Australian Government
Department of Industry, Science and Resources

National Measurement Institute

Proficiency Test Final Report
AQA 24-11
Heroin

November 2024

ACKNOWLEDGMENTS

This study was conducted by the National Measurement Institute (NMIA). Support funding was provided by the Australian Government Department of Industry, Science and Resources.

I would like to thank the management and staff of the participating laboratories for supporting the study. It is only through widespread participation that we can provide an effective service to laboratories.

The assistance of the following NMIA staff members in the planning, conduct and reporting of the study is acknowledged.

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SUMMARY

AQA 24-11 Heroin commenced in April 2024. Three test samples were sent to 31 laboratories, with one laboratory requesting two sample sets to be analysed independently by different analysts. All participants submitted results.

Samples were prepared at the NMIA Sydney laboratory using heroin hydrochloride samples supplied by the Australian Federal Police.

The assigned values in this study were the robust averages of participants' results.

Traceability: The consensus of participants' results is not traceable to any external reference, so although expressed in SI units, metrological traceability has not been established.

The outcomes of the study were assessed against the aims as follows:

- *Assess the proficiency of participants measuring heroin in samples typical of a routine seizure.*

Participant performance was assessed by *z*-scores and E_n-scores.

Of 96 *z*-scores, 92 (96%) returned $|z| \leq 2.0$, indicating an acceptable performance.

Of 96 E_n-scores, 92 (96%) returned $|E_n| < 1.0$, indicating agreement of the participant's result with the assigned value within their respective expanded uncertainties.

Laboratories **1**, **2**, **3**, **4**, **5**, **6**, **8**, **9**, **10**, **11**, **12**, **13**, **14**, **15**, **16**, **18**, **19**, **20**, **21**, **22**, **23**, **24**, **25**, **26**, **27**, **28**, **30**, **31** and **32** returned acceptable *z*-scores and E_n-scores for all results.

- *Develop a practical application of traceability and measurement uncertainty, and provide participants with information that will assist uncertainty estimates.*

Of 96 reported results, 93 (97%) were reported with an associated expanded measurement uncertainty. The magnitude of reported uncertainties was within the range 0.6% to 20% relative.

- *Test the ability of participants to identify cutting agents commonly found in controlled drug preparation.*

Sample S1 was left uncut, Sample S2 was cut with caffeine, and Sample S3 was cut with phenacetin.

Participants correctly identified both caffeine in Sample S2 and phenacetin in Sample S3, except for one participant who reported only phenacetin in Sample S3.

- *Produce materials that can be used in method validation and as control samples.*

The test samples produced for this study are homogeneous and well characterised. Surplus samples are available for purchase and can be used for quality control and for method validation purposes.

1 INTRODUCTION

1.1 NMIA Proficiency Testing Program

The National Measurement Institute (NMIA) is responsible for Australia's national measurement infrastructure, providing a range of services including a chemical proficiency testing program.

Proficiency testing (PT) is the 'evaluation of participant performance against pre-established criteria by means of interlaboratory comparisons'.[1] NMIA PT studies target chemical testing in areas of high public significance such as trade, environment, law enforcement and food safety. NMIA offers studies in:

- pesticide residues in fruit, vegetables and herbs, soil and water;
- petroleum hydrocarbons in soil and water;
- per- and polyfluoroalkyl substances in water, soil, biota and food;
- inorganic analytes in soil, water, filters, food and pharmaceuticals;
- controlled drug assay, drugs in wipes and clandestine laboratory; and
- allergens in food.

1.2 Study Aims

The aims of the study were to:

- assess the proficiency of participants measuring heroin in samples typical of a routine seizure;
- develop a practical application of traceability and measurement uncertainty, and provide participants with information that will assist uncertainty estimates;
- test the ability of participants to identify cutting agents commonly found in controlled drug preparation; and
- produce materials that can be used in method validation and as control samples.

The choice of the test method was left to the participating laboratories.

1.3 Study Conduct

The conduct of NMIA proficiency tests is described in the NMIA Study Protocol for Proficiency Testing.[2] The statistical methods used are described in the NMIA Chemical Proficiency Testing Statistical Manual.[3] These documents have been prepared with reference to ISO/IEC 17043,[1] and The International Harmonized Protocol for the Proficiency Testing of Analytical Chemistry Laboratories.[4]

NMIA is accredited by the National Association of Testing Authorities, Australia (NATA) to ISO/IEC 17043:2023 as a provider of proficiency testing schemes.[1] This controlled drug study is within the scope of NMIA's accreditation.

2 STUDY INFORMATION

2.1 Study Timetable

The timetable of the study was:

Invitations sent	22/04/2024
Samples sent	8/07/2024
Results due	30/09/2024
Interim Report	3/10/2024
Preliminary Report	4/10/2024

The study timeline was extended to accommodate sample delivery delays to some international participants.

2.2 Participation and Laboratory Code

Thirty-one laboratories registered to participate, with one laboratory requesting two sets of samples each to be analysed independently by different analysts. All participants were assigned a confidential laboratory code number for this study. All participants submitted results.

2.3 Test Material Specification

Three test samples were prepared in June 2024. The starting material was two different batches of heroin hydrochloride (approximately 69% heroin base (m/m) and 80% heroin base (m/m)) supplied by the Australian Federal Police.

Caffeine and phenacetin purchased from Sigma-Aldrich were used as cutting agents. Sample S1 was prepared using the lower purity heroin and left uncut. Samples S2 and S3 were prepared using the higher purity heroin and cut with caffeine and phenacetin respectively.

The heroin hydrochloride was ground and sieved through a 180 µm sieve. The cutting agents were processed similarly. Test samples were prepared by adding a known mass of sieved cutting agent to a known mass of sieved drug material, and then mixing this in a tumbler overnight. Portions of 150 mg of each of the test samples were weighed into labelled glass vials.

Sample S1 was prepared to contain approximately 69% heroin base (m/m).

Sample S2 was prepared to contain approximately 41% heroin base (m/m).

Sample S3 was prepared to contain approximately 23% heroin base (m/m).

2.4 Test Sample Homogeneity and Stability

The preparation of homogeneous test samples is an important part of a PT study. Given the small (usually < 150 mg) test portions normally used for controlled substances analysis, the particle size must be sufficiently small and uniformly distributed to ensure minimal influence on analytical precision. The procedure for the preparation of the study samples has been validated in previous studies, and no additional homogeneity testing was conducted in this proficiency study. Results returned by the participants also gave no reason to question the homogeneity of the test samples.

To assess stability of the samples, results returned by participants were compared to the date of analysis. The results gave no reason to question the stability of the test samples (Section 6.7).

2.5 Sample Dispatch and Receipt

Sets of three test samples, with each sample containing approximately 150 mg of material, were dispatched to participants on 8 July 2024.

The following items were also sent with the samples:

- a covering letter which included a description of the test samples and instructions for participants; and
- a form for participants to confirm the receipt of the test samples.

An Excel spreadsheet for the electronic reporting of results was emailed to participants.

2.6 Instructions to Participants

Participants were instructed as follows:

- Analyse each sample for amount of heroin base by your routine test method.
- Identify and report the diluent(s) and/or adulterant(s) in all samples if this is within your normal scope of analysis.
- For each sample, report % m/m heroin as base. Report this figure as if reporting to a client.
- For each result, report an estimate of your expanded uncertainty as % m/m heroin as base.
- Give brief details of your:
  - basis of uncertainty estimate (e.g. uncertainty budget, repeatability precision)
  - analytical method (e.g. sample treatment, instrument type, calibration method)
  - reference standard (e.g. source, purity)

  as requested by the results sheet.
- Please complete the results sheet by 2 September 2024 and return by email to jenny.xu@measurement.gov.au. Late results may not be included in the study report.

The reporting due date was extended to 30 September 2024 due to significant sample delivery delays experienced by some international participants.

2.7 Interim Report and Preliminary Report

An Interim Report was emailed to all participants on 3 October 2024.

A Preliminary Report was emailed to all participants on 4 October 2024. This report included a summary of the results reported by participants, assigned values, performance coefficients of variation (PCVs), *z*-scores and E_n-scores for each analyte in this study. No data from the Preliminary Report has been changed in this Final Report.

3 PARTICIPANT LABORATORY INFORMATION

3.1 Test Methods Reported by Participants

Participants' reported test methods are presented in Table 1. Responses may have been modified so that the participant cannot be identified.

Table 1 Summary of Participants' Test Methods

Lab. Code	Extraction Solvent	Internal Standard	Calib. Points	Technique	Detector	Column	Instrument Comments
1	Chloroform	2,2,2-triphenylacetophenone	1	GC	FID	HP5	
2	Methanol	none	5	HPLC	DAD	kinetex c-18-xb	Wavelength: 215 nm
3	Acetonitrile, acetic acid, water	NO ISTD	4	HPLC	UV DAD	Poroshell 120 Ec-18	
4	acetonitrile/H20 (80/20)	External standard	3	HPLC	DAD	NH2	
5	HPLC Methanol	-	1	UPLC	DAD	Thermo Scientific Hypersil-5-ODS	Wavelength: 280 nm
6	Methanol	Methadone	4	GC	FID	Rxi-5ms	
7	Ethanol	Propyl Paraben	8	UPLC	DAD	BEH Shield RP18	
8	Acetonitrile	Strychnine	6	GC	FID	HP1	
9	Methanol	Diazepam	6	GC	FID	J&W 128-5512	
10	ethanol:dimethylformamide (9:1)	tribenzylamine	6	GC	FID	HP1	
11	Ethanol	2,2,2-triphenylacetophenone (TPAP)	3	GC	FID	HP-1MS	
12	dichloromethane	5a-cholestane	5	GC	FID	HP5	
13	Chloroform:Methanol (9:1)	β-benzopinacolone	1	GC	FID	HP5	Measurement concentration
14	Water:Acetonitrile	N/A	3	HPLC	DAD	Luna 2.5um C18(2)-HST 100 A (LC Column 100 x 3mm)	
15	Chloroform	2,2,2-triphenylacetophenone	4	GC	FID	HP-1	

Lab. Code	Extraction Solvent	Internal Standard	Calib. Points	Technique	Detector	Column	Instrument Comments
16	Methanol	N/A	5	HPLC	PDA	Silica 15cm	
17	Methanol	Mepivacaine	4	LC	MS	Kinetex EVO C18 2.6 µm 2.1x100mm	
18	Acetonitrile/Methanol (95:5)	Pholcodine 1mg/ml	3	UPLC	PDA	ACQUITY C-18	
19	Acetonitrile	None	7	HPLC	DAD	Phenomenex C8 Luna 3u Narrow Bore 100 mm	Wavelength: 214 nm
20	Ethanol	N/A	4	HPLC	UV/Vis	Lichrocart 125-4 RP18	
21	Chloroform	Octacosane	5	GC	MS	Zebron ZB-5MSplus	
22	Chloroform	2,2,2-Triphenylacetophenone	1	GC	FID	HP5	
23	Methanol	No	7	HPLC	DAD	Poroshell 120C18 (4.6x150mm, 2.7 microns particle size)	
24	ACN/MEOH/ H2O	Analog of heroin	7	UPLC	MS/MS	C-18 Column	
25	HPLC Methanol	-	1	UPLC	DAD	Thermo Scientific Hypersil-5-ODS	Wavelength: 280 nm
26	Methanol	none	2	HPLC	DAD	Luna 3 µm PFP 100 Å 150x4.6 mm	
27	Chloroform	Octacosane	5	GC	FID	HP5	
28	acetonitrile/water (86/14)	none	4	HPLC	DAD	NH2	Wavelength: 280 nm
29	Acetonitrile:Water (75:25)	Benzocaine	3	UPLC	DAD	Acquity BEH C18	
30	acetonitrile/water	none	1	HPLC	UV/Vis	Kromasil	Wavelength: 280 nm
31	water/acetonitrile/2.5M sulphuric acid 90:10:1	None	3	HPLC	Diode Array	Shimpack XR-ODS	Wavelength: 279 nm
32	Absolute ethanol	Tribenzylamine	6	GC	FID	DB-5	20 m column, 0.1 um film, 0.1 mm diameter.

3.2 Details of Participant Calibration Standards

Participants' responses regarding their calibration standard are presented in Table 2. Responses may have been modified so that the participant cannot be identified.

Table 2 Participant Calibration Standard

Lab. Code	Reference Standard	Purity (%)
1	In-house	91.88
2	Chiron	Net pur: 99.8 (±4.0)
3	Lipomed	99.88
4	LIPOMED	86.4
5	Lipomed	99.912±0.018
6	LGC	1.011mg/ml
7	NMI	99.4
8	NMI	99.3
9	Lipomed	99.1
10	LGC NMIA D752d	99.3
11	NMI	99.3 +/- 0.5
12	Lipomed	98.6
13	In-house reference material	91.88
14	British Pharmacopeia	99.3
15	In-house synthesis	97.3
16	Johnson Matthey	99.4
17		
18	NMI	99.3
19	NMI	99.4
20	Lipomed	99.600 +/- 0.020
21	Lipomed	99.912
22	In-house	91.88
23	Lipomed	99.879
24	Lipomed	100
25	Lipomed	99.912±0.018
26	Lipomed (M-29-FB-1LA)	1 mg/mL
27	NMI	99.3
28	Lipomed	99.912
29	NMI	99.3
30	Lipomed	98.64
31	Cayman Chemical	99.1
32	Lipomed	99.912%+/-0.018% free base content 86.4%

3.3 Reported Basis of Participants' Measurement Uncertainty Estimates

Participants were requested to provide information about their basis of measurement uncertainty (MU). Responses are presented in Table 3. Responses may have been modified so that the participant cannot be identified.

Table 3 Reported Basis of Uncertainty Estimate

Lab. Code	Approach to Estimating MU	Information Sources for MU Estimation*		Guide Document for Estimating MU
		Precision	Method Bias	
1	Top Down - precision and estimates of the method and laboratory bias k = 3	Duplicate analysis	Matrix effects Standard purity	Eurachem/CITAC Guide
2	Standard deviation of replicate analyses multiplied by 2 or 3 k = 3 (99%)	Control samples - RM Duplicate analysis		Eurachem/CITAC Guide
3	Top Down - precision and estimates of the method and laboratory bias k = 2		Recoveries of SS	ISO 5725-2 years and ISO/TS 21748
4	Top Down - precision and estimates of the method and laboratory bias Coverage factor not reported	Duplicate analysis	Instrument calibration Standard purity	Eurachem/CITAC Guide
5	Top Down - precision and estimates of the method and laboratory bias k = 2	Control samples - SS Duplicate analysis	Laboratory bias from PT studies Recoveries of SS	Eurachem/CITAC Guide
6	Standard deviation of replicate analyses multiplied by 2 or 3 Coverage factor not reported	Duplicate analysis	Masses and volumes	ISO/GUM
7	Coverage factor not reported			
8	Top Down - precision and estimates of the method and laboratory bias k = 2	Control samples - CRM Duplicate analysis	Homogeneity of sample Masses and volumes	ISO/GUM
9	Uncertainty measurement estimation by black box with pairs of values Coverage factor not reported	Standard deviation from PT studies only		ISO/GUM ENAC G 09 Guide or ISO 21748
10	Top Down - precision and estimates of the method and laboratory bias Coverage factor not reported	Control samples - RM	Standard purity	

Lab. Code	Approach to Estimating MU	Information Sources for MU Estimation*		Guide Document for Estimating MU
		Precision	Method Bias	
11	Bottom Up (ISO/GUM, fish bone/cause and effect diagram) k = 2	Control samples - CRM Duplicate analysis	Instrument calibration Homogeneity of sample Masses and volumes Matrix effects Recoveries of SS Standard purity	Eurachem/CITAC Guide
12	repeatability, ME of standard and ME of calibration curve k = 2	Control samples - RM Duplicate analysis	Instrument calibration Standard purity	Eurachem/CITAC Guide
13	Top Down - precision and estimates of the method and laboratory bias k = 3	Control samples - RM	Homogeneity of sample Matrix effects Standard purity	ASCLD/LAB Guidance on the Estimation of Measurement Uncertainty, AL-PD-3061
14	Top Down - precision and estimates of the method and laboratory bias k = 2	Control samples - Previously analysed samples retained	Recoveries of SS	ISO/GUM
15	Validation Coverage factor not reported			
16	Standard deviation of replicate analyses multiplied by 2 or 3 Coverage factor not reported	Control samples - CRM	Instrument calibration Masses and volumes Laboratory bias from PT studies	ISO/GUM
17	Top Down - precision and estimates of the method and laboratory bias k = 1	Control samples - authentic sample Duplicate analysis	Instrument calibration Matrix effects Laboratory bias from PT studies Recoveries of SS Standard purity	EA-04/16, EA guidelines on the expression of uncertainty in quantitative testing
18	Top Down - precision and estimates of the method and laboratory bias k = 3	Control samples - Certified Reference Material	Instrument calibration Homogeneity of sample Masses and volumes	NATA GAG Estimating and Reporting Measurement Uncertainty of Chemical Test Results
19	Top Down - precision and estimates of the method and laboratory bias k = 2	Control samples - RM Duplicate analysis	Instrument calibration Homogeneity of sample Masses and volumes Matrix effects Standard purity	NATA Technical Note 33

Lab. Code	Approach to Estimating MU	Information Sources for MU Estimation*		Guide Document for Estimating MU
		Precision	Method Bias	
20	Uncertainty Budget Method k = 3	Control samples - CRM Duplicate analysis	Instrument calibration Masses and volumes Standard purity	Internal SOP Document
21	Top Down - precision and estimates of the method and laboratory bias k = 2	Control samples - RM	Laboratory bias from PT studies	ISO/GUM
22	Top Down - precision and estimates of the method and laboratory bias k = 3	Control samples - CRM	Instrument calibration Homogeneity of sample Masses and volumes Recoveries of SS	Eurachem/CITAC Guide
23	Top Down - precision and estimates of the method and laboratory bias Coverage factor not reported	Control samples - CRM Duplicate analysis	Instrument calibration Homogeneity of sample Masses and volumes Laboratory bias from PT studies Standard purity	
24	Top Down - precision and estimates of the method and laboratory bias Coverage factor not reported			
25	Top Down - precision and estimates of the method and laboratory bias k = 2	Control samples - SS Duplicate analysis	Laboratory bias from PT studies Recoveries of SS	Eurachem/CITAC Guide
26	Top Down - precision and estimates of the method and laboratory bias Coverage factor not reported	Control samples Duplicate analysis	Laboratory bias from PT studies	Nordtest Report TR537
27	Top Down - precision and estimates of the method and laboratory bias k = 2	Control samples - previously analysed police seizures Duplicate analysis	Instrument calibration Homogeneity of sample Masses and volumes Matrix effects Standard purity	Eurachem/CITAC Guide
28	Top Down - precision and estimates of the method and laboratory bias k = 2	Control samples	Laboratory bias from PT studies	ISO/GUM ISO 11352
29	Top Down - precision and estimates of the method and laboratory bias Coverage factor not reported	Control samples - RM Duplicate analysis	Homogeneity of sample Standard purity	Eurachem/CITAC Guide

Lab. Code	Approach to Estimating MU	Information Sources for MU Estimation*		Guide Document for Estimating MU
		Precision	Method Bias	
30	Standard deviation of replicate analyses multiplied by 2 or 3 Coverage factor not reported	Control samples - RM		ISO/GUM
31	Standard deviation of replicate analyses multiplied by 2 or 3 k = 3	Control samples - RM Duplicate analysis	Instrument calibration Standard purity	ISO/GUM
32	Black Box Coverage factor not reported	Control samples - CRM Duplicate analysis	Laboratory bias from PT studies Standard purity	Eurachem/CITAC Guide

*SS = Spiked Samples, RM = Reference Material, CRM = Certified Reference Material

3.4 Participants' Comments

Participants were invited to comment on the samples, their methodology, the PT study in general and suggestions for future PT studies. Such feedback allows for the improvement of future studies. Participants' comments are presented in Table 4, along with the study coordinator's response where appropriate. Some responses may be modified so that the participant cannot be identified.

Table 4 Participant Comments

Lab. Code	Participants' Comments	Study Coordinator's Response
1	Methodology: Quantification of heroin and monoacetylmorphines by GC-FID	
3	Methodology: 0 ; 5 ; 20 ; 100 mg/l	
6	Please could sample vials be labelled with an ID number rather than the name of the analyte - part of the process we use PT for is to check our ID process	This PT study is not intended to be a qualitative study. All participants are informed of what analyte they are assessing for, on the sample label, the dispatch letter sent with the samples, as well as the results sheet.
10	Methodology: S1 above calibration range	
11	Elevated acetylcodeine was indicated in S1 but, as per standard practice at our laboratory, its identity was not confirmed due to acetylcodeine being commonly found in heroin samples. Methodology: A small amount of dichloromethane was used to dissolve the TPAP prior to the addition of ethanol.	
12	The original results (in heroin HCl monohydrate form) have been converted to base using a base factor 0.871. Methodology: 3 replicates per sample	
13	Methodology: Quantification of heroin and monoacetylmorphines by GC-FID	

Lab. Code	Participants' Comments	Study Coordinator's Response
16	Uncertainty: The reported result (in routine case samples) is defined as the mean of the individual results multiplied by the uncertainty correction factor and is rounded down to the nearest whole number (unless<1%w/w). E.g. a mean result of 21.7% with an uncertainty correction value of 96.08% would give a reported result of 21.7*0.9608=20.8 therefore rounded down to 20%.	
21	Methodology: GC-MS	
23	Methodology: External standard	
28	We would like to receive 3 samples of very different concentrations and if possible at 3% to check our limit of quantification. Methodology: Eluant acetonitrile/water (86/14)+2.25 ml pic A/litre	A range of drug purities are selected to cater for the needs of different laboratories participating in this study. In this study, the samples contained 71.8%, 40.4% and 22.7% heroin base (m/m).
31	Uncertainty: MuM determined from multiple injections of reference material. 3x(Std Dev/mean)x100.	
32	Methodology: Dilution of sample in 10 mL of iSTD (0.25 mg/mL of TBA in abs. ETOH)	

4 PRESENTATION OF RESULTS AND STATISTICAL ANALYSIS

4.1 Results Summary

Participant results are listed in Tables 5 to 7 with summary statistics: robust average, median, mean, number of numerical results (N), maximum (Max), minimum (Min), robust standard deviation (Robust SD) and robust coefficient of variation (Robust CV).

Bar charts of results and performance scores are presented in Figures 2 to 4. An example chart with interpretation guide is shown in Figure 1.

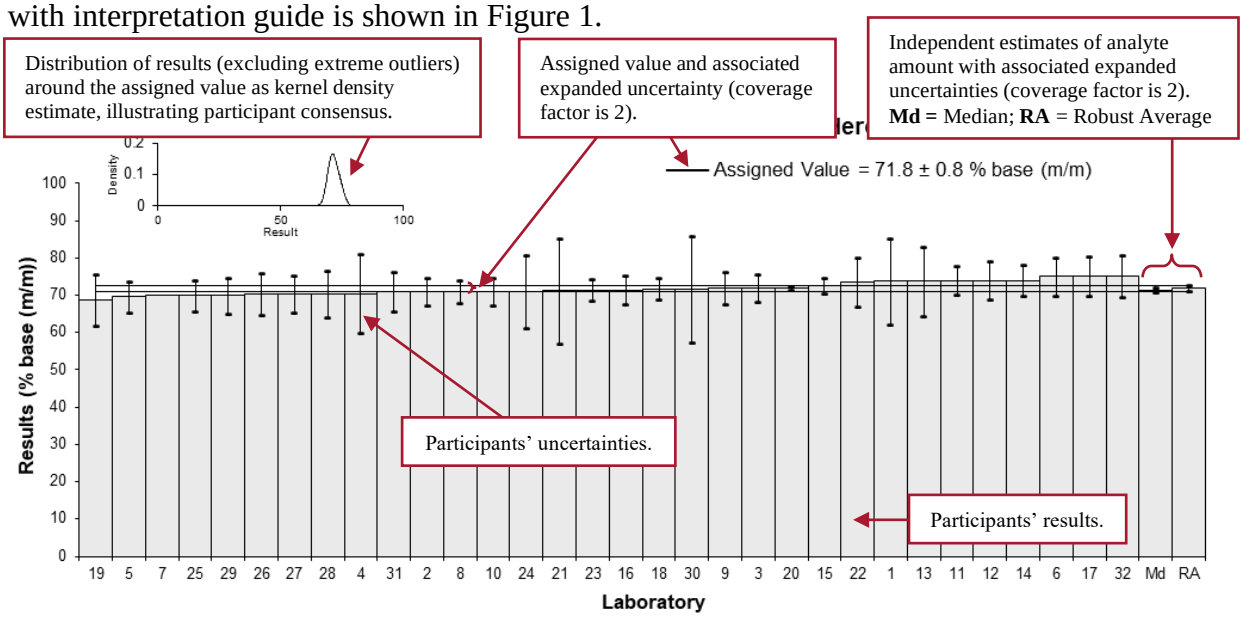


Figure 1 Guide to Presentation of Results

4.2 Outliers and Extreme Outliers

Outliers were results less than 50% and greater than 150% of the robust average, and these were removed before the calculation of the assigned value, if applicable.[3,4] Extreme outliers were obvious blunders, e.g. results reported with incorrect units or for a different analyte or sample, and such results were removed for the calculation of all summary statistics.[3,4]

4.3 Assigned Value

The assigned value is defined as the 'value attributed to a particular property or characteristic of a proficiency test item'.[1] In this study, the property is the % heroin base (m/m) in the test samples. Assigned values were the robust averages of participants' results and the expanded uncertainties were estimated from the associated robust SDs (Appendix 1).

4.4 Robust Average and Robust Standard Deviation

The robust averages and associated expanded MUs, and robust SDs (a measure of the variability of participants' results), were calculated using the procedure described in ISO 13528.[5]

4.5 Performance Coefficient of Variation (PCV)

The PCV is a fixed measure of the between-laboratory variation that in the judgement of the study coordinator would be expected from participants given the levels of analytes present, and is supported by mathematical models such as the Thompson-Horwitz equation.[6] It is important to note that this is a performance measure set by the study coordinator and it is not the robust CV of participants' results. By setting a fixed and realistic value for the PCV, a participant's performance does not depend on other participants' performances, and can be compared from study to study.

4.6 Target Standard Deviation for Proficiency Assessment

The target standard deviation for proficiency assessment (σ) is the product of the assigned value (X) and the PCV, as presented in Equation 1.

$$\sigma = X \times PCV \qquad \textit{Equation 1}$$

4.7 *z*-Score

For each participant's result, a *z*-score is calculated according to Equation 2.

$$z = \frac{(\chi - X)}{\sigma} \qquad \textit{Equation 2}$$

where:

z is *z*-score

χ is a participant's result

X is the assigned value

σ is the target standard deviation for proficiency assessment from Equation 1

For the absolute value of a *z*-score:

- $|z| \leq 2.0$ is acceptable;
- $2.0 < |z| < 3.0$ is questionable; and
- $|z| \geq 3.0$ is unacceptable.

4.8 E_n-Score

The E_n-score is complementary to the *z*-score in assessment of laboratory performance. E_n-score includes measurement uncertainty and is calculated according to Equation 3.

$$E_n = \frac{(\chi - X)}{\sqrt{U_\chi{}^2 + U_X{}^2}} \qquad \textit{Equation 3}$$

where:

E_n is E_n-score

χ is a participant's result

X is the assigned value

U_χ is the expanded uncertainty of the participant's result

U_X is the expanded uncertainty of the assigned value

For the absolute value of an E_n-score:

- $|E_n| < 1.0$ is acceptable; and
- $|E_n| \geq 1.0$ is unacceptable.

4.9 Traceability and Measurement Uncertainty

Laboratories accredited to ISO/IEC 17025 must establish and demonstrate the traceability and measurement uncertainty associated with their test results.[7]

Guidelines for quantifying uncertainty in analytical measurement are described in the Eurachem/CITAC Guide.[8]

5 TABLES AND FIGURES

Table 5

Sample Details

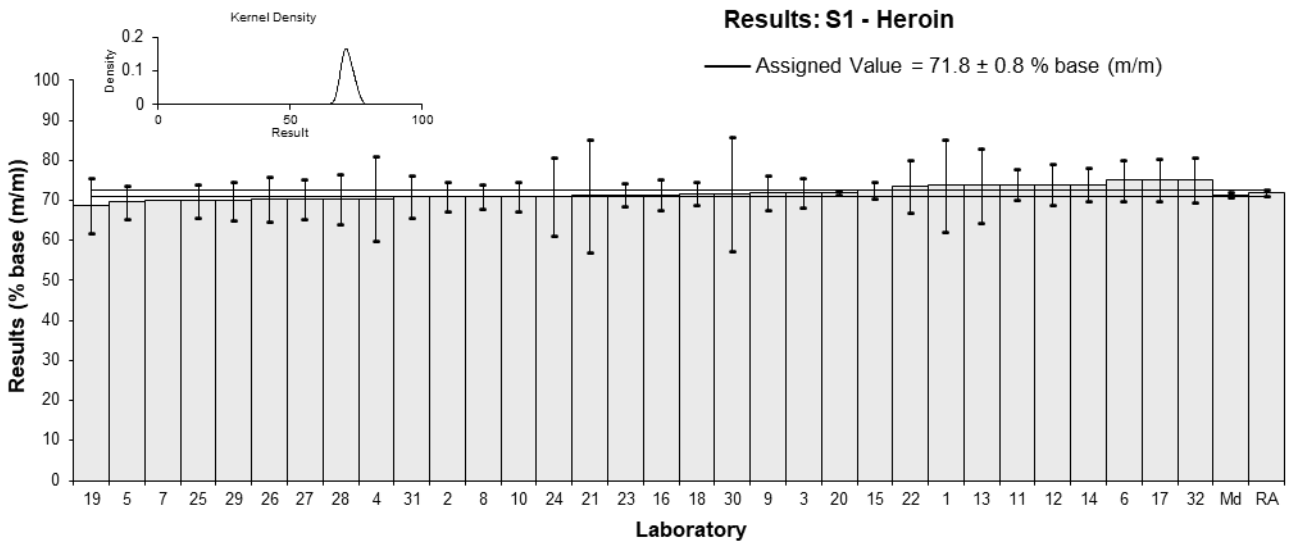
Sample No.	S1
Matrix	Powder
Analyte	Heroin
Unit	% base (m/m)

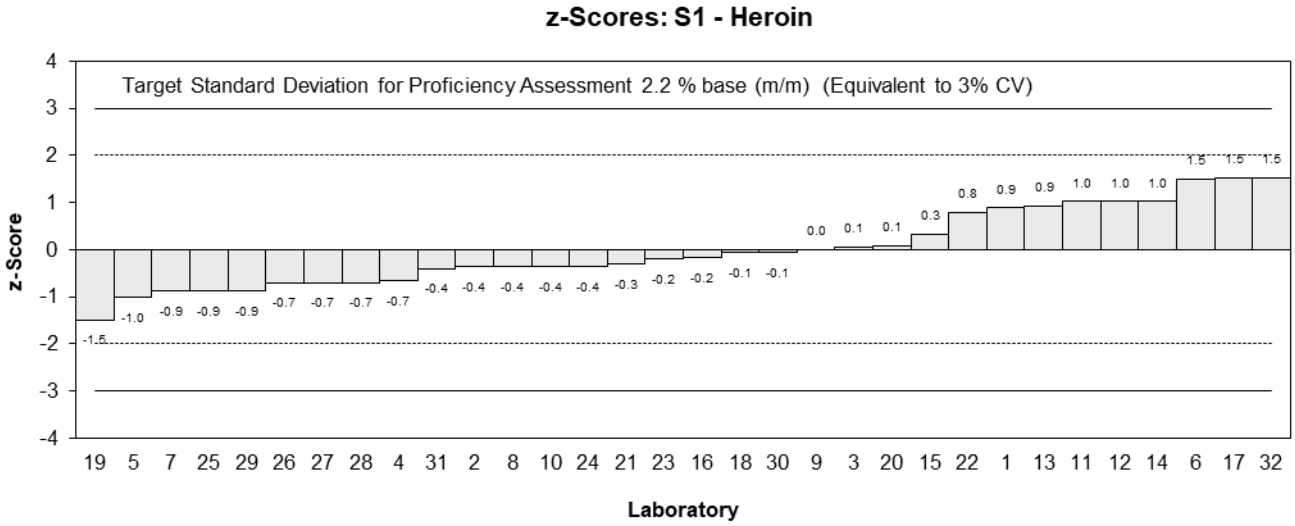
Participant Results

Lab. Code	Result	Uncertainty	z	E_n
1	73.7	11.6	0.88	0.16
2	71	3.6	-0.37	-0.22
3	71.9	3.8	0.05	0.03
4	70.4	10.6	-0.65	-0.13
5	69.6	4.2	-1.02	-0.51
6	75	5.21	1.49	0.61
7	69.9	NR	-0.88	-2.37
8	71.0	3.1	-0.37	-0.25
9	71.8	4.3	0.00	0.00
10	71.0	3.6	-0.37	-0.22
11	74.0	3.8	1.02	0.57
12	74	5	1.02	0.43
13	73.8	9.3	0.93	0.21
14	74	4.091	1.02	0.53
15	72.5	2.1	0.32	0.31
16	71.45	3.69	-0.16	-0.09
17	75.1	5.3	1.53	0.62
18	71.7	2.8	-0.05	-0.03
19	68.6	6.86	-1.49	-0.46
20	72.0	0.4	0.09	0.22
21	71.14	14.23	-0.31	-0.05
22	73.5	6.5	0.79	0.26
23	71.4	2.8	-0.19	-0.14
24	71	9.9	-0.37	-0.08
25	69.9	4.2	-0.88	-0.44
26	70.3	5.6	-0.70	-0.27
27	70.3	4.9	-0.70	-0.30
28	70.3	6.3	-0.70	-0.24
29	69.9	4.9	-0.88	-0.38
30	71.7	14.3	-0.05	-0.01
31	70.94	5.26	-0.40	-0.16
32	75.1	5.6	1.53	0.58

Statistics

Assigned Value	71.8	0.8
Robust Average	71.8	0.8
Median	71.4	0.7
Mean	71.8	
N	32	
Max	75.1	
Min	68.6	
Robust SD	1.9	
Robust CV	2.6%	


Results: S1 - Heroin
Assigned Value = 71.8 ± 0.8 % base (m/m)
Kernel Density
Density
Result
Results (% base (m/m))
Laboratory
19 5 7 25 29 26 27 28 4 31 2 8 10 24 21 23 16 18 30 9 3 20 15 22 1 13 11 12 14 6 17 32 Md RA


z-Scores: S1 - Heroin
Target Standard Deviation for Proficiency Assessment 2.2 % base (m/m) (Equivalent to 3% CV)
z-Score
Laboratory
19 5 7 25 29 26 27 28 4 31 2 8 10 24 21 23 16 18 30 9 3 20 15 22 1 13 11 12 14 6 17 32

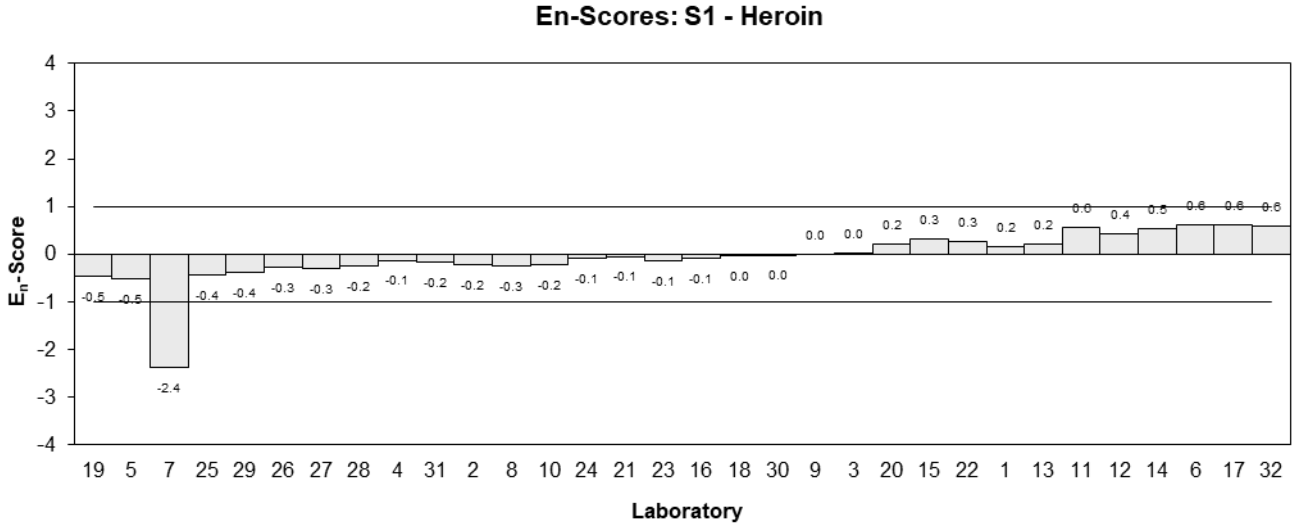

En-Scores: S1 - Heroin
En-Score
Laboratory
19 5 7 25 29 26 27 28 4 31 2 8 10 24 21 23 16 18 30 9 3 20 15 22 1 13 11 12 14 6 17 32

Figure 2

Table 6

Sample Details

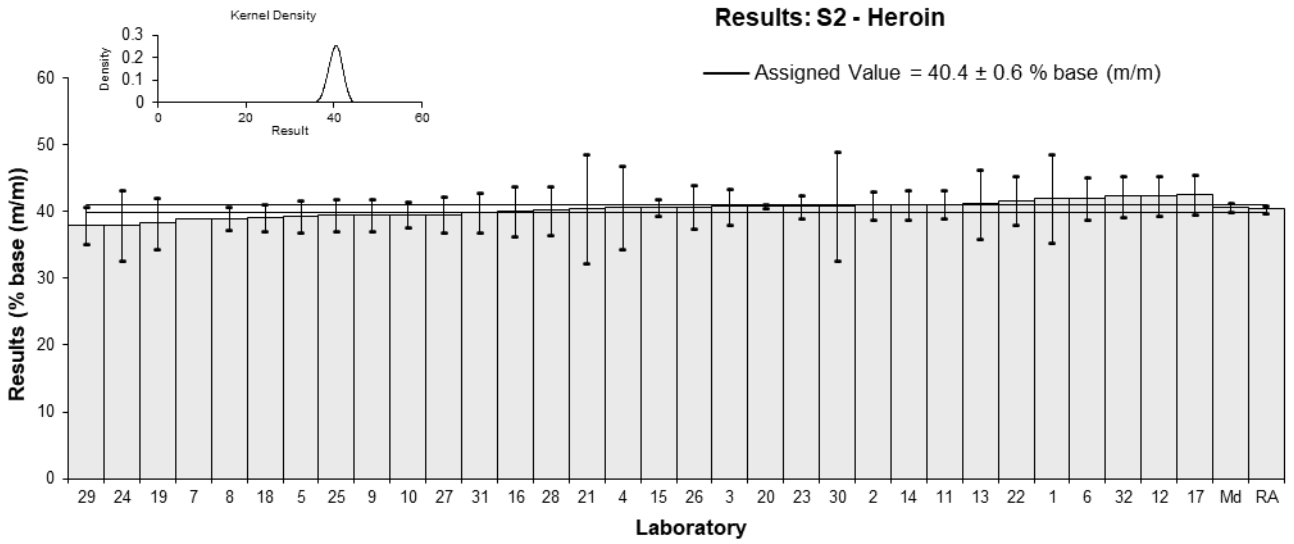
Sample No.	S2
Matrix	Powder
Analyte	Heroin
Unit	% base (m/m)

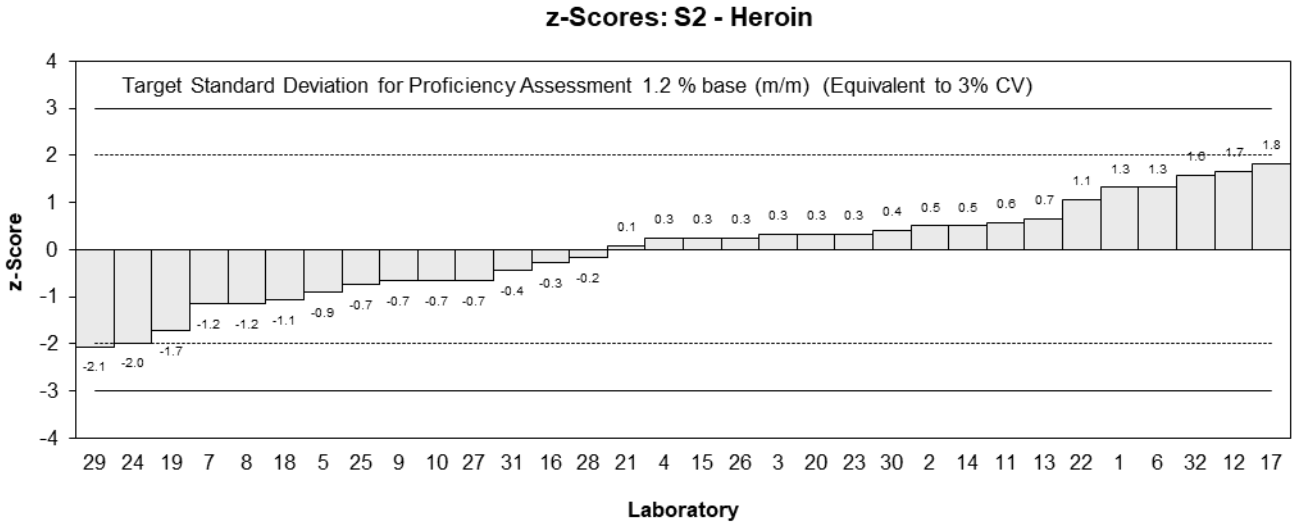
Participant Results

Lab. Code	Result	Uncertainty	z	E_n
1	42.0	6.6	1.32	0.24
2	41	2.1	0.50	0.27
3	40.8	2.7	0.33	0.14
4	40.7	6.2	0.25	0.05
5	39.3	2.4	-0.91	-0.44
6	42	3.26	1.32	0.48
7	39.0	NR	-1.16	-2.33
8	39.0	1.7	-1.16	-0.78
9	39.6	2.4	-0.66	-0.32
10	39.6	2.0	-0.66	-0.38
11	41.1	2.1	0.58	0.32
12	42.4	2.9	1.65	0.68
13	41.2	5.2	0.66	0.15
14	41	2.261	0.50	0.26
15	40.7	1.2	0.25	0.22
16	40.05	3.69	-0.29	-0.09
17	42.6	3	1.82	0.72
18	39.1	2	-1.07	-0.62
19	38.3	3.83	-1.73	-0.54
20	40.8	0.3	0.33	0.60
21	40.48	8.1	0.07	0.01
22	41.7	3.6	1.07	0.36
23	40.8	1.7	0.33	0.22
24	38	5.3	-1.98	-0.45
25	39.5	2.4	-0.74	-0.36
26	40.7	3.3	0.25	0.09
27	39.6	2.7	-0.66	-0.29
28	40.2	3.6	-0.17	-0.05
29	37.9	2.8	-2.06	-0.87
30	40.9	8.2	0.41	0.06
31	39.88	2.96	-0.43	-0.17
32	42.3	3.1	1.57	0.60

Statistics

Assigned Value	40.4	0.6
Robust Average	40.4	0.6
Median	40.7	0.7
Mean	40.4	
N	32	
Max	42.6	
Min	37.9	
Robust SD	1.3	
Robust CV	3.3%	


Results: S2 - Heroin
Kernel Density
Density
Result
Assigned Value = 40.4 ± 0.6 % base (m/m)
Results (% base (m/m))
29 24 19 7 8 18 5 25 9 10 27 31 16 28 21 4 15 26 3 20 23 30 2 14 11 13 22 1 6 32 12 17 Md RA
Laboratory


z-Scores: S2 - Heroin
Target Standard Deviation for Proficiency Assessment 1.2 % base (m/m) (Equivalent to 3% CV)
z-Score
29 24 19 7 8 18 5 25 9 10 27 31 16 28 21 4 15 26 3 20 23 30 2 14 11 13 22 1 6 32 12 17
Laboratory

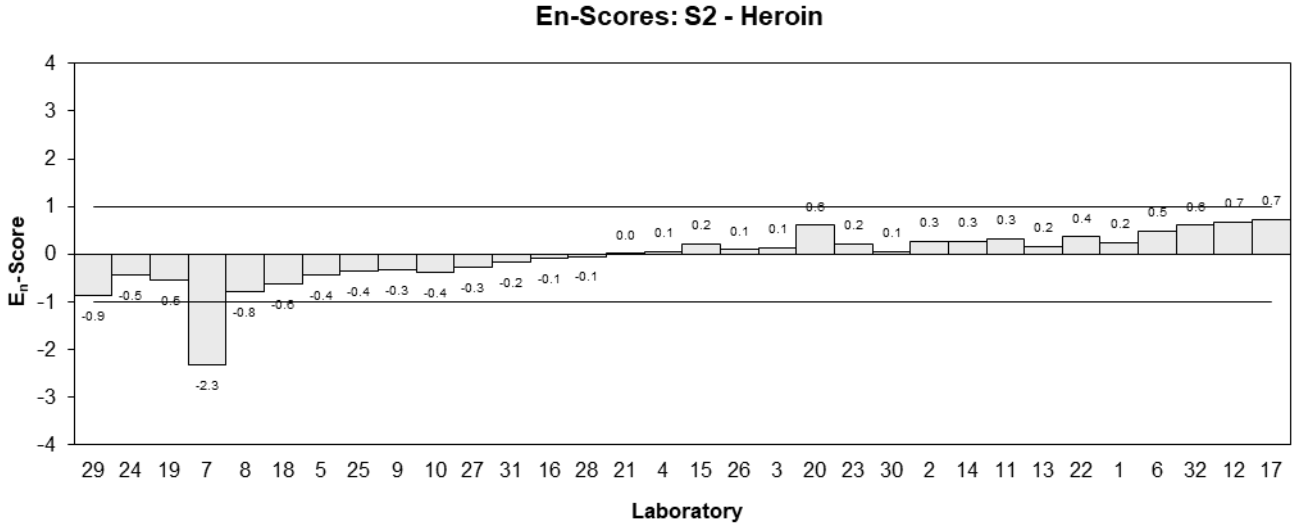

En-Scores: S2 - Heroin
En-Score
29 24 19 7 8 18 5 25 9 10 27 31 16 28 21 4 15 26 3 20 23 30 2 14 11 13 22 1 6 32 12 17
Laboratory

Figure 3

Table 7

Sample Details

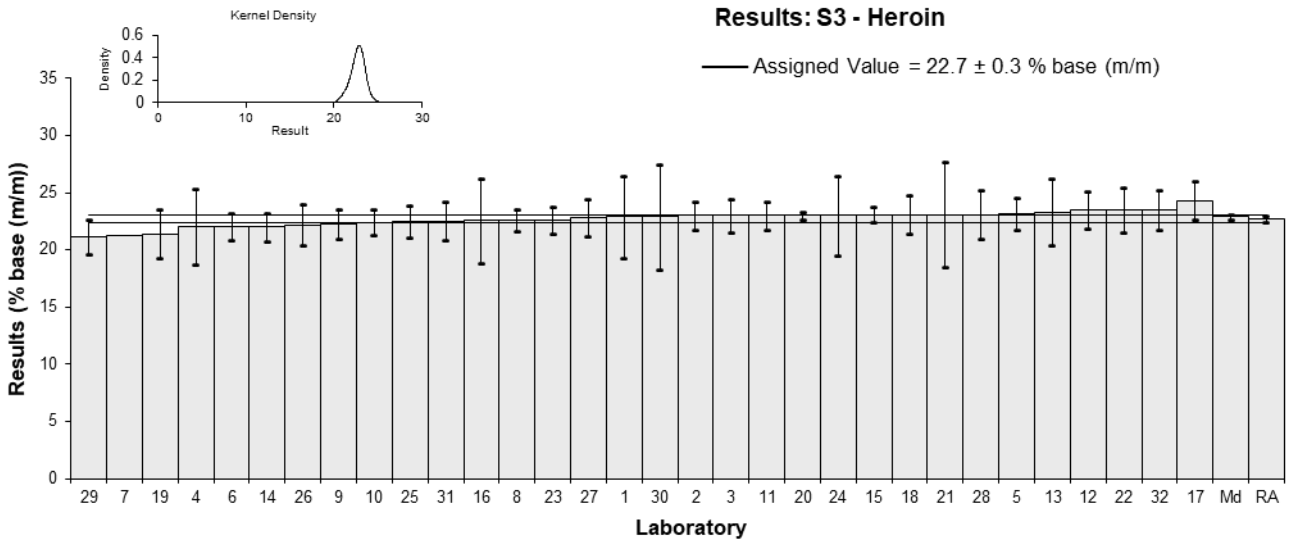
Sample No.	S3
Matrix	Powder
Analyte	Heroin
Unit	% base (m/m)

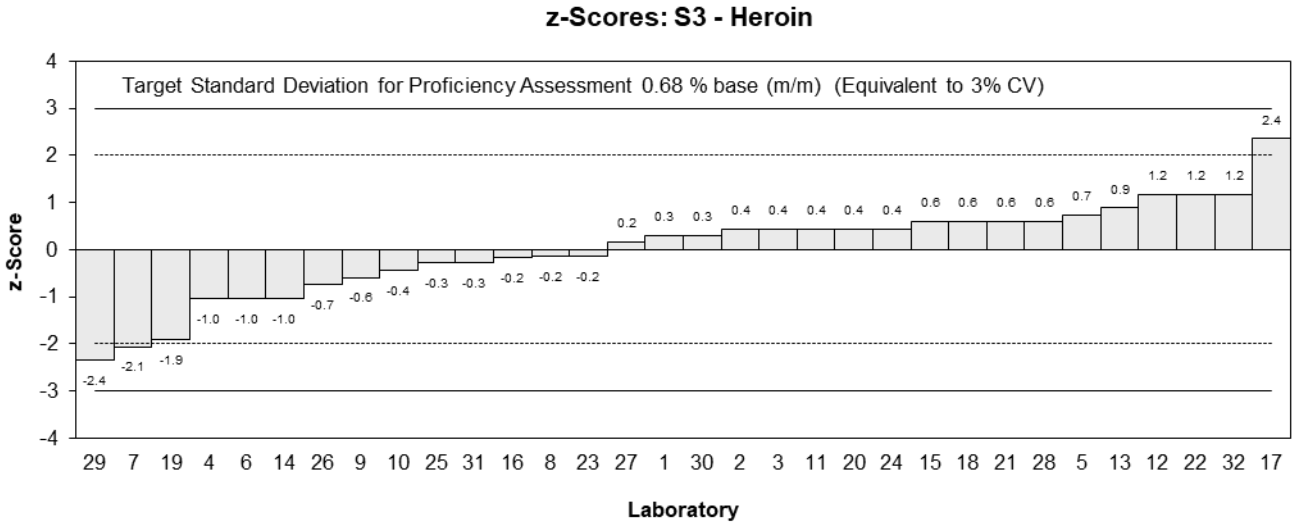
Participant Results

Lab. Code	Result	Uncertainty	z	E_n
1	22.9	3.6	0.29	0.06
2	23	1.2	0.44	0.24
3	23	1.5	0.44	0.20
4	22.0	3.3	-1.03	-0.21
5	23.2	1.4	0.73	0.35
6	22	1.19	-1.03	-0.57
7	21.3	NR	-2.06	-4.67
8	22.6	1.0	-0.15	-0.10
9	22.3	1.3	-0.59	-0.30
10	22.4	1.1	-0.44	-0.26
11	23.0	1.2	0.44	0.24
12	23.5	1.6	1.17	0.49
13	23.3	2.9	0.88	0.21
14	22	1.24	-1.03	-0.55
15	23.1	0.7	0.59	0.53
16	22.58	3.69	-0.18	-0.03
17	24.3	1.7	2.35	0.93
18	23.1	1.7	0.59	0.23
19	21.4	2.14	-1.91	-0.60
20	23.0	0.3	0.44	0.71
21	23.1	4.62	0.59	0.09
22	23.5	2.0	1.17	0.40
23	22.6	1.2	-0.15	-0.08
24	23	3.5	0.44	0.09
25	22.5	1.4	-0.29	-0.14
26	22.2	1.8	-0.73	-0.27
27	22.8	1.6	0.15	0.06
28	23.1	2.1	0.59	0.19
29	21.1	1.5	-2.35	-1.05
30	22.9	4.6	0.29	0.04
31	22.5	1.67	-0.29	-0.12
32	23.5	1.7	1.17	0.46

Statistics

Assigned Value	22.7	0.3
Robust Average	22.7	0.3
Median	22.9	0.2
Mean	22.7	
N	32	
Max	24.3	
Min	21.1	
Robust SD	0.61	
Robust CV	2.7%	


Results: S3 - Heroin
Assigned Value = 22.7 ± 0.3 % base (m/m)
Kernel Density
Density
Result
Results (% base (m/m))
Laboratory
29 7 19 4 6 14 26 9 10 25 31 16 8 23 27 1 30 2 3 11 20 24 15 18 21 28 5 13 12 22 32 17 Md RA


z-Scores: S3 - Heroin
Target Standard Deviation for Proficiency Assessment 0.68 % base (m/m) (Equivalent to 3% CV)
z-Score
Laboratory
29 7 19 4 6 14 26 9 10 25 31 16 8 23 27 1 30 2 3 11 20 24 15 18 21 28 5 13 12 22 32 17

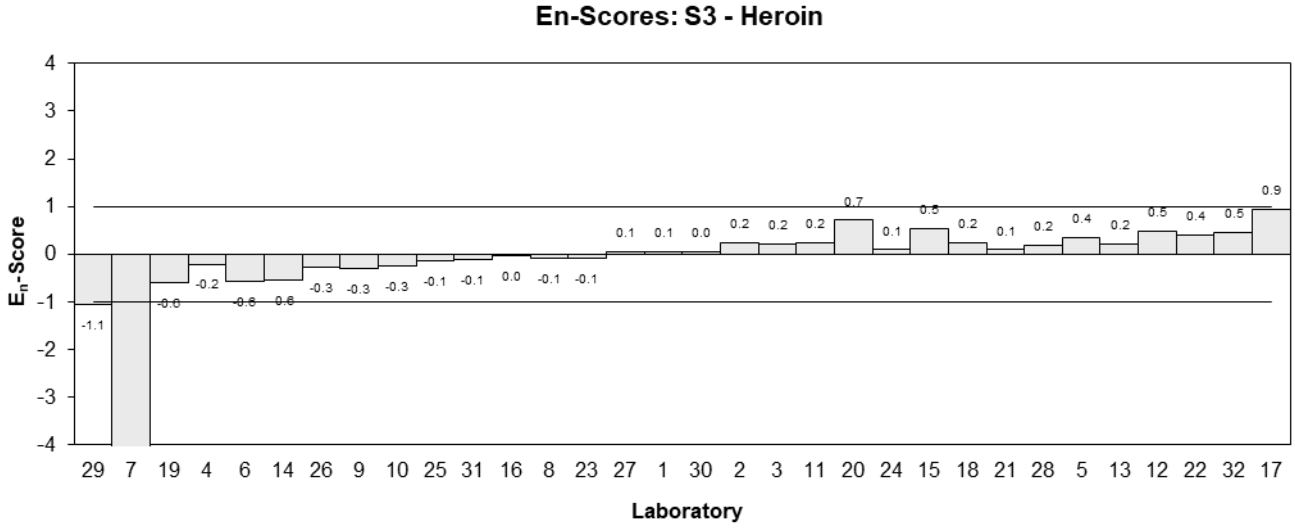

En-Scores: S3 - Heroin
En-Score
Laboratory
29 7 19 4 6 14 26 9 10 25 31 16 8 23 27 1 30 2 3 11 20 24 15 18 21 28 5 13 12 22 32 17

Figure 4

Table 8 Reported Cutting Agents*

Lab. Code	Cutting Agents		
	S1	S2	S3
Preparation	-	Caffeine	Phenacetin
1	-	Caffeine	Phenacetin
2	MAM, acetylcodeine	caffeine, acetylcodeine, MAM	phenacetin, acetylcodeine, MAM
3	-	Caffeine	phenacetin
4	./.	CAFFEINE	PHENACETIN
5	-	Caffeine	Phenacetin
6		Caffeine	Phenacetin
7	/	caffeine : 44.9 %	phenacetin : 71.1 %
8		Caffeine	Phenacetin
9	Acetylcodeine, 6-monoacetylmorphine	Acetylcodeine, 6-monoacetylmorphine and caffeine.	Acetylcodeine, 6-monoacetylmorphine and phenacetin.
10		caffeine	phenacetin
11	Nil	Caffeine	Phenacetin
12	N.D.	caffeine	phenacetin
13	-	Caffeine	Phenacetin
14	N/A	Caffeine	Phenacetin
15		Caffeine	Phenacetin
16	Acetylcodeine	Acetylcodeine	Acetylcodeine, Phenacetin
17		Caffeine	Phenacetin
18		caffeine	phenacetin
19	Acetylcodine 9.66% +/-0.966	Caffeine	Phenacetin
20		Caffeine (not confirmed)	Phenacetin
21	Acetylcodeine + 6-MAM	Caffeine + acetylcodeine + 6-MAM	Phenacetine + acetylcodeine
22	NA	Caffeine	Phenacetin
23		Caffeine	Phenacetin
24	none	Caffeine	Phenacetin
25	-	Caffeine	Phenacetin
26		Caffeine	Phenacetin
27		Caffeine	Phenacetin
28	acetyl codeine and monoacetylmorphine	caffeine,acetyl codeine and monoacetylmorphine	phenacetin, acetyl codeine and monoacetylmorphine
29	Acetylmorphine, Acetylcodeine	Acetylmorphine, Acetylcodeine & Caffeine	Acetylmorphine, Acetylcodeine & Phenacetin
30		caffeine	phenacetin

Lab. Code	Cutting Agents		
	S1	S2	S3
31	Acetylcodeine, Codeine	Acetylcodeine, Caffeine	Acetylcodeine, Phenacetin
32	-	Caffeine	Phenacetin

* Responses may have been modified so that the participant cannot be identified.

6 DISCUSSION OF RESULTS

6.1 Assigned Value

The assigned values for all scored analytes were the robust averages of participants' results. If there were results less than 50% or greater than 150% of the robust average, these were excluded from the calculation of each assigned value.[3,4] The robust averages and associated expanded uncertainties were calculated using the procedure described in ISO 13528.[5] The calculation of the expanded uncertainty for a robust average, using Sample S1 as an example, is presented in Appendix 1.

Traceability: The consensus of participants' results is not traceable to any external reference, so although expressed in SI units, metrological traceability has not been established.

6.2 Measurement Uncertainty Reported by Participants

Participants were asked to report an estimate of the expanded MU associated with their results and the basis of this uncertainty estimate (Table 3). Two participants reported using NATA MU documents as their guide; NATA no longer publishes these documents.[9]

It is a requirement of ISO/IEC 17025 that laboratories have procedures to estimate the uncertainty of chemical measurements and to report this uncertainty in specific circumstances, including when the client's instruction so requires.[7]

Of 96 reported results, 93 (97%) were reported with an associated expanded MU. Laboratory **7** did not report any uncertainties; this participant reported that they were not accredited.

The magnitude of reported uncertainties was within the range 0.6% to 20% relative. In general, an expanded uncertainty of less than 3% may be unrealistically small for the routine measurement of illicit drugs, while over 10% may be too large and not fit for purpose. Of the 93 expanded MUs, 69 (74%) were between 3% and 10% relative to the result, five were less than 3% and 19 were greater than 10%.

Uncertainties associated with results returning an acceptable *z*-score but an unacceptable E_n-score may have been underestimated.

In some cases, results were reported with an inappropriate number of significant figures. Including too many significant figures may inaccurately reflect measurement precision. The recommended format is to write the uncertainty to no more than two significant figures, and then to write the result with the corresponding number of decimal places. For example, instead of reporting 22.58 ± 3.69%, the recommended format is 22.6 ± 3.7%.[8]

6.3 z-Score

Target SDs equivalent to 3% PCV were used to calculate *z*-scores. CVs predicted by the Thompson-Horwitz equation,[6] between-laboratory CVs obtained in this study, and target SDs (as PCVs) are presented for comparison in Table 9.

Table 9 Comparison of Thompson-Horwitz CVs, Between-Laboratory CVs and Target SDs

Sample	Analyte	Assigned Value (% base (m/m))	Thompson-Horwitz CV[a] (%)	Between-Laboratory CV[b] (%)	Target SD (as PCV) (%)
S1	Heroin	71.8	1.2	2.6	3
S2	Heroin	40.4	1.6	3.3	3
S3	Heroin	22.7	2.1	2.7	3

[a] Calculated from the assigned value.

[b] Robust between-laboratory CV with outliers removed, if applicable.

Of 96 results for which *z*-scores were calculated, 92 (96%) returned a *z*-score of $|z| \leq 2.0$, indicating an acceptable performance.

Twenty-nine participants: **1**, **2**, **3**, **4**, **5**, **6**, **8**, **9**, **10**, **11**, **12**, **13**, **14**, **15**, **16**, **18**, **19**, **20**, **21**, **22**, **23**, **24**, **25**, **26**, **27**, **28**, **30**, **31** and **32** returned acceptable *z*-scores for all three samples. Three participants returned at least one questionable or unacceptable *z*-score.

The dispersal of participants' *z*-scores is presented graphically in Figure 5.

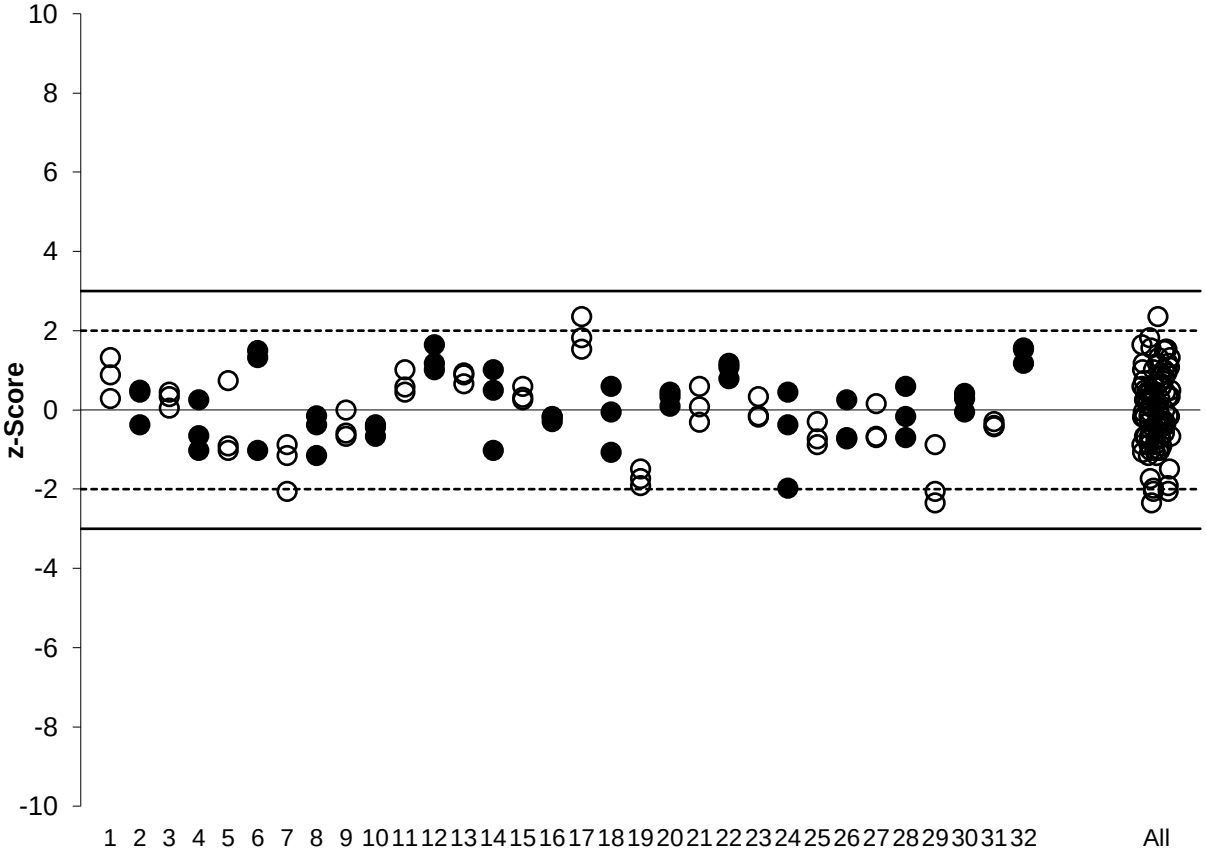


Figure 5 *z*-Score Dispersal by Laboratory

6.4 E_n-Score

E_n-Scores can be interpreted in conjunction with *z*-scores, as an unacceptable E_n-score can be caused by an inappropriate measurement, or uncertainty, or both. If a participant did not report an uncertainty with a result, an expanded uncertainty of zero (0) was used to calculate the E_n-score.

Of 96 results for which E_n-scores were calculated, 92 (96%) returned an acceptable E_n-score of $|E_n| < 1.0$, indicating agreement of the participant's result with the assigned value within their respective expanded uncertainties.

Thirty participants: **1**, **2**, **3**, **4**, **5**, **6**, **8**, **9**, **10**, **11**, **12**, **13**, **14**, **15**, **16**, **17**, **18**, **19**, **20**, **21**, **22**, **23**, **24**, **25**, **26**, **27**, **28**, **30**, **31** and **32** returned acceptable E_n-scores for all three samples. Two participants returned at least one unacceptable E_n-score.

Laboratory **7** returned unacceptable E_n-scores across all reported results; this participant did not report any uncertainties.

The dispersal of participants' E_n-scores is presented graphically in Figure 6.

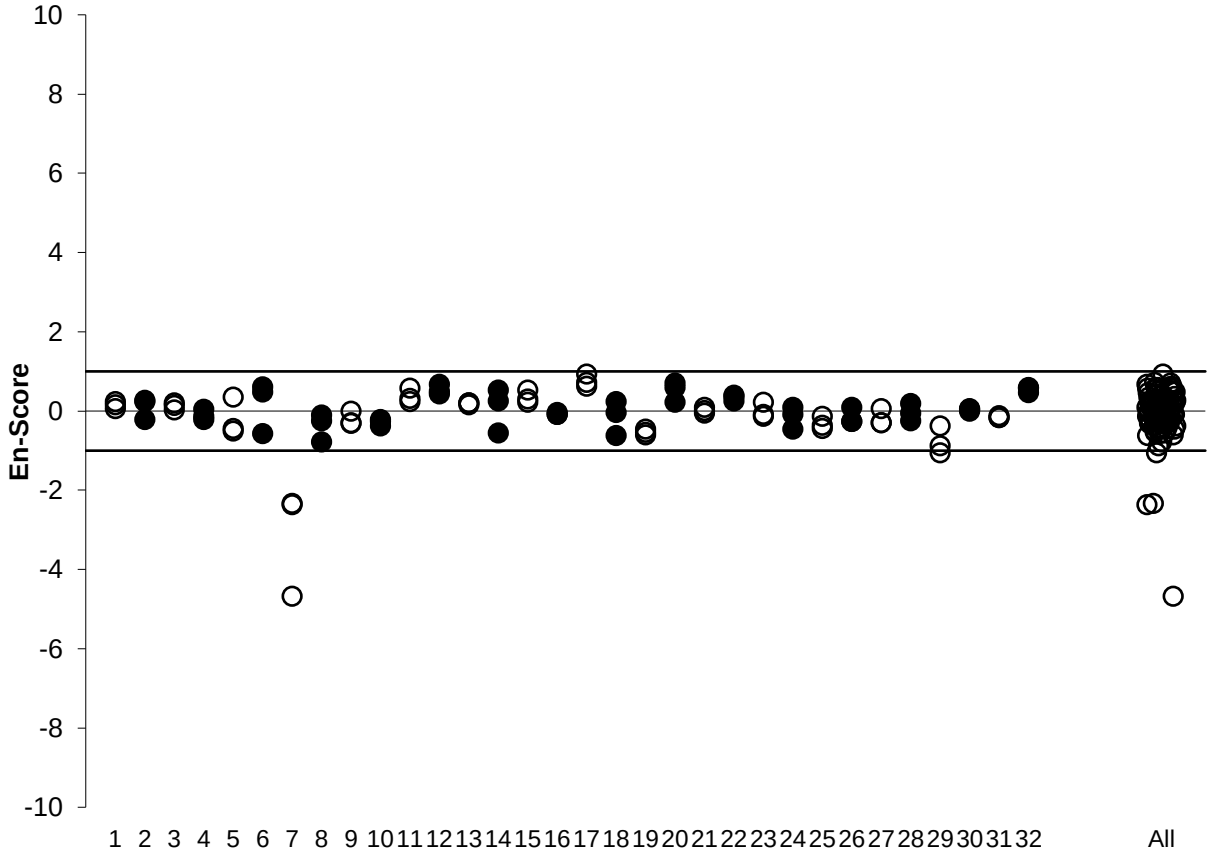


Figure 6 E_n-Score Dispersal by Laboratory

6.5 Identification of Cutting Agents

Cutting agents were added to Samples S2 (caffeine) and S3 (phenacetin). No additional cutting agent was added to Sample S1 by the study coordinator.

Results reported by participants are presented in Table 8. All participants reported on the identity of at least one sample's cutting agent.

Participants correctly identified both caffeine in Sample S2 and phenacetin in Sample S3, except for Laboratory **16** who reported only phenacetin in Sample S3.

6.6 Participants' Analytical Methods

Participants were requested to analyse the samples using their normal test methods and to report a single result for each sample as they would normally report to a client. Results reported in this way reflect the true variability of results reported to laboratory clients. The methodologies provided by participants are presented in Table 1.

A summary of accreditation status, participants' methods and reference standards is presented in Table 10.

Table 10 Summary of Participants' Analytical Methods

		Lab. Code
Accreditation	Yes to ISO/IEC 17025	1, 2, 5, 6, 8, 9, 10, 11, 12, 13, 14, 15, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30, 31, 32
	Not Accredited / Not Reported	3, 4, 7, 16

		Lab. Code
Average Sample Mass Used per Analysis (mg)	< 20	9, 11, 12, 14, 16, 21, 28, 30, 32
	20 – 30	1, 2, 3, 4, 5, 6, 10, 13, 18, 19, 22, 25, 26
	31 – 50	7, 17, 20, 23, 24, 27, 29, 31
	51 – 100	8
	> 100	15
Instrument Used for Quantification	HPLC-DAD	2, 3, 4, 14, 16, 19, 23, 26, 28, 31
	HPLC-UV/Vis	20, 30
	UPLC-DAD	5, 7, 18, 25, 29
	UPLC-MS/MS	24
	LC-MS	17
	GC-FID	1, 6, 8, 9, 10, 11, 12, 13, 15, 22, 27, 32
	GC-MS	21
Solvent	Acetonitrile	8, 19
	Acetonitrile/Methanol(/Water)	18, 24
	Acetonitrile/Water(/Acid)	3, 4, 14, 28, 29, 30, 31
	Chloroform	1, 15, 21, 22, 27
	Ethanol	7, 11, 20, 32
	Methanol	2, 5, 6, 9, 16, 17, 23, 25, 26
	Other	10, 12, 13
Source of Calibration Standard	NMIA	7, 8, 10, 11, 18, 19, 27, 29
	Lipomed	3, 4, 5, 9, 12, 20, 21, 23, 24, 25, 26, 28, 30, 32
	Other / Not Reported	1, 2, 6, 13, 14, 15, 16, 17, 22, 31

Plots of *z*-scores against various parameters are presented in Figures 7 to 10. One participant reported using LC-MS for their analysis and their results were biased high, however they did not return any unacceptable results.

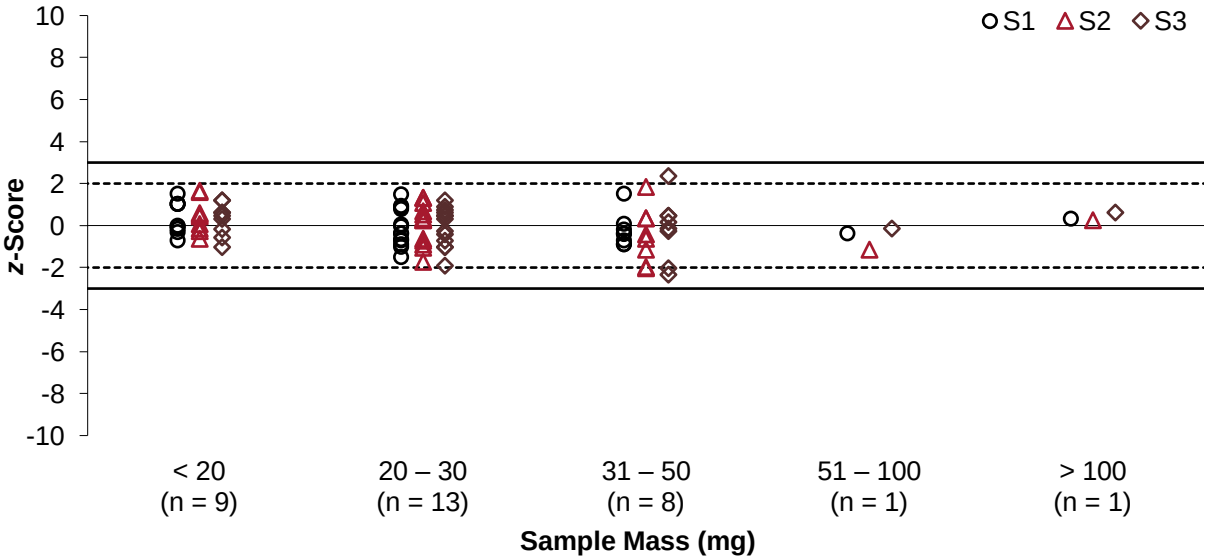


Figure 7 *z*-Score vs Sample Mass Used per Analysis

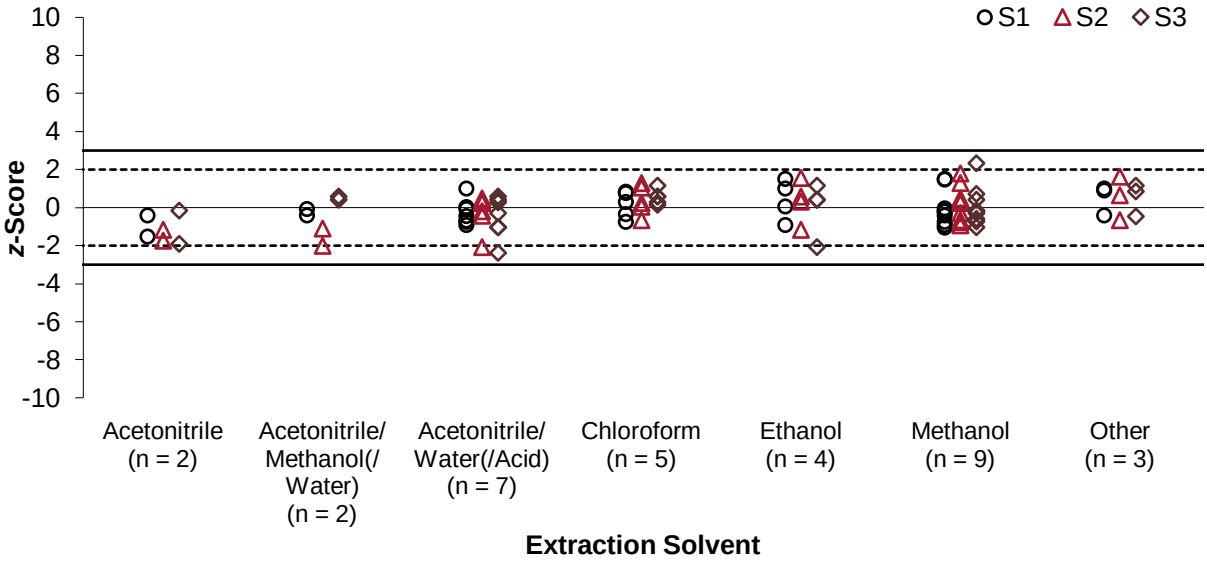


Figure 8 *z*-Score vs Extraction Solvent

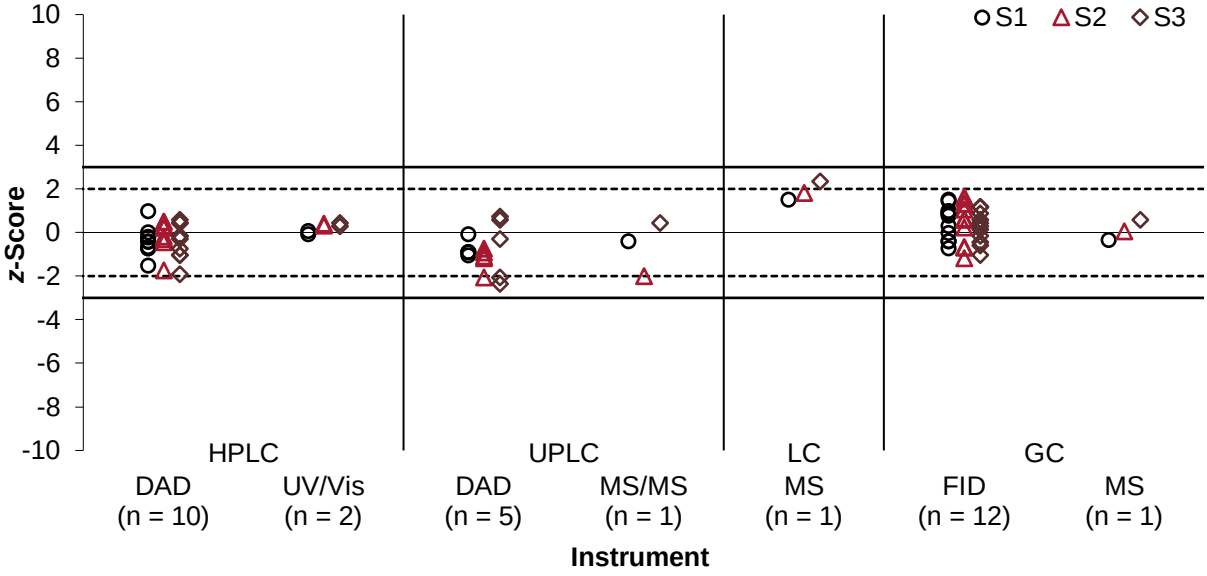


Figure 9 *z*-Score vs Measurement Instrument

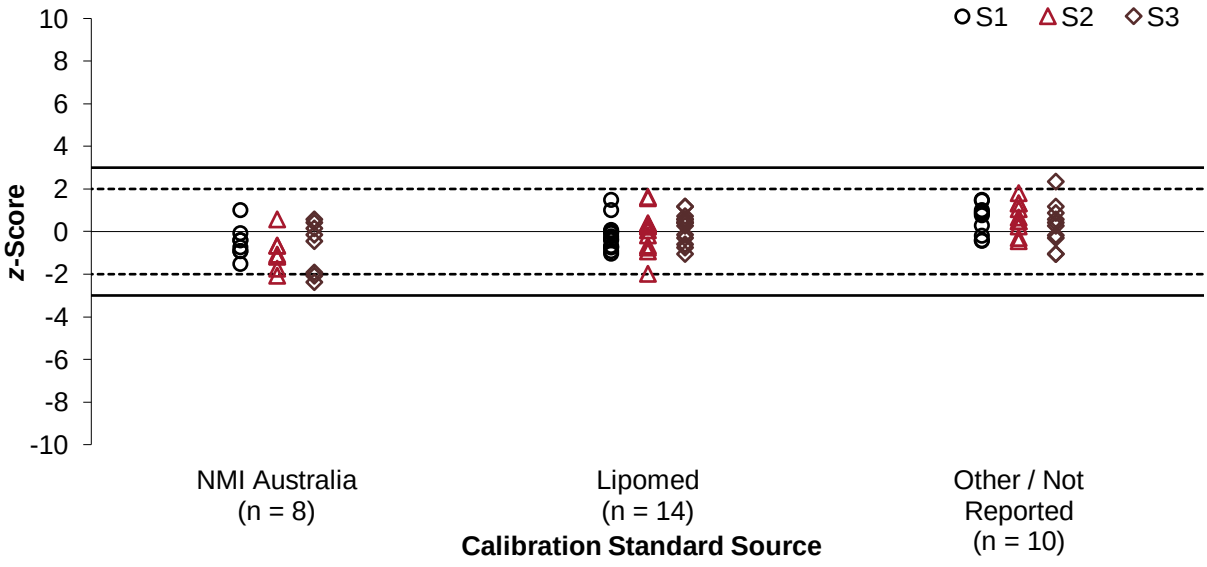


Figure 10 *z*-Score vs Calibration Standard Source

6.7 Comparison of Results and Date of Analysis

As there were delays with sample delivery to some participants, the test samples were analysed over the course of approximately three months. There was no evidence of sample degradation over this period (Figure 11).

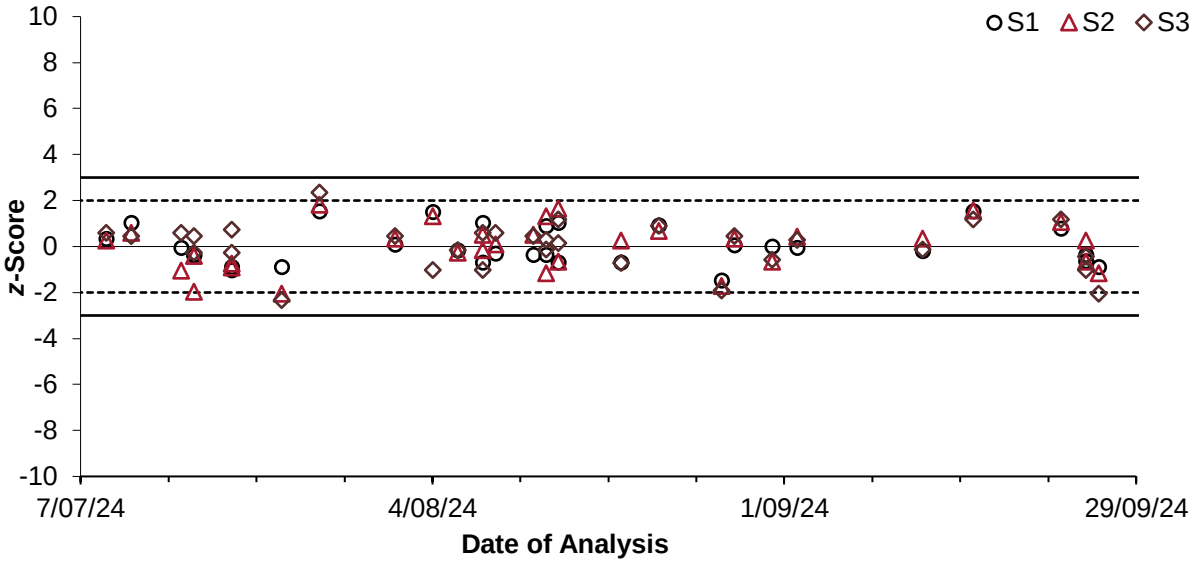


Figure 11 *z*-Score vs Sample Analysis Date

6.8 Comparison with Previous Heroin PT Studies

To enable direct comparison with previous NMIA heroin PT studies, the target SD used to calculate *z*-scores has been kept constant at 3% PCV.

A summary of the acceptable performance, presented as a percentage of the total number of scores, obtained by participants from 2015 to 2024 (last ten studies) is presented in Figure 12. The proportion of acceptable *z*-scores and E_n-scores over this period on average is 86% for both. Participants performed very well in this study, with the highest proportion of acceptable scores over this period.

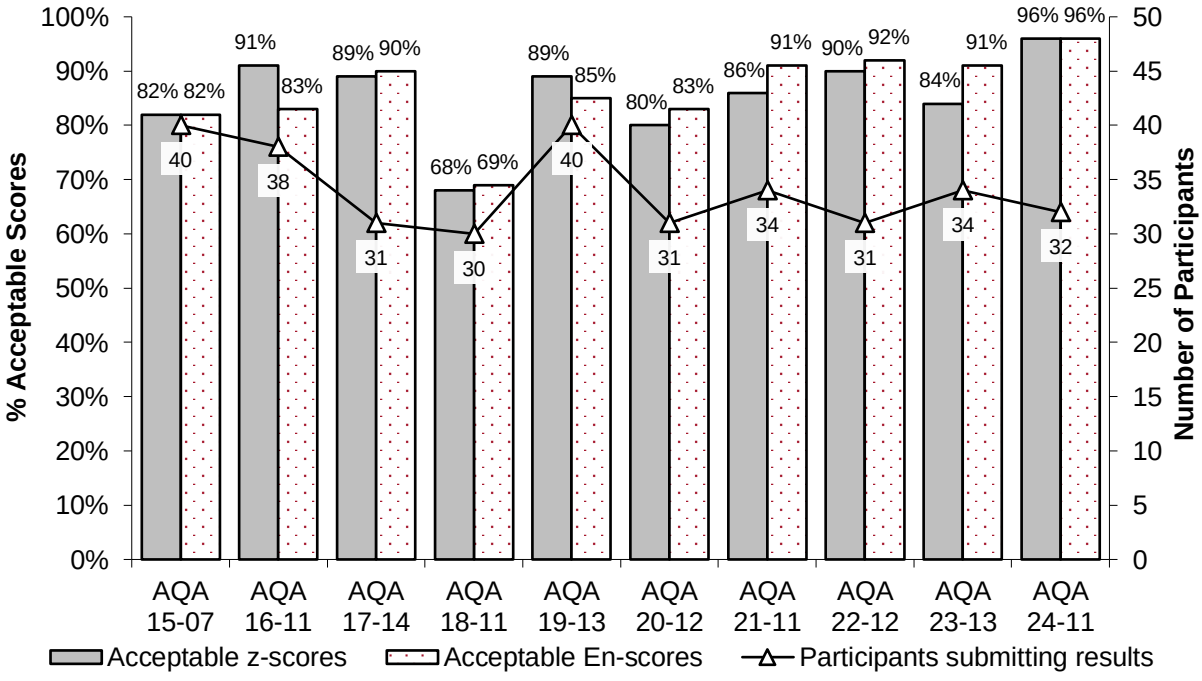


Figure 12 Summary of Participants' Performance in NMIA Heroin PT Studies

Several participants have consistently participated in NMIA heroin PT studies, and individual performance history reports are emailed to each participant at the end of each study. The consideration of *z*-scores for an analyte over time provides much more useful information than a single *z*-score. Over time, laboratories should expect at least 95% of their scores to lie within the range $|z| \leq 2.0$. Scores in the range $2.0 < |z| < 3.0$ can occasionally occur, however, these should be interpreted in conjunction with the other scores obtained by that laboratory. For example, a trend of *z*-scores on one side of the zero line is an indication of method or laboratory bias.

A comparison of all results from Australian and international laboratories in NMIA heroin PT studies over the last ten studies is presented in Figure 13. Overall, both groups have performed very similarly, with Australian and international laboratories both achieving 86% acceptable *z*-scores respectively over this period.

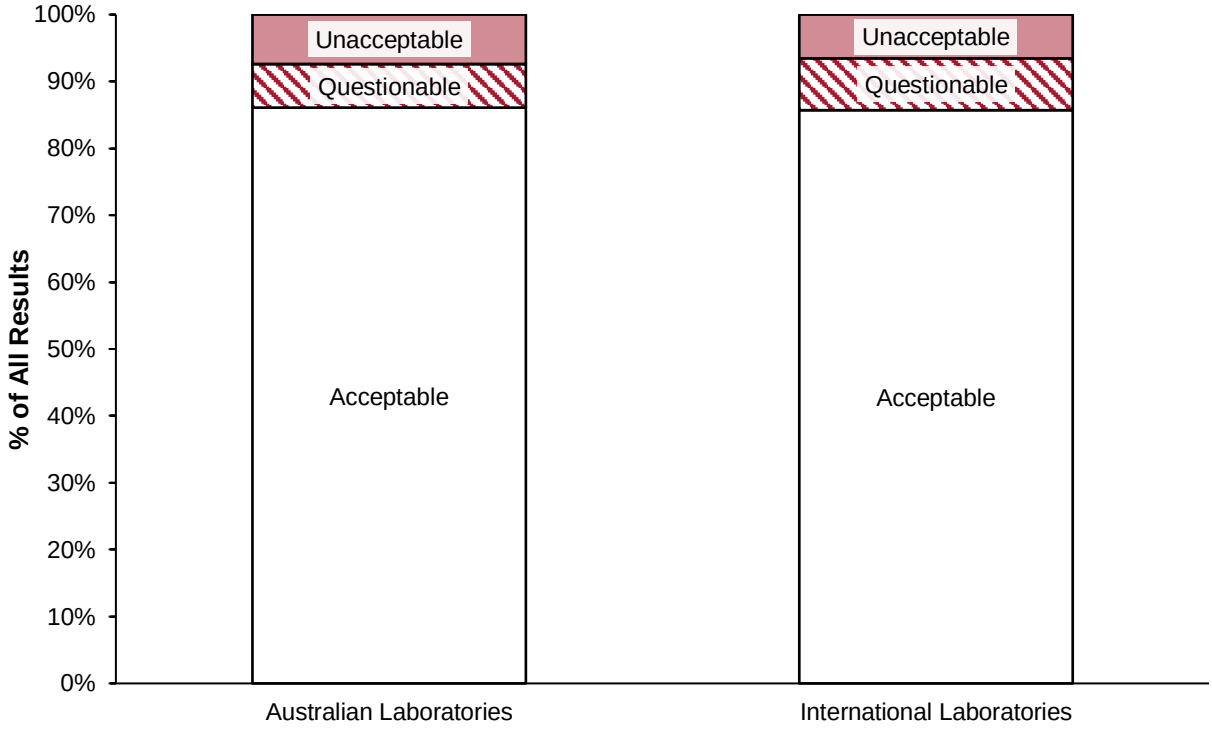


Figure 13 Comparison of Australian and International Laboratories in NMIA Heroin PT Studies

A summary of individual laboratories' performances over the last ten studies is presented in Figures 14 and 15 for Australian and international laboratories respectively. *z*-Scores greater than 10.0 or less than -10.0 have been plotted at 10.0 or -10.0 respectively. Two Australian and four international laboratories have achieved acceptable *z*-scores across all samples in all heroin PT studies participated in over this period.

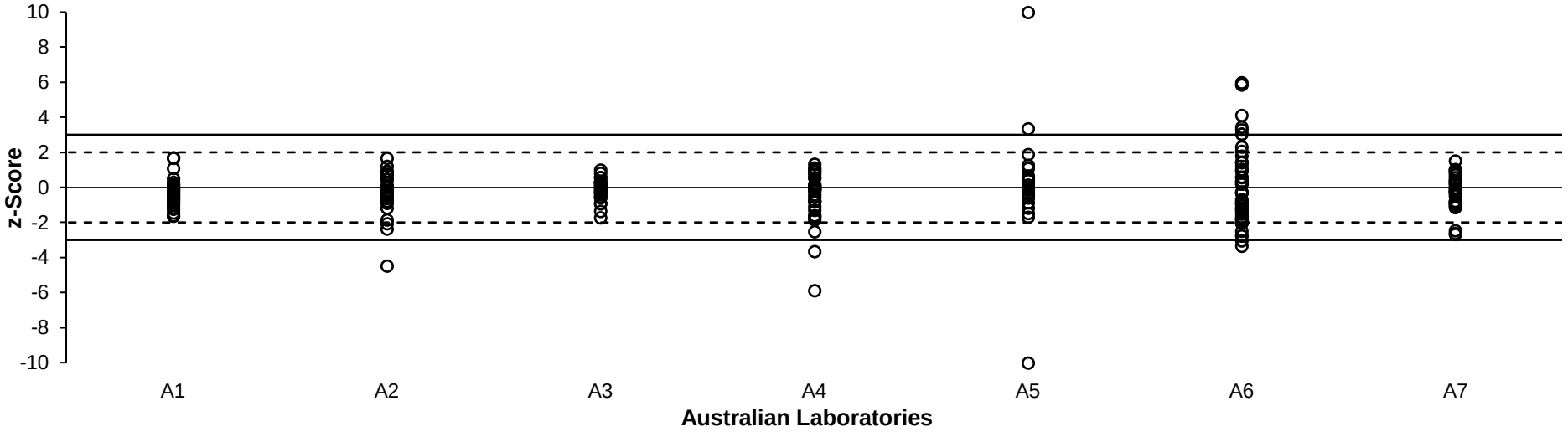


Figure 14 Summary of Australian Participants' *z*-Scores in NMIA Heroin PT Studies

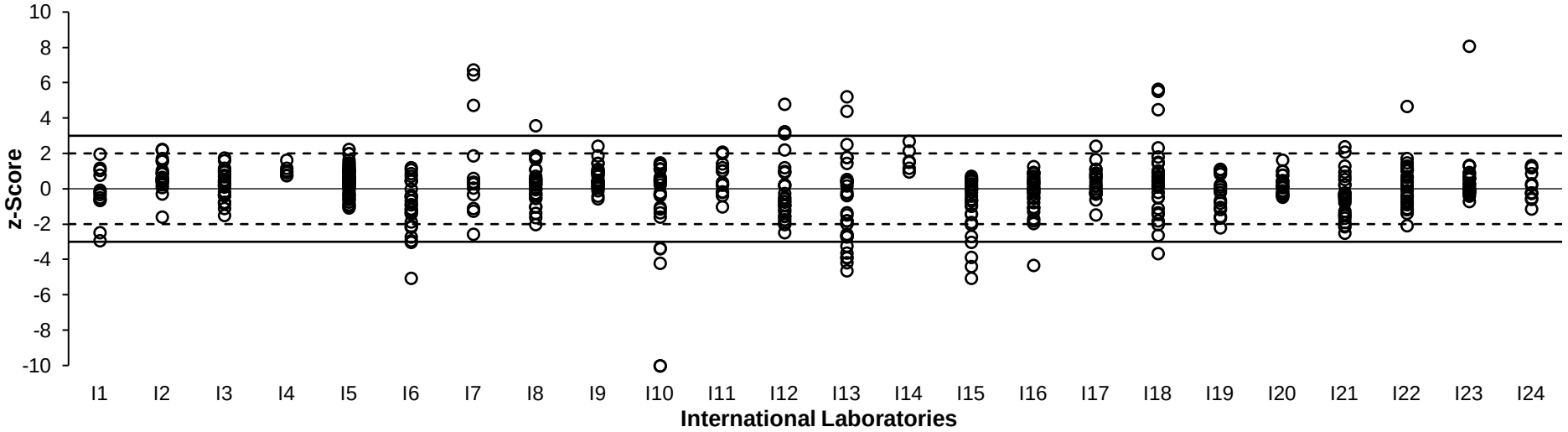


Figure 15 Summary of International Participants' *z*-Scores in NMIA Heroin PT Studies

7 REFERENCES

Please note that for all undated references, the latest edition of the referenced document (including any amendments) applies.

[1] ISO/IEC 17043, *Conformity assessment – General requirements for the competence of proficiency testing providers*.

[2] NMIA, 2024, *Study Protocol for Proficiency Testing*, viewed October 2024, <https://www.industry.gov.au/sites/default/files/2020-10/cpt_study_protocol.pdf>.

[3] NMIA, 2024, *Chemical Proficiency Testing Statistical Manual*, viewed October 2024, <https://www.industry.gov.au/sites/default/files/2019-07/cpt_statistical_manual.pdf>.

[4] Thompson, M., Ellison, S.L.R. and Wood, R., 2006, 'The International Harmonized Protocol for the Proficiency Testing of Analytical Chemistry Laboratories', *Pure Appl. Chem.*, vol. 78, pp. 145-196.

[5] ISO 13528, *Statistical methods for use in proficiency testing by interlaboratory comparison*.

[6] Thompson, M., 2000, 'Recent trends in inter-laboratory precision at ppb and sub-ppb concentrations in relation to fitness for purpose criteria in proficiency testing', *Analyst*, vol. 125, pp. 385-386.

[7] ISO/IEC 17025, *General requirements for the competence of testing and calibration laboratories*.

[8] Eurachem/CITAC Guide CG 4, QUAM:2012.P1, *Quantifying Uncertainty in Analytical Measurement*, 3rd ed., viewed October 2024, <http://www.eurachem.org/images/stories/Guides/pdf/QUAM2012_P1.pdf>.

[9] NATA, 2020, *Update to Measurement Uncertainty resources*, viewed October 2024, <https://nata.com.au/news/update-to-measurement-uncertainty-resources/>

APPENDIX 1 ROBUST AVERAGE AND ASSOCIATED UNCERTAINTY, z-SCORE AND E_n-SCORE CALCULATIONS

A1.1 Robust Average and Associated Uncertainty

Robust averages were calculated using the procedure described in ISO 13528.[5] The associated uncertainties were estimated as according to Equation 4.

$$u_{rob\ av} = \frac{1.25 \times S_{rob\ av}}{\sqrt{p}} \qquad \textit{Equation 4}$$

where:

$u_{rob\ av}$ is the standard uncertainty of the robust average

$S_{rob\ av}$ is the standard deviation of the robust average

p is the number of results

The expanded uncertainty ($U_{rob\ av}$) is the standard uncertainty multiplied by a coverage factor of 2 at approximately 95% confidence level.

A worked example is set out below in Table 11.

Table 11 Uncertainty Estimate for Robust Average of Sample S1

Number of Results (p)	32
Robust Average	71.8% base (m/m)
$S_{rob\ average}$	1.9% base (m/m)
$u_{rob\ average}$	0.4% base (m/m)
k	2
$U_{rob\ average}$	0.8% base (m/m)

Therefore, the robust average for Sample S1 is 71.8 ± 0.8% base (m/m).

A1.2 z-Score and E_n-Score Calculations

For each participant's result, a *z*-score and E_n-score are calculated according to Equations 2 and 3 respectively (Section 4).

A worked example is set out below in Table 12.

Table 12 *z*-Score and E_n-Score Calculation for Sample S1 Result Reported by Laboratory 1

Participant Result (% base (m/m))	Assigned Value (% base (m/m))	Target Standard Deviation	z-Score	E_n-Score
73.7 ± 11.6	71.8 ± 0.8	3% as PCV, or: 0.03 × 71.8 = 2.154% base (m/m)	$z = \frac{73.7 - 71.8}{2.154} = 0.88$	$E_n = \frac{73.7 - 71.8}{\sqrt{11.6^2 + 0.8^2}} = 0.16$

APPENDIX 2 ACRONYMS AND ABBREVIATIONS

ASCLD/LAB	American Society of Crime Laboratory Directors – Laboratory Accreditation Board
CITAC	Cooperation on International Traceability in Analytical Chemistry
CRM	Certified Reference Material
CV	Coefficient of Variation
DAD	Diode Array Detection
EA	European Accreditation
ENAC	Entidad Nacional de Acreditación (Spanish National Accreditation Body)
FID	Flame Ionisation Detection
GAG	General Accreditation Guidance (NATA)
GC	Gas Chromatography
GUM	Guide to the expression of Uncertainty in Measurement
HPLC	High Performance Liquid Chromatography
IEC	International Electrotechnical Commission
ISO	International Organization for Standardization
k	Coverage factor
LC	Liquid Chromatography
Max	Maximum
Md	Median
Min	Minimum
MS	Mass Spectrometry
MS/MS	Tandem Mass Spectrometry
MU	Measurement Uncertainty
N	Number of numeric results
NATA	National Association of Testing Authorities, Australia
NMIA	National Measurement Institute, Australia
NR	Not Reported
PCV	Performance Coefficient of Variation
PDA	Photodiode Array Detection
PT	Proficiency Testing
RA	Robust Average
RM	Reference Material
SD	Standard Deviation
SI	International System of Units

SS	Spiked Samples
TS	Technical Specifications (ISO)
UPLC	Ultra Performance Liquid Chromatography
UV/Vis	Ultraviolet/Visible Detection

END OF REPORT