	0	0.15	0.15			0.63	1.3	0.20	2.0	1.3	-0.05	-0.03 (z')	-0.02
NO	1	250	250	250	250	5.8	12	246	2.9	7.2	4.1	0.58 (z)	0.35
NO	2	98	98	97	97	2.6	5.3	96	2.1	3.6	1.5	0.43 (z)	0.27
NO	3	38	38	38	38	1.4	2.8	38	1.9	2.2	0.38	0.16 (z')	0.11
NO	4	28	28	28	28	1.2	2.4	28	2.0	1.9	0.33	0.15 (z')	0.11
NO	5	76	76	76	76	2.2	4.4	75	2.0	3.0	1.4	0.42 (z')	0.28
NO	6	46	46	46	46	1.6	3.1	45	1.9	2.3	1.3	0.53 (z')	0.36
NO	7	461	461	461	462	10	20	453	4.2	12	8.1	0.67 (z)	0.39
NO	8	324	324	324	325	7.3	15	318	3.2	8.9	6.0	0.67 (z)	0.40
NO	9	353	353	353	353	7.9	16	347	3.4	9.6	5.9	0.62 (z)	0.37
NO	10	199	199	199	200	4.7	9.4	196	2.5	6.0	3.0	0.50 (z)	0.30
NO ₂	0	-1.7	-1.7			1.5	2.9	0.22	3.2	2.7	-1.9	-0.62 (z')	-0.45
NO ₂	1	0.01	0.67	-0.10	-0.53	2.3	4.6	6.4	4.0	2.9	-6.4	-1.8 (z')	-1.1
NO ₂	2	232	232	232	233	6.9	14	237	4.1	9.3	-4.7	-0.50 (z)	-0.33
NO ₂	3	-0.79	-0.63	-0.84	-0.90	2.2	4.5	0.67	3.0	2.7	-1.5	-0.47 (z')	-0.27
NO ₂	4	13	13	13	13	1.7	3.3	16	3.1	3.1	-2.6	-0.75 (z')	-0.57
NO ₂	5	-2.1	-2.0	-2.2	-2.2	2.2	4.5	0.47	3.2	2.7	-2.6	-0.83 (z')	-0.47
NO ₂	6	43	43	43	43	2.4	4.8	46	3.1	4.0	-2.9	-0.67 (z')	-0.50
NO ₂	7	155	155	155	155	5.0	10	169	5.6	7.4	-14	-1.7 (z')	-1.2
NO ₂	8	366	367	366	366	10	20	378	6.2	13	-12	-0.87 (z)	-0.55
NO ₂	9	-2.1	-2.2	-2.2	-2.0	2.2	4.5	7.8	4.1	2.9	-9.9	-2.8 (z')	-1.6
NO ₂	10	232	233	232	231	6.8	14	239	4.5	9.4	-7.4	-0.79 (z)	-0.51
O ₃	0	-0.09	-0.09			1.6	3.1	0.04	2.4	2.0	-0.13	-0.06 (z')	-0.03
O ₃	1	240	238	240	240	4.6	9.2	244	1.9	6.9	-4.1	-0.60 (z)	-0.43
O ₃	2	141	141	141	141	3.4	6.7	143	1.2	4.9	-2.0	-0.42 (z)	-0.30
O ₃	3	163	163	162	163	3.6	7.3	164	1.3	5.3	-1.4	-0.26 (z)	-0.19
O ₃	4	380	380	380	381	6.4	13	383	3.0	9.6	-2.4	-0.25 (z)	-0.19
O ₃	5	239	238	238	239	4.6	9.2	241	2.0	6.8	-2.5	-0.36 (z)	-0.26
SO ₂	0	0.29	0.29			0.96	1.9	0.10	3.8	2.7	0.19	0.06 (z')	0.05
SO ₂	1	350	349	350	350	8.0	16	342	5.1	10	7.9	0.78 (z)	0.47
SO ₂	2	116	117	117	116	3.3	6.6	114	4.0	5.2	2.5	0.45 (z')	0.32
SO ₂	3	30	29	30	30	1.6	3.1	29	3.8	3.3	0.61	0.16 (z')	0.12
SO ₂	4	76	75	76	76	2.5	5.0	74	3.9	4.3	1.9	0.40 (z')	0.30
SO ₂	5	158	158	158	158	4.2	8.3	154	4.3	6.1	4.1	0.64 (z')	0.44

Source: JRC 2026

Figure 21: Diagnostic plots for laboratory EKONERG. Left: measured value vs assigned value. Centre: z or z' score (limits at 2 and 3). Right: En score (limit at 1).



Source: JRC 2026

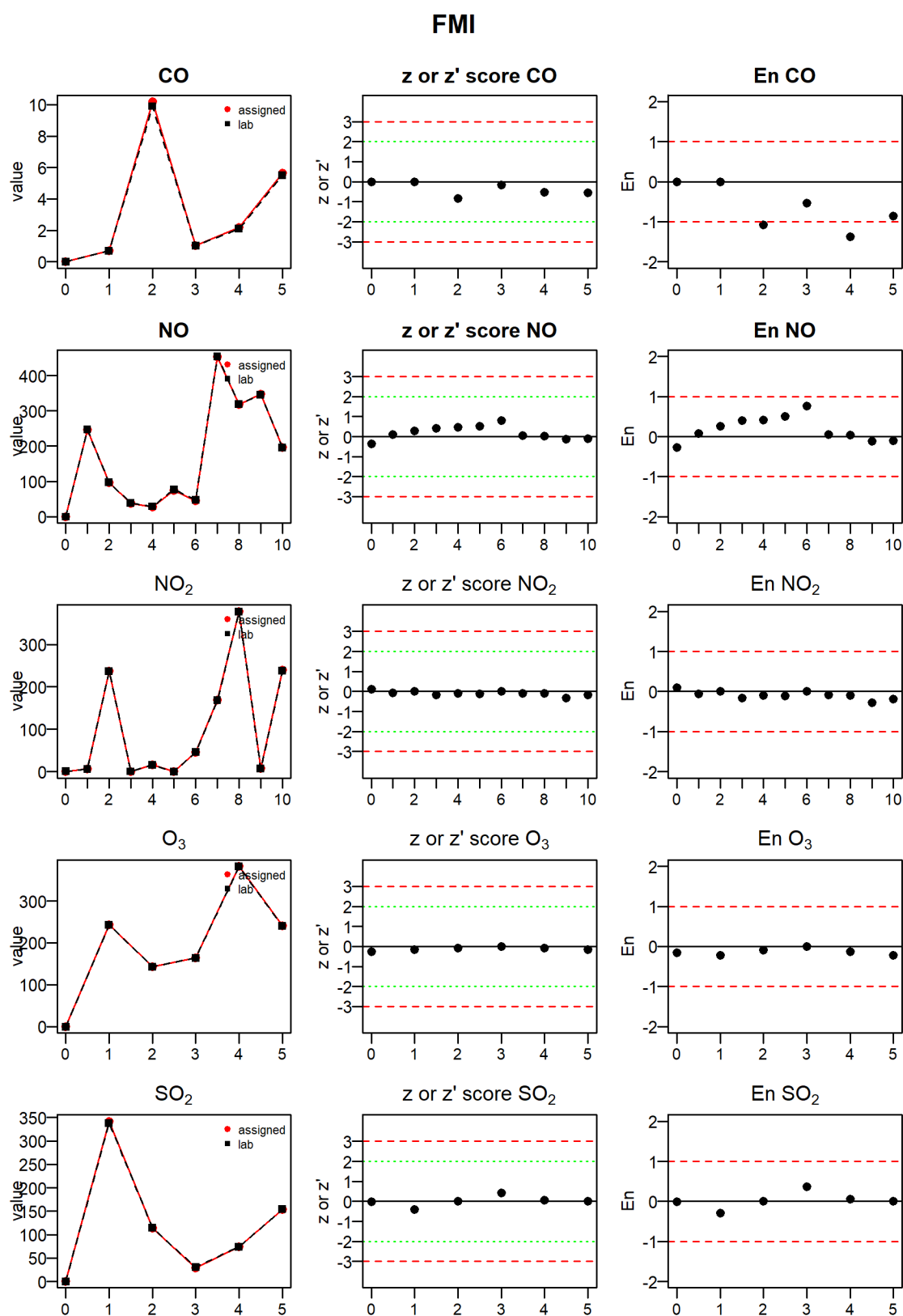
FMI

Table 19: Results for laboratory FMI. Units: CO in mg/m³; NO in µg/m³; NO₂ in µg/m³; O₃ in µg/m³; SO₂ in µg/m³.

Lab values								Assigned value					
Pollutant	Run	Avg	Step 1	Step 2	Step 3	Std u	Exp U	Avg.	Exp U.	σPT	D	z or z' score	En score
CO	0	0.00	0.00			0.01	0.02	0.00	0.01	0.12	0.00	0.00 (z)	0.00
CO	1	0.69	0.69	0.69	0.69	0.01	0.03	0.69	0.02	0.13	0.00	0.00 (z)	0.00
CO	2	9.9	9.9	9.9	9.9	0.13	0.26	10	0.10	0.36	-0.30	-0.83 (z)	-1.1
CO	3	1.0	1.0	1.0	1.0	0.02	0.04	1.0	0.02	0.14	-0.02	-0.17 (z)	-0.54
CO	4	2.1	2.1	2.1	2.1	0.03	0.06	2.2	0.03	0.17	-0.09	-0.53 (z)	-1.4
CO	5	5.5	5.5	5.5	5.5	0.07	0.15	5.6	0.06	0.25	-0.14	-0.54 (z)	-0.86
NO	0	-0.37	-0.37			0.29	0.59	0.20	2.0	1.3	-0.57	-0.36 (z')	-0.27
NO	1	247	246	247	247	3.7	7.4	246	2.9	7.2	0.67	0.09 (z)	0.08
NO	2	97	97	97	97	1.6	3.2	96	2.1	3.6	1.00	0.28 (z)	0.26
NO	3	39	39	39	39	0.77	1.6	38	1.9	2.2	1.00	0.42 (z')	0.40
NO	4	29	29	29	29	0.63	1.3	28	2.0	1.9	1.00	0.46 (z')	0.42
NO	5	77	76	77	77	1.3	2.6	75	2.0	3.0	1.7	0.52 (z')	0.51
NO	6	47	47	47	47	0.88	1.8	45	1.9	2.3	2.0	0.79 (z')	0.76
NO	7	454	454	454	454	6.6	14	453	4.2	12	0.67	0.05 (z)	0.05
NO	8	319	318	319	319	4.7	9.5	318	3.2	8.9	0.33	0.04 (z)	0.03
NO	9	346	345	346	346	5.1	11	347	3.4	9.6	-1.3	-0.14 (z)	-0.12
NO	10	196	195	196	196	3.0	6.0	196	2.5	6.0	-0.67	-0.11 (z)	-0.10
NO ₂	0	0.57	0.57			0.55	1.2	0.22	3.2	2.7	0.35	0.11 (z')	0.10
NO ₂	1	6.2	6.7	6.1	5.7	0.58	1.2	6.4	4.0	2.9	-0.27	-0.08 (z')	-0.06
NO ₂	2	237	236	237	238	3.9	7.8	237	4.1	9.3	0.00	0.00 (z)	0.00
NO ₂	3	0.18	0.51	0.11	-0.08	0.40	0.80	0.67	3.0	2.7	-0.49	-0.16 (z')	-0.16
NO ₂	4	16	15	16	16	0.64	1.3	16	3.1	3.1	-0.33	-0.10 (z')	-0.10
NO ₂	5	0.08	0.15	-0.05	0.15	0.51	1.1	0.47	3.2	2.7	-0.38	-0.12 (z')	-0.11
NO ₂	6	46	46	46	46	1.00	2.1	46	3.1	4.0	0.00	0.00 (z')	0.00
NO ₂	7	168	168	168	168	2.8	5.7	169	5.6	7.4	-0.67	-0.08 (z')	-0.08
NO ₂	8	377	377	377	376	6.0	13	378	6.2	13	-1.3	-0.10 (z)	-0.09
NO ₂	9	6.6	6.6	6.4	6.8	0.49	1.00	7.8	4.1	2.9	-1.2	-0.33 (z')	-0.28
NO ₂	10	238	238	238	237	3.9	7.9	239	4.5	9.4	-1.7	-0.18 (z)	-0.18
O ₃	0	-0.58	-0.58			1.5	3.0	0.04	2.4	2.0	-0.62	-0.27 (z')	-0.16
O ₃	1	243	242	243	243	2.0	4.0	244	1.9	6.9	-1.00	-0.15 (z)	-0.23
O ₃	2	143	143	142	143	1.8	3.6	143	1.2	4.9	-0.33	-0.07 (z)	-0.09
O ₃	3	164	164	164	164	1.8	3.7	164	1.3	5.3	0.00	0.00 (z)	0.00
O ₃	4	382	382	382	382	2.2	4.5	383	3.0	9.6	-0.67	-0.07 (z)	-0.12
O ₃	5	240	240	240	240	2.0	4.0	241	2.0	6.8	-1.00	-0.15 (z)	-0.22
SO ₂	0	0.05	0.05			0.76	1.6	0.10	3.8	2.7	-0.05	-0.02 (z')	-0.01
SO ₂	1	338	338	337	338	6.2	13	342	5.1	10	-4.0	-0.39 (z)	-0.29
SO ₂	2	114	114	114	114	2.6	5.3	114	4.0	5.2	0.00	0.00 (z')	0.00
SO ₂	3	31	30	31	31	1.3	2.6	29	3.8	3.3	1.7	0.44 (z')	0.36
SO ₂	4	74	74	74	74	2.0	4.0	74	3.9	4.3	0.33	0.07 (z')	0.06
SO ₂	5	154	154	154	154	3.2	6.5	154	4.3	6.1	0.00	0.00 (z')	0.00

Source: JRC 2026

Figure 22: Diagnostic plots for laboratory FMI. Left: measured value vs assigned value. Centre: z or z' score (limits at 2 and 3). Right: En score (limit at 1).



Source: JRC 2026

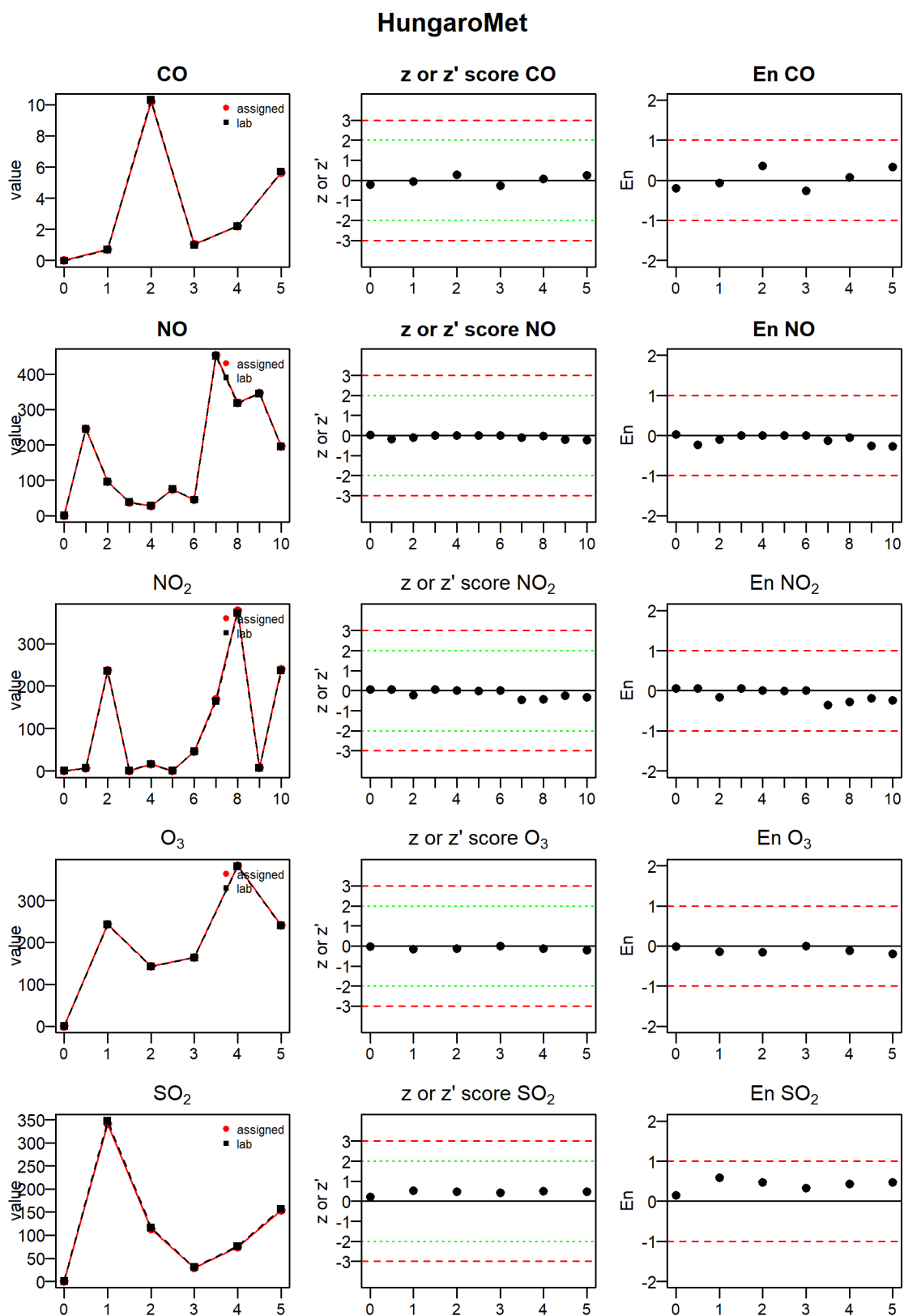
HungaroMet

Table 20: Results for laboratory HungaroMet. Units: CO in mg/m³; NO in µg/m³; NO₂ in µg/m³; O₃ in µg/m³; SO₂ in µg/m³.

Lab values								Assigned value					
Pollutant	Run	Avg	Step 1	Step 2	Step 3	Std u	Exp U	Avg.	Exp U.	σPT	D	z or z' score	En score
CO	0	-0.03	-0.03			0.07	0.13	0.00	0.01	0.12	-0.03	-0.22 (z)	-0.20
CO	1	0.68	0.68	0.68	0.68	0.07	0.13	0.69	0.02	0.13	-0.01	-0.08 (z)	-0.08
CO	2	10	10	10	10	0.13	0.26	10	0.10	0.36	0.10	0.28 (z)	0.36
CO	3	1.00	1.00	1.00	1.00	0.07	0.14	1.0	0.02	0.14	-0.04	-0.26 (z)	-0.26
CO	4	2.2	2.2	2.2	2.2	0.07	0.14	2.2	0.03	0.17	0.01	0.06 (z)	0.07
CO	5	5.7	5.7	5.7	5.7	0.09	0.18	5.6	0.06	0.25	0.06	0.25 (z)	0.34
NO	0	0.26	0.26			0.66	1.3	0.20	2.0	1.3	0.06	0.04 (z')	0.03
NO	1	245	244	245	245	2.6	5.1	246	2.9	7.2	-1.3	-0.19 (z)	-0.23
NO	2	96	96	96	95	1.2	2.3	96	2.1	3.6	-0.33	-0.09 (z)	-0.11
NO	3	38	38	38	38	0.77	1.5	38	1.9	2.2	0.00	0.00 (z')	0.00
NO	4	28	28	28	28	0.72	1.4	28	2.0	1.9	0.00	0.00 (z')	0.00
NO	5	75	75	75	75	1.00	2.0	75	2.0	3.0	0.00	0.00 (z')	0.00
NO	6	45	45	45	45	0.81	1.6	45	1.9	2.3	0.00	0.00 (z')	0.00
NO	7	452	452	452	452	4.6	9.2	453	4.2	12	-1.3	-0.11 (z)	-0.13
NO	8	318	318	318	318	3.3	6.5	318	3.2	8.9	-0.33	-0.04 (z)	-0.05
NO	9	345	345	345	345	3.5	7.1	347	3.4	9.6	-2.0	-0.21 (z)	-0.25
NO	10	195	195	195	195	2.1	4.1	196	2.5	6.0	-1.3	-0.22 (z)	-0.28
NO ₂	0	0.46	0.46			1.2	2.4	0.22	3.2	2.7	0.24	0.08 (z')	0.06
NO ₂	1	6.7	7.2	6.6	6.2	0.91	1.8	6.4	4.0	2.9	0.23	0.07 (z')	0.05
NO ₂	2	235	234	235	236	6.0	12	237	4.1	9.3	-2.0	-0.21 (z)	-0.16
NO ₂	3	0.88	1.1	0.82	0.71	1.2	2.4	0.67	3.0	2.7	0.21	0.07 (z')	0.05
NO ₂	4	16	16	16	16	1.3	2.5	16	3.1	3.1	0.00	0.00 (z')	0.00
NO ₂	5	0.45	0.52	0.44	0.39	1.2	2.4	0.47	3.2	2.7	-0.02	-0.01 (z')	-0.00
NO ₂	6	46	46	46	46	1.7	3.3	46	3.1	4.0	0.00	0.00 (z')	0.00
NO ₂	7	165	165	165	165	4.3	8.6	169	5.6	7.4	-3.7	-0.46 (z')	-0.36
NO ₂	8	372	373	372	372	9.4	19	378	6.2	13	-5.7	-0.43 (z)	-0.28
NO ₂	9	6.9	6.8	6.8	7.1	1.2	2.4	7.8	4.1	2.9	-0.87	-0.25 (z')	-0.18
NO ₂	10	236	237	237	235	6.1	12	239	4.5	9.4	-3.0	-0.32 (z)	-0.23
O ₃	0	0.00	0.00			0.63	1.3	0.04	2.4	2.0	-0.04	-0.02 (z')	-0.01
O ₃	1	243	242	243	243	3.4	6.9	244	1.9	6.9	-1.00	-0.15 (z)	-0.14
O ₃	2	142	142	143	142	2.1	4.2	143	1.2	4.9	-0.67	-0.14 (z)	-0.15
O ₃	3	164	164	164	164	2.4	4.7	164	1.3	5.3	0.00	0.00 (z)	0.00
O ₃	4	381	382	381	381	5.4	11	383	3.0	9.6	-1.3	-0.14 (z)	-0.12
O ₃	5	240	240	239	240	3.4	6.8	241	2.0	6.8	-1.3	-0.20 (z)	-0.19
SO ₂	0	0.84	0.84			1.7	3.4	0.10	3.8	2.7	0.74	0.23 (z')	0.15
SO ₂	1	347	346	347	348	3.8	7.5	342	5.1	10	5.3	0.52 (z)	0.59
SO ₂	2	117	117	117	116	2.0	4.1	114	4.0	5.2	2.7	0.48 (z')	0.47
SO ₂	3	31	30	31	31	1.7	3.4	29	3.8	3.3	1.7	0.44 (z')	0.33
SO ₂	4	76	76	76	76	1.8	3.7	74	3.9	4.3	2.3	0.49 (z')	0.43
SO ₂	5	157	157	157	157	2.3	4.6	154	4.3	6.1	3.0	0.47 (z')	0.48

Source: JRC 2026

Figure 23: Diagnostic plots for laboratory HungaroMet. Left: measured value vs assigned value. Centre: z or z' score (limits at 2 and 3). Right: En score (limit at 1).



Source: JRC 2026

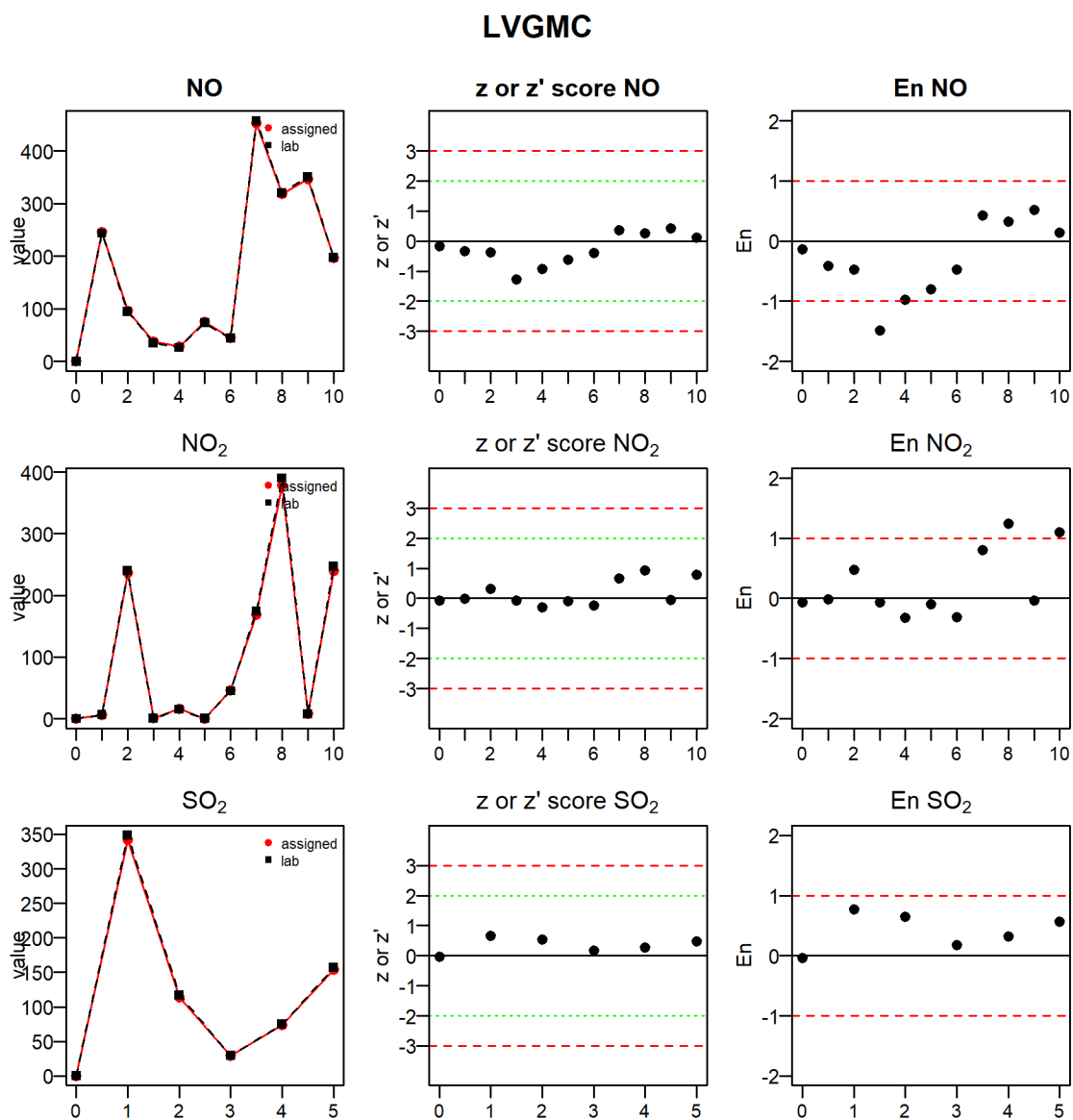
LVGMC

Table 21: Results for laboratory LVGMC. Units: NO in $\mu\text{g}/\text{m}^3$; NO₂ in $\mu\text{g}/\text{m}^3$; SO₂ in $\mu\text{g}/\text{m}^3$.

Lab values								Assigned value					
Pollutant	Run	Avg	Step 1	Step 2	Step 3	Std u	Exp U	Avg.	Exp U.	σ_{PT}	D	z or z' score	En score
NO	0	-0.08	-0.08			0.10	0.20	0.20	2.0	1.3	-0.28	-0.18 (z')	-0.14
NO	1	244	242	244	245	2.5	4.9	246	2.9	7.2	-2.3	-0.33 (z)	-0.41
NO	2	95	95	95	94	0.90	1.9	96	2.1	3.6	-1.3	-0.38 (z)	-0.47
NO	3	35	35	35	35	0.40	0.70	38	1.9	2.2	-3.0	-1.3 (z')	-1.5
NO	4	26	26	26	26	0.30	0.50	28	2.0	1.9	-2.0	-0.93 (z')	-0.97
NO	5	73	73	73	73	0.80	1.5	75	2.0	3.0	-2.0	-0.62 (z')	-0.80
NO	6	44	44	44	44	0.50	0.90	45	1.9	2.3	-1.00	-0.40 (z')	-0.48
NO	7	458	457	458	458	4.6	9.2	453	4.2	12	4.3	0.36 (z)	0.43
NO	8	321	320	321	321	3.2	6.4	318	3.2	8.9	2.3	0.26 (z)	0.33
NO	9	351	350	351	352	3.5	7.0	347	3.4	9.6	4.0	0.42 (z)	0.51
NO	10	197	196	197	198	2.0	4.0	196	2.5	6.0	0.67	0.11 (z)	0.14
NO ₂	0	0.00	0.00			0.10	0.20	0.22	3.2	2.7	-0.22	-0.07 (z')	-0.07
NO ₂	1	6.4	7.1	6.0	6.0	0.20	0.30	6.4	4.0	2.9	-0.07	-0.02 (z')	-0.02
NO ₂	2	240	239	240	241	2.4	4.8	237	4.1	9.3	3.0	0.32 (z)	0.48
NO ₂	3	0.46	0.55	0.45	0.37	0.10	0.20	0.67	3.0	2.7	-0.21	-0.07 (z')	-0.07
NO ₂	4	15	15	15	15	0.10	0.20	16	3.1	3.1	-1.00	-0.29 (z')	-0.32
NO ₂	5	0.15	0.10	0.13	0.23	0.10	0.20	0.47	3.2	2.7	-0.31	-0.10 (z')	-0.10
NO ₂	6	45	45	45	45	0.40	0.90	46	3.1	4.0	-1.00	-0.24 (z')	-0.31
NO ₂	7	174	173	175	174	1.8	3.5	169	5.6	7.4	5.3	0.67 (z')	0.81
NO ₂	8	390	390	391	390	3.9	7.8	378	6.2	13	12	0.93 (z)	1.2
NO ₂	9	7.6	7.7	7.8	7.3	0.20	0.30	7.8	4.1	2.9	-0.17	-0.05 (z')	-0.04
NO ₂	10	247	247	246	247	2.5	4.9	239	4.5	9.4	7.3	0.78 (z)	1.1
SO ₂	0	-0.03	-0.03			0.02	0.03	0.10	3.8	2.7	-0.13	-0.04 (z')	-0.03
SO ₂	1	348	348	349	348	3.5	7.0	342	5.1	10	6.7	0.65 (z)	0.77
SO ₂	2	117	117	117	117	1.2	2.3	114	4.0	5.2	3.0	0.54 (z')	0.65
SO ₂	3	30	29	30	30	0.30	0.60	29	3.8	3.3	0.67	0.17 (z')	0.17
SO ₂	4	75	75	75	75	0.80	1.5	74	3.9	4.3	1.3	0.28 (z')	0.32
SO ₂	5	157	157	157	157	1.6	3.1	154	4.3	6.1	3.0	0.47 (z')	0.57

Source: JRC 2026

Figure 24: Diagnostic plots for laboratory LVGMC. Left: measured value vs assigned value. Centre: z or z' score (limits at 2 and 3). Right: En score (limit at 1).



Source: JRC 2026

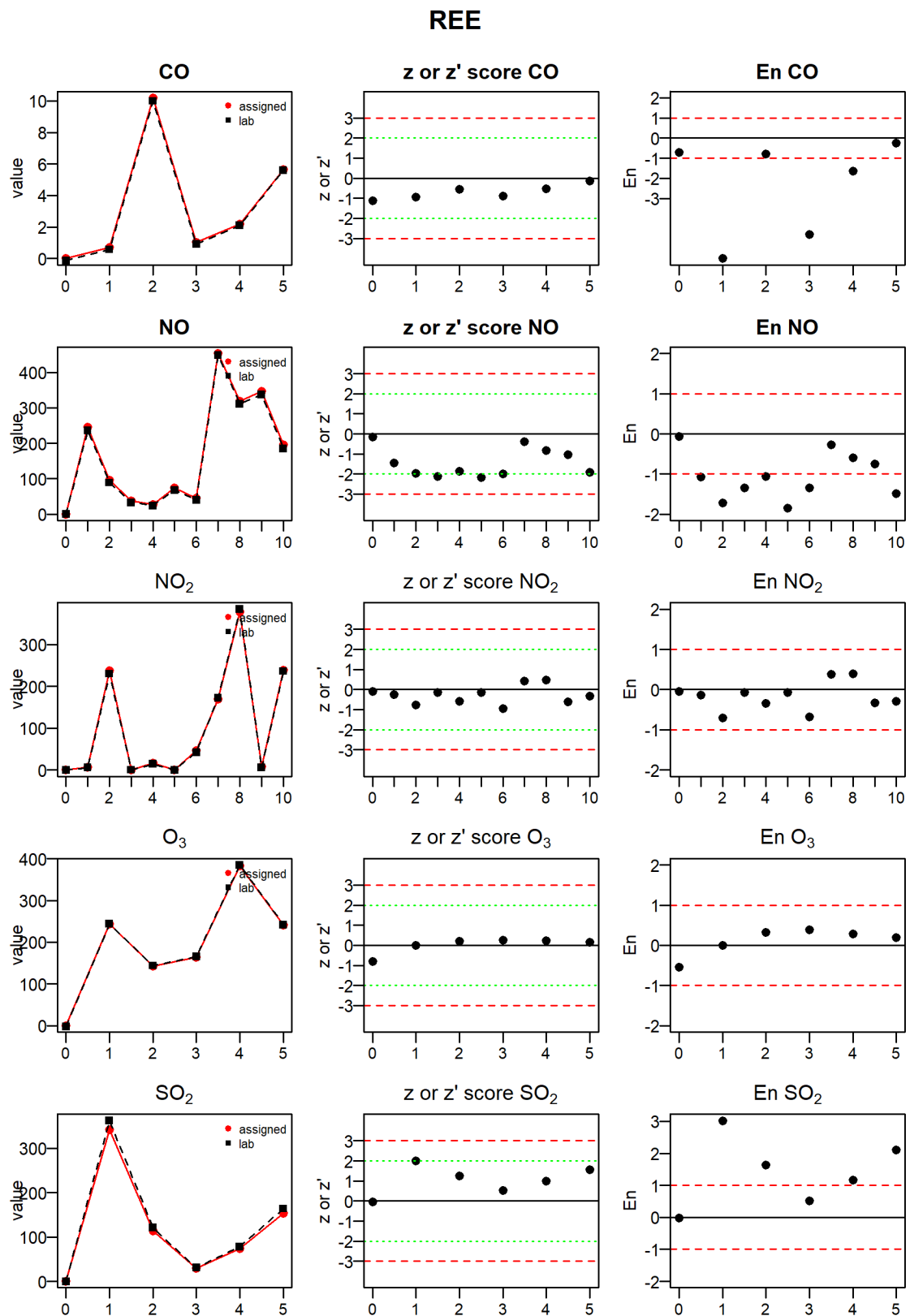
REE

Table 22: Results for laboratory REE. Units: CO in mg/m³; NO in µg/m³; NO₂ in µg/m³; O₃ in µg/m³; SO₂ in µg/m³.

Lab values								Assigned value					
Pollutant	Run	Avg	Step 1	Step 2	Step 3	Std u	Exp U	Avg.	Exp U.	σPT	D	z or z' score	En score
CO	0	-0.13	-0.13			0.09	0.18	0.00	0.01	0.12	-0.13	-1.1 (z)	-0.71
CO	1	0.57	0.57	0.57	0.56	0.01	0.01	0.69	0.02	0.13	-0.12	-0.93 (z)	-6.0
CO	2	10.0	10.0	10.0	10.0	0.12	0.23	10	0.10	0.36	-0.20	-0.55 (z)	-0.80
CO	3	0.91	0.91	0.91	0.91	0.01	0.02	1.0	0.02	0.14	-0.13	-0.90 (z)	-4.8
CO	4	2.1	2.1	2.1	2.1	0.02	0.05	2.2	0.03	0.17	-0.09	-0.53 (z)	-1.6
CO	5	5.6	5.6	5.6	5.6	0.06	0.13	5.6	0.06	0.25	-0.04	-0.15 (z)	-0.26
NO	0	-0.07	-0.07			1.6	3.2	0.20	2.0	1.3	-0.27	-0.17 (z')	-0.07
NO	1	236	235	236	236	4.6	9.2	246	2.9	7.2	-10	-1.4 (z)	-1.1
NO	2	89	89	89	89	1.7	3.5	96	2.1	3.6	-7.0	-2.0 (z)	-1.7
NO	3	33	33	33	33	1.6	3.2	38	1.9	2.2	-5.0	-2.1 (z')	-1.3
NO	4	24	24	24	24	1.6	3.2	28	2.0	1.9	-4.0	-1.9 (z')	-1.1
NO	5	68	68	68	68	1.6	3.2	75	2.0	3.0	-7.0	-2.2 (z')	-1.9
NO	6	40	40	40	40	1.6	3.2	45	1.9	2.3	-5.0	-2.0 (z')	-1.3
NO	7	449	448	449	449	8.7	17	453	4.2	12	-4.7	-0.38 (z)	-0.27
NO	8	311	311	311	311	6.0	12	318	3.2	8.9	-7.3	-0.83 (z)	-0.59
NO	9	337	337	337	337	6.5	13	347	3.4	9.6	-10.0	-1.0 (z)	-0.74
NO	10	185	185	185	185	3.6	7.2	196	2.5	6.0	-11	-1.9 (z)	-1.5
NO ₂	0	-0.03	-0.03			2.5	5.0	0.22	3.2	2.7	-0.25	-0.08 (z')	-0.04
NO ₂	1	5.6	6.2	5.1	5.4	2.5	5.0	6.4	4.0	2.9	-0.87	-0.25 (z')	-0.14
NO ₂	2	230	229	230	231	4.6	9.1	237	4.1	9.3	-7.0	-0.75 (z)	-0.70
NO ₂	3	0.25	0.31	0.29	0.15	2.5	5.0	0.67	3.0	2.7	-0.42	-0.14 (z')	-0.07
NO ₂	4	14	14	14	14	2.5	5.0	16	3.1	3.1	-2.0	-0.58 (z')	-0.34
NO ₂	5	0.02	-0.03	0.07	0.02	2.5	5.0	0.47	3.2	2.7	-0.45	-0.14 (z')	-0.08
NO ₂	6	42	42	42	42	2.5	5.0	46	3.1	4.0	-4.0	-0.94 (z')	-0.68
NO ₂	7	172	172	172	172	3.4	6.8	169	5.6	7.4	3.3	0.42 (z')	0.38
NO ₂	8	384	385	384	384	7.6	15	378	6.2	13	6.3	0.48 (z)	0.39
NO ₂	9	5.7	5.7	5.7	5.6	2.5	5.0	7.8	4.1	2.9	-2.1	-0.60 (z')	-0.32
NO ₂	10	236	237	236	236	4.7	9.4	239	4.5	9.4	-3.0	-0.32 (z)	-0.29
O ₃	0	-1.8	-1.8			1.2	2.4	0.04	2.4	2.0	-1.8	-0.79 (z')	-0.54
O ₃	1	244	243	244	244	2.4	4.8	244	1.9	6.9	0.00	0.00 (z)	0.00
O ₃	2	144	144	144	144	1.4	2.8	143	1.2	4.9	1.00	0.21 (z)	0.33
O ₃	3	165	165	165	166	1.6	3.2	164	1.3	5.3	1.3	0.25 (z)	0.39
O ₃	4	385	385	385	385	3.8	7.5	383	3.0	9.6	2.3	0.24 (z)	0.29
O ₃	5	242	242	242	242	2.4	4.7	241	2.0	6.8	1.00	0.15 (z)	0.20
SO ₂	0	0.01	0.01			1.5	2.9	0.10	3.8	2.7	-0.09	-0.03 (z')	-0.02
SO ₂	1	362	362	362	362	2.2	4.4	342	5.1	10	20	2.0 (z)	3.0
SO ₂	2	121	121	121	121	0.74	1.5	114	4.0	5.2	7.0	1.3 (z')	1.6
SO ₂	3	31	31	31	31	0.19	0.38	29	3.8	3.3	2.0	0.52 (z')	0.52
SO ₂	4	78	78	79	78	0.48	0.96	74	3.9	4.3	4.7	0.99 (z')	1.2
SO ₂	5	164	164	164	164	1.00	2.0	154	4.3	6.1	10.0	1.6 (z')	2.1

Source: JRC 2026

Figure 25: Diagnostic plots for laboratory REE. Left: measured value vs assigned value. Centre: z or z' score (limits at 2 and 3). Right: En score (limit at 1).



Source: JRC 2026

Annex B: SO₂ cross-interference during NO_x generation

During this PT, in agreement with all participants, an extra set of values was asked to be reported. In order to verify the impact of the interference of NO/NO₂ during SO₂ measurement, all participants quantified sulphur dioxide while high concentrations of NO and NO₂ were generated in the sampling line.

Annex E of EN 14212:2024 [5] defines the type-approval performance characteristics for UV-fluorescence SO₂ analysers. Table E.1, prescribes the cross-sensitivity test: the change of SO₂ indication shall not exceed 5.0 nmol/mol when the analyser is exposed to 500 nmol/mol of NO (test 8d) or 200 nmol/mol of NO₂ (test 8e). Both the zero-level response ($X_{NO,z}$ and $X_{NO_2,z}$) and the concentration-level response ($X_{NO,ct}$ and $X_{NO_2,ct}$) must remain within this limit.

The purpose of this supplementary measurement during the PT is to verify whether the SO₂ analysers used by participants maintain acceptable cross-interference levels under field conditions that are representative of actual ambient monitoring. The results depend on the specific make and model of the SO₂ analyser deployed by each laboratory; the instrumentation is listed in the table “Instrumentation reported by the participating laboratories” (see section Participants and instrumentation). Modern UV-fluorescence analysers from the main manufacturers (e.g. Thermo Fisher Scientific 43i/43iQ, Teledyne API T100/T100U, Environnement AF22e/AF22M, Horiba APSA-370/APSA-380) incorporate optical and electronic interference-rejection features (e.g. hydrocarbon kicker, pulsed fluorescence with selective bandpass filters) designed to minimise cross-sensitivity to NO and NO₂; however, the effectiveness may vary depending on instrument age, maintenance status and firmware version.

Table 23: SO₂ readings (µg/m³) reported by participants during NO/NO₂ generation (interference test).

Run	NO/NO ₂ ref. val.	ERLAP		DHZ	DCE	DLI	Ekonerg	AAA	FMI	HungaroMet	LVGMC	REE
				SO ₂								
				µg/m ³								
7	455/168	4.6	6.4	20.8	0.1	6.7	5.8	6.4	n.r.	6.3	2.8	6.1
		4.6	6.4	20.9	0.3	6.8	5.6	6.3	n.r.	5.5	2.9	6.1
		4.6	6.4	20.7	0.6	6.6	5.6	6.4	n.r.	6.1	2.8	6.1
8	322/375	3.3	5.0	14.6	1.3	4.0	4.1	4.5	n.r.	4.7	1.9	4.4
		3.2	5.1	14.8	0.9	4.1	4.1	4.5	n.r.	5.0	2.0	4.4
		3.2	4.9	14.9	0.2	4.0	4.0	4.5	n.r.	6.3	2.3	4.2
9	347/7.5	3.5	5.3	16.7	2.6	4.8	4.7	5.0	n.r.	6.1	1.8	4.5
		3.5	5.2	16.5	2.2	4.8	4.6	5.0	n.r.	5.5	1.9	4.5
		3.5	5.2	16.6	1.7	4.8	4.6	5.1	n.r.	6.1	1.8	4.8
10	197/238	2.0	3.5	9.3	1.3	1.8	2.7	3.0	n.r.	4.2	0.7	2.8
		2.0	3.6	9.2	0.9	1.6	2.8	3.0	n.r.	3.4	0.6	2.7
		2.0	3.7	9.5	0.5	1.4	2.9	3.0	n.r.	3.7	0.8	2.6
		Thermo 43iTLE	Horiba APSA370	Teledyne API T100	Teledyne API T100	Serinus 50	HORIBA APSA 370	Horiba APSA370	Thermo 43i	Thermo 43i	Teledyne API T100	Thermo 43i

Source: JRC 2026

The supplementary measurements performed during the 3 PT exercises show a reproducible apparent SO₂ response in the presence of NO/NO₂, although the magnitude of the effect varies considerably among individual analysers.

For most instruments, replicate measurements within each run were closely grouped, indicating that the observed response was systematic rather than dominated by random variability. A comparison of the different concentration levels also shows that the apparent SO₂ response generally increases with increasing NO concentration.

Particularly informative is the comparison between the runs characterised by similar NO concentrations but markedly different NO₂ concentrations. In these conditions, most analysers showed comparable apparent SO₂ responses despite the large change in NO₂ concentration. The same pattern was observed consistently across the 3 different PT exercises. This suggests that,

under the conditions investigated, the observed cross-interference is predominantly associated with NO rather than with NO₂.

The magnitude of the interference was strongly instrument dependent. Differences were observed not only between different analyser models, but also among instruments of the same make and model. Therefore, cross-interference performance cannot be inferred solely from analyser type and may also depend on instrument-specific factors such as configuration, condition, maintenance history, calibration status and the performance of the interference-rejection system.

The consistency of the response patterns observed across the different PT exercises provides evidence that the apparent SO₂ signal represents a reproducible instrument-specific cross-interference effect rather than random measurement variability. These supplementary measurements are intended to provide information on analyser behaviour under PT conditions and should not be interpreted as a formal conformity assessment against the interference requirements of the applicable EN standard unless all prescribed test conditions are reproduced.

Annex C: Repeatability and reproducibility

In this PT, ISO 5725-6:1994 [19] was applied to assess the **precision of the measurement method under repeatability and reproducibility conditions**.

Reproducibility refers to the closeness of agreement between measurement results obtained under reproducibility conditions, i.e. with relevant factors such as laboratory, operator, equipment and calibration allowed to vary. The reproducibility limit (R) represents the value below which the absolute difference between two results obtained under reproducibility conditions may be expected to lie with a probability of 95 %.

Repeatability refers to the closeness of agreement between successive measurement results obtained under repeatability conditions, i.e. using the same measurement procedure, under the same operating conditions and within a short period of time. The repeatability limit (r) represents the value below which the absolute difference between two results obtained under repeatability conditions may be expected to lie with a probability of 95 %.

Repeatability and reproducibility limits were calculated according to ISO 5725-6:1994 [19]. Prior to the calculation, the dataset was screened for statistical outliers in accordance with ISO 5725-2:2025 [20], using the Cochran test on within-laboratory variances and the iterative Grubbs test on laboratory means. Results identified as statistical outliers at the 1 % significance level were excluded from the calculation. The figures and tables presented below refer to the dataset after outlier exclusion.

The resulting repeatability and reproducibility limits provide quantitative measures of the within-laboratory and between-laboratory variability, respectively, observed under the conditions of this PT.

Equation 6

$$r = s_r \cdot \sqrt{2} \cdot t_{95\%, \nu_r} \quad \text{where } \nu_r = p \cdot (n - 1)$$

Equation 7

$$R = s_R \cdot \sqrt{2} \cdot t_{95\%, \nu_R} \quad \text{where } \nu_R = p - 1$$

where p is the number of participating laboratories and n the number of replicates per laboratory.

The reference reproducibility (R_{ref} , dashed green line) represents the expected method performance based on the standard deviation for proficiency assessment ($\sigma_{PT} = a \times \text{concentration} + b$) established by the AQUILA network. It is calculated as:

Equation 8

$$R_{ref} = \sqrt{2} \cdot t_{95\%, p-1} \cdot \sigma_{PT}$$

The red dotted line represents the Data Quality Objective (DQO) from Directive (EU) 2024/2881 [1], expressed as the expanded uncertainty at the regulatory limit value (15 % for NO₂, SO₂ and O₃; 10 % for 8 hours mean CO).

When the reproducibility achieved by the NRLs during the PT is better than that corresponding to the fitness-for-purpose criterion established by the AQUILA network, indicating satisfactory interlaboratory precision. Conversely, $R > R_{ref}$ indicates that the observed between-laboratory variability is greater than expected on the basis of the proficiency assessment criterion.

The DQO line is included for contextual comparison with the uncertainty requirements applicable to ambient air measurements. Since the reproducibility limit R and the DQO expanded uncertainty are different metrological quantities, their direct comparison should not be interpreted as a formal assessment of compliance with the DQO. Nevertheless, an R value of comparable magnitude to, or greater than, the DQO highlights a level of between-laboratory variability that may be relevant when assessing the overall measurement performance required for regulatory purposes.

C.1 Overview

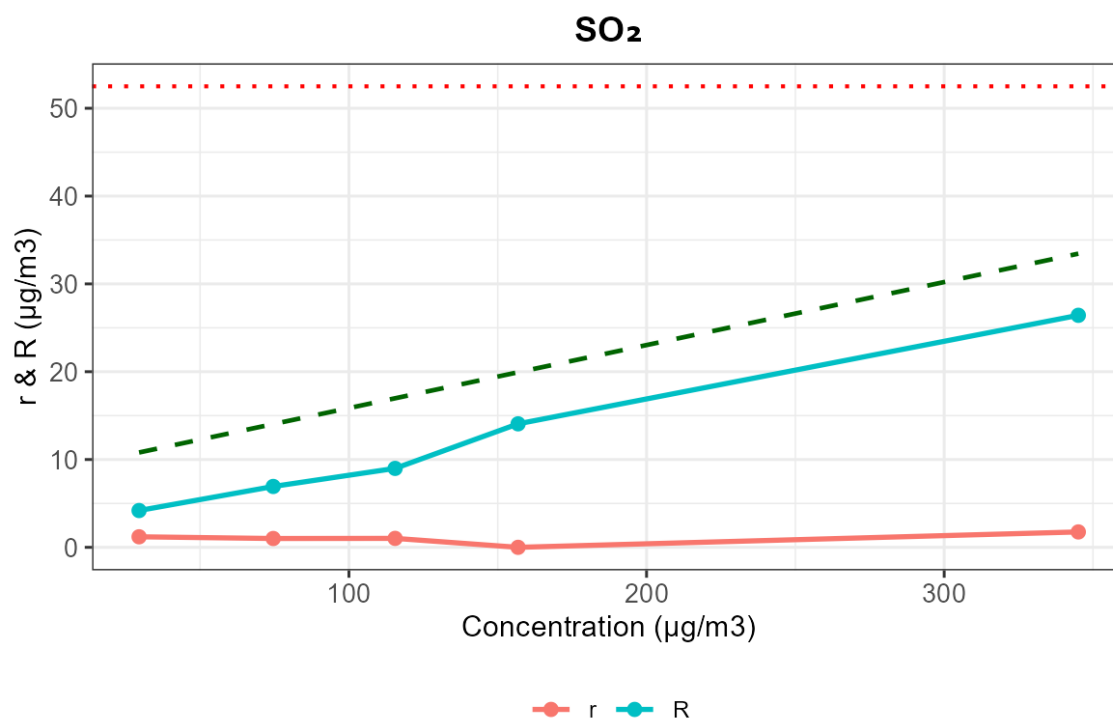
Table 24: Summary of repeatability and reproducibility limits across all pollutants.

Pollutant	Conc. range	r range	R range	R % range	R > R _{ref}	R > DQO
SO ₂	29–345 µg/m ³	0.00–1.8	4.2–26	8–14 %	0/5	0/5
CO	0.66–10 mg/m ³	0.00–0.01	0.16–0.96	7–25 %	0/5	0/5
O ₃	143–382 µg/m ³	0.00–2.6	5.8–8.6	2–5 %	0/5	0/5
NO	27–456 µg/m ³	0.00–2.0	3.7–17	3–23 %	0/10	—
NO ₂	15–378 µg/m ³	0.81–2.5	3.1–22	4–21 %	0/5	0/5

Source: JRC 2026

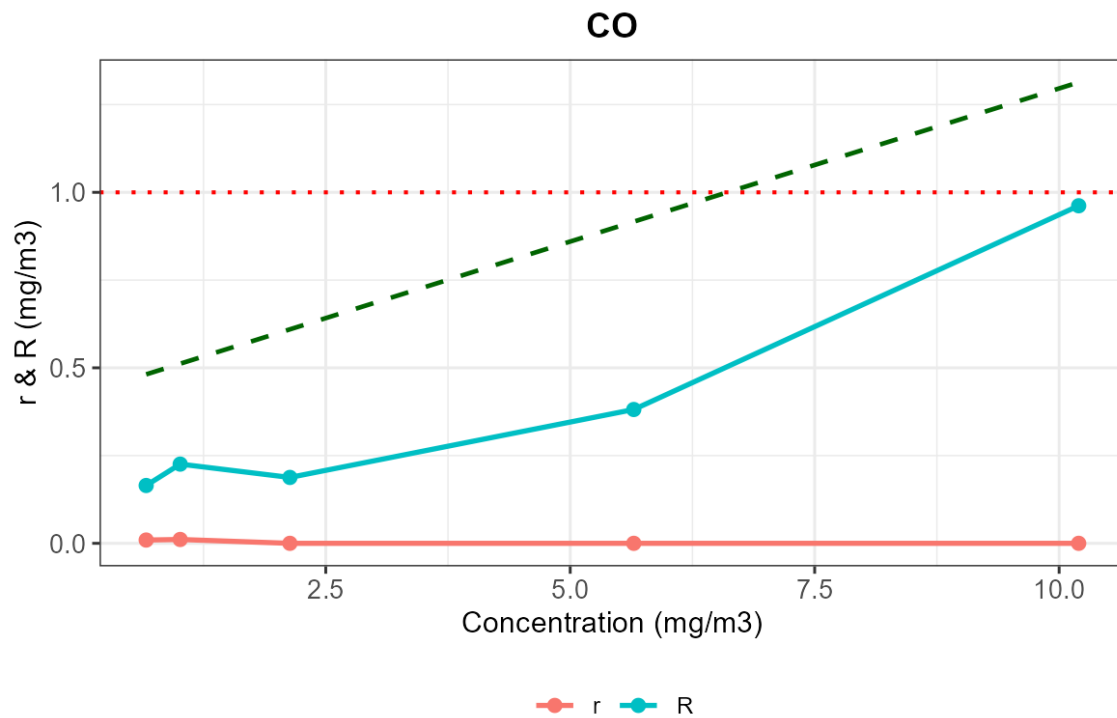
C.2 SO₂, CO and O₃

Figure 26: Repeatability (r) and reproducibility (R) limits for SO₂. Dashed green line: reference R from σPT. Dotted red line: DQO from Air Quality Directive.



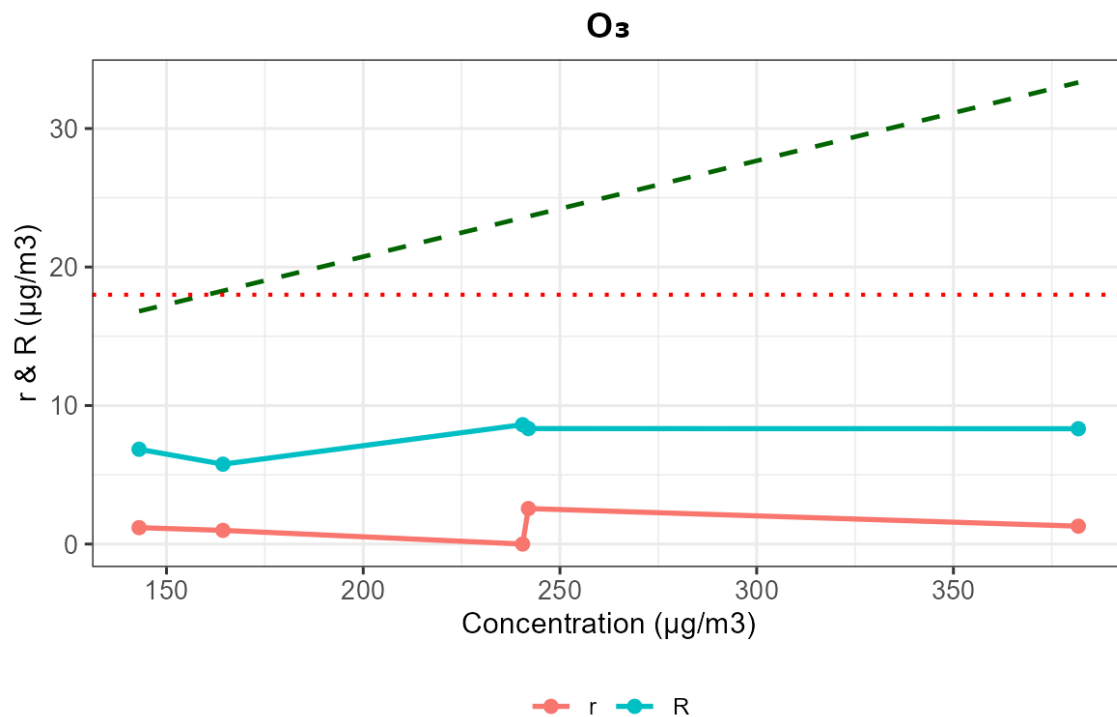
Source: JRC 2026

Figure 27: Repeatability (r) and reproducibility (R) limits for CO. Dashed green line: reference R from σ_{PT} . Dotted red line: DQO from Air Quality Directive.



Source: JRC 2026

Figure 28: Repeatability (r) and reproducibility (R) limits for O₃. Dashed green line: reference R from σ_{PT} . Dotted red line: DQO from Air Quality Directive.



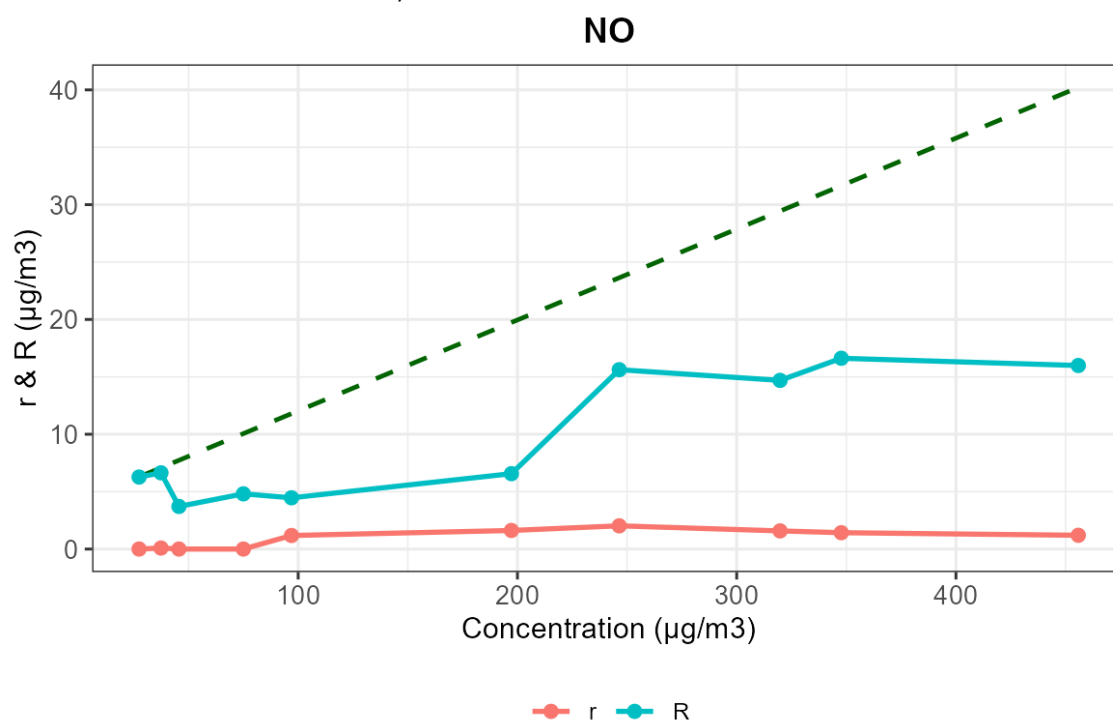
Source: JRC 2026

The repeatability values for SO₂ and CO and O₃ are consistently low relative to the reproducibility across all tested concentrations, confirming stable short-term analyser response and good within-

laboratory precision. For SO₂ and CO and O₃, R remains below R_{ref} at all tested concentration levels, confirming satisfactory inter-laboratory precision. R remains below the DQO benchmark for all pollutants and concentration levels. Relative reproducibility (R %) decreases with increasing concentration for all pollutants (SO₂: 8–14 %; CO: 7–25 %; O₃: 2–5 %), as expected from the linear σ_{PT} model.

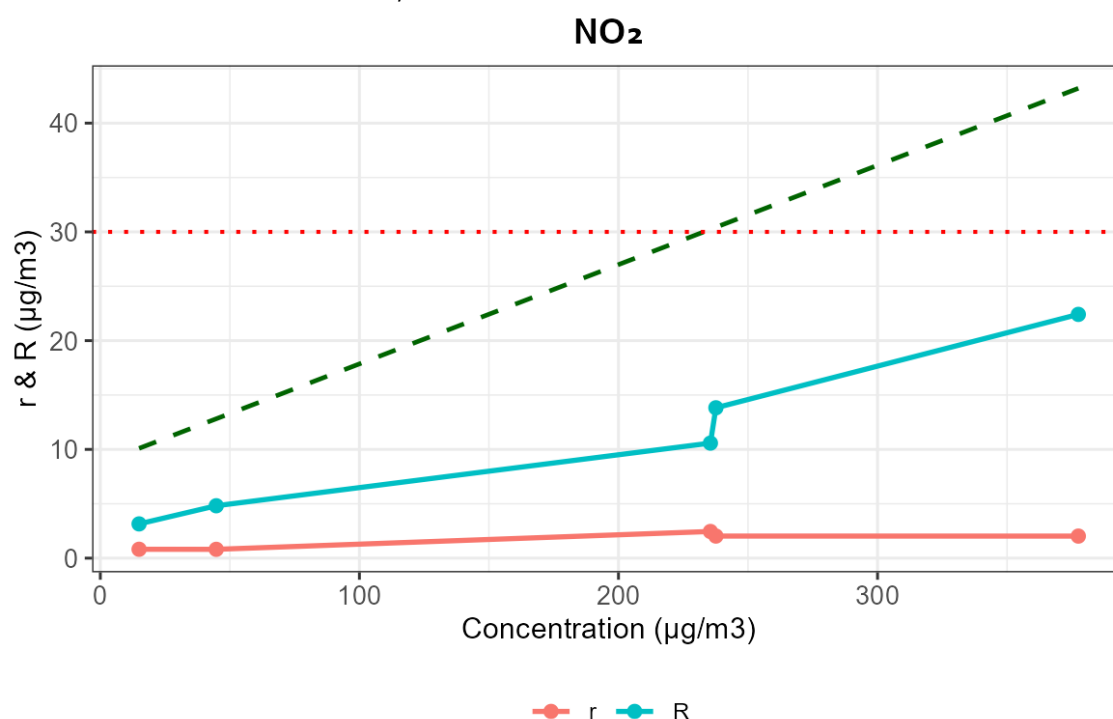
C.3 NO and NO₂

Figure 29: Repeatability (r) and reproducibility (R) limits for NO. Dashed green line: reference R from σ_{PT} . Dotted red line: DQO from Air Quality Directive.



Source: JRC 2026

Figure 30: Repeatability (r) and reproducibility (R) limits for NO₂. Dashed green line: reference R from σ_{PT} . Dotted red line: DQO from Air Quality Directive.



Source: JRC 2026

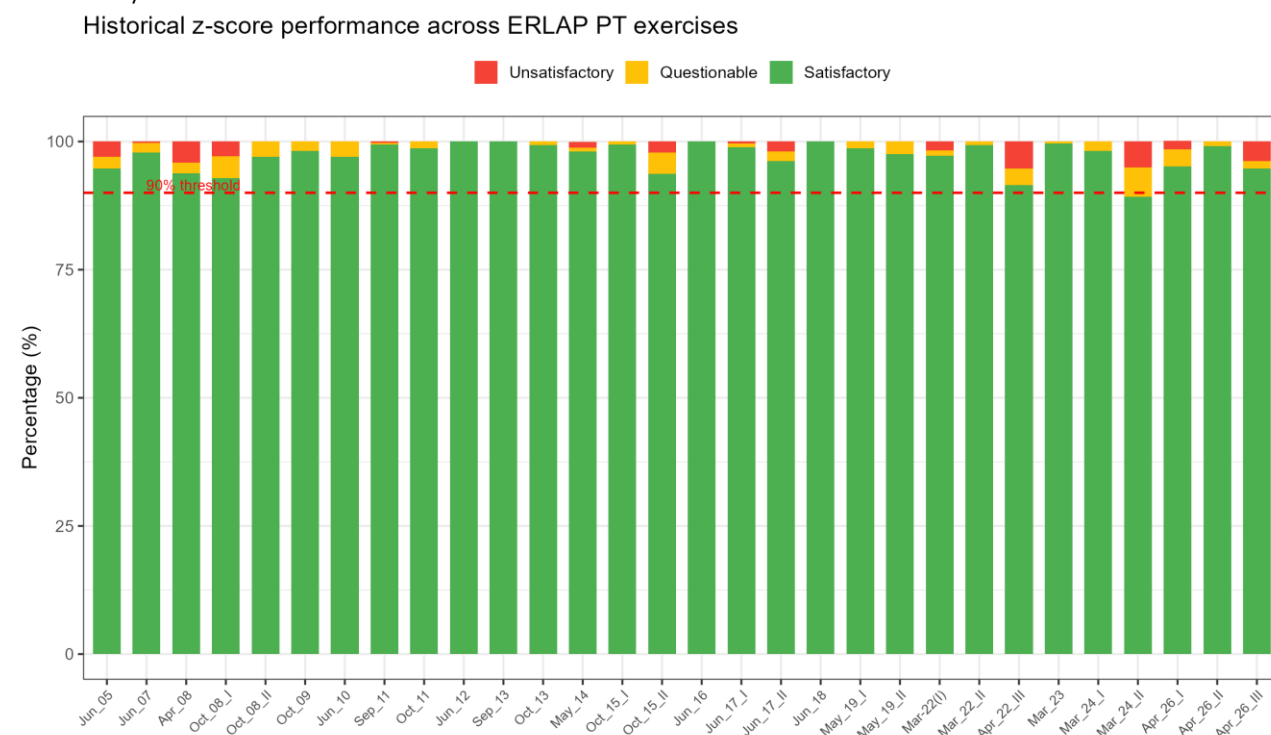
The repeatability values for NO and NO₂ are consistently low relative to the reproducibility across all tested concentrations, confirming stable short-term analyser response and good within-laboratory precision.

For NO and NO₂, R remains below R_{ref} at all tested concentration levels, confirming satisfactory inter-laboratory precision. R remains below the DQO benchmark for all pollutants and concentration levels. Relative reproducibility (R %) decreases with increasing concentration for all pollutants (NO: 3–23 %; NO₂: 4–21 %), as expected from the linear σ_{PT} model.

Annex D: Historical z-score performance

The figure below presents the historical performance of participating laboratories across all ERLAP PT exercises since 2005, summarised as the percentage of z scores classified as satisfactory ($|z| \leq 2$), questionable ($2 < |z| \leq 3$) and unsatisfactory ($|z| > 3$). The dashed red line at 90 % represents the threshold for good overall performance.

Figure 31: Historical z-score performance summary across ERLAP PT exercises. Dashed red line = 90 % satisfactory threshold.



Source: JRC 2026

Over 30 PT exercises conducted since 2005, the average satisfactory rate is 97.2 %, ranging from 89.2 % to 100 %. 29 out of 30 exercises (97 %) achieved satisfactory rates at or above the 90 % threshold, confirming the consistently high measurement capability of the NRL network. One exercise fell below 90 % (Mar_24_II), generally associated with specific analytical challenges or changes in the PT protocol. The most recent exercise (Apr_26_III) recorded 94.7 % satisfactory results. Over the last 5 exercises, the average satisfactory rate is 95.3 %. The current performance confirms the positive long-term trend and the effectiveness of the quality assurance framework implemented by the AQUILA network.

End of report

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